Surface Evaluation and Wear of Explanted Conventional and Highly Cross-linked Polyethylene Acetabular Liners

M. J. Salineros[a], M. P. Laurent[b], J. J. Jacobs[b], M.A. Wimmer[b], R. D. Crowninshield[b]
[a] Hospital Militar de Santiago, Chile; [b] Rush University Medical Center, Chicago, IL 60612

Introduction. Efforts to reduce the wear of ultrahigh molecular weight polyethylene (UHMWPE) in hip prostheses has led to the development of highly cross-linked (HXL) UHMWPEs. Although testing in simulators has indicated significant wear rate reductions with HXL PEs,[1,2] there is still a paucity of data on the clinical performance of the various HXL PEs. This study compares the performance of an HXL and conventional UHMWPE with respect to surface damage and wear for a series of explanted acetabular liners of the same design. Implantation times for the HXL liners ranged from 14 to 48.6 months.

Methods: In an IRB approved study *Trilogy*® (Zimmer, Inc., Warsaw, IN) acetabular liners were retrieved at revision hip surgery at the Rush University Medical Center between January 1998 and December 2005. Articulation was against 28 or 32 mm Co-Cr-Mo heads. Three groups of liners machined from the following materials were studied: (1) ram extruded GUR 4150 UHMWPE, gamma-sterilized in air (γ-Air); (2) compression molded GUR 1050 sheet, gamma-sterilized in nitrogen (γ-N_2); (3) highly cross-linked UHMWPE (*Longevity*®, Zimmer, Inc.),[3] plasma-sterilized. The number of liners, implantation time, and gender distribution for the three groups are given in Table 1. The most common reason for revision in the γ-Air and γ-N_2 groups was implant loosening, while in the HXL group it was dislocation.

Table 1. Liner demographics.

Group	Implant. Time (Mean months)	Gender M/F	No. of Cases
All	37	17/29	46
γ-Air	53	4/8	12
γ-N_2	33	7/16	23
HXL	28	6/5	11

The liners were examined under magnification up to 50X with a stereomicroscope (Stemi 200-C, Carl Zeiss, Germany). A surface scoring system similar to that previously reported was used to comparatively rank the appearance of component surface wear and damage[4]. The lower the visual score, the lower the surface damage. Component socket volume was determined using a 3D coordinate measuring machine (CMM) (SmartScope Flash, UK) by a method previously reported[5]. Unworn liners were used to estimate the original articular hemisphere volume.

Results/Discussion: No significant differences ($p > 0.05$) were found for patient weight, height, and BMI between the groups. Cup inclination and anteversion angles were also not significantly different among the groups. On the other hand, the implantation time for the HXL liners was significantly lower than for the other two groups ($p < 0.05$). The visual scores of the HXL liner were significantly lower (better) than for the other two groups (Table 2). This finding held when comparing only liners with similar implant times (< 49 mo). The liner wear and creep volume loss per year was also lowest for the HXL. The 28 mm HXL liners averaged a slightly negative value, which however was not significantly different from 0. This indicates that the wear was so low that the estimate of the unworn cup volume became the limiting factor of the methodology. As with other dimensional methods of wear measurement, socket volume change due to wear and creep could not be separated. Previous studies suggest that the contribution from creep becomes small after 2 years in vivo[6]. Due to recovery, some of this *in vivo* creep will be reversed in the explanted cups because they are unloaded. However, given its lower implantation time, the HXL group is likely to have a greater proportion of socket volume loss due to creep than the other two groups.

Table 2. Visual scores for the three liner groups: averages and standard deviations. Shading indicates a significant difference ($p \leq 0.05$) compared with the corresponding HXL value.

Group	Total	Scratching	Burnishing	Delamin.
All	31.3 ±18.4	8.2 ±5.2	8.6 ±6.3	1.8 ±4.2
γ-Air	36.2 ±19.4	9.3 ±6.3	11.4 ±7.5	2.0 ±6.4
γ-N_2	35.6 ±18.6	9.0 ±5.1	9.4 ±5.6	2.0 ±3.7
HXL	17.0 ±7.1	5.4 ±3	3.8 ±3	0 ±0

Table 3. Liner wear and creep volume loss: averages and standard deviations. Shading indicates a significant difference ($p \leq 0.05$) compared with the corresponding HXPE value.

Group	Total Volume (mm^3)	Annual Volume (mm^3/year)
γ-Air, 28 mm	394 ± 403	100 ± 79
γ-N_2, 28mm	156 ± 113	64 ± 46
HXL, 28 mm	-21 ± 36	-13 ± 21

Examination by scanning electron microscopy (SEM) of the HXL liner that had been implanted only 14 months clearly revealed unworn machining lines (Fig. 1). The smoother morphology may suggest a more ductile behavior than reported for another HXL UHMWPE[4].

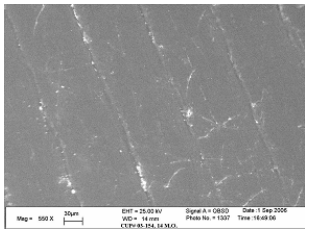

Fig. 1. SEM micrograph of HXL PE implanted 14 months. Scale bar is 30 μm.

Conclusions: The three generations of polyethylene examined in the study demonstrate progressive improvements in annualized wear. The significantly lower wear rate of the HXL PE is consistent with simulator studies. For comparable implantation times, the HXL polyethylene experienced less mechanical surface damage than the earlier generation materials. Longer-term studies are needed to determine if the HXL maintains its lower wear rate and if its use will lead to a lower incidence of osteolysis and aseptic loosening.

References: 1. Muratoglu OK. J Arthroplasty 16 (2001) 149. Laurent MP., ASTM STP 1445 (2004) 86. 3. Kurtz SM., UHMWPE Handbook, Elsevier (2004) 345-348. 4 Bradford L. J Bone Joint Surg, 86-A (2004) 1271. 5.Wimmer MA et al., Trans ORS 23 (1998) 78. 6. Digas G. et al., CORR 429 (2004) 6.