Tribology of joint implants: characterization of frictional properties between bone and implant and coated knee implants using a pin-on-disk tribometer

Jiri Nohava[1)*], Charlotte Voutat[2)], Philippe Zysset[2)], Maria Herbster[3)]

[1)]Anton Paar TriTec SA, Corcelles, Switzerland
[2)]University of Bern, Institute for Surgical Technology and Biomechanics, Bern, Switzerland
[3)]Institute of Materials and Joining Technology, Otto-von-Guericke University, Magdeburg, Germany
*Corresponding author: jiri.nohava@anton-paar.com

Tribology of joint implants is very important because it affects the post-operational stability and performance of the joint implant during life. In this study we focused on the friction between the bone and the hip implant and on the frictional properties of coated knee implants. The coefficient of friction in relevant post operational conditions was measured and the effect of load, sliding speed and material was analyzed. The coefficient of friction of knee implants coated with several ceramic coatings against UHMWPE showed that the coated implants have similar CoF compared to uncoated implants.

Keywords: Friction coefficient, hip implant, knee implant, ceramic coating

1. Introduction

The bone-implant and implant-implant interface plays a key role in the clinical success of orthopedic implants. While the mechanical properties of joint implants are well known, the friction behavior between bone and implant was investigated only in a few studies. In this work we studied the effect of load, sliding speed and material on the tribological behavior between bovine bone and metallic implants. In the second study we focused on the friction behavior between knee implant with ceramic coatings against UHMWPE. The coatings on implants are used to prevent the release of metallic ions which can cause allergic reaction. The goal of this study was to confirm that ceramic coatings on metallic knee joints have similar or better friction properties compared to bare substrate.

2. Methods

All experiments were done using a pin-in-disk tribometer in linear reciprocating motion with the samples fully immersed in liquid. In the bone-implant friction study we applied load from 1 N (elastic regime) to 50 N (plastic regime); the sliding speed varied from 10^2 to 10^5 µm/s. Three implant materials were tested: 316L steel, Ti6Al7Nb and pure Ti. In addition, pure Ti was provided with different surface treatments. The counterbody was bovine bone in all cases. In the coated knee implant versus UHMWPE we applied load of 5 N and the average sliding speed was 48 mm/s. These conditions correspond to arthrokinematics of a knee movement. The coatings measured were TiN, TiNbN and ZrN deposited on CoCrMo and TiAl6V4 substrates. For comparison, also substrate without coating was tested. The counterbody was UHMWPE.

3. Results and discussion

Bone-implant interface: Our investigations showed that the CoF of bone versus implant is strongly affected by the load and the sliding speed. The decrease of the CoF with both factors suggested that under the selected conditions the contact is occurring in a mixed lubrication regime with an increasing load bearing by the fluid at larger speeds. The CoF for realistic physiological conditions (8 N load and 100 µm/s sliding speed) was determined for the three tested materials.

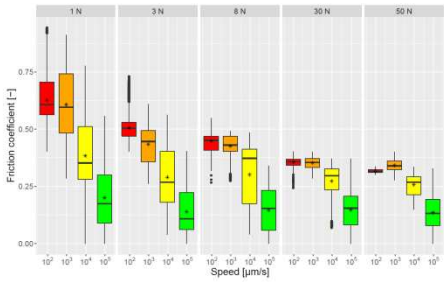

Figure 1: CoF as a function of sliding speed and load.

Coated knee implants: The friction tests revealed that the TiN and TiNbN coatings have similar friction behavior as the uncoated CoCrMo alloy. The ZrN coating has slightly lower CoF while the uncoated TiAlV has the highest CoF. The difference in the CoF is very likely due to the variation in surface roughness and lower elastic modulus of the TiAlV. The results show that the frictional behavior of coated implants is similar or even better than that of uncoated substrate alloys. The tested ceramic coatings are therefore suitable for patients with allergic reaction to metallic ions.

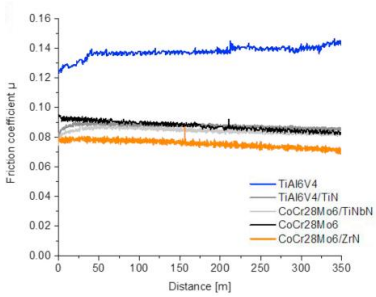

Figure 2: Evolution of the CoF as a function of sliding distance for the coated and uncoated knee implants.

4. References

[1] Voutat, C. et al: "The dynamic friction coefficient of the wet bone-implant interface: influence of load, speed, material and surface finish." Biotrib. 17, 2019.

[2] Herbster, M. et al., "Retrieval Study of Commercially Available Knee Implant Coatings TiN, TiNbN and ZrN on TiAl6V4 and CoCr28Mo6." J. Mech. Behav. Biomed. Mat. 112, 2020.