Contribution ID: **12** Type: **Oral Communication**

Chemical imaging of bone regeneration induced by bioactive glass implants in vivo: a multimodal and quantitative micro-ion beam analysis of mineralization and trace elements at the bone interface

Wednesday, 9 July 2014 09:30 (20 minutes)

This communication will focus on the contribution of nuclear microprobes to the highly sensitive elemental analysis of bone tissues, in the context of evaluating the efficiency of bone regeneration induced by a bone substitute. Indeed the mineral composition of bone can give key clues on the maturity and the quality of the bone formed, the content in trace elements being especially meaningful.
Among all bone substitutes, bioactive glasses are particularly interesting due to their high biomineralization capabilities. When implanted, bioactive glasses endure major changes as a result of both the chemical reactivity of the glass and osteointegration, which lead to quick bonding of the implanted glass to bone with simultaneous stimulation of new bone growth. Here the presence of trace elements like zinc can indicate the maturity of bone tissues formed, as Zn is recognized as a co-enzymatic factor and is an essential component of a large number of enzymes.
Moreover recent advances in the field are the development of bioactive glasses able to release osteoinductive ions directly onto the site of implantation. The osteoinductive ions locally delivered help increase osteogenesis. Of special interest is the delivery of strontium (Sr) ions, since Sr has marked stimulatory effects onto bone cells resulting in strengthening of bone, stimulation of bone formation and decrease in bone resorption. Other trace elements of interest are Si and Mg due to their promotion of bone formation and cellular adhesion.
Studying bone traces in vivo is thus of high interest but calls for an extremely sensitive technique. An excellent spatial resolution is also required for characterizing the bone/bioactive glass interface at the micrometer scale. We propose here an original approach based on a multimodal analysis of bioactive glasses implanted in vivo. Histological studies of the bone/bioactive glass interface are coupled to micro-PIXE (Particle-Induced X-ray Emission) analysis for quantitative chemical imaging and a complete micro-analysis of the interface with a special focus on trace elements.

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Session Classification: Session 4 - Nuclear Microprobe Applications: Biology 2