EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

Experiment Report Form

	Experiment title: Evaluation of human joint structures by CT-Diffraction Enhanced Imaging (DEI)	**Experiment number**: MD44
Beamline: ID17	**Date of experiment**: from: 30 October 2003 to: 03 November 2003	**Date of report**: 06 September 2005
Shifts: 12	**Local contact(s)**: Alberto BRAVIN	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

***Juergen A. MOLLENHAUER[2], *Paola COAN[2], *Joachim METGE[3], Bernd REIME[4], *Klaus SCHMUCK[2], *Norbert SIEBER[2], *Andreas WAGNER[2]**

[1]Department of Orthopaedics of the University of Jena, Rudolf-Elle-Hospital Eisenberg, Klosterlausnitzer Straße 81, 07607 Eisenberg, Germany

[2]ESRF Grenoble, 6 rue J. Horowitz – B.P. 220, 38043 Grenoble, France

[3]GKSS-Research Centre Geesthacht GmbH, c/o HASYLAB at DESY

[4]HASYLAB at DESY Hamburg, Notkestr. 85, 22607 Hamburg, Germany

Report:

Description of purpose: Treatment of osteoarthritis in stages of reversible disease requires high resolution visualization of early cartilage damage and of subchondral bone. Here, DEI (Diffraction Enhanced Imaging) is compared to MRI, computed X-ray tomography (CT) and ultrasound (UI) in its ability to detect early degeneration of articular cartilage. In contrast to conventional absorptive X-ray examination where cartilage is poorly visible DEI captures cartilage by detection of selected refraction.

Methods: Human femoral heads were investigated by macroscopic inspection, conventional X-ray examination, DEI, MRI, CT, UI and histology. DEI is an imaging technique applying a monochromatic parallel synchrotron X-ray beam. Image features were verified by histology.

Results: DEI, MRI and ultrasound lead to interpretable images of cartilage. Of all techniques, DEI provided highest image resolution revealing the structural tissue architecture. MRI needs a very long exposure time (more than 5 hours) to achieve comparable quality. Application of ultrasound is limited because of joint geometry and, at high sound frequency, the necessity of close contact between cartilage and transducer. DEI is an experimental technique which needs synchrotron radiation.

Conclusion: DEI is a very promising imaging technique for visualization of cartilage and bone. It may serve as an excellent analytical tool for experimental studies. Our pictures show a part of future of optimised techniques for imaging. Synchrotron based DEI may lead the way towards optimisation of improved techniques for imaging. Upon development of adequate small-scale X-ray sources, DEI will also be an important supplementation for medical imaging.

(Abstract from reference 1)

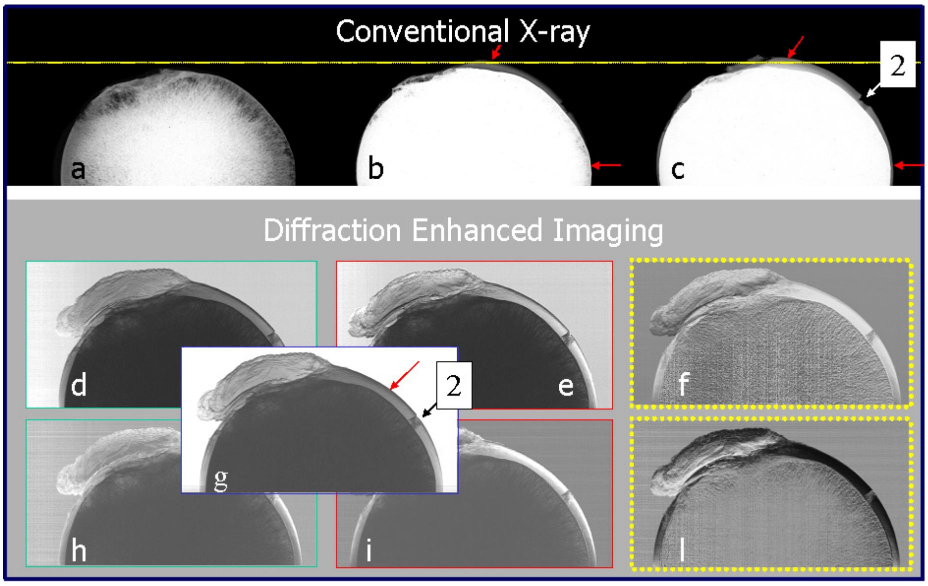

Figure 1. (a-c) Experimental conventional absorptive X-ray examination of a femoral head. (a) 38kV, 12.5mAs, (b) 24kV, 31mAs, (c) 24kV, 18mAs. (a) Conventional absorptive X-ray examination, cartilage is invisible. Only conditions with experimental kV and mAs selected allow to visualize cartilage but the surface and the cartilage height are still not clearly defined (see red arrows). (d-l) DEI projection images from the same femoral head: (d) + 50%, (e) –50%, (f) Refraction-Image at 50%, (g) Top-Image, (h) + 15%, (i) –15%, (l) Refraction-Image at 15%. Cartilage height is clearly defined in all images (red arrow).

