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Ultra-low friction in cornea-lens contact: analysis of dynamic free responses measured by the Dynamic Oscillating Tribometer

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Friction coefficient is considered as a measurement for clinical comfort of soft contact lenses. In this work, we aim to evaluate the friction at the cornea-lens contact using a new technique. This technique is based on a single-degree-of-freedom (SDOF) mass-spring system having a sliding contact. The experimental technique measures the free responses of the mechanical system. Then, the friction is evaluated from the damped free responses with a high accuracy. A variety of soft contact lenses is tested with and without lubricant at many physiological conditions. The results are finally discussed and compared with those in the literature.

Keywords: Soft Contact Lenses (SCL), friction, free response, dynamic oscillating tribometer, damping

1. Introduction

Comfort is the most significant factor for soft contact lenses (SCL) wearers. The comfort of SCL is affected by many factors, including those related to the patients and to contact lens material [1]. The friction coefficient is considered as a measurement for clinical comfort of soft contact lenses. This study aims to evaluate the friction at the cornea-lens contact. In order to evaluate precisely the ultra-low friction at the cornea-lens contact, an original technique developed at the Laboratory of Tribology and System Dynamics (LTDS), called "Dynamic Oscillating Tribometer" [2], is used.

2. Methods

A variety of soft contact lenses is tested in contact with and without lubricants. Moreover, different materials are used as counter-surfaces with the SCL. Some eye drops lubricants are added to mimic the tear.

2.1. Experimental Setup

The tribometer consists of a pin-on-plane contact tribometer. This tribometer is based on a single-degree-of-freedom (SDOF) mass-spring oscillator system supporting the sliding contact. Figure 1(a) and (b) shows respectively a schematic representation of the tribometer and the measured velocity response of the contact between a sapphire pin against a SCL fixed on a steel plane, swelled in diluted boric acid as a lubricant, with an applied load of 700 mN. The friction is analyzed from the decaying envelope of the free response [3]. The surfaces are modified in order to test different scenarios for the contact lenses.

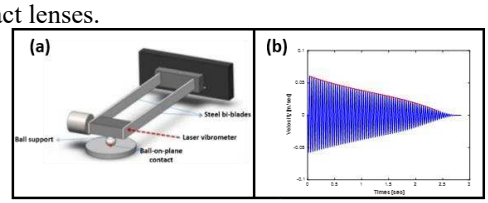

Figure 1: Dynamic oscillating tribometer measurement

2.2. Operating conditions

The experiments are performed at room temperature with different applied normal loads and sliding velocities (Table 1). The sliding speed corresponds to the typical eye blink speed. A maximum sliding speed of $60mm/s$ is applied which corresponds almost to the maximum blinking speed while opening the eyelid. The contact pressure is related to the normal load as well as the elastic deformation of the lens. It is determined using the elastic-foundation model (EFM). An ageing protocol has been applied to the soft contact lenses.

Table 1: Operating conditions.

Normal load (mN)	50-700
Sliding speed (mm/s)	0-60

2.3. Results

The free responses are measured at the pin-plane contact thanks to the new technique. Using a defined friction law, the different friction contributions, μ_j,are identified [4] by solving the following non-linear equation of motion:

$$m\ddot{x} + kx = -\sum_{j=0}^{n}[\mu_{2j}\dot{x}^{2j}\mathrm{sgn}(\dot{x}) + \mu_{2j+1}\dot{x}^{2j+1}]\,N \quad (1)$$

3. Discussion

Preliminary results show the feasibility of measuring friction at the cornea-lens contact using the oscillating dynamic tribometer. The results have also demonstrated that precision is high for low friction coefficients. The friction coefficients of the different soft contact lenses at different operating conditions are compared to the results found in literature.

4. References

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