Chemical Makeup of Microdamaged Bone Differs from Undamaged Bone

Beamline: U10B

Technique: Infrared Microspectroscopy

Researchers:
Meghan E. Ruppel, David B. Burr, Lisa M. Miller

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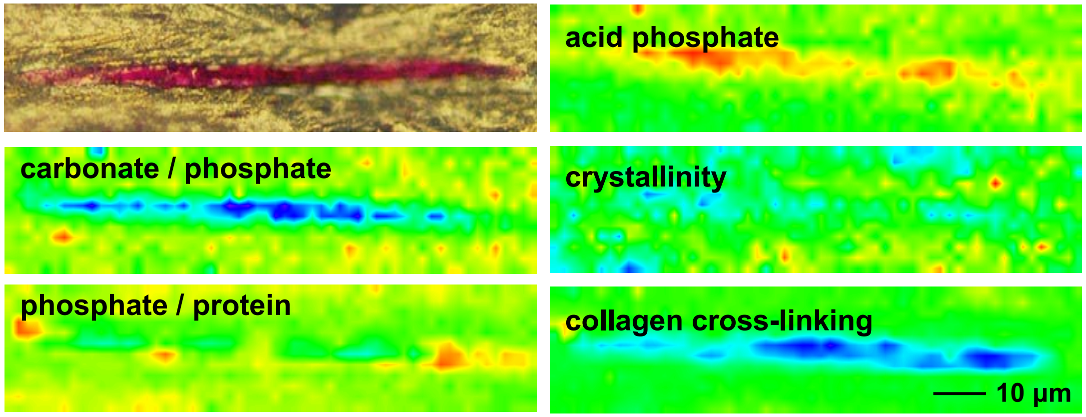
Motivation: Microdamage occurs in bone tissue as a result of cyclic loading placed on the body during daily activities. Normally, the bone remodeling process specifically targets these microcracks for repair. Current anti-resorptive bisphosphonate treatments for osteoporosis allow the microdamage burden to increase because these drugs reduce targeted bone remodeling which would normally repair the damage. The goal of this study was to examine whether areas of microdamaged bone are chemically different than undamaged areas. By using infrared microspectroscopy, the mineral and protein content, and stoichiometry were examined in regions of microdamage and surrounding undamaged areas.



(Top, left) Visible image of a microcrack indicating the area imaged with the IR microscope. The fuchsin stain (magenta) highlights the microcrack. Data were collected within the crack and from the surrounding area. The false-color images correspond to the IR images of the same area. The individual images illustrate the carbonate/phosphate ratio, the acid phosphate/total phosphate ratio, the phosphate/protein ratio, crystallinity, and collagen cross-linking. Results revealed no differences in phosphate/protein or crystallinity, suggesting that microdamaged bone was not more brittle. However, other compositional changes were observed in the carbonate content, acid phosphate content, and collagen cross-linking. Scale bar is 10 microns.

Results: Carbonate content was consistently lower in areas of microdamage compared to undamaged bone. This lowered carbonate content could be due to the fact that when microcracks form, the collagen lattice is stretched and mineral crystals are lost. Carbonated crystals would be preferentially lost, due to their increased solubility when compared to noncarbonated mineral. No differences were seen in the level of mineralization (phosphate/protein) between damaged and undamaged areas of tissue. However, the absorbance intensities of both the phosphate and protein peaks was decreased in areas of microdamage, suggesting that the collagen matrix was stretched and mineral crystals were dissolved and displaced. There was also a significant decrease in the non-reducible/reducible collagen cross-links in areas of microdamage. This suggests that cross-links could have been ruptured in the microdamaged tissue, reducing it's fracture resistance.