Relevance of the Spatial Distribution Pattern of Mechanical Properties of Articular Cartilage in Animal Studies

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Statement of Purpose: In cartilage regeneration and repair, mechanical testing of articular cartilage characterizes functional restoration of the repair site [1] and can detect early degeneration of articular cartilage [2]. However, the experimental design often incorporates the use of cartilage adjacent to the treated site or at contralateral sites as normal references to evaluate the effect of treatment [1]. In doing so, the natural spatial distribution of the properties of the normal articular cartilage is rarely taken into account. Neglecting this spatial variation of the cartilage properties will increase variability of the results and could compromise study outcome. The purpose of this study was therefore to assess the importance of taking into account the spatial distribution of the mechanical properties of normal articular cartilage in animal models of cartilage repair, specifically the distributions of thickness and instantaneous modulus.

Methods: Visually normal tibial plateau and femoral condyles (right and left joints) from three rats (aged 8 weeks, female), three rabbits (aged 13-14 weeks, male) and one sheep (aged 4-5 years, male) were used in this study since they are widely chosen in cartilage regeneration and repair studies [3]. Mechanical properties were mapped *ex vivo*, using a novel technique allowing for automated indentation mapping. The multiaxial mechanical tester Mach-1 v500css (Biomomentum Inc., Laval, Quebec) indents the articular surface at each position (at least 50 positions per articular surface) by moving a spherical indenter (radius=0.5 mm) along a vector perpendicular to the surface while measuring the resulting perpendicular load. Subsequently, the thickness was measured with an adapted version of the needle technique [4]. The instantaneous modulus at each position was obtained by fitting the load-displacement curve (with corresponding thickness) to an elastic model of indentation [5].

Results: Mappings of the thickness and the instantaneous modulus for the tibial plateau and femoral condyles of the three species were generated (Fig. 1). Measured thickness agrees with those reported in the literature [6]. The spatial distribution of thickness and instantaneous modulus reveals a large difference between regions covered and not covered by the meniscus and also between the medial and lateral sides for both articular surfaces. Effectively, a thinner and stiffer cartilage can be observed in regions in contact with the meniscus while a thicker and softer cartilage is observed on the rest of the surface whereas this topographic pattern is more striking in tibial plateau than femoral condyles.

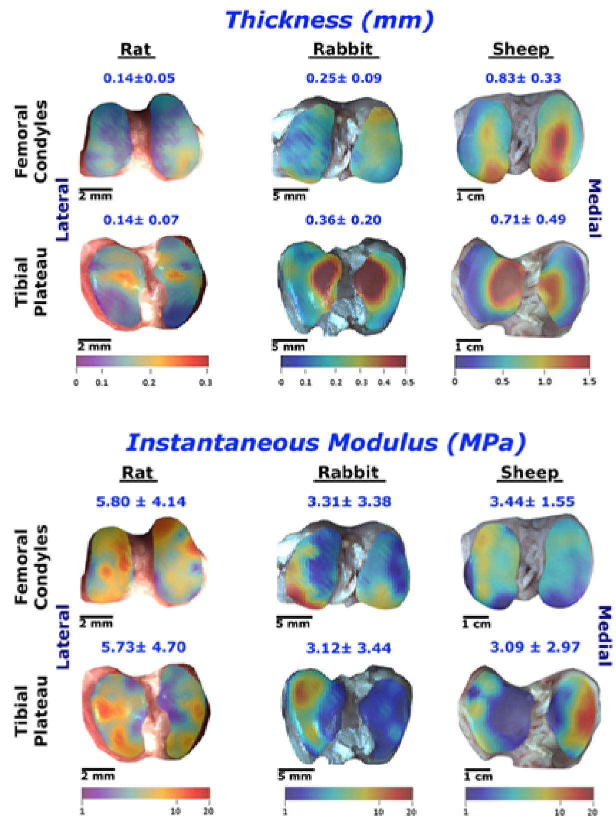

Figure 1. High-resolution mapping of the thickness and instantaneous modulus obtained on rat, rabbit and sheep articular surfaces

Conclusions: For the three species, cartilage thickness and instantaneous modulus can vary by a factor up to 10 over a distance of only 5% of the total articular surface width (Fig. 1). These steep spatial variations in the mechanical properties of cartilage could easily obscure the real effects of a treatment. Therefore, we strongly recommend taking into account the spatial distribution of cartilage properties in the study design. These thickness and modulus maps clearly show that any difference between treated and normal cartilage could be due to a natural topographic variability rather than the treatment itself. In conclusion, this study shows the relevance of biomechanical characterization of the entire surface in animal studies of cartilage regeneration or repair.

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