Experimental study on the lubrication in total knee replacements: The influence dynamics and synovial fluid constituents

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The amount of total knee arthroplasties has been continuously increasing. The estimations say that in ten years, number of the replaced knees will overtake hips in a global scale. In order to extend the durability of implants, tribological processes need to be understood. The present study utilizes knee simulator in combination with fluorescent microscopy, enabling *in situ* observation of the contact of knee implant components. Real geometry is considered and transient dynamics is applied. The main attention is paid to the clarification of the behavior of individual synovial fluid constituents. A novel lubrication model for knee replacement is further proposed.

Keywords (from 3 to 5 max): total knee replacement, lubrication, synovial fluid, dynamics

1. Introduction

Total knee arthroplasty has become a routine procedure for patients suffering from knee osteoarthritis. Since limited longevity due to osteolysis [1] associated with excessive wear is often recognized as one the main drawbacks of the replacements, better understanding of tribological processes is desired. The present study is aimed at an identification of lubrication mechanisms occurring in the knee replacement, focusing on the contact behavior, dynamics, and the role of specific synovial fluid (SF) constituents. The experiments are validated by means of the established numerical model.

2. Methods

A knee simulator, enabling to apply transient dynamic conditions according to ISO standard, was used. Contact of real femoral component and transparent polymer insert was observed *in situ*, adopting optical fluorescent method [2]. Initially, the contact was lubricated by mineral oil enabling to compare the experimental data with the developed EHL model. Further, the contact was lubricated by various model solutions mimicking human SF. Specific constituents, i.e. albumin, γ-globulin, and hyaluronic acid (HA) were fluorescently stained allowing to focus on its role in film formation process. Evolution of film thickness as a function of time was studied.

3. Results and Discussion

The results showed substantial migration and change of the contact zone throughout the cycle. The experiments performed with mineral oil revealed good compliance with numerical prediction based on the model presented in another contribution. Focusing on the specific constituents of SF, the results have pointed at the importance of mutual interaction. Specifically, it was found that γ-globulin together with HA form thin boundary film. Further development of lubricant film is attributed to layering of albumin. Focusing on the lateral and medial compartments, the lateral part exhibited improved lubrication conditions, which is in compliance with literature [3] and worse conditions of medial part often observed during revising surgeries. The time test later showed that continuous loading lasting for minutes leads to thinning of the lubricant layer. Therefore, rest periods during walking are highly recommended while these may be essential to improve implant durability.

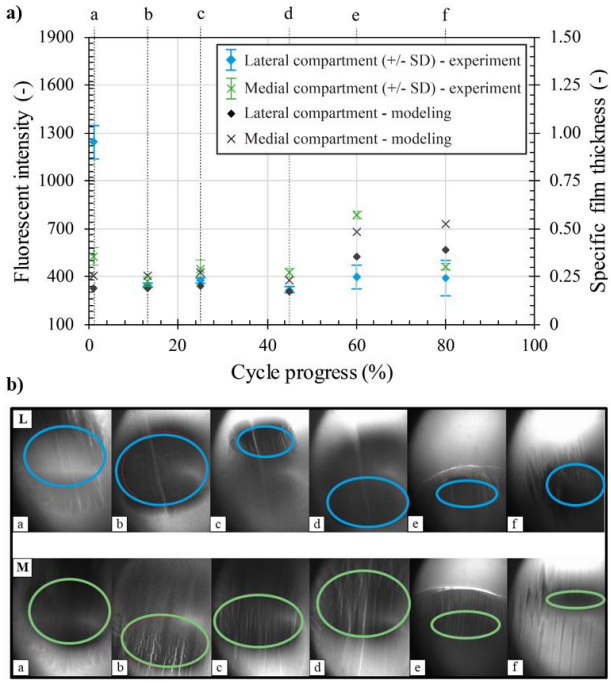

Figure 1: (a) Dimensionless film thickness at specific locations. (b) Contact images of the observed zone.

4. References

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