# A NUMERICAL MODELLING APPROACH TO STUDY THE ARTICULAR CARTILAGE AT DIFFERENT SCALES

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## Introduction

Both the structure and composition as the mechanical properties of articular cartilage are strongly tissue depth-dependent. Afterwards, when the scale of phenomena decreases, experimental studies on native or engineered cartilage become more difficult, and we must rely on the numerical analysis. The FE analysis of cartilage has been extensively used [Ateshian, 2007]. However, it is well known that the accuracy of numerical results is strongly dependent on the prescribed boundary conditions, which are not very easy to set at a subscale modelling. The main purpose of this work is to develop a multi-scale computational FE model to contribute to improve our understanding about the biomechanical properties of the native cartilage, by linking the boundary conditions at the subscale model with a numerical simulation on the macro-scale.

## Methods

A multi-scale FE approach is being proposed to study the complex structure and growth of articular cartilage. Using a FORTRAN home-code FE solver [Alves, 2010] and adopting a biphasic formulation, it is possible to investigate the macro domain and calculate the strain, pressure and flux fields under different loadings. The numerical simulation with the macro-scale FE model (Fig. 1) will be used to determine the so-called "natural" boundaries to be imposed to the 1st subdomain FE model, which are automatically determined from the larger scale simulation. This new feature will allow to jump successively from scale, taking successively the naturally boundary conditions from the larger to the next. Simultaneously, an analysis of the volume fraction of tissue constituents, the orientation of collagen fibres and the permeability in the mechanical response of the cartilage is performed.

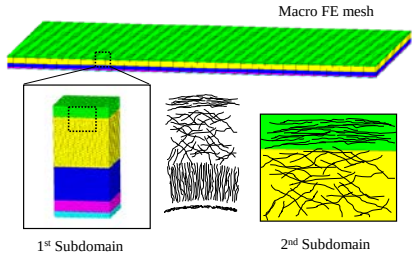


*Figure 1 - Schematic representation of macro and 1st and 2nd subdomain of the articular cartilage with five different layers.*

## Results

Deformation and pressure gradients of the tissue under different loading conditions at macro and subdomain models are investigated. Through the 2nd subdomain (Fig.1), it is possible to analyse the behaviour of collagen fibres, the proteoglycans and consequently the permeability for each layer of the tissue. The first results will be drawn.

## Discussion

This new multi-scale approach has a great potential to investigate the biomechanical response and growth of native and engineered cartilage, in order to determine the intrinsic growing factors and the mechanical stimuli associated to regeneration and degeneration mechanisms of the tissue. This new approach can be applied in tissue engineering, to improve culture protocols for clinical application.

## References

Ateshian, Biomech Model Mechanobiol, 6:1-3, 2007; Alves *et al.*, Proc CMBBE Symp, 43-48, 2010.

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