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Wear of the acetabular socket

Comparison of polyacetal and polyethylene

Frictional characteristics of polyacetal (Delrin®) sockets and of ultra-high molecular weight polyethylene sockets retrieved in revision after aseptic loosening were compared with measurements of friction in new sockets. Friction in retrieved polyacetal sockets was twice as great as in retrieved polyethylene sockets. We also found that frictional characteristics of polyacetal changed as the material aged *in vivo*. In contrast, friction in polyethylene sockets remained fairly constant, even though most of them contained bone-cement particles. Friction in polyacetal sockets may be important for the relatively high incidence of socket loosening of the Christiansen prosthesis.
Measurements of wear of the polyacetal sockets showed a mean annual dimensional change of 240 mm^3, four times greater than that reported for the Charnley polyethylene acetabular prosthesis.

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The Christiansen hip has been widely used in Scandinavia; and more than 10,000 prostheses have been implanted worldwide (Clarke & McKellop 1980). Early results were promising and comparable to those of conventional hip prostheses (Sundal et al. 1974, Goldie & Raner 1979). However, we now know that the Christiansen prosthesis is inferior to the Charnley prosthesis and other devices (Josefson et al. 1981, Sudmann et al. 1983, Alho et al. 1984), and it has been taken off the market.

In most total hip prostheses, ultra-high molecular weight (UHMW) polyethylene is used for the socket material; but Christiansen preferred polyacetal (Delrin®), a polymer of greater hardness and higher creep resistance. There has been no study of friction and wear characteristics as the material is worn in the patient. We compared friction in new and implanted acetabular prostheses retrieved at revision. We also estimated wear of polyacetal *in vivo*.

Materials and methods

Friction

Twelve polyacetal (Delrin® 150 or 500) acetabular components were retrieved from 3 men and 9 women, 65±7 months after insertion. Eleven polyethylene components from 7 men and 4 women were likewise removed after 50±10 months. Methacrylate inclusions were seen only in the polyethylene cups; on a three-grade scale 0–2, seven cups were considered to have a grade 1 and three to have a grade 2 amount of methacrylate embedded in the polyethylene. Sockets with any sign of damage to the articulating surface produced during the revision were excluded.

Frictional characteristics of acetabular sockets retrieved from patients with aseptically loosened THR were compared with new sockets. The sockets were embedded in methacrylate (PMMA) and mounted at 45 degrees to the horizontal plane on a disc that created an oscillating motion of 60 degrees against a femoral component at 60 cycles per min. The femoral component was centered in the worn area of the socket and different loads were applied to the system. Strain gauges attached to the oscillating disc continuously recorded frictional torque. The axial load and temperature at the surface of the prosthetic head were also measured. Frictional torque, with axial loads of 100, 150, and 250 kp, was measured under dry conditions and with human plasma as a lubricant. The temperature of the surface of the prosthetic head was not allowed to exceed 45°C.

We conducted preliminary friction testing for several hours to determine whether friction changed during testing. Under dry conditions, steady-state friction occurred after about 15 min. Least friction was measured immediately after lubrication with human plasma.

Table 1. Frictional torque under varying loads. The measurements were made with and without lubrication with human plasma (mean ± SE)

	Frictional torque (Nm)					
	Load (kp) dry			Load (kp) lubricated		
	100	150	250	100	150	250
New sockets						
Polyacetal (n=3)	0.58±0.09	0.85±0.08	1.47±0.12	0.97±0.12[c]	1.52±0.14[c]	2.65±0.19[c]
Polyethylene (n=6)	2.13±0.18[a]	2.90±0.30[a]	4.48±0.53	1.05±0.09[c]	1.47±0.14[c]	2.13±0.19[c]
Used sockets						
Polyacetal (n=12)	3.97±0.48[b]	5.17±0.58[b]	6.91±0.67[b]	2.93±0.31[b,c]	3.77±0.31[b,c]	4.98±0.30[b,c]
Polyethylene (n=6)	2.97±0.58	3.52±0.64	4.69±0.83	1.27±0.17[a,c]	1.66±0.21[a,c]	2.24±0.27[a,c]

[a] Different from the corresponding polyacetal value; $P < 0.001$.
[b] Different from the corresponding polyacetal value of new sockets; $P < 0.001$.
[c] Different from the corresponding polyacetal value of dry sockets; $P < 0.001$.

Wear

We applied a volume-measuring device to 12 retrieved Christiansen sockets. The embedded sockets were placed on a disc that was adjustable, so that the cups were accurately positioned in the horizontal plane. The socket was filled with water to the rim, and the water level was determined with an electronic device at the center of a tripod plate covering the socket. This plate had a water level that allowed for horizontal adjustment of the apparatus. The volume of the socket was measured by weighing a 20-ml syringe before and after it had been used for filling the socket.

With repeated testing, we reproduced friction measurements within 5 per cent and volume measurements within 0.5 per cent.

We used the Student's t-test for both paired and for unpaired observations. Two-tailed t scores were used in the evaluation of friction, and one-tailed t scores were used for the study of wear.

Results

Frictional torque was lower for new than for retrieved sockets in the polyacetal group (Table 1). The addition of human plasma as a lubricant reduced friction by about 50 per cent in both new and used sockets in the polyethylene group; but in the polyacetal group, lubrication increased frictional torque in new sockets and lowered friction in retrieved sockets. When testing new sockets with plasma lubrication, we were unable to demonstrate differences between the two plastic materials. In contrast, when retrieved polyacetal sockets were tested after lubrication with plasma, the frictional torque increased.

