INTRODUCTION

The use of large femoral heads in total hip arthroplasty can increase range of motion and decrease the incidence of dislocation, but requires the use of thin ultra high molecular weight polyethylene (UHMWPE) acetabular liners to retain acetabular bone. The introduction of highly cross-linked polyethylenes with improved wear performance has allowed for the marketing of thin liners in conjunction with large heads. A potential disadvantage of highly cross-linked UHMWPE is the decrease in mechanical properties that accompanies some cross-linking/thermal processes. This is particularly worrisome under impingement or near impingement conditions, a common occurrence in THA patients as seen in recent retrieval studies.

The question remains, therefore, as to the wear performance of thin highly cross-linked acetabular liners articulating against large femoral heads under near impingement conditions. To address this question, we examined the effect of liner thickness on wear performance on the basis of gravimetric measurements and observations of damage modes on liners tested in vitro using a hip simulator under conditions in which the femoral head swept close to the edge of the liner.

MATERIALS & METHODS

Three groups of liners were tested in a hip simulator. Two groups were made of X3® material, which is highly cross-linked by three sequential exposures to gamma irradiation at 3 Mrads followed by annealing below the melt temperature. One highly cross-linked group had a thickness of 7.9mm, the other a thickness of 3.8mm. The third group of liners was made from conventional UHMWPE with a thickness of 7.9mm. There were four test specimens per group as well as three soak controls for each of the highly cross-linked groups and two soak controls for the conventional group.

The polyethylene liners were articulated against cobalt chrome alloy femoral heads of either 36 or 44 mm diameter. A stainless steel sleeve was manufactured to interface between the trunnion taper on the hip simulator and the taper of the femoral heads. The liners were seated in the shells (Trident® PSL® HA cluster). All components were supplied by Stryker Orthopedics, Mahwah, NJ. The polyethylene locking bead was removed from the liners to assist in removal and reassembly for weight measurements throughout the wear test.

The liners were oriented in the stations of the hip simulator so that near impingement occurred at maximum load during each wear cycle (Fig. 1). Anatomically, this orientation corresponded to 101° of flexion with acetabular anteversion of 20° and acetabular inclination of 45°.

The wear rate was significantly lower with cross linking and did not vary with thickness (Fig. 2). The difference between the wear rate of the thick (7.9mm) and thin (3.8mm) cross-linked groups was not significant (p=1.00). Wear rate of the conventional liners was significantly higher than both cross-linked groups (p<0.001). inadvertent impingement was observed in 2 of the 4 conventional and 3 of the 4 thick cross-linked liners. Liners that impinged had a higher gravimetric weight loss than the non-impinging liners in those groups.

Burining and scratching were the main wear damage modes, with the greatest scratching observed on the cross-linked liners. Fracture or cracking was not observed in any of the samples. Conventional liners were burnished with removal of the original machining marks. Further damage was observed on the backsides of all of the liners with evidence of creep of the polyethylene into the screw holes of the metallic shells.

RESULTS

The wheels were run for five million cycles on a twelve station Shore-Western hip simulator (Monrovia, CA) using a Paul-type hip-load profile with a maximum load of 2000 N applied at a frequency of 1Hz. Components were tested in 50% bovine calf serum with the addition of EDTA. The liners were removed, cleaned, weighed, photographed, and viewed with a stereomicroscope (10X-32X) every half-million cycles. Comparisons among groups for wear rate were performed using one-way ANOVA followed by a post-hoc analysis with a Tukey test.

DISCUSSION

We expected that wear and damage would be greater with the thinner liners, but our results did not support this hypothesis. Regardless of thickness, the cross-linked liners had significantly lower wear than conventional UHMWPE, and no evidence of cracking was observed.

Our results can be explained by considering how material properties and geometry affect stresses associated with wear and damage. The X3® cross-linked material does not display the decreased mechanical properties of other cross-linked UHMWPEs in terms of yield and ultimate strengths and ductility. Furthermore, while there is an increase in stress due to the decrease in liner thickness, it is likely offset by the large diameter head which distributes the same load over a larger contact area.

Our study supports the use of large femoral heads with highly cross-linked polyethylene liners as thin as 3.8 mm thickness. Further retrieval analyses and continued in vivo monitoring will be necessary to elucidate the efficacy of these devices.

ACKNOWLEDGEMENTS

The authors acknowledge Stryker Orthopedics for their support and Joseph Lipman and Jonathan Danoff for their contributions to the study.

REFERENCES