Continuous non-destructive conductivity monitoring of chondrogenesis using bioimpedance tensor probe

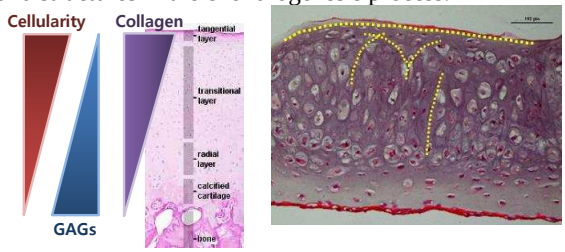
Geuk Young Jang[1], EunAh Lee[2], Hun Wi[1], Eung Je Woo[1] and Tong In Oh[1]

[1]Department of Biomedical Engineering, Kyung Hee University, Yongin, Republic of Korea, tioh@khu.ac.kr
[2]College of Life Science and Graduate School of Biotechnology, Kyung Hee University, Yongin, Republic of Korea

Abstract: A continuous non-destructive monitoring method is required to apply proper feedback controls during chondrogenesis. We measured the apparent conductivity and the amount of anisotropy on the top and bottom surfaces of samples in the chondrogenesis process to evaluate the ECM structure and composition changes. We compared them with histological trait to analyse the results.

1 Introduction

There are many reports to demonstrate that nerve or tissue regeneration is a successful treatment modality in skin, muscle, nerve and periodontal reconstruction. Implantation of tissue engineered cartilage replacing degenerated cartilage tissue is expected to show the normal cartilage function shortly with reference to other methods [1]. In order to control the quality of productions, non-destructive, continuous monitoring and proper feedback control based on monitoring results are required during chondrogenesis. We considered that the conductivity of cartilage after formation was quite different from the conductivities of chondrocytes and stem cell growth medium. Additionally, the cellularity and contents in the extracellular matrix (ECM) structure are different depending on the zonal organization as shown in Figure 1 [2]. In this study, we observed the apparent conductivity and anisotropic conductivity on the top and bottom surfaces related with different ECM compositions and structures in the chondrogenesis process.



(a) (b)

Figure 1: (a) Structure of depth-dependent ECM components in articular cartilage and in-vitro constructed cartilage.

2 Methods

Fragments of costal cartilages were obtained from lower false rib of 3-4 month old New Zealand White rabbits [3]. Perichondrium was extracted from cartilage tissue and minced. We filtered the digested cartilage in 0.5% collagenase type I with Mesenchymal stem cell growth medium. In-vitro expanded chondrocytes were seeded in a Millicell cell culture inserts in order to construct disc-type cartilage.

We used the bioimpedance tensor probe employing a conductivity estimation algorithm with 16 electrodes to eliminate the geometrical effects and accurately measure the tissue conductivity and its degree of anisotropy [4]. For 6 weeks, we measured conductivity and the ratio of eigenvalue to estimate the degree of anisotropy. We could not measure conductivity on the bottom surface before two weeks because chondrocyte was not formed as the gel type.

3 Results

Conductivities on the top and bottom surfaces were decreased by the time continuously. Even though the thickness of the sample was not increased much after 4 weeks, the conductivity was changed. Also, we can clearly discriminate the top and bottom after 2 weeks. This difference may be caused by the ECM compositions. The ratio of eigenvalue also differed between them after 3 weeks. It revealed that the ECM had different shape in the depth-dependent stratified structure.

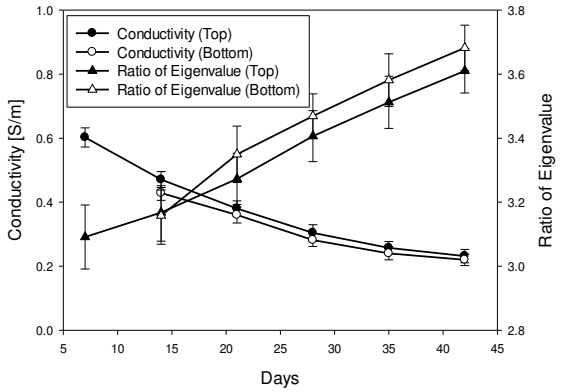


Figure 2: Variation of conductivity and the ratio of eigenvalue during chondrogenesis (6 weeks).

4 Conclusions

Tissue or nerve regeneration is the most promising treatment to replace and heal the functionality inside the body. However, it requires a continuous, non-destructive, and label-free monitoring method for proper feedback controls to improve the productivity and the quality of the final implant. Impedance characterisation will be a feasible technique for tissue regeneration monitoring.

References

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