Viscous behavior of different concentrations of bovine calf serum before and after wear testing

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Statement of Purpose: Each year, approximately 1.3 million total hip and knee replacement surgeries are performed worldwide. The service life requirements of these implants can be up to 30 years in elderly, inactive patients. Younger and more active patients, however, will place higher stress on the prosthesis and require a much longer service life. Therefore, there is a continuing need to increase the service life of hip and knee implants. One approach to increasing the service life is to increase the wear resistance of the current materials, or create new materials, and develop suitable testing environments for the new materials. Hip and knee testing machines have been developed to simulate the loading and kinematics of implant materials under conditions believed to represent the patient's gait. Simulating the chemical environment surrounding the *in vitro* implant, however, is less established.

The test lubricant has been identified as one of the major factors affecting *in vitro* behavior of joint implants [1]. One of the difficulties in evaluating and comparing wear studies performed in different labs is the lack of consistent test parameters. The type of lubricant fluid, the protein concentration in the lubricant, the lubricant volume and temperature are all important test variables. Different implant material combinations may react differently to the same lubricant. This research examines the rheological properties of bovine calf serum (BCS), a common lubricant used to simulate natural joint fluid for *in vitro* tribological studies of artificial joints, before and after multiple wear cycles. The study also compares how different wear couple materials behave when tested with the same lubricants.

Methods: Bovine calf serum (BCS), with and without an antibacterial agent, was used to simulate synovial fluid during tests of new artificial joint materials. A previous study of the rheological properties of bovine calf serum (BCS) and other lubricants used in testing artificial joints provided base-line data for this study [2]. To conduct the rheological studies on the lubricants used for the wear tests, different concentrations of BCS diluted with deionized water were created: 100% (0% DI water), 75%, 50%, 25% and 0% (100% DI water). Either penicillin/streptomycin (P/S) or sodium azide were added to some samples to investigate their effect on the viscosities. The apparent viscosity was determined using:

$$\eta = \frac{\sigma}{\dot{\gamma}}$$

where η is the apparent viscosity, and σ and γ are the shear stress and shear rate, respectively.

Wear tests were conducted using the standard CoCrMo-on-UHMWPE, and a novel micro-textured carbide surface [3] (carbide-on-UHMWPE), Data were analyzed by ANOVA with post-hoc Tukey tests for multiple comparisons.

Results: The average apparent viscosity results after wear were different, depending on the wear couple system. (Figures 1 and 2). Figure 1 shows the average apparent viscosities for BCS 100%, 50%, and 25% with P/S antibacterial agent at 250,000, 500,000 and 1,000,000 wear cycles for the carbide-on-UHMWPE wear couple system. The viscosity increased for all three concentrations of BCS as the number of wear cycles increased from 250K to 1,000K. BCS 100%-P/S produced the greatest viscosity at 1,000K cycles. In Figure 2, the average viscosity for all the lubricant concentrations BCS 100%, 50% and 25% increased more for the carbide-on-UHMWPE wear couple system than the CoCrMo-on-UHMWPE wear couple system for all the three intervals: 250,000, 500,000 and 1,000,000 cycles. The viscosity increased with an increase in cycles from 250K to 500K for all the lubricant concentrations (BCS 100, 50 and 25%) and increased with increase in cycles from 500K to 1,000K for BCS 100% lubricant.

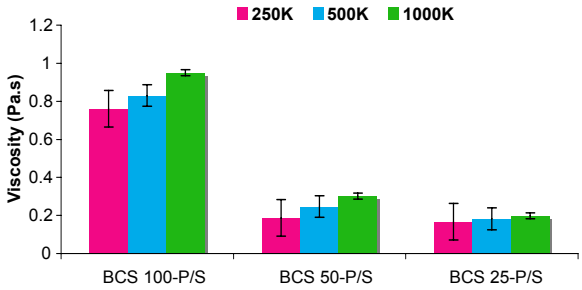

Figure 1: *The average apparent viscosities for BCS 100, 50, and 25 % with P/S antibacterial agent at 250,000, 500,000 and 1,000,000 wear cycles for the carbide-on-UHMWPE wear couple system*

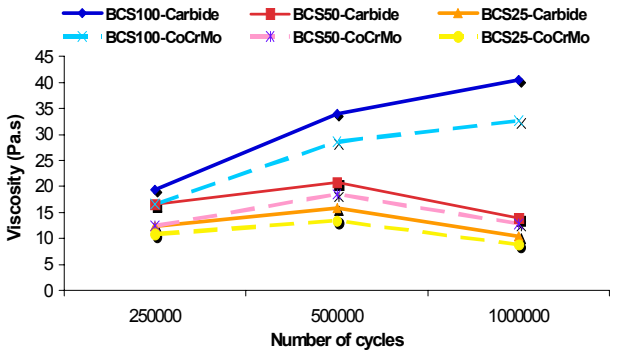

Figure 2*: BCS effect on wear for the carbide-on-UHWMPE and CoCrMo-on-UHWMPE wear couple systems*

Conclusions: The results showed that the apparent viscosity of bovine calf serum increased as the number of wear cycles increased, regardless of the initial concentration. The apparent viscosity also decreased with decreasing concentration of BCS, as expected. Future research extends the exploration of using bovine calf serum (BCS) as the lubricant for studying the wear properties of the seven different wear couple systems.

References: [1] Ferguson J,. *Applied Fluid Rheology*, Elsevier Science Publishers Ltd 1991: 47-133.
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[3] VanDamme, NS, Que, L, Topoleski, LDT, "*J. Materials Science*, 1999: **34**: 3525-3531.
[4] Mazzucco D. *J of Orthop. Res.* 2002;20:115-1163.