Effect of negative Poisson's ratio of polyurethane scaffold on chondrocyte behavior with mechanical stimulus

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Introduction: Material with negative Poisson's ratio (NPR) exhibits unusual properties, such as, fatter when stretched and thinner when compressed [1]. In last two decades, NPR behavior was predicted, discovered, or deliberately introduced in various materials, such as, foams and microstructued polymers [1, 2]. NPR materials are known to exhibit various enhanced physical characteristics over their conventional counterparts [1]. They showed increased indentation resistance and improved acoustic damping properties. These enhanced characteristics make NPR materials perform better in many practical applications. Although these enhanced properties of NPR material have been focused on industrial and academic fields, there were few studies in tissue engineering fields. In cartilage tissue engineering, many researchers studied relationship between chondrocytes' response and physical properties of scaffold (i,e. stiffness, hydrophilicity). However, there is lack of basic understandings for chondrocytes' behavior with mechanical stimulus in NPR scaffold. Therefore, in this study, we prepared NPR scaffold for cartilage regeneration to investigate chondrocyte proliferation according to the scaffold's Poisson's ratio with mechanical stimulus.

Methods: Control specimens were prepared with 60ppi PU (polyurethane) foam. Pore size and shape of experimental specimens were controlled by heating and compression. Poisson's ratio was estimated by image process [3]. The relative positions of these points were used to estimate strain and Poisson's ratio. Taken images were processed in Photoshop to evaluate Poisson's ratio. Cellular proliferation test and SEM observation were performe. Cellular proliferation rate was measured by using Cell Counting Kit (CCK-8). Chondrocytes were seeded into both specimens with 2.0×10^5 (cells/scaffolds) initial cell density. The cells were cultured in the prepared scaffold with static compression (20% strain of compression). For the tests, 1st, 3rd, and 5th day observation were performed. T-test was used to determine the significance of differences (P <0.05).

Results: In control group, the Poisson's ratio was 0.9 (20% strain control). On the other hand, experimental group showed negative Poisson's ratio as shown in Figure 1. The Poisson's ratio of experimental group was about -0.4 with 20% strain control. In cellular proliferation test, experimental group showed 1.3 times higher cellular proliferation rate than that of control group at 3rd day from cell seeding. At 5th day, experimental group showed 1.2 times higher proliferation but there was no significant difference between both groups in statistics (Figure 2). In SEM observation, the cells were more adhered and distributed on experimental group than control group at 3rd day.

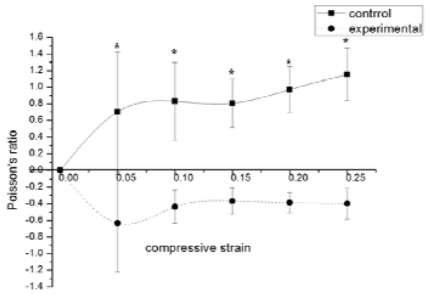

Figure 1. Poisson's ratio of PU scaffold (n=5, *p<0.05, , indicates significant difference)

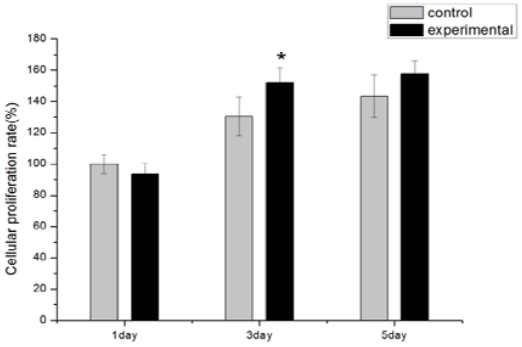

Figure 2. Proliferated cell numbers on PU caffold. Values were normalized.(n= 5, p<0.05, * indicates significant difference)

Conclusions: NPR scaffold could be effective on chondrocyte proliferation with mechanical stimulus. Long term culture (5th day) showed less effective on proliferation from this study. This may due to the stress relaxation of the scaffold. Compressive force may be diminished from the scaffold. In future study, degree of compression should be considered that the specimens undergo an isotropic or anisotropic stress in long time culture.

References:

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