Socket wear in ceramic-on-polyethylene total hip arthroplasties

Fixed versus rotating heads

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We measured radiographically the polyethylene socket wear in 34 hip prostheses with a 32 mm Al_2O_3-ceramic head with a rotating bearing and in 37 prostheses with a "fixed" ceramic head. The mean follow-up was 12 years in both groups. The mean annual linear wear of the polyethylene was 0.034 and 0.069 mm, respectively, (Mann-Whitney U-test p < 0.0001) in the "rotation" and the "fixed" group. A rotating bearing between the head and neck in a modular total hip system seems to reduce socket wear as compared to fixed taper junctions.

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In modular hip prostheses, the taper junction between head and neck has been thought to be a source of particulate metallic debris, leading to third-body wear of the socket (Saikko et al. 1993). For more than 20 years, we have used a prosthesis in which the head-neck junction consists of a cylindrical joint, a rotating bearing, which allows both rotating and telescoping movements of the head. The rotating bearing was designed to reduce movements between head and socket and to reduce torque stress on the femoral component (Weber 1981). To determine whether this secondary joint indeed reduces socket wear, we compared the wear of cemented all-polyethylene sockets of 2 almost identical modular total hip prostheses. The sole difference between the 2 prostheses was that one had a fixed taper connection between the head and neck and the other a rotating bearing.

Patients and methods

Implant design and operation technique

In the Orthopaedic Department of the University of Amsterdam, the cemented Weber-Rotation total hip prosthesis (Allo Pro, Baar, Switzerland) with a 32-mm Al_2O_3 ceramic head (Biolox®; Feldmühle, Plochingen, Germany) placed on a metal-on-metal (Protasul® 2) rotating bearing was used (Figure 1). In Het Slotervaart Ziekenhuis, the cemented Weber-Stühmer total hip prosthesis with a taper cone "fixed" 32-mm Al_2O_3 ceramic (Biolox®) head was used. In both hospitals, the femoral component was combined with a hemispherical, all-polyethylene (RCH-1000 Chirulen®, Hoechst, Germany) cemented socket. Diameter and material of the ceramic head, stem design and alloy (Protasul® 10), cup design and material were identical for both prostheses; the only difference was the rotating bearing. Furthermore, in both hospitals, the same operative technique with anterolateral (Watson-Jones) approach, type of bone cement (Sulfix-6®,

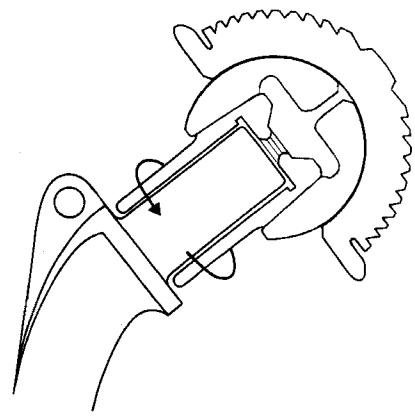

Figure 1. Schematic drawing of the rotating bearing. The ceramic head is placed on top of a metal cylinder.

Table 1. Number of hip arthroplasties remaining in both groups for radiographic wear measurement

	Rotation	Fixed
Number operated on	52	71
Lost to FU or dead	7	17
Infection	0	2
Aseptic loosening		
Revision		
Cup	1	2
Stem	2	6
Both	2	3
Radiographic [a]		
Cup	2	0
Both	0	0
Anteversion of cup > 20°	4	4
Number evaluated	34	37

[a] Grade 3 (Dall et al. 1992); the radiographic stem loosenings (3 in each group) have not been excluded.

Sulzer AG, Winterthur, Switzerland) and cementing technique, with intramedullary plug and postoperative rehabilitation program, was followed.

Patients

Between 1981 and 1985, 52 consecutive patients underwent total hip arthroplasty in the Department of Orthopaedics of the Academic Medical Centre and were operated on by one of the senior authors (RKM). In the same period, 71 patients were operated on in Het Slotervaart Ziekenhuis by the other senior author (HKD) and 3 other orthopedic surgeons. The diagnosis in all patients was arthrosis, either primary or secondary to dysplasia.

The patients were regularly followed by clinical and radiographic examinations 6–12 weeks after surgery and then every second year. At follow-up, in the rotation group 1 patient had died and 6 were lost to follow-up, while in the fixed group 5 patients had died and 12 were lost to follow-up. In the rotation group, 5 prostheses (all aseptic loosenings) and, in the fixed group, 13 prostheses (2 infections and 11 aseptic loosenings) had been revised (Table 1).