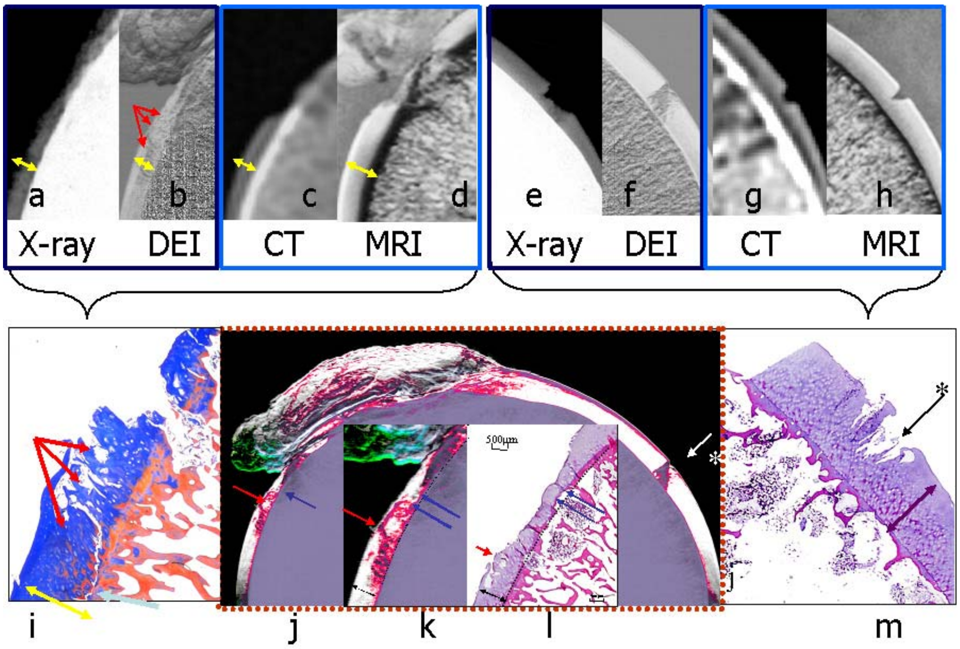

Figure 2. (a-d) Comparison of projection images (X-ray [detail of fig. 1 (c)], DEI [detail of fig. 1 (f)]) and tomographies (Conventional CT [130kV, 60mA, window 1500, level 400], MRI [T1 SPIR TFE TE 22, TR 95, Flip 50 (d)] from an arthritic lesion of the femoral head shown in fig. 1. Yellow doubleheaded arrows indicate the identical height (real height of cartilage). Despite (b) is a projection image structural damage of cartilage is displayed that is invisible in CT, MRI. Conventional X-ray shows only deep zone of cartilage but although structural irregularities like DEI. (e-h) Comparison of projection images and tomographies of the artefact made by a knife. Specification like (a-d). (i-m) Color coded (minus 50% - red; plus 50% - green; top – blue) refraction image (j, l) and histological correlation (i [Masson-Goldner 1.25x], l, m [HE]). Color coded DEI unmask internal structures in cartilage (red arrows). Note the green arrow showing a preparation artefact of histologic sectioning (cleft), while the red arrows show real cartilage damage. Blue arrows detect a nascent osteophyte. Asterisks mark the artefact (made by knife). In the projection image the defect is obscured because of overlapping.

References

1. A. Wagner, M. Aurich, M. Stoessel, N. Sieber, W. Wetzel, J. Mollenhauer, K. Schmuck, C. Muehleman, M. Lohmann, B. Reime, J. Metge, P. Coan, A. Bravin, F. Arfelli, L. Rigon and R. Menk, in *SPIE Medical Imaging* (SPIE, 2005), Vol. 5746, p. 542-549.

2. A. Wagner, M. Aurich, N. Sieber, M. Stoessel, W. Wetzel, K. Schmuck , M. Lohmann, J. Metge, B. Reime, P. Coan, A. Bravin, F. Arvelli, G. Heitner, R. Menk, T. Irving, Z. Zhong, C. Muehleman and J. Mollenhauer,"Options and Limitations of Joint Cartilage Imaging: DEI in Comparison to MRI and Sonography," Nucl. Instr. Meth. A **548**, 47-53 (2005).