Role of phospholipidic structures in the tribological performances of synovial fluids associated with different types of human joint pathologies

Layth Ben Trad [1,2,6] , Constantin Ionut Matei [1,3] , Mirela Maria SAVA[1], Yves Berthier [1], Marie-Geneviève Blanchin [3], Michel Guichardant [4], Pierre Miossec [5] , Ahmed Landoulsi [6],Ofelia Maniti [2], Thierry Granjon [2], Ana-Maria Trunfio-Sfarghiu [1]

1 Université de Lyon, INSA-Lyon, LaMCoS & CNRS UMR-5259, 69621 Villeurbanne, France,

2 Institut de Chimie et Biochimie Moléculaires et Supramoléculaires, ICBMS UMR 5246, CNRS, Univ Lyon, Université Lyon 1, Lyon, France

3 Université Lyon 1, Institut Lumière Matière & CNRS UMR-5506, 69621 Villeurbanne, France,

4 Université de Lyon, INSA-Lyon, Institut Multidisciplinaire de Biochimie des Lipides de Lyon, 69621 Villeurbanne, France

5 Université Lyon 1, Unit of Immunogenetics & Inflammation EA-4130 & Department of Clinical Immunology and Rheumatology, Hôpital Edouard Herriot, 69437 Lyon, France ∗

6 Laboratoire de Biochimie et Biologie moléculaire, Risques liés au Stress Environnementaux : lutte et prévention, Faculté des sciences de Bizerte, 7021 Tunisie

Corresponding author: layth.ben-trad@insa-lyon.fr

The quality of the joint lubrication between the cartilage surfaces is responsible for the remarkable mechanistic properties of synovial articulations. The synovial fluid (SF), which acts as a lubricating film, is discontinuous and contains micro vesicular structures coated by lipid/water multilayers. The goal was to define the ultrastructural, biochemical and tribological signature of SFs from healthy donors, patients with degenerative (osteoarthritis) or inflammatory (rheumatoid arthritis) joint pathologies. SFs collected in these contexts were analyzed by transmission electron microscopy, by biophysical methods including spectroscopy, rheological tribological tests and by biochemical assays.

Keywords (from 3 to 5 max): lubrification, synovial fluid, biophysics

1. Introduction

Synovial articulations have remarkable mechanistic properties: they can sustain various types of movement combined with an exceptional lifetime of up to 80 years. Several hypotheses have been formulated to explain the mechanisms of joint lubrication, in particular the nature of the interactions between the cartilage and the synovial fluid (SF), and the SF tribological behavior. It was first proposed that the SF consisted of a continuous full-fluid lubricating film of ~ 0.5 µm, which separated the two cartilage surfaces and reduced both friction and wear {Dowson, 1967 #1}. However, recent biological studies showed the presence of discontinuities in the lubricating film, and microvesicles of a few µm in diameter were identified in samples of rat synovial fluid {Watanabe, 2000 #2}.

2. Methods

SFs collected in these contexts were analyzed by transmission electron microscopy, and by biophysical methods included spectroscopy, rheological and tribological tests.

2.1. Transmission electron microscopy (TEM)

Samples of SF were adsorbed on carbon-coated copper grids negatively stained then air-dried were observed under a TOPCON 02B electron microscope

2.2. Tribological and Rheological analyses

Tribological measurements were carried out using a home-made biotribometer, in order to mimic as realistically as possible the operating conditions for a synovial joint in a boundary lubrication regime

2.3. Biochemical assays

The exact lipid composition of synovial fluid was determined using different analytical techniques like gas chromatography and thin layer chromatography

2.4. Results

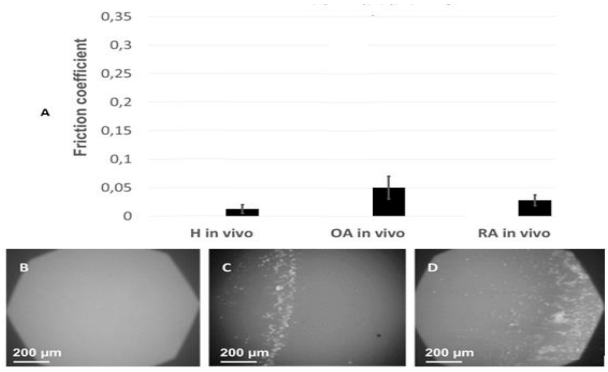

Figure 1: Tribological results: at the top the values of the friction coefficients and at the bottom the fluorescence images showing: non-degradation (B healthy synovial fluid: image showing uniform fluorescence - bright field inside the black octagon of the diaphragm focus of the microscope) and degradation (C human pathological non-inflammatory synovial fluid and D human inflammatory pathological synovial fluid - images showing clearer stains) of the lipid bilayers format the friction interface of a model joint contact (HEMA hydrogel / glass) joint contact.

3. Discussion

The aim of the present study was to try and correlate ultrastructural, biochemical, and nanomechanical properties of various types of clinical SF samples with the nature of the human joint pathologies involved. The short-term goal was to obtain some clues for a better diagnosis and prognosis of joint diseases. In the long term, the results of our study should help to establish more precise guidelines for potential therapeutic substitution of defective SFs by an in vitro reconstituted, nanomechanically functional SF