Mean follow-up was 12 years in both groups (range, rotation, 9.1–15.4; range, fixed, 9.7–14.6). The female:male ratio was 4:1 in the rotation group and 5:1 in the fixed group. The mean age was 64 (49–85) and 67 (54–77) years, respectively. The mean body weight was 72 kg in both groups. The degrees of daily activity were similar in the groups: most women were housewives, most men were retired. In the rotation group, 4 patients and in the fixed group, 3 patients were still working at the time of follow-up; none, however, performed heavy labor. The Harris hip score was determined at follow-up.

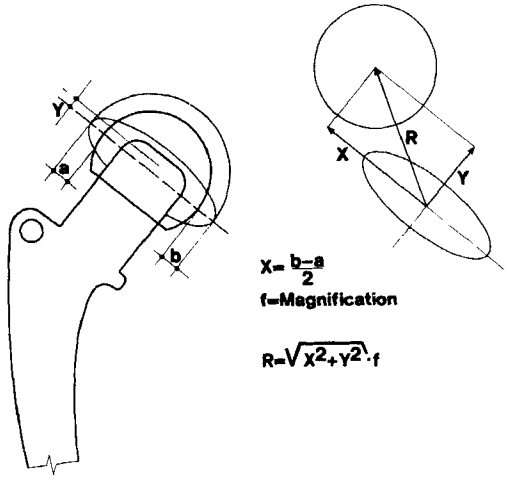

Figure 2. Technique of measuring wear of the polyethylene socket. The migration of the center of the ball head along the long axis of the elliptical wire marker and perpendicular to this axis is measured. Linear wear is calculated using the Pythagorean theorem taking into consideration the magnification of the radiograph.

Radiographic evaluation

Radiographs at 6 weeks to 3 months postoperatively and at follow-up were studied. All radiographs had been made standing (weight bearing), with the central ray centered on the hip joint (Goergen and Resnick 1975). The radiographic evaluation was performed, using the standard system of terminology for reporting results (CART), as proposed by Johnston et al. (1990) and by using the scoring system of Dall et al. (1992). In both groups, aseptic loosening (grades 2 and 3) as judged from the radiographs was recorded. Only radiographically stable sockets, grades 0 and 1 according to the criteria of Dall et al. (1992), were used for wear measurement in this study (Table 1). Measurements of polyethylene wear (Figure 2) were made using the method of Scheier and Sandel (1976) as modified by Buchhorn et al. (1984) and a measuring device with 8× magnification (Series 183, No 6; Mitutoyo Corporation, Utsunomiya, Japan). 2 observers (HV and RZ) measured independently all radiographs and the mean values were recorded. The center of the head was determined using a template, as described by Buchhorn et al. (1984), with concentric rings with radii increasing in steps of one millimeter (Figure 3). Correction for magnification was made by dividing the known (16 mm) radius by the measured radius of the head. Linear wear of the socket between the postoperative and the follow-up radiographs was thus recorded. Since measurement in the Y-direction (Figure 2) is influenced by the degree of anteversion of the socket (Buchhorn et al. 1984), sockets with

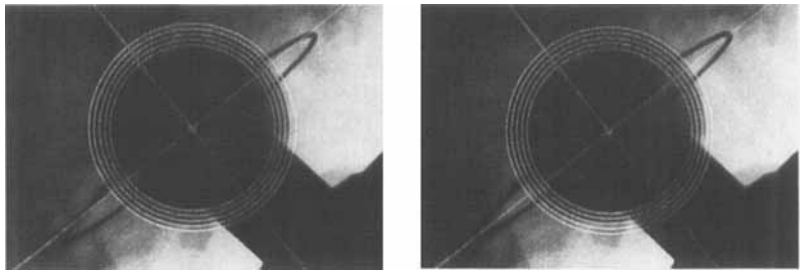

Figure 3. Measuring the shift in the Y-direction by using the special template. Through the small central hole in the template, a fine-pointed needle can be inserted to mark the center of the head and the equator of the elliptical wire marker on the radiograph.

Table 2. Average total and annual linear wear of sockets, mm (SD)

	Rotation	Fixed
Number	34	37
Wear	0.39 (0.20)	0.79 (0.36)
Wear/year	0.034 (0.016)	0.069 (0.032)
No.of loose stems [a]	3	3
Wear/year loose stems	0.046	0.11

[a] Aseptic loosening, radiographic grade 3 (Dall et al. 1992)

more than 20° anteversion were excluded (ratio of maximum to minimum diameter of the wire marker less than 3.0 (McLaren 1973)) (Table 1).

The Mann-Whitney U-test was used to determine the statistical significance of the difference in annual linear socket wear between the groups.

