Medical Applications

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Depiction of knee joint structure by means of X-ray diffraction enhanced imaging

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Introduction

X-ray refraction contrast imaging with a silicon analyzer (XDEI) was used to provide a high depiction image on soft tissues such as mammary tissue, articular cartilage, cruciate ligament and meniscus [1,2]. If clinical imaging with this method is used, the application of X-ray image diagnosis will be expanded drastically. In order to investigate the depiction performance of the XDEI using a 2D exposure field, an experiment was performed with a raw knee joint of a Landrace Large White Duroc (LWD-pig) whose soft tissue was formed into a human-like joint. This sample was chosen because it was homologous to a human knee joint in bone size and fine structures. The Experimental arrangement, preparation of the sample, image qualities of the sample are described as follows.

Experiment

The experiment was performed at BL 14C1. The maximum ring current was 60mA under single bunch operation. The experimental arrangement is shown in Fig1. The Si (220) asymmetrical diffraction crystal extends the size of the horizontal exposure field, simultaneously improving the angular divergence of incident X-ray. The Bragg angle at the crystal was 6.18 degrees at an X-ray energy of 30 keV. The crystal surface had a 5 degree inclination to the Si (220) diffraction plane; therefore the asymmetric factor was 0.11. Since the length of the crystal was 180 mm, the horizontal size of exposure field was about 36 mm. The vertical size of the exposure field was restricted by the present design of the beam-line, with a maximum value of 30 mm. The Laue-type analyzer with a diffraction plane of (220) was located behind the sample. The analyzer crystal was adjusted near the symmetric Si (220) diffraction condition in the Laue-geometry. In this configuration, two kinds of X-ray with almost the same intensity were acquired by the forward diffracted and diffracted X-rays. Both X-rays were detected by a high resolution imaging-plate and/or a mammography film.

The sample was the right side of the knee joint from a part of the raw LWD-pig without skin. The fat and soft tissue around the joint was removed adequately to a thickness of 5 to 10 mm. The remaining main soft tissues c were the articular cartilage at the distal end of the femur and the proximal end of the leg, ligaments in the inter-condylar fossa, and the meniscuses of both lateral and medial sides. The sample images are shown in Figs. 2 (a) to (d). In the absorption contrast images, anatomical condylar fossa, and the meniscuses of both lateral and medial sides. The sample images are shown in Figs. 2 (a) to (d). In the absorption contrast images, anatomical structure cannot be observed except for the compact bone. In the DEI of (c), in addition to the compact bone, the cruciate ligament image with a width of about 10 mm was clearly delineated. In the DEI of (d), the image of the articular cartilage with a width of about 2 mm and a wedge-shaped organ image of the meniscus were clearly delineated. Image qualities, image contrast and resolution, of these DEI were better than that of present clinical MRI.

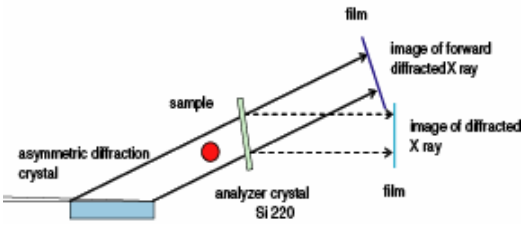
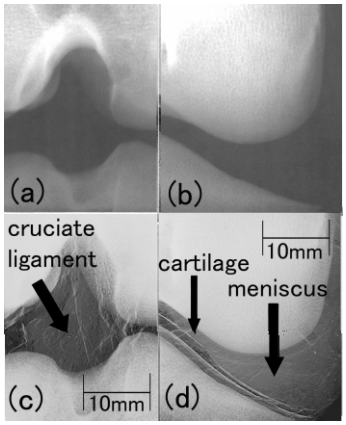


Fig. 1 The experimental arrangement of XDEI at BL14C1. The exposure time was about 90 sec in case of the film.



Figs. 2 The frontal views of the knee joint. Both (a) and (b) are absorption contrast images, and (c) and (d) based on the DEI of diffracted images, respectively.

References

[1] D. Shimao et al., JJAP. 44 1A 450-451 (2005).
[2] M. Ando et al., NIM. A 548. 1-16 (2005).