Monitoring Early-Stage Osteoarthritis in a Tissue-Engineered In Vitro Model Using Near-Infrared Spectroscopy

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Abstract:
Osteoarthritis (OA) is a highly disabling condition of the joint characterized by persistent inflammation and the degradation of articular cartilage. Currently, there is no cure for OA due to limited understanding of OA pathophysiology. As animal models fail to accurately replicate the human condition, we aim to develop a human stem cell-based model of early-stage OA using tissue engineering (TE). This approach will yield a platform for personalized OA drug screening.

In our previous work, we developed a near-infrared (NIR) spectroscopy-based setup for monitoring TE constructs without interfering with the culture process. In the current study, we aim to develop spectral data analysis pipelines capable of estimating OA disease state.

In this study, TE constructs were prepared by embedding human bone marrow-derived mesenchymal stem/stromal cells in gellan gum hydrogels. The constructs were cultured for up to 21 days in chondrogenic differentiation medium to promote cartilage formation. After 14 days of culture, OA was induced using pro-inflammatory cytokines (human recombinant TNF-α, IL-6 and IL-1). NIR spectra were obtained every 24h using our custom setup.

Our preliminary analyses show that NIR spectra from constructs treated with pro-inflammatory cytokines and especially its conditioned medium were distinct from control constructs. A support vector machines model classified in situ spectra and conditioned medium with high accuracy as coming from OA-induced or control constructs. We also observed a progressive increase in secreted hyaluronan concentration in conditioned medium after OA was induced. Overall, our results are promising and would be utilized for the development of a machine learning model for monitoring early-stage OA using NIR spectroscopy.