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Investigating depth-wise cell properties in articular cartilage via synchrotron phase-contrast microtomography

Introduction: Osteoarthritis (OA) is a debilitating joint disease affecting the middle-aged and elderly population, characterized by the progressive degeneration of cartilage and other joint tissues (1). Since the mechanisms are not fully understood, there is a need for non-destructive, high-resolution methods to identify structural changes in different disease stages. Phase-contrast synchrotron microtomography is a novel technique which enables high contrast in soft tissues such as cartilage and meniscus (2). Here we aim to investigate depth-wise cell properties in human cartilage, in order to understand the potential interplay between cell morphology change and tissue matrix degradation during OA progression.

Methods: We imaged ~4 mm diameter medial compartment human articular cartilage plugs (n=51, ages 18-84y), from donors without known knee OA (n=47) and total knee replacement (TKR) patients (n=4). Samples were imaged at the TOMCAT beamline (PSI, Switzerland) (2.7 µm voxel size, 21 keV, 40 cm propagation distance, 9 ms exposure time, 2000 projections) for an effective resolution of ~9 µm. Cells were segmented using an adaptive thresholding algorithm to determine depth-wise properties.

Results: Images clearly visualize cells in healthy samples as well as substantial fibrillation and cell morphology changes in TKR samples (Fig. 1). Qualitative analysis showed increased cell density and cell cluster size in deeper layers of cartilage.

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Discussion: Being a full 3D technique, synchrotron tomography reduces the intra-sample variance inherent in studying 2D-slices allows for more robust studies of cell properties and their connection to donor age and disease state. Furthermore, this technique is non-destructive and does not require fixation or contrast agents, enabling in-situ experiments as well as combination with other techniques.

(1) Hunter and Bierma-Zeinstra. The Lancet, 2019
(2) Einarsson, et al. Osteoarthritis and Cartilage, 2022

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