FEMORAL COMPONENT WEAR IN RETRIEVED HIP PROSTHESES

A. KUSABA, Y. KUROKI

From Showa University Fujigaoka Hospital, Yokohama, Japan

We retrieved 159 femoral heads at revision surgery to determine changes in surface configuration. Macroscopic wear of the head was observed in three bipolar hip prostheses as a result of three-body wear. There was a considerable change in surface roughness in the internal articulation of bipolar hip prostheses. Roughness in alumina heads was almost the same as that in new cobalt-chromium heads. The annual linear wear rate of polyethylene cups with alumina heads was less than that of cups with cobalt-chromium alloy heads. Polyethylene wear was increased in the prostheses which had increased roughness of the head.

J Bone Joint Surg [Br] 1997;79-B:331-6.

Received 2 September 1996; Accepted after revision 23 December 1996

Wear is one of the most important factors which influence the long-term results of hip arthroplasty¹⁻⁵ and occurs principally in the polyethylene cup.²⁻¹¹ It also occurs in the femoral component the surface configuration of which affects the rate of polyethylene wear.⁹⁻¹² There have been few reports about the wear of femoral components and our aim was to evaluate the in vivo changes in the surface configuration.

MATERIALS AND METHODS

We studied 149 head components retrieved from 128 patients (8 men and 120 women). Details of the implants, the diagnoses and revision rates are given in Table I. The removal procedure was performed with great care in order not to damage the prosthesis during revision surgery.

We used a roughness meter (SE 3300, Kosaka Co Ltd,

Tokyo, Japan) to measure the mean surface roughness (Ra: arithmetical mean value of arithmetical mean roughness) of the retrieved heads calculating the mean roughness (μm) (Ra) as follows (Fig. 1):

where L is the length of the measured area (1.25 mm) and the cut-off value is 0.25 mm. The wavelength corresponding to the trace speed was 0.05 mm/s. The Ra value was taken as the mean of nine points measured in sagittal and coronal planes on the upper half of the head (Figs 2a and 2b; Table II).

The linear wear value of the cups was measured using Wroblewski's shadow-graph technique¹³ in the 105 hips in which the cups and heads were retrieved concurrently.

RESULTS

Macroscopic changes. Deformity of the head (Fig. 3) resulting from wear was observed in the internal articulation in three bipolar prostheses. The mean loss of volume was 2142 mm^3 (1999 to 2328). The acetabula had been reamed at the primary surgery and acetabuloplasty had been performed using the resected femoral neck which had been fixed with alumina screws. The heads had migrated until they contacted the screws which were broken in two cases and worn in one. Circular scratches were observed on the

Fig. 1

Diagram to show measurement of the Ra value which is obtained by sampling the reference length in the direction of the mean line, taking the X-axis as the direction of mean line and Y-axis the direction of longitudinal magnification of the sampled part. The roughness curve is expressed as $y = f(x)$.

A. Kusaba, MD, Instructor
Department of Orthopaedic Surgery, Showa University Fujigaoka Hospital, 1-30 Fujigaoka, Aoba-Ku, Yokohama 227, Japan.

Y. Kuroki, MD, Director of the Hospital
Showa University Fujigaoka Rehabilitation Hospital, 2-1-1 Fujigaoka, Aoba-Ku, Yokohama 227, Japan.

Correspondence should be sent to Dr A. Kusaba at 824-9 Kamoshida-Cho, Aoba-Ku, Yokohama 227, Japan.

©1997 British Editorial Society of Bone and Joint Surgery
0301-620X/97/27217 \$2.00

Table I. Details of implants, fixation and revision in 149 hips

	Type of implant*			
	Müller	Weber-Stühmer	Kyocera	Bipolar (UHR, Bateman)
Number of heads	36	54	19	40
Head diameter in mm	32	32	28	22
Head material	CoCr alloy	Alumina	Alumina	CoCr alloy
Number of cups	24	54	16	40
Cup material	UHMWPE†	UHMWPE	UHMWPE	UHMWPE
Years in situ (range)	9.0 (4.7 to 15.7)	8.5 (1.5 to 16.5)	6.6 (0.6 to 10.4)	5.1 (0.6 to 10.7)
Fixation				
Cup	Cemented	Cemented	Cemented	—
Stem	Cemented	Cemented	Cemented	Uncemented
Diagnosis at primary replacement				
Dysplastic osteoarthritis	36	50	19	33
Others	0	4	0	7
Diagnosis at revision				
Aseptic loosening	35	50	18	33
Others	1	4	1	7
Age at revision in years (range)	55.0 (29 to 55)	51.6 (30 to 73)	53.3 (39 to 64)	53.8 (36 to 78)
Mean follow-up in years	16.9	13.1	11.7	6.5
Revision rate (%) (number)	49 (39/80)‡	19 (67/354)‡	20 (19/99)	13 (40/301)

* Müller and Weber-Stühmer, Gebrüle and Sulzer AG, Winterthur, Switzerland; Kyocera, Kyocera Corporation, Kyoto, Japan; UHR, Osteonics, New Jersey; Bateman, 3M Company, Minnesota

† ultra-high-molecular-weight polyethylene

‡ prostheses which were damaged during the revision surgery were excluded from this study

Fig. 2a

Measuring points of the retrieved head, see Table II. Figure 2a – Anterior and posterior view of the head (right hip). The stem axis line is parallel to the line through the north and south poles (N, north pole; EQ, equator; N 30°, north 30 degrees; N 60°, north 60 degrees; E 0°, east 0 degrees; and W 0°, west 0 degrees). Figure 2b – Diagram of right and left heads from above showing the measuring points.

