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Contribution of each synovia constituent to friction of UHMWPE/CoCrMo sliding pair for joint prosthesis

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ABSTRACT – To gain the understanding of *in vivo* friction and wear behavior of implanted joint prosthesis, effect of each synovia constituent on the friction between UHMWPE and CoCrMo, the most popular material combination for the sliding surfaces of artificial joints, was examined in the reciprocating sliding tests. Proteins, phospholipids and hyaluronic acid were selected as major constituents of synovial fluid and several test lubricants containing these macromolecules with different combination were prepared to compare the effect on the sliding test results. The result of this study clearly indicated that protein molecules had the predominant effect and it made the effects of other molecules inconspicuous.

1. INTRODUCTION

It has been widely recognized that biological macromolecules contained in synovial fluid, such as proteins, lipids and hyaluronic acid, are playing certain roles in the highly sophisticated lubrication mechanism of natural synovial joints and contributing their excellent low friction and low wear characteristics [1,2]. At the same time, many studies have indicated that these macromolecules existing in the joint space also have large influence on the friction and wear of joint prostheses implanted to replace the diseased joint parts [3,4]. However, detailed mechanism of friction and wear of prosthetic materials in synovial fluid has not been explained clearly yet and there are still active discussions about the role of each synovial constituent. In this study, the sliding pair of ultra-high molecular weight polyethylene (UHMWPE) and CoCrMo alloy was selected as the most popular material combination for the sliding surfaces of joint prostheses and the effect of each synovial constituent on its frictional behaviour was examined.

2. MATERIALS AND METHODS

Friction coefficient between CoCrMo alloy and UHMWPE was evaluated in the reciprocating pin-on-plate sliding test. The schematic of the tribometer used in this study is shown in Figure1 [5]. Medical grade cast CoCrMo (ASTM-F75) was used as the pin specimen. The pin surface was finished to have the curvature radius of 110 mm and Ra value of 0.01 ± 0.005 µm. The plate specimen was machined from an UHMWPE bar stock which is compression moulded from medical grade GUR1050 compound and not sterilized. The plate surface was polished to have Ra value of 0.1 ± 0.02 µm.

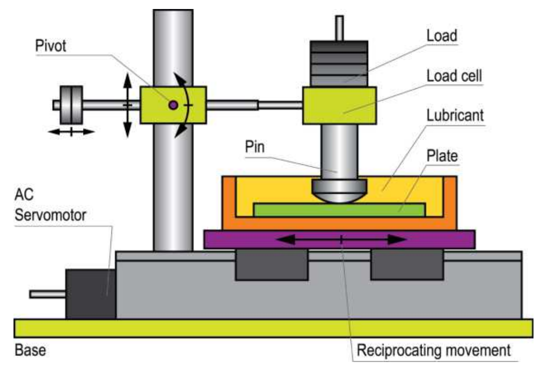

Figure 1 Schematic of reciprocating pin-on-plate type tribometer.

In this study, the friction coefficient was evaluated in six test lubricants with different compositions, listed in Table 2, to elucidate the influence of each synovia constituents added to the lubricant. Phosphate buffered saline (PBS) was used as a macromolecular-free control lubricant and also as a base solution of test lubricants containing synovia constituents. The macromolecule constituents of synovial fluid examined in this study are bovine serum albumin (BSA), γ-globulin (BSG), phospholipids (DPPC) and hyaluronic acid (HA). Each constituent was dissolved in PBS with physiological range of concentrations

Table 1 Composition of test lubricants.

Lubricant No.	Amount of synovia constituents (wt%)			
	HA	DPPC	Albumin	γ-globulin
1				
2	0.5			
3		0.01		
4	0.5		1.4	0.7
5	0.5	0.01		
6	0.5	0.01	1.4	0.7

In all sliding tests, the applied load was 4.9 N resulting to a maximum contact pressure of 6.3 MPa. Two different sliding speeds, 10 and 50 mm/s, were used, respectively. The stroke length was 25 mm, while the total sliding distance was 90 m. All the tests were carried out under controlled ambient temperature of 25 °C. To confirm the repeatability, the experiments were iterated three times under each condition with all the lubricants.

Results were compared with our previous results obtained in several protein solutions containing only serum proteins, BSA or/and BSG with different concentrations [5].

3. RESULTS AND DISCUSSION

Results of the friction measurement are compared in Figure 2. The UHMWPE / CoCrMo sliding pair showed very low friction coefficient less than 0.05 in the macromolecule-free PBS and the HA solution (Lubricant 1 and 2). However, it increased by adding DPPC to PBS (Lubricant 3). The effect of DPPC was further enhanced by mixing it with HA (Lubricant 5) and the friction coefficient reached 0.1. The influence of protein molecules was the most significant and the friction coefficient between UHMWPE and CoCrMo alloy exceeded 0.25 in protein-containing lubricants (Lubricant 4 and 6) especially under the higher sliding speed.

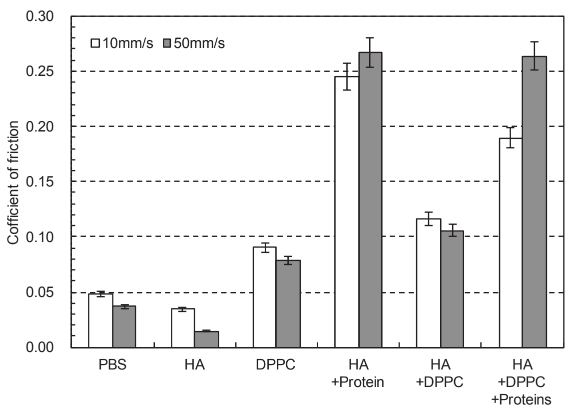

Figure 2 Comparison of friction coefficient.

In our previous experiments [5], the UHMWPE/CoCoMo sliding pair showed similar high friction with the friction coefficient of 0.25 in PBS-based lubricants containing only protein molecules. At that time, a linear relationship could be found between friction coefficient and the thickness of adsorbed protein film under the sliding speed of 10 mm/s and the friction coefficient increased as the protein film thickness increased. It might be indicating that larger percentage of real contact area was covered with adsorbed proteins as the amount of adsorbed protein increased and subsequently the friction coefficient was increased by the adsorbed and denatured proteins molecules.

The protein molecules also exhibited the predominant effect and increased the friction coefficient between UHMWPE and CoCrMo significantly even if they were mixed with DPPC and/or HA. Some interactions between these macromolecules could be expected to form complex aggregates if they were mixed together in aqueous solutions. However, the protein adsorption on the PE and metal surfaces might be strong enough to make effects of other molecules inconspicuous.

4. SUMMARY

Proteins and phospholipids contained in synovial fluid clearly increased friction of the UHMWPE / CoCrMo sliding pair. The effect of protein molecules was more conspicuous compared with DPPC and the friction coefficient exceeded 0.25 in the protein-containing lubricants, while it was less than 0.05 in the macromolecular free PBS. On the other hand, the effect of HA was quite limited.

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