Integration of Biomechanics and Biotribology for Functional Prediction of Artificial Joints

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Tribological considerations have improved the materials selection and design of the bearing surfaces of artificial joints and consequently extended the clinical life-time of the prostheses. However it has become increasingly recognised that tribological considerations alone may be limited to further improve the clinical performance of artificial joints and biomechanical considerations may also be necessary. Biomechanical considerations not only provide the load and motion inputs required for the tribological studies, but also tribological considerations may affect the biomechanical predictions. Such an integrated approach is able to consider the implants as well as the patients and the surgeons. The purpose of this study is to review the current literature and to highlight the integrated biomechanical and biotribological studies of artificial joints.

Keywords: artificial joints, biotribology, biomechanics

1. Introduction

Artificial joints have been developed considerably in the last fifty years, with significant progresses particularly evident in the last twenty years. One of the major developments is the application of tribological principles to the deign and optimisation of the bearing surfaces for artificial joints. Significant improvements have been made in the use of of bearing surface combinations, design optimisations and manufacturing techniques. Consequently, wear and wear debris induced osteolysis has become less an issue and the general life-time expectancy of these man-made bearings has been shown to be much increased, often exceeding 25 years.

However many problems have also been recently encountered in the development of artificial joints. Some of the advantages found in laboratory testing have not been translated into clinical practice, particularly for metal-on-metal hip implants. Furthermore, once the wear of the bearing surfaces has been greatly reduced such as in the case of using highly cross-linked polyethylene, other issues have become more evident. The requirements of the artificial joints have been shifted from mainly life-time expectancy to functional performances. For example, there are still a significant proportion of the patients with joint replacements who are not satisfied with their implants. It is becoming increasingly clear that surgical techniques and patients anatomy and biomechanics, along with implants are all important. A holistic approach is required to balance the functional requirements of the patient and life-time of the implant in the context of the patient specificity. Coupling biomechanics of the joints and biotribology of the bearing surfaces become one of the most important considerations.

2. Methods

Biomechanics and biotribology studies of artificial joints were firstly reviewed separately. This was then followed by identifications of potential interactions, particularly when the change of one aspect would significantly affect the other. Two main interactions with varying coupling degrees between patients, implants and surgical techniques were reviewed, including:

- The change of the biotribology of the bearing surfaces of artificial joints as a result of the change of the biomechanics of the joints
- The change of the biomechanics of the joints as a result of the change of the patients, the implants and the surgical implantation as well as tribology such as wear (1).

3. Discussion

The importance of the loading and motion inputs for the tribological testing of artificial joints is well recognised. There are many recent studies as well as ISO and ASTM standards which have focused on the developments of more realistic input conditions and under more adverse conditions and worst case scenarios. Despite of these developments, the loading and motion in a patient depends on not only the patient itself but also the implant and the surgical implantation. Such inputs are important considerations for the tribology of the bearing surfaces of the implant, but equally important are the consideration of the tribology of the implants which may influence the biomechanics of the joint. The interaction between the biomechanics of the joints and the biotribology of the bearing surfaces becomes important. An integrated biomechanics and biotribology analysis framework of artificial joints needs to be developed such that the patient specificity can be considered and both the life-time of the implant and the functions of the patients can be addressed.

4. References

[1] Zhang J et al "A patient-specific wear prediction framework for an artificial knee joint with coupled musculoskeletal multibody-dynamics and finite element analysis", Trib Int., 109, 2017, 382-389