A CONTRAST-ENHANCED X-RAY IMAGING APPROACH FOR CHARACTERIZING ARTICULAR CARTILAGE

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Introduction

Articular cartilage is a highly heterogeneous tissue mainly composed by water, proteoglycans and type II collagen. The onset of degenerative diseases (i.e. osteoarthritis) deregulates the homeostasis of this tissue since their early stages, requiring diagnostic techniques capable of detecting any subtle initial changes. Despite X-ray imaging is widely used for joint examination, low differentiation of soft tissues hinders the evaluation of cartilage tissue. The affinity of contrast agents (CAs) to specific components of cartilage tissue has been proposed to increase X-ray absorption of cartilage tissue. Nevertheless, the use of CAs should not impair the functionality of soft tissues. The aim of this study is to investigate the impact of a cationic, iodine-based CA (CA4+) on cartilage mechanical behaviour and radiopacity.

Methods

Osteochondral cores (Ø=10mm, h=10mm) were harvested from bovine stifle joints. Osteochondral cores underwent indentation test at a strain rate of $0.15s^{-1}$ (Mach-1, Biomomentum). The maximum nominal deformation of 15%, applied by a 6-mm spherical indenter, was maintained for 300s [1]. Three test repetitions were performed at 40 min time intervals. Experimental curves were fitted to Hayes [2] and stretched exponential model [3] to estimate cartilage elastic (instantaneous modulus E_0) and viscous response (time constant τ and stretching parameter β), respectively. Afterwards, cores were subdivided into treated and control groups, exposing their cartilage tissue to CA4+ and PBS bath, respectively, for 22 h at room temperature [4]. Cores from both groups were then subjected to the previously described indentation protocol, (i) to investigate possible changes in cartilage mechanical properties induced by CA4+, and (ii) to assess any dependence of cartilage response on test repetition. Aiming to investigate the distribution of CA4+ in cartilage tissue, cores from treated group were then acquired with a clinical HR-pQCT (XtremeCT II, SCANCO Medical AG), at 60-µm isotropic voxel size. Data analysis – i.e., cartilage thickness, data fitting, CA4+ volumetric distribution – was performed with custom-made codes (MATLAB 2022b, MathWorks).

Results and Discussion

Contrast enhancement did not induce significant changes in E_0 values, although large data scattering was found in treated specimens. Conversely, both PBS preservation and contrast enhancement significantly decreased τ values, although the effect was higher in control group. Negligible effects were found in β values, regardless the core treatment or test repetition.

Volumetric analysis provided depth-wise distribution of the CA4+ across the entire cartilage thickness (**Fig. 1)**, allowing to differentiate its main sub-layers. Overall attenuation significantly correlated to E_0 ($R = 0.75$, $p < 0.05$).

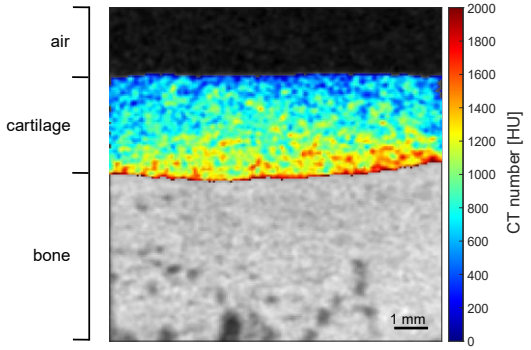

Figure 1: HR-pQCT image of one sample from the treated group, acquired after 22h of immersion in CA4+ solution.

Conclusions

Preliminary results support the use of CA4+ for pre-clinical purposes. Proteoglycan content pointed out by contrast-enhanced HR-pQCT suggests correlation with cartilage instantaneous response to indentation. Due to overall effects, induced on tissue parameters by CA4+, correlation with cartilage properties measured prior to contrast enhancement should be considered. Further investigation on reversibility of CA4+ effects on cartilage properties, and CA4+ safety for eventual clinical applications, are required. Future activities will deal with correlations between cartilage mechanical properties and composition.

References

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