Effects of Protein Concentration in the Serum Lubricant on the Wear of Crosslinked, Thermally Treated UHMWPE

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Statement of Purpose: Existing clinical evidence indicates different levels of protein concentration in joint fluid among patients after THR [1]. The variation of protein levels may affect the lubrication of joint implants and the wear performance of the implants. Previous simulation studies have investigated the effects of serum lubricant concentration on the wear of PTFE and UHMWPE [2,3]. This study is to compare the effect of different concentrations of serum lubricant on the wear rate of moderately crosslinked, thermally treated UHMWPE against 28mm CoCr heads.

Materials and Methods: Polyethylene liners were machined from 3" diameter GUR 1050 ram extruded bar. The bars were sealed in a vacuum foil bag and underwent 5Mrad irradiation. After irradiation the bars were heated above the melting temperature in a reduced oxygen environment to quench free radicals by crosslinking or recombination. The bars were then cooled to room temperature. The liners were tested against 28mm CoCr heads (DePuy, Warsaw, IN).

The heads and liners were divided into four groups. Each group (three head-liner pairs) was lubricated with different concentrations of bovine serum (BS). Group A: de-ionized water, Group B: 25%BS, Group C: 50%BS, and Group D: 90%BS, with final protein concentrations of 0, 17, 34 and 61.2 mg/ml, respectively. The bovine serum (HyClone, Logan, UT) was pre-treated with 20mM ethylenediaminetetraacetic (EDTA) and sodium azide (0.2% w/v) to make the 90%BS. The 25%BS and 50%BS were diluted from the 90%BS by adding de-ionized water. Serum volume for each test station was 500ml. Serum was changed every half million cycles.

Implants were placed anatomically (head below liner) on a 12-station hip simulator (AMTI, Boston, MA). The J-Paul load curve (max load 2000N) was applied at the implants at the frequency of 1Hz for 2 million cycles (M.C.) [4]. The load was synchronized with physiological kinematic inputs (abduction/adduction ±8.5°, flexion/extension ±23°, and internal/external at ±10°).

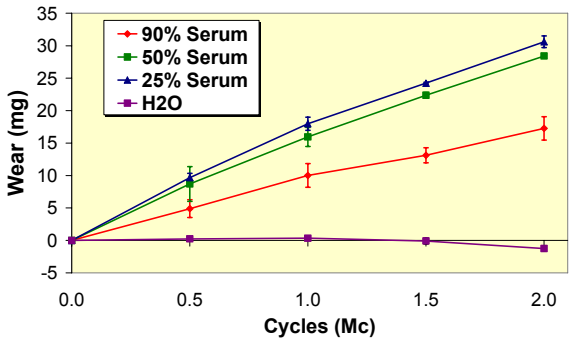
Gravimetric analysis was performed on the cleaned implants before testing and every half million cycles afterwards. Load soak weights (the liner's weight gain from the absorption of lubricant) were subtracted from test specimen to obtain net wear.

Two-tailed equal variance t-test was performed to analyze the significance between the wear rates difference.

Results / Discussion: The accumulate wear of each group appeared to be linear as shown in Figure 1. Table 1 shows the average wear in different levels of protein concentrations. There was critically no wear in water (A). The wear rates were similar between 25%BS and 50%BS groups (B and C). The wear rate in 90%BS group (D) differs considerably from groups B and C. Figure 2 shows the effect of protein concentration on the wear of crosslinked UHMWPE. The similar pattern was reported previously [2], in which the non-crosslinked UHWMPE was tested.

The lower polyethylene wear in the 90% group (than groups 50% and 25%) may be due to protein precipitation from the serum lubricant, which form a solid lubricant at the articulating surface and reduce wear. High amount of protein precipitates was observed in the bottom of the vessel, especially in the higher concentration group.

Fig 1. Accumulation Wear

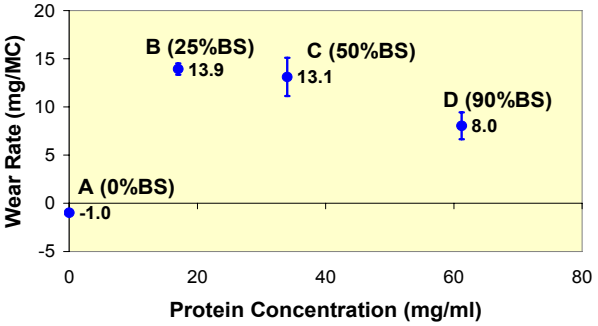


The mechanism for the non-detectable wear shown in de-ionized water group (A) was not clear. One plausible explanation is that polymer transferred between heads and liners without the interference of protein molecules. Further study on this phenomenon is in progress.

Table1. Wear Summary

Group ID	A	B	C	D
Lubricant	Water	25%BS	50%BS	90%BS
[Protein] (mg/ml)	0	17	34	61.2
Wear Rate (mg/M.C.)	-1.0 ±0.2	13.9 ±0.6	13.1 ±2.0	8.0 ±1.4
p-value	A<B (0.0002), B>C (0.63), C>D (0.04)			

Fig 2. Effect of Protein Concentration on PE Wear



Conclusions: The data indicated the wear rate of the moderately crosslinked, thermally treated UHMWPE liners varied in different protein concentrations. The data suggested the protein concentration in the joint fluid played a key role in wear performance of joint implants.

References: [1] Liao, et al., Biomaterials 2003, v24: 3047-3059 [2] Wang, et al., SFB 1999, p178 [3] Good, et al., Acta Orthop Scand 2000, 71(4): 365-369 [4] Paul, Proc Inst Mech Eng 1967, v23: 8-15.