Measuring Three-dimensional Strain Distribution of Knee Joint Cartilage under Compressive Load

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Introduction. Articular cartilage is a connective tissue of joints, plays a role in load transfer, impact absorption and lubrication, and so is an important tissue to facilitate daily activities. Population of elderly people has been increasing all over the world due to progress in medical technology and the prevalence of advanced medical treatment. Thus, the number of cases of osteoarthritis (OA), a disease of articular cartilage, are rapidly increasing. OA develops when aging articular cartilage is worn down and damaged. To diagnose the disease at an early stage, a non-contact diagnostic method is required.

In this research, the objective is to establish a less-invasive method to visualize the cartilage deformation under compressive load by using Digital Volume Correlation ⁽¹⁾.

Compression test and micro-CT scanning. The sample used was a distal end of the femur, 50 mm long sample including the suboccipital bone and the articular cartilage was taken out from the femur. The compression experiment was performed using a compression device made with acrylic (Fig.1(a)), and the image acquisition was performed using a micro-CT scanner (inspeXio SMX-100CT, SHIMAZU). The micro-CT scanning was conducted at 100kV and 150uA, all of which were imported as 16bit images with a size of 512×512 pixels. The resolution of the images were $0.181 \times 0.181 \times 0.049$ mm³/voxel. The captured images are shown in Fig.1(b) and (c).

Displacement and strain distributions. Displacement and strain distributions in three-dimension are calculated using the acquired volume images of unloaded and loaded conditions. The analysis area (Fig.1 (b)) is $40 \times 40 \times 25$ mm³ which the deformation of the cartilage can be confirmed on the images, the arrows indicate the compression direction (z direction). The subset size used for the analysis is $11 \times 11 \times 11$ pixels to $71 \times 71 \times 71$ pixels and the gauge length when calculating the strain is $21 \times 21 \times 21$ pixels. The calculation step is 2 pixels in each of the x, y and z direction.

Fig. 1 Compression test and micro-CT scanning.

Fig. 2 Strain in the x direction.

Fig. 3 Strain in the y direction.

Fig. 4 Strain in the z direction.

- (1) Bay, B. K., Smith, T. S., Fyhrie, D. P. and M. Saad, *Digital Volume Correlation: Three-dimensional Strain Mapping Using X-ray Tomography*, (1999), 39, Experimental Mechanics