ESRF	**Experiment title:** Microtomography on femoral human bones	**Experiment number**: IN 405
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Shifts:	**Local contact(s)**: E. Boller	*Received at ESRF:*

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Report:

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The prevalence of osteoporosis is severely increasing with life expectancy in industrial countries. Osteoporosis is a bone disease characterized by low bone mass and structural deterioration of bone tissue, leading to bone fragility and an increased susceptibility to fractures of the hip, spine, and wrist. The clinical evaluation of osteoporosis relies on Dual X-ray Absorptiometry (DXA) which provides an estimation of the Bone Mineral Density (BMD) typically on the spine and on the hip. Unfortunately, an important overlap of BDM values is observed in patients with and without fractures, and BMD alone is not sufficient to predict individual fracture risk. Another factor to take into account in the biomechanical resistance of bone, is its micro-architecture. This later has conventionally been investigated using histomorphometry, but during the last decade tomographic techniques have been more and more employed. Though due to the requirements in terms of spatial resolution this investigation is limited to in vitro examinations on bone biopsies.
Standard x-ray radiography associated to texture analysis has been proposed by different teams to get in vivo architectural information. Although the information delivered by a single radiograph is somehow limited, the discrimination of osteoporotic patients and healthy subjects has been demonstrated in clinical studies 11. However, it is still unknown what is the most appropriate texture parameter(s) to describe bone micro-architecture, and what are the optimal imaging conditions.

The purpose of this collaborative project (CEA-LETI, CREATIS, ESRF, CHU Nîmes and Lillle) was to develop a method for evaluating the relationships between 3D micro-architecture parameters and 2D texture parameters, and optimizing the conditions for radiographic image acquisition. It is expected that such conditions could be implemented on new generations of bone densitometers such as the LEXXOS, developed by CEA-LETI and DMS, based on a 2D detector technology.

We developed a procedure based on the use of reference images of representative human bone samples acquired using 3D-synchrotron x-ray microtomography at the ESRF. Thirty three cylindrical samples (diameter 15mm) were taken in calcaneus and femoral neck, from cortical to cortical to be close to in-vivo conditions.

Imaging was performed on the microtomography setup developed on beam-line ID19 [1]. To have a sufficient field of view, a spatial resolution of 15 µm was used, and three to four scans at different height were performed to encompass the entire sample (total height : 30 to 40 mm). Thee different images were then reconstructed, corrected and stacked to reconstitute the entire sample. Figure 1 displays the reconstitution of the entire 2D slice in a bone sample. The two corticals may be seen at the top and bottom of the image.

The so-obtained digital three-dimensional images were further used both for calculating quantitative architecture parameters of the entire three-dimensional images, and simulating realistic x-ray radiographs under different acquisition conditions using the Sindbad software (LETI) [2]. Figure 2 illustrates a simulated radiograph of the entire sample at a spatial resolution of 50 µm.

Texture analysis was then applied to these simulated 2D radiographs using a large variety of methods (co-occurrence, spectrum, fractal…) yielding more than one hundred parameters. The set of parameters was sequentially reduced according to different criteria to find the most relevant to three dimensional architecture. Finally, six texture parameters significantly correlated to bone micro-architecture parameters in two sub-series of images were selected [3].

The relevance of these parameters will be confirmed by further tests on physical radiographs of the samples acquired in different experimental conditions (energy range and spatial resolution). The implementation of such a technique on a bone densitometer would allow to supplement the standard BMD with an architectural index, and hopefully more discriminant of the fracture risk.

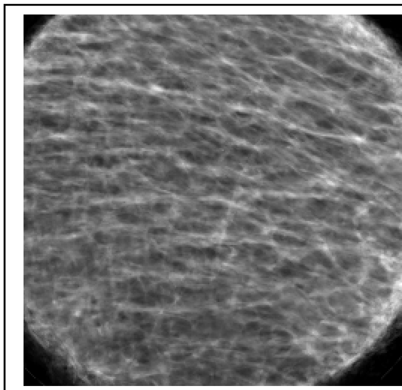

Figure 2 : simulated 2D radiograph of the bone sample

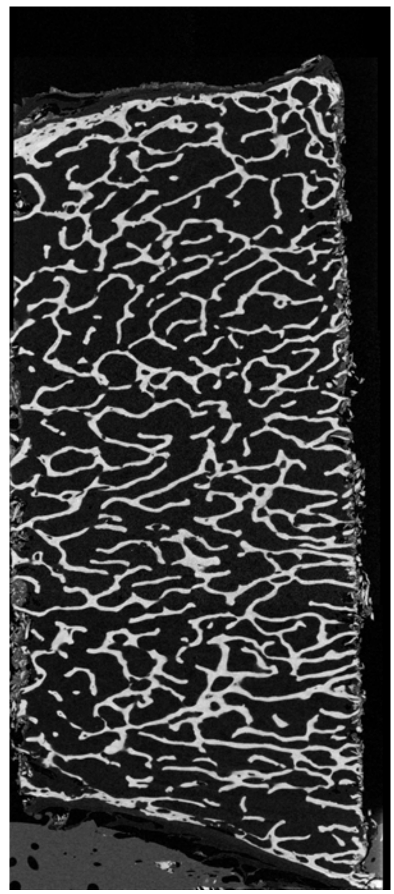

Figure 1 : reconstituted slice of an entirebone sample

References

[1] Peyrin F., Salome M., Nuzzo S., Cloetens P., Laval-Jeantet A.M., Baruchel J., *Cellular and Molecular Biology*, **46**(6) : 1089-1102, (2000).

[2] Tabary J, Dinten J.M, Guillemaud R., Peyrin F, Simulation of trabecular bone samples x-ray microradiography, Proc SPIE Medical Imaging, vol 4030, Physics of Medical Imaging, June 2003, p. 309-318

[3] Apostol L, Peyrin F, Yot S, Odet C, Basset O, Tabary J, Dinten J.M, Boller E, Simulation of trabecular bone samples x-ray microradiography, Proc SPIE Medical Imaging, vol 4030, Physics of Medical Imaging, 2004.