Results

The average linear wear per year was 0.034 mm (SD 0.016) for the rotating bearing and 0.069 mm (SD 0.032) for the fixed bearing ($p < 0.0001$). The inter-observer errors were 0.010 and 0.011, respectively. The average annual linear wear for the loose stems was clearly higher in both groups (0.046 and 0.11, respectively) (Table 2).

Socket inclination was 52° and 47°, anteversion 15° and 13° and socket coverage by bone 100% and 97%, respectively, for the rotation and the fixed groups.

Finally, the Harris Hip Score at follow-up was 88 (57–100) in the rotation group and 84 (60–100) in the fixed group.

Discussion

The accuracy of radiographic wear measurements is limited. Clarke et al. (1976) have criticized the methods described by Charnley and Halley (1975) and Charnley and Cupic (1973) as being unreliable and stated that estimates of wear cannot be made from radiographs at all. In contrast, however, Wroblewski (1985) found a very good correlation between radiographic and actual wear. Livermore et al. (1990) and Bankston et al. (1994) reported an accuracy of 0.075–0.2 mm with the use of a duo-radiographic method (Griffith et al. 1978). By using the method of Scheier and Sandel (1976), as modified by Buchhorn et al. (1984), estimates of wear are possible with a standardized radiographic technique, if the socket is equipped with a circular wire marker. This method is reported to be as accurate as the technique of Griffith et al. (1978), provided the anteversion of the socket is less than than 20° (Schüller and Marti 1990). Finally, Ohlin and Selvik (1993) presented a study of 3 different radiographic methods, which they compared by direct measurement of the retrieved sockets by means of a coordinate measuring device. They concluded that wear rate calculations made by any radiographic method are justified only if they are based on radiographically stable sockets. Although each radiographic measurement technique has its drawbacks due to the limited accuracy, a comparison between 2 types of prostheses can be made, especially when the technique of radiographic wear measurements is identical. In our study, it was clearly not possible to perform blinded radiographic measurements; therefore each radiograph was measured separately by two observers and the mean value was recorded.

Shift of the head in the socket is thought to be the result of wear and creep of the polyethylene (Rose et al. 1980). Recent analysis of retrieved sockets by polarized light microscopy has suggested that wear is responsible for most of the dimensional change seen in the polyethylene socket (McDonald and Bloebaum 1995). This indicates that conclusions concerning wear can be drawn from radiographic measurements.

In metal-on-polyethylene hip prostheses with a 32 mm head, radiographically measured wear rates have

been reported to be in the range of 0.1–0.2 mm per year (Scheier and Sandel 1976, Buchhorn et al. 1984, Weber and Fiechter 1989, Livermore et al. 1990, Schüller and Marti 1990, Egli et al. 1991, Kesteris et al. 1996). Few reports exist concerning wear in ceramic-on-polyethylene hip prostheses: radiographic measurements in total hips with 32 mm ceramic total hips showed wear in the range of 0.03–0.08 mm per year (Weber and Fiechter 1989, Schüller and Marti 1990, Bos et al. 1991, Egli et al. 1991). Hip simulator testing has confirmed this lower wear rate of ceramic heads, even with larger heads (Clarke et al. 1996, Saikko et al. 1993).

Although our study was retrospective and the patients were not randomized, we found both groups to be comparable. The main difference between the two groups was that the rotation group was a one-surgeon series and the fixed group had been operated on by four surgeons. However, operation methods, cementing technique, rehabilitation program and follow-up regime—at 2-year intervals—were identical. No difference existed between the groups concerning diagnosis, duration of follow-up, age, sex, body weight, activity or employment. The significantly lower wear rate in the rotation group may therefore be interpreted as the result of the motion occurring in two planes in the prosthesis, leading to a decrease in movement between head and socket. The higher wear rates in the cases of stem loosening might have been caused by the presence of cement particles in the pseudojoint. That the loosening was caused by the higher wear volume seems less probable, as a direct relation between socket wear and loosening could not be established in several studies (Franzén and Mjöberg 1990, Schüller and Marti 1990). Furthermore, both groups in our study were too small to allow conclusions concerning any relation between wear and aseptic loosening.

Our findings correlate well with the reports concerning polyethylene wear rates in total hip prostheses with 32 mm ceramic heads (Weber and Fiechter 1989, Schüller and Marti 1990, Bos et al. 1991, Egli et al. 1991). In addition, the rotating bearing reduced the annual wear of the socket. This rotating bearing may therefore compensate for the higher wear volume that is expected with the use of a larger, 32 mm, ceramic head.

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