TISSUE/MATERIAL PROPERTIES OF ENZYMATICALLY-DEGENERATED ARTICULAR CARTILAGE EVALUATED BY USING VISCOELASTIC MODEL CONSIDERING DEPTH-DEPENDENT MICROSTRUCUTRE

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Articular cartilage is responsible for the load transmission and stress redistribution in articulation joints, and the viscoelastic property of cartilage is a key feature for these functions. The cartilage tissue has a characteristic depth-dependent microstructure governing its mechanical properties as the tissue [1]. The microstructure exhibits three-dimensional anisotropic arrangement of cells and collagen fibres in extracellular matrix. It was disordered in degenerated cartilage such as of osteoarthritis and thus the dysfunctions of cartilage affect the loss of daily life activities seriously. Medical images have been extensively used for clinical evaluation of cartilage degeneration by referring to the cartilage thickness and others, although mechanical properties of cartilage are the critical features required to understand the biomechanical functions.

Many experimental and theoretical efforts have been devoted to this end. However, it is not straight forward even in *in vitro* experiments due to its tissue nonhomogeneity. The work by Federico and co-workers [2, 3] is one of most recent advances taking the microstructural nonhomogeneity of cartilage tissue. The authors have extended their theoretical model by taking the viscoelasticity of solid phase components into account [4]. This model provides us a computational way to evaluate the mechanical properties as the cartilage tissue and those of individual tissue component when it is combined with a conventional indentation test. This study conducted the model-based evaluation for the depth-dependent distribution of

mechanical properties based on an *in vitro* indentation test of stress relaxation using bovine femoral heads purchased from meat market. The computational indentation test was carried out in terms of finite element analysis for the cartilage model of the same thickness as that used in each indentation test. The time history of resultant reaction force at the indenter by computational test was sent to the least square fitting to the time history of experimental indentation force, and determined were the material properties of individual tissue component including elasticity and viscoelasticity constants of solid phase components. The same evaluation process was also conducted for the same femoral head specimens but following to a collagenase-treatment for enzymatical tissue degeneration.

The least square fitting reproduced the time history of indentation force with R^2 almost equal to 0.99 for both of normal and treated cartilage at medical load-supporting and the lateral non-load-supporting regions. The elastic moduli were decreased by the collagenase-treatment at both regions throughout all layers of cartilage. The mobility of interstitial fluid in tissue was increased by the treatment at both regions. It was also found that the different tissue properties between medial and lateral regions are coming from the difference in depth-dependent distribution of elastic properties, and that the region-dependence of change in mechanical properties by collagenase-treatment was from the difference in viscoelastic properties of solid phase. These results coincide with the past findings and reports [e.g. 5, 6]. These results showed the effectiveness of the cartilage model considering depth-dependent microstructure of viscoelastic solid components in the evaluation of biomechanical properties from the conventional indentation test.

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