Influence of Inherent Anisotropic Stiffness Induced Degradation on Articular Surface

Boonyong Punantapong[1*,2] , Somchai Thongtem[1], Michael J. Fagan[3] and Chairoj Soorapanth[4]

[1] *Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*

[2] *Faculty of Applied Science, King Mongkut's Institute of Technology North Bangkok, Bangkok 10800, Thailand*

[3] *Centre for Medical Engineering and Technology, University of Hull, Hull, UK*

[4] *Department of Orthopedic Surgical, Bangkok Metropolitan Administration Medical College and Vajira Hospital, Bangkok 10300, Thailand*

**Corresponding author. E-mail: bpp@kmitnb.ac.th*

ABSTRACT

The role of viscoelasticity of collagen fibers in articular cartilage was examined in compression and tension, using stress relaxation measurements in axial direction (normal to the articular surface). In this study, the degree of inherent stiffness anisotropy of completely-decomposed element was evaluated using finite element method. The model accounted for elastic deformations of the nanostructure in contact and assumed laminar flow in the created voids. The stiffness parameters from the laboratory tests were utilized in analysis which the elasticity of the solid phase was investigated in the present study. The results were suggested that the dominant mechanism for stress relaxation arose from fluid pressurization, while the associated relaxation in collagen fibers mainly was resulted in an increase in radial strain. Furthermore, Young's modulus normal to the contact surface was increased from the superficial to the deep zone in articular cartilage.

Key words: Stiffness, Degradation, Articular surface

INTRODUCTION

Articular cartilage consists of three major structural constituents: collagen fibers, proteoglycan matrix and interstitial water. The function of articular cartilage serves mainly as a load-bearing medium in joints, thus the structure of cartilage is customarily designed to carry high stresses. Articular cartilage is a poroelastic material consisting of a fluid component (75% wet weight) and a solid matrix (20–25% wet weight), which the solid phase of articular cartilage is mainly composed of collagen (65%), proteoglycan (25%), glycoprotein and chondrocytes (<10%), and lipid (<10%) (Minns and Steven, 1977; Stockwell, 1979; Jones et al., 1997).

Recent developments in mathematical modeling have improved the understanding of cartilage mechanics, such as Mow et al.,(1980), Holmes and Mow (1990), Guilak et al.,(1995), Garcia et al.,(1998), and Donzelli et al.,(1999). They have suggested that the proteoglycans are negatively-charged and produce a swelling pressure that depends on the saline concentration of the fluid. At equilibrium and physiological conditions, the swelling pressure is counteracted by the external load and the structural elements in the solid matrix, mainly the collagen fibers. Since collagen fibers, chondrocytes and the other components in the solid