The Influence of Model Synovial Fluid Chemistry on the Wear of CoCrMo Alloy in Sliding Tests

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INTRODUCTION

Despite significant advances in recent years surface wear of metal-on-metal (MoM) hip joints remains an issue. There are concerns about the formation of nano-wear particles, which lead to increased metal ion levels in the body [1] and reports of periarticular erosion [2]. These concerns have resulted in the issue of a medical device alert by the MHRA (April 2010) for MoM implants [3].

Our analysis of failed, explanted MoM hips has shown that in a significant number of cases severe wear occurred in joints that were well-fixed and not misaligned. One possible reason for this is differences in the chemistry of the patient synovial fluid (SF), which have an adverse effect on the lubrication and wear. SF is a complex mixture of large and surface-active molecules including; proteins, hyaluronic acid, and phospholipids [4]. The properties of SF are affected by disease and trauma and this can result in a significant decrease in the viscosity and changes in the protein content and pH [5]. Wear of MoM joints is controlled by the nature of the lubricant film (thickness, composition) and the properties of the rubbing surfaces. In our earlier work with model SF (protein solutions and bovine serum) lubricant film thickness was found to be both time and speed dependent [6]. Film formation was dominated by protein agglomeration in and around the sliding contact. In this paper we have restricted our tests to constant speed and measured film formation and wear as a function of time. We examine the effect of solution pH, which was chosen to represent healthy (7.4) and diseased (8.0, 8.5) values.

MEASUREMENT METHODS

Film thickness was measured using thin film optical interferometry [6]. The test used a commercial femoral resurfacing head (38 mm diameter, as-cast) loaded (5N) against the glass disc to form a sliding contact. This provides a simple, steady state simulation of the gait cycle. A diagram of the method is shown in Fig. 1. Film thickness and wear (both during and after the test) were measured at constant sliding speed (10 mm/s represents an average gait speed) over a period of 20 minutes at 37°C. After each test the femoral head was cleaned and examined under a microscope and a final wear measurement taken. The test fluid was bovine calf serum (BS) (Sigma Aldrich, B-8655/12133C) diluted to 25% w/w in different solvents. The solutions were as follows:
1. Deionised water: DIW
2. Tris buffer at three pH values: TRIS - pH7.4, pH8.0, pH8.5

RESULTS AND DISCUSSION

Film thickness results at constant speed are plotted in Fig. 2. Wear scar measurements are given in Fig. 3; the results are normalised against the initial (t = 0) contact radius to indicate true contact growth. Film thickness is observed to grow with rubbing time for all solutions. There is little difference between thickness results for DIW and TRIS at high pH levels. However, a surprisingly large amount of wear is observed for all three solutions. For each solution the contact size has doubled over the short test period. It is likely that the femoral head is being corroded rather than, or as well as, mechanically worn away.

TRIS 7.4 forms a thick film within the first few minutes of sliding, which is observed to grow until a constant value of ca 200 nm is reached. This thick layer appears to be protective as a much smaller wear scar is formed.

However for all solutions tested wear of the femoral head was observed; this is surprising as the counterface is glass. This suggests that material removal is dominated by corrosive rather than mechanical (adhesion/abrasion) mechanisms [7].

CONCLUSIONS

We report for the first time simultaneous film thickness and wear scar measurements for model SF lubricants. The conclusions are as follows;
1. Deposition of proteins occurs over time/rubbing to form a solid surface layer, which supports the load.
2. Surface wear increases with increasing BS solution pH.
3. Corrosion of surface is a significant wear mechanism. From our study we conclude that patient SF chemistry does play a role in determining wear and possibly failure of MoM joint.

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REFERENCES

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Fig. 1 Measurement method

Fig. 2 Film thickness results for BS solutions 10 mm/s

Fig. 3 Wear scar measurements (normalized) at end of the test.