EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

ESRI

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office via the User Portal:

https://wwws.esrf.fr/misapps/SMISWebClient/protected/welcome.do

Reports supporting requests for additional beam time

Reports can be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** Assessment of bone properties using Resonant Ultrasound Spectroscopy (RUS) and SRµCT	**Experiment number**: MD-927
Beamline: ID19	**Date of experiment**: from: 2015-12-07 to: 2015-12-09	**Date of report**: 2016-09-09
Shifts: 6	**Local contact(s)**: Lukas Helfen	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

F Peyrin*, C Olivier, M Langer*, Univ Lyon, CNRS 5220, INSERM U1206, INSA Lyon, UCBl, CREATIS, 69621 Villeurbanne Cedex

Q Grimal*, X Cai*, L Peralta*, P Laugier, Sorbonne Université, UPMC Univ Paris 06, INSERM UMR-S 1146, CNRS UMR 7371, Laboratoire d'Imagerie Biomedicale (LIB),75006 Paris, France

Report:

The aim of this experiment was to use Synchrotron Radiation µCT to assess bone porosity and bone mineralization in complement to resonant ultrasound spectroscopy (RUS) to analyze the relationships between elastic stiffness (provided by RUS) and porosity and mineralization (provided by SRµCT).

57 cuboid femur cortical bone specimens were harvested at the mid-diaphysis site from 26 donors. All 57 specimens were first measured using Resonant ultrasound spectroscopy at LIB to asses elasticity estimation. SR-µCT was performed at beamline ID19, with a pixel size of 6.5µm, and an energy of 26 keV. Ideally, a monochromatic energy of 26keV was requested. However, due to limited time, we could scan 26 specimens using monochromatic beam (1 hour/specimen) and 31 using pink beam (15 mins/specimen).

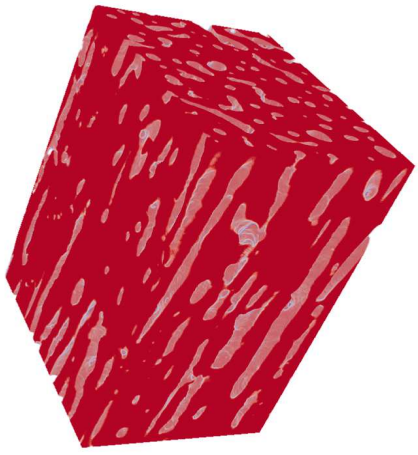

Figure 1: A typical 3D bone microstructure recorded by SR-µCT

After SR-µCT scanning, the 3D bone microstructure were reconstructed and the porosity and Degree of mineralized bone content (DMB) were calculated for all the specimens. The results show significant correlations between porosity and all the elastic coefficients were found (0.46<R2<0.80). Figure 2 demonstrates an example of such relationship between porosity and the elastic coefficient C11. For the 26 specimens scanned by monochromatic beam, significant correlations between DMB and the elastic coefficients (C11, C33 and C44) were found (0.23<R2<0.29). Figure 3 demonstrated the relationship between DMB and C11. However such correlations were not observed on the specimens scanned by pink beam, since pink beam may be not pure enough to accurately quantify DMB. However, we expect to critically improve the investigation by scanning the remaining specimens with monochromatic beam in a future experiment if possible.

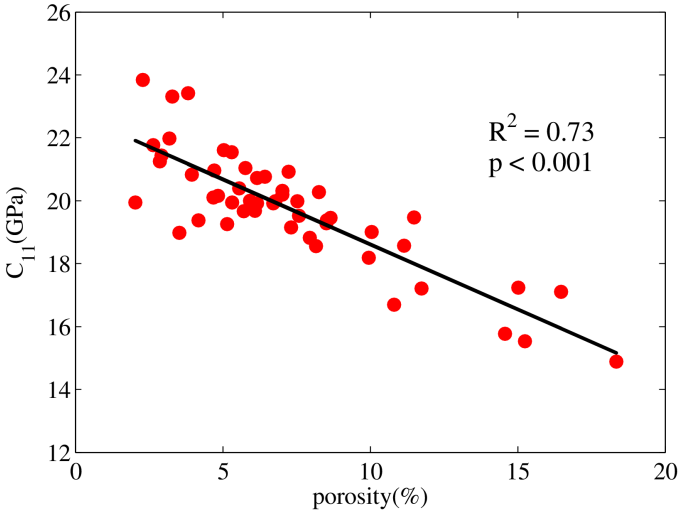

Figure 2: The relationship between porosity and the elastic coefficient C11

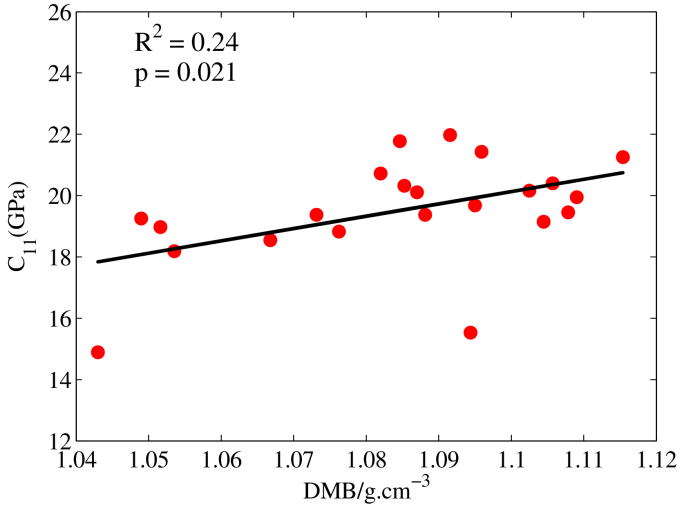

Figure 3: The relationship between DMB and the elastic coefficient C11

The work was presented at several conferences, and 2 publications are on-going :
Conferences :
– Cai X, Peralta L, Peyrin F, Helfen L, Oliver C, Grimal Q and Laugier P. Will the anisotropic elasticity of human cortical bone be altered by defatting and SR-µCT scanning? 22nd Congress of European Society of Biomechanics 2016 (abstract)
– Cai X, Peralta L, Peyrin F, Oliver C, Laugier P and Grimal Q. On the relationship between cortical bone anisotropic elastic properties, porosity and mineral content. 22nd Congress of European Society of Biomechanics 2016 (abstract)
– Cai X, Peralta L, Peyrin F, Helfen L, Laugier P and Grimal Q. Defatting and synchrotron X-ray imaging of the vascular network do not alter bone elasticity measured by resonant ultrasound spectroscopy. International Ultrasonics Symposium 2016 (abstract)

Papers to be submitted:
– Cai X, et al., Cortical bone elasticity measured by Resonant Ultrasound Spectroscopy is not altered by defatting and synchrotron X-ray imaging, 2016 (to be submitted)
– Cai X, et al., Influence of imperfect rectangular parallelepiped sample geometry on the elasticity measured by resonant ultrasound spectroscopy, 2016 (to be submitted).