Fig. 2b

Table II. Measuring points on the head of the prosthesis. The head is considered as a terrestrial globe; the line passing through the north and south poles is parallel to the axis of the stem (see Fig. 2)

Point number	Right hip		Left hip	
	Latitude	Longitude	Latitude	Longitude
1 (top)	North pole		North pole	
2 (anterior)	North 60	East 0	North 60	West 0
3 (posterior)	North 60	West 0	North 60	West 90
4 (medial)	North 60	East 90	North 60	East 90
5 (lateral)	North 60	West 90	North 60	West 90
6 (anterior)	North 30	East 0	North 30	West 0
7 (posterior)	North 30	West 0	North 30	East 0
8 (medial)	North 30	East 90	North 30	West 90
9 (lateral)	North 30	West 90	North 30	East 90

Fig. 3

Severely deformed inner head of a bipolar hip prosthesis, showing its rugby-ball shape.

metal shell of the outer heads and numerous black alumina particles on the articulation surface of the polyethylene which had abraded the inner head. A mass of black tissue was seen during revision and all three patients had a high serum concentration of chromium (13.5 to 46.2 $\mu\text{g/dl}$) and nickel (0.9 to 1.1 $\mu\text{g/dl}$). Such changes were not seen in the heads of fixed-cup prostheses. Since they were caused by obvious three-body wear they were excluded from the measurement of the surface roughness of the head and polyethylene wear.

Microscopic changes. The mean Ra values of the other retrieved heads are shown in Figure 4. The roughness of the alumina heads was less than that of new cobalt-chromium alloy heads (Figs 4 to 6). The maximum change was observed in the area near the pole, with statistically significant differences between the ranges of Ra values in 32 mm cobalt-chromium alloy heads, 32 mm alumina heads, and 28 mm alumina heads ($p < 0.01$) (Fig. 7).

Fig. 4

The mean ($\pm$ SD) Ra values of the retrieved heads.

Fig. 5

Scanning electron micrograph of a retrieved 32 mm alumina head after 15.7 years in situ ($\times 420$).

Fig. 6

The relationship of roughness to the years in situ in alumina and cobalt-chromium heads.

Fig. 7a

Fig. 7b

Fig. 7c

Fig. 7d

Local roughness of a retrieved 32 mm alumina head (a), a 32 mm cobalt-chromium alloy head (b), a 28 mm alumina head (c) and a 22 mm cobalt-chromium alloy inner head of a bipolar prosthesis (d).

Fig. 8

The relationship of head roughness (Ra) to linear polyethylene wear.

Table III. The mean ($\pm$ SD) wear rate of retrieved cups (mm/year)

	Type of implant			
	Müller	Weber-Stühmer	Kyocera	Bipolar
Number of cups	24	35	16	37
Wear rate	0.21 $\pm$ 0.09*	0.13 $\pm$ 0.05	0.15 $\pm$ 0.03	0.21 $\pm$ 0.17

* t-study: $t = 3.85$, $p < 0.05$

Polyethylene wear. Table III shows the annual linear wear rate which was smaller in 32 mm alumina heads than in 32 mm cobalt-chromium alloy heads (t-study: $t = -3.85$, $p < 0.05$). Polyethylene wear was directly related to the roughness of the head (Fig. 8).

DISCUSSION

The roughness of the internal articulation of bipolar hip prostheses was high compared with that of other prostheses and was associated with severe polyethylene wear. Radiological measurements of polyethylene cups in situ have shown that wear rates of bipolar hip prostheses are higher than those with fixed cups.^{14,15}

The polyethylene wear rate of fixed cups in our study is higher than those which have previously been reported.¹⁶⁻²¹ It is clear that wear is worse in failed prostheses and is one of the most important factors in the cause of failure.²¹⁻²³ Most of the patients were young and had dysplastic hips treated by arthroplasty; their high level of activity may also have contributed to early failure.²²

The wear rate of polyethylene cups with 32 mm alumina

heads was less than that of the cups with cobalt-chrome heads of similar size. Our radiological analyses have also shown that wear in situ of alumina/polyethylene prostheses is less than that of cobalt-chrome alloy/polyethylene prostheses.²⁴

