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Mineralization and Mechanical Insights of Cement Lines in Human Osteonal Bone

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Abstract

Objective: Cement lines (CLs) are thin layers separating osteons from each other or from interstitial bone. Previous evidence suggests that CLs protect osteons by deflecting microcracks. However, CLs are still a poorly understood structure. Here, we characterize mineral content and mechanical properties of CL from human femurs at the micrometer scale. Method: We perform quantitative backscattered electron imaging to obtain 2D maps of mineral content of 35 osteons from which we manually segment CLs from their corresponding osteon. We also measure the elastic modulus (Er) using nanoindentation to correlate it with the mineral content. Results: CLs appear 10 ± 3.5% more mineralized than their corresponding osteon. A spatial mapping of Er across two adjacent osteons exhibits a periodic alternation of stiffer and softer regions corresponding to bone lamellae, with a distinctive peak characterizing the CL. This increase in stiffness is spatially correlated with the mineral content. Conclusions: We highlight a contrast in mineral content and elastic properties between the CL and corresponding osteon. This mechanical contrast may allow CLs to act as effective interfaces for hampering crack propagation. Recent findings that CLs have reduced nanoscale porosity compared to adjacent bone is consistent with the measured higher mineralization and stiffness [1].

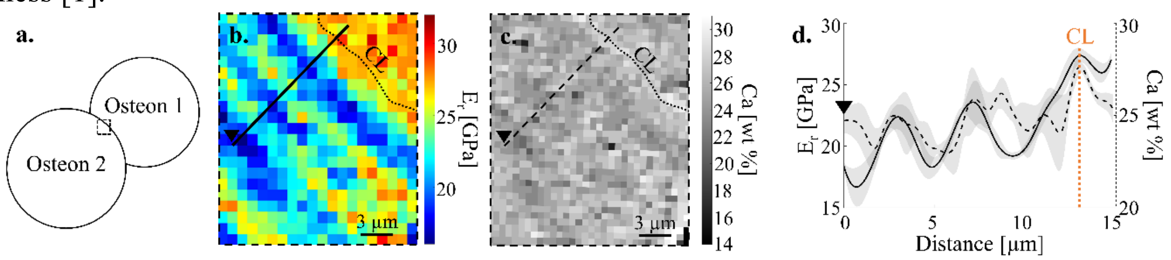

Fig. (a) Schematic of a typical indented zone across 2 osteons. **(b)** 2D map of Er with the CL highlighted by the dotted line. **(c)** 2D map of mineral content with CL highlighted by the dotted line. **(d)** Spatial evolution of Er (solid line) and mineral content (dashed line) measured along the corresponding lines in (b) and (c).

Key words: Cement line, Osteon, Mineralization, Nanoindentation.

Reference: [1] T. Tang, W. Landis, S. Blouin, et al. Journal of Bone and Mineral Research. 2022.