

# QUANTITATIVE ANALYSIS OF SERUM DEGRADATION AND ITS EFFECT ON THE OUTCOME OF HIP JOINT SIMULATOR WEAR TESTING OF UHMWPE

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**Introduction:** Bovine serum is the most widely used lubricant in wear and joint simulator testing of prostheses. However, recent studies have raised serious questions about the chemical stability of bovine serum and its subsequent effect on the outcome of hip simulator wear test of UHMWPE [1-3]. Because of frictional heating generated at the articulating interface during testing, the protein constituents in serum deteriorate with time [1]. The degradation product was insoluble precipitates that are generally absent in synovial joint fluid in-vivo. These insoluble precipitates, if trapped at the ball/cup interface, act like a solid lubricant which may artificially shield the polyethylene from wear [1-3]. The present study examines some important factors that affect the degradation of bovine serum and consequently the wear rate of UHMWPE.

**Materials and Method:** 32 mm ID and 60 mm OD UHMWPE acetabular cups were machined from a GUR4150 rod and then sterilized by gamma-irradiation at 2.5 Mrads in air. Wear tests were conducted on these cups against CoCr femoral heads (Ra: 0.015  $\mu$ m) using a multi-station hip joint simulator (MTS, Eden prairie, MN) under various lubrication conditions. All tests were carried out at 1 Hz under physiological loading (2450 N maximum and 50 N minimum), cross-path motion ( $\pm 23^\circ$  biaxial rocking motion) and inverted anatomical position (head on top and cup at bottom). Three different types of serum were used as lubricants. The first was a regular bovine calf serum which has an initial protein concentration of 65 mg/ml (Hyclone Labs, Logan, UT, Cat. #SH30087.03). The second was a low-calcium, low-protein alpha-fraction calf serum which contains 40 mg/ml proteins (Hyclone Labs, Logan, UT, Cat#A-2162). The third was the alpha-fraction serum diluted by 50% with D.I. water (protein concentration: 20 mg/ml). Lubricant chambers of three different sizes were used to contain the lubricant and the test components: 100 ml, 200 ml and 400 ml. All cups were fully immersed in the lubricant. All lubricants were replaced every 250,000 cycles (ca. 3 days). The used lubricants were collected and centrifuged to separate the insoluble precipitates from the rest of the lubricant. The precipitates were then dried in an oven at 80°C for 24 hours. The amount of precipitates from each chamber was determined by weighing them with an electronic balance (resolution: 0.01 mg). The concentration of precipitates per chamber was then calculated by dividing the weight of the precipitates by the initial volume of the lubricant in each chamber. The ratio between the precipitate concentration and the initial protein concentration defines the severity of serum degradation, a quantity which will be referred to as the degradation index, a quantity which will be referred to as the degradation index. The wear rate of each cup was also determined by weight loss measurements.

**Results:** Fig. 1 shows the final precipitate concentration and the wear rate as a function of the lubricant volume used in testing. The precipitate concentration was seen to decrease significantly as the lubricant volume increases while the wear rate showed the opposite trend. Fig. 2 shows the precipitate concentration and the wear rate as a function of the serum type at a constant lubricant volume of 400 ml. The 50% diluted alpha-fraction serum showed the lowest precipitate concentration and the highest wear rate while the regular bovine serum showed the highest precipitate concentration and the lowest wear rate. Fig. 3 shows the serum degradation index as a function of serum volume and serum type. More than 25% of proteins degraded in the 100 ml regular serum while less than 3% of proteins degraded in the 400 ml alpha-fraction serum.

**Discussion and Conclusions:** The degradation of serum has a significant effect on the wear of UHMWPE during hip simulator testing. A serum degradation index which is defined as the ratio between the precipitate concentration and the initial protein concentration can be used as a quantitative indicator of the severity of serum degradation. A smaller quantity of serum per chamber and a higher initial protein content resulted in a higher degradation index. The wear rate of UHMWPE was inversely affected by the degradation index, i.e., the higher the degradation index, the lower the wear rate. In order to minimize the artifact due to serum degradation, say a degradation index < 5%, the alpha-fraction calf serum of ca. 400 ml volume is recommended. Regular bovine serum and small chamber sizes should be avoided. In addition, mounting the components in an anatomical position may help reduce the effect of precipitate entrapment at the articulating interface.

**References:** [1] Z. Lu and H. McKellop, Proc Instn Mech Engrs Vol 211 Part H, 1996, 101-108. [2] A. Wang, et al., 24th Society For Biomaterials, 1998, p. 218. [3] Z. Lu, et al., 24th Society For Biomaterials, 1998, p. 6.

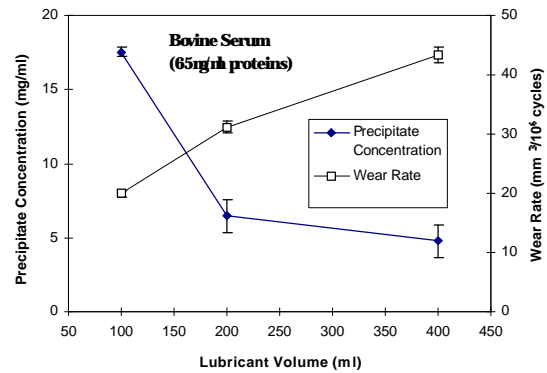


Fig. 1: Precipitate concentration and wear rate vs. lubricant volume.

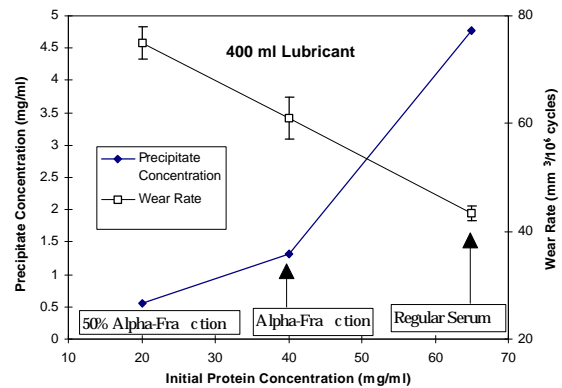


Fig. 2: Precipitate concentration and wear rate vs. serum type.

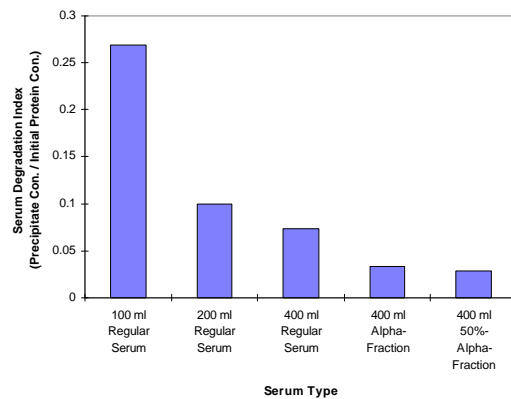


Fig. 3: Serum degradation index vs. lubricant volume and serum type.

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