MICROSCOPIC STRAIN MEASUREMENT IN ARTICULAR CARTILAGE USING IMAGE CORRELATION METHOD

Nobuyuki Shibata[1] and Naohide Tomita[2]
[1]National Institute of Industrial Health, Kawasaki, Japan, shibata@niih.go.jp
[2]International Innovation Center, Kyoto University, Kyoto, Japan

INTRODUCTION

Articular cartilage is composed of chondrocytes and extracellular matrices (ECMs) in which chondrocytes are embedded. Especially ECM, mainly composed of a meshwork of collagens and proteoglycans, plays an important role in the mechanical property and metabolic activity of the cartilage tissue (Mow et al.; 1984). However, the relationship between the spatially varying mechanical properties and the metabolism of chondrocytes are not fully understood. The objectives of this study are to develop a microscopic image correlation method to measure the local strains in bio-tissues under a certain kind of loading and to evaluate the effect of the spatially varying mechanical properties on local strain fields articular in cartilage.

MATERIALS AND METHODS

A femora-tibial joint of a six-month-old pig slaughtered for eating, kept frozen at a temperature of –34 degrees Celsius, was thawed at room temperature (25 degrees Celsius) on the day of experiment. Thin slices of articular cartilage were dissected from the femoral condyle of the joint with a scalpel and were immediately immersed in a physiological salt solution controlled at room temperature. The slices were sectioned into specimens 4.5×3.8×1.8 mm in size.

Loading equipment was fixed on the stage of a confocal laser scanning microscope (CLSM). The cartilage specimen was held with a pair of rods between which a physiological salt solution was filled. The specimen was compressed at a speed of 0.27 mm/sec until the maximum compressive strain of 30 % in the thickness direction. One of cross-sections in the specimen was observed through CSLM and its image was taken before deformation and intermittently during the compression test.

Given a pair of digital images, an image before deformation and that during deformation, the image pair can yield a field of linear displacement vectors where each vector is formed by analyzing the movement of localized segments with random pixel patterns. This is accomplished by extracting segments and analyzing them statistically. Concretely, the best match between segments out of these two images is found by obtaining the maximum of the discrete cross-correlation function on the segments. In this study each segment was an array of 10×10 pixels. If deformation is small enough, homogeneous deformation can be assumed in the small segments and therefore local strains are calculated based on solid mechanics.

RESULTS AND DISCUSSION

As shown in Figure 1, localization of strain fields was observed in ECM. Peaks of principal strain were found more at the deep zone than at the subsurface zone. Even under simple compression, chondrocytes were subjected to a complex mechanical environment being composed of tension, compression and shearing. Guilak et al. have numerically predicted the localization of stress fields within cartilage tissues under simple compression. The localization of stress-strain fields can be attributed to the fact that the average aggregate modulus of ECM (about 1.0MPa) is 10^3 times larger than that of chondrocyte (about 1.0 KPa). As cartilage tissue have no blood vessels, mechanical stimuli due to articular movement can have a significant influence on the metabolic activity of chondrocytes.

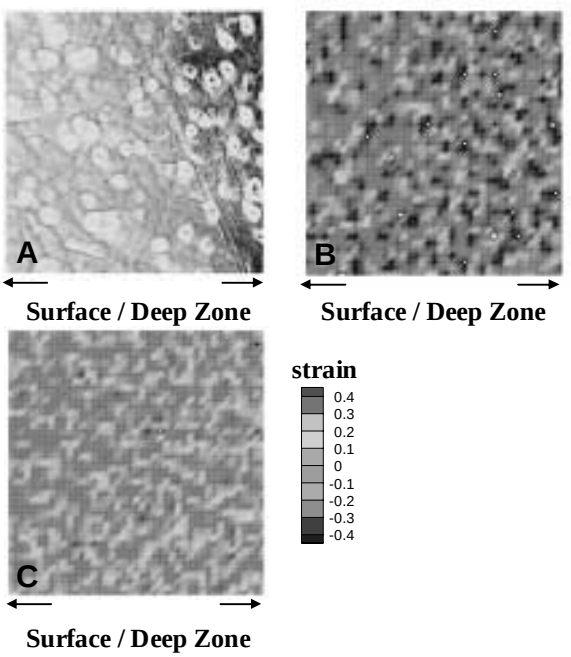

Figure 1: **A**: The CLSM image of the cartilage specimen corresponding to the domain analyzed using the image correlation method. **B**: The local shear strain field and **C**: the principal strain obtained from the image (Figure 1A).

REFERENCES

Guilak F., Mow V.C. (2000) *J. Biomechanics*, **33**: 1663-1673.
Mow V.C., Holmes M.H. et al. (1984) *J. Biomechanics*, **102**: 73-84.

ACKNOWLEDGEMENTS

This work was supported by the Grant-in-Aid for Scientific Research (B) (No. 13450092) from the Ministry of Education, Science, Sports and Culture of Japan.