Adaptation of Near Infrared (NIR) Spectroscopy for In Situ Monitoring and Optimisation of Tissue Engineered Cartilage Growth

Authors:

Harini Karunarathna[1,2,3], Nithin Sadeesh[1], Omar Elkadi[1], Antti Eskelinen[4,5], Ervin Nippolainen[1], Arjen Gebraad[1,2,]3, Susanna Miettinen[2,3], Isaac O. Afara[1]

[1] Biomedical Spectroscopy Laboratory, Department of Technical Physics, University of Eastern Finland, Kuopio, Finland
[2] Adult Stem Cell Group, Faculty of Medicine and Health Technology, Tampere University, Tampere, Finland.
[3] Tays Research Services, Wellbeing Services County of Pirkanmaa, Tampere University Hospital, Tampere, Finland.
[4] Coxa Hospital for Joint Replacement, Tampere, Finland.
[5] Faculty of Medicine and Health Technology, Tampere University

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Abstract

Articular cartilage lesions may remain clinically silent and unnoticed for decades while morphologically progressing to osteoarthritis. As current cartilage repair procedures often fail to restore long-term physiological tissue function, tissue engineering (TE) poses an alternative for creating viable replacement tissues. In this project we develop new protocols for monitoring and controlling cartilage TE using near infrared spectroscopy (NIRS), an optical spectroscopic technique that has gained interest for evaluating connective tissue integrity.

We conducted cartilage TE using human bone marrow mesenchymal stem/stromal cells seeded in gellan gum hydrogel. Constructs were cultured for up to 4 weeks in established serum-free chondrogenic differentiation medium. NIRS measurements were conducted every 24h, directly on the TE constructs using a custom setup without interfering with the TE process. Constructs were harvested at various time points (1, 3, 7, 14 and 28 days) and subjected to biomechanical testing and extensive tissue reference analysis to determine key biochemical constituents, such as glycosaminoglycans, collagen and water content, which are important biomarkers of tissue growth and development. We have assessed the relationship between the spectra and culture duration using machine learning models. Out of them, the top performing model was AdaBoost.

Results of spectral data analysis show that NIRS can predict the duration of culture, indirectly linked to the quantity of matrix deposition. Hence, our preliminary analyses suggests that NIRS can accurately predict TE cartilage properties in real-time. We will use our novel NIRS monitoring protocols to assess the effect of mechanical loading on tissue growth in a bioreactor.