CARTILAGE BOUNDARY LUBRICATION – THEORY OF SELF-ASSEMBLING NANOLAYERS

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Introduction

Articular cartilage has a frictional properties that remains unmatched by industrial joints. The mechanisms by which the synovial joint achieves these properties involve combination of biomechanical and biomolecular factors. Synovial fluid plays multiple roles in joint lubrication by providing a high viscosity "squeeze film" layer that delays cartilage to cartilage contact under compression but also serves as a source of boundary lubricant molecules within the joint. The principles of cartilage lubrication has been studied for many decades, but the exact lubrication mechanism remains unclear. In the last decades, it has been proposed that surface-active phospholipids (SAPL) serve as the major boundary lubricant. Lamellar structures of phospholipids reduce the coeffcient of friction thus lessening wear of the articular surfaces, even under high loads. The aim of this contribution is to propose mechanisms of cartilage lubrication mediated by self-assembling phospholipid layers.

Superficial cartilage layer

The upper-most layer of cartilage is crucial in boundary friction of cartilage. Recent studies identified additional surface layer over the lamina splendens . This layer was revealed as being acellular and nonbrous, i.e. amorphous and is beeing denoted as the surface amorphous layer (SAL). Based on the AFM and histochemical analysis, it can be concluded that SAP consists of phospholipids, hyaluronan and proteins.

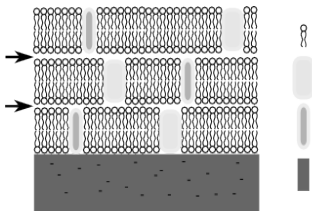

Figure 1: Structure of surface cartilage layer.Adapted after Pawlak, 2008. Arrows inidicate friction surfaces.

Lubrication theory

Based on the fact that phospholipids have been identified in appreciable quantities in synovial fluid and cartilage SAP, it was hypothesized that a lamellar phospholipid adsorbed to the articular surface contributes to joint lubrication [Pawlak, 2008]. However multiple experiments indicate that the effective lubrication of synovial joint is multifactorial and includes active interactions of SAPL, hyaluronic acid and lubricating proteins within the surface amorphous cartilage layer and in the synovial fl
uid. It seems that single lubrication molecule does not exist and synovial joint highly effective lubrication is a results of synergic effect of various molecules or complexes. The similar situation might be observed in biolocal membranes that are fluid complexes of phospholipids and proteins. It is reasonable to expect similar structure at cartilage surface. That structure would be virtually undestroyable as it can form itself after destruction while the relative motion between the protein/phospholipid layers might provide low friction interface.

Conclusions

Further research in this field might be directed towards creating articially prepared films using advances in nanotechnology as model structures to study the properties and complex mechanisms of native cartilage lubrication. For treatment of ostearthritis, it is important to clarify how exactly the synthetic mixtures act when introduced into the body and in contact with worn articular cartilage. New material and/or functional surfaces in arthroplasty that mimics healthy joint lamellar lubrication are worthy of further consideration as well.

References

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