CCEM Canadian Centre for Electron Microscopy **USER STORY**

Bones: How are they really structured?

This is a collaborative work between McMaster University and the Université Grenoble Alpes.

Problem: A better understanding of the attachment between human bone tissue and synthetic implant devices is needed to help develop long-lasting orthopedic and dental implant devices. But first, long standing questions on bone structure must be answered

The Solution: Multi-length scale characterization of bone-implant interfaces and natural human bone tissue using electron microscopy techniques can shed light on the micro to atomic scale structure of bone, cells and interfaces.

- Scanning electron microscopy (SEM) and X-ray energy dispersive spectroscopy (EDS) were used to examine the structural and chemical composition of bone and bone-implant interfaces to find sites of interest, such as structural bone units, and bone-implant or cell-implant connections.
- Scanning transmission electron microscopy (STEM) high angle annular dark field (HAADF) imaging was used to observe the nano-scale composition and orientation of human bone tissue to better understand its natural structure. The superior contrast generated in HAADF STEM allows for easy differentiation between the collagen and mineral phases in the tissue. In other work, the same characterization technique was employed to image bone-implant interfaces to assess the nano-scale connection between the bone tissue and the synthetic device.
- Focused ion beam (FIB) microscopy was used as a site-specific approach for sample preparation.
- STEM tomography combined with electron energy loss spectroscopy (EELS) and atom probe tomography (APT) was used to visualize and identify the chemical composition of the implant interface in 3D at the nanoscale to further understand the biological connectivity of bone to titanium.

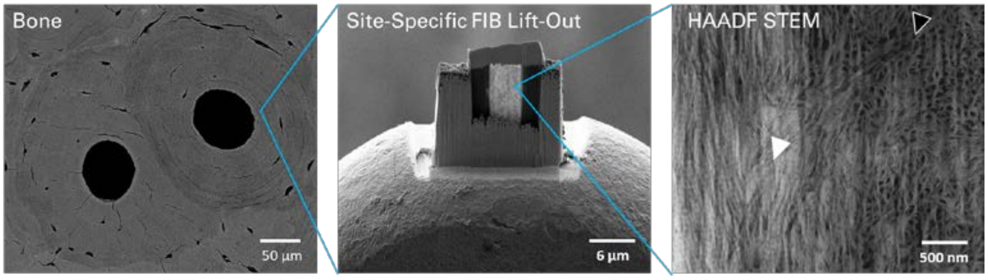
> Understanding the structure of healthy bone tissue will allow us to better understand its connection to implant materials, and provide insights to the cellular changes upon the onset of diseases such as osteoporosis.
>
> *Dakota Binkley, MASc candidate, McMaster University 2018*

The Results:

- **Assessment of bone structure:** Multi-scale characterization from the micro- to nano-scale with electron microscopy provides an understanding of bone structure.
- **Provide recommendations for next steps:** We can use this foundational knowledge to aide in the assessment of diseased bones to help better understand the impact biochemical changes have on bone structure and its function. We can further investigate how diseased tissue bonds at the interface of synthetic devices, such as dental and orthopedic implants. This will lead to reduced costs to the health care system by reducing hospitalization of patients and improved quality of life.

Instruments Used:

JEOL JSM-7000F, FEI Titan 80-300 LB, Zeiss NVision 40, Cameca LEAP 4000X HR



Human bone investigated at two length scales. The low magnification SEM image (a) shows bone structural units, osteons, which are mineralized "packets" of bone. (b) A FIB lift out from an osteon, which can be imaged using (c) HAADF STEM, where different orientations of collagen can be revealed. The white arrow points to longitudinal and the black arrow points to transverse collagen orientations.

References:

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