We wish to thank Dr T. Tateishi of the National Mechanical Engineering Laboratory, Dr Y. Shirasaki of the National Mechanical Engineering Laboratory and Dr Morio Tsuge of Sumitomo Bakelite Techno-research for their valuable advice.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES

1. Charnley J. Wear of hip sockets. In: *Low friction arthroplasty*. New York: Springer-Verlag, 1979:320-31.
2. Griffith MJ, Seidenstein MK, Williams D, Charnley J. Socket wear in Charnley low friction arthroplasty of the hip. *Clin Orthop* 1978; 137:37-47.
3. Hernandez JR, Keating EM, Faris PM, Meding JB, Ritter MA. Polyethylene wear in uncemented acetabular components. *J Bone Joint Surg [Br]* 1994;76-B:263-6.
4. Tooms RE, Harkess JW. Arthroplasty. In: Crenshaw AH, ed. *Campbell's operative orthopaedics*. Vol 3. 8th ed. St. Louis: Mosby Inc, 1992:371-87.
5. Wroblewski BM. 15-21 year results of the Charnley low friction arthroplasty. *Clin Orthop* 1986;211:30-5.

6. **Black J.** Materials retrieval and analysis. In: Black J, ed. *Orthopaedic biomaterials in research and practice*. New York: Churchill Livingstone, 1988:319-31.
7. **Dowling JM, Atkinson JR, Dowson D, Charnley J.** The characteristics of acetabular cups worn in the human body. *J Bone Joint Surg [Br]* 1978;60-B:375-82.
8. **Kabo JM, Gebhard JS, Loren G, Amstutz H.** In vivo wear of polyethylene acetabular components. *J Bone Joint Surg [Br]* 1993; 75-B:254-8.
9. **McKellop HA, Sarmiento A, Schwinn CP, Ebrahimzadeh E.** In vivo wear of titanium-alloy hip prostheses. *J Bone Joint Surg [Am]* 1990; 72-A:512-7.
10. **Plitz W, Walter A.** Tribological aspects of metal/polymer couplings. In: Buchhorn GH, Willert HG, eds. *Technical principles, design and safety of joint implants*. Seattle, etc: Hogrefe and Huber Publishers, 1994:82-9.
11. **Streicher RM.** Tribology of artificial joints. In: Morscher EW, ed. *Endoprosthesis*. Berlin, etc: Springer-Verlag, 1995:34-48.
12. **Kumar P, Oka M, Ikeuchi K, et al.** Low wear rate of UHMWPE against zirconia ceramic (Y-PSZ) in comparison to alumina ceramic and SUS 316L alloy. *J Biomed Mater Res* 1991;25:813-28.
13. **Wroblewski BM.** Direction and rate of socket wear in Charnley low-friction arthroplasty. *J Bone Joint Surg [Br]* 1985;67-B:757-61.
14. **Kusaba A.** In vivo wear of bipolar endoprosthesis. *Nippon Seikeigeka Gakkai Zasshi* 1995;69:411-25.
15. **Kusaba A, Kuroki Y, Kondo S.** Radiologic wear measurement of bipolar hip prosthesis. *Orthopaedic Transactions* 1996;20:in press.
16. **Dumbleton JH, Black J.** Some long-term complications. In: Ling RSM, ed. *Complications of total hip replacement*. Edinburgh, etc: Churchill Livingstone, 1984:212-30.
17. **Livernore J, Ilstrup D, Morrey B.** Effect of femoral head size on wear of the polyethylene acetabular component. *J Bone Joint Surg [Am]* 1990;72-A:518-28.
18. **Semlitsch M, Lehmann M, Weber H, Doerre E, Willert H-G.** New prospects for a prolonged functional life-span of artificial hip joints by using the material combination polyethylene/aluminium oxide ceramic metal. *J Biomed Mater Res* 1977;11:537-52.
19. **Weber BG.** Total hip replacement: rotating versus fixed and metal versus ceramic heads. In: Salvati EA, ed. *The hip*. St Louis: Mosby, 1981:264-75.
20. **Bono JV, Sanford L, Toussaint JT.** Severe polyethylene wear in total hip arthroplasty. *J Arthroplasty* 1994;9:119-25.
21. **Schmalzried TP, Guttman D, Grecula M, Amstutz HC.** The relationship between the design, position, and articular wear of acetabular components inserted without cement and the development of pelvic osteolysis. *J Bone Joint Surg [Am]* 1994;76-A:677-88.
22. **Feller JA, Kay PR, Hodgkinson JP, Wroblewski BM.** Activity and socket wear in the Charnley low-friction arthroplasty. *J Arthroplasty* 1994;9:341-5.
23. **Zichner LP, Willert H-G.** Comparison of alumina-polyethylene and metal-polyethylene in clinical trials. *Clin Orthop* 1992;282:86-94.
24. **Kusaba A, Kuroki Y, Kawauchi K, et al.** Clinical results of ceramic hip prosthesis. *Orthopaedic Ceramic Implant* 1994;14:59-63.