The twelve polyacetal sockets had an average wear of 1.36 (0.08–3.75) cm^3 in 68 months or 0.24±0.05 cm^3 annually. The volume of three new sockets was 14.1±0.25 cm^3.

The wall of one of the polyacetal cups was worn down to the surrounding methacrylate (Figure 1).

Discussion

The Christiansen prosthesis differed from other total hip prostheses in both design and type of material. The varus position of the neck increased the offset of the femoral shaft. The 37-mm head-and-neck piece was mounted on a trunnion with an interposed polyacetal sleeve. This arrangement had been supposed to reduce bone-cement stresses and wear of the socket by allowing motion between the trunnion and the sleeve, in addition to the ball-and-socket joint. For the socket, polyacetal (Delrin®) was chosen because of its greater hardness and creep resistance.

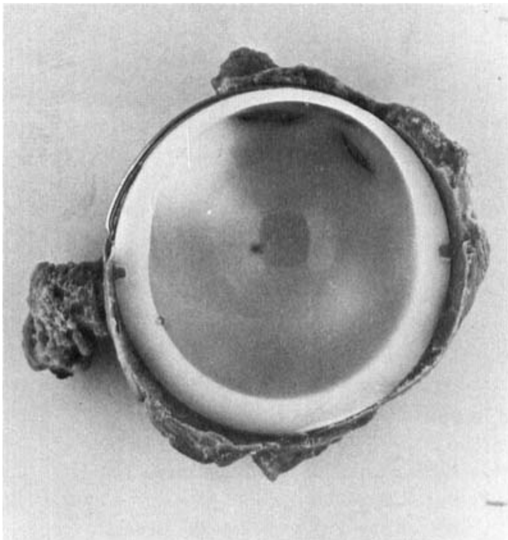

Figure 1. Acetabular component manufactured from Delrin®. There has been excessive wear in the upper portion of the cup, so that cement is exposed.

Our polyacetal and polyethylene groups differed with respect to sex and interval between the implantation and retrieval of prosthesis. There were more women in the polyacetal group, and this difference may have influenced the results; the prostheses of the three men in this group had somewhat higher frictional torque than those of the women. However, we did not find any correlation between friction and time in use.

The orientation of the socket in our testing device mimicked the orientation of the socket in the patient because we tested the visibly worn parts. The axial loads and running speed were of the same order of magnitude as in prostheses under normal and increased activity (Rydell 1966).

Because of damage to the edges of the sockets during the revision operation, our method for volume measurement was not applicable to the soft polyethylene sockets. Wear rates of polyethylene sockets in hip prostheses have, however, been extensively evaluated previously (Charnley 1975, Weightman 1977, Rose et al. 1980, 1982).

By comparing frictional torque in new sockets, we found, somewhat surprisingly, that the addition of plasma lubricant increased friction in the polyacetal group. Duff-Barclay & Spillman (1967), however, reported similar observations. In contrast, lubrication lowered friction in both retrieved polyacetal sockets and retrieved polyethylene sockets. We found no differences in friction between new polyacetal and new polyethylene sockets when lubricated.

There were distinct differences between the two groups of used sockets. Friction in lubricated polyacetal sockets was twice as high as in lubricated polyethylene sockets; even under dry conditions friction in polyacetal sockets was higher. These results are similar to those of Amstutz (1968) and Clarke & McKellop (1980). Our results, therefore, indicate that friction increases as polyacetal is worn *in vivo*. Friction in the polyethylene group remained fairly constant, even though most of the sockets contained visible methacrylate particles. High friction in the polyacetal socket may well be an explanation of the high incidence of loosening with the Christiansen prosthesis, notably of the socket. Because conditions at the trunnion are similar to the ball and socket joint, our data should be valid for the total assembly. Furthermore, Alho and associates (1984) observed that the trunnion often jammed, which would prevent it from diminishing wear at the ball-and-socket joint. In our tests, all but one of the Christiansen prostheses allowed easy movement between the trunnion and trunnion sleeve.

Weightman (1977) reported that wear in Charnley and Müller prostheses produces 50 to 100 mm^3 of debris annually. However, Rose and associates (1980, 1982) have pointed out that most of the dimensional changes in the polyethylene socket are due to creep (cold flow), and only a small part (1–30 per cent) results from the actual loss of material. We found an annual wear of 240 mm^3, about four times that of the polyethylene cup of the Charnley prosthesis. Because creep resistance for polyacetal is about ten times greater than for polyethylene (Dumbleton 1979), cold flow for the Christiansen prostheses will likely be about ten times less than for the Charnley prosthesis. Thus, our wear measurements probably reflect a very high production of wear debris compared with conventional polyethylene sockets. This debris may perhaps contribute to the aseptic loosening of the Christiansen prostheses through the formation of aggressive foreign body granulomas.

Earlier, we have examined the morphology of soft-tissue reactions to wear products from polyacetal and polyethylene around loosened hip prostheses (B. Mathiesen et al. 1983). We concluded that, although there was a somewhat more intensive tissue reaction around polyacetal, the difference did not convincingly explain an increased rate of loosening. In the light of our observations presented here, the high incidence of loose Christiansen sockets is better explained by frictional torque on the socket than by a more severe foreign body reaction.

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