Nano-mechanical Characterization of Sea Urchin Teeth: A Comparison Study with Human Teeth

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Statement of Purpose: Understanding the mechanical property of human teeth is important for development of new dental materials, and is prerequisite to reveal the function and mechanisms of human hard tissues. Human tooth is a hard and tough, functionally-gradient composite. The exterior structure is enamel composed of almost 100% prismatic hydroxyapatite (HAP) crystallites, making it hard and wear resistant, but brittle. The interior adjacent structure is dentin, composed predominantly of collagen fibrils and HAP, which is considerably softer but resilient. Sea urchins are small, spiny sea creatures of the class *Echinoidea* found in oceans all over the world[1]. On the oral surface of the sea urchin is a centrally located mouth made up of five united calcium carbonate teeth or jaws, with a fleshy tongue-like structure within. The purpose of this study is to know the structural and mechanical properties of sea urchin teeth as well as human teeth and try to understand how they are different. Further we will formulate a model on how the change of the diet can change the morphology and mechanical properties of the teeth structure of sea urchin and how we can relate this with the human teeth.

Methods: The sea urchins used in this study were collected at Saint Josephs Bay, Florida (Latitude 29.81167, Longitude -85.30306). Surface morphology of human teeth and sea urchin teeth were examined by Atomic Force microscopy (AFM). AFM measurements were carried out with a Surface Probe Microscope TopoMetrix Explorer.® The images were collected in contact imaging mode in ambient atmosphere. The images obtained were processed by TopoMetrix SPM Lab NT Version 5.0 software supplied with the microscope. Nanoindentation measurements[2] on teeth samples were carried out using a Nanoindenter XP (MTS Systems, Oak Ridge TN) system. Before doing indentation on the samples, indenter to microscope calibration was done in order to properly locate the indentation site for each sample. The data was processed using software provided by the instrument using load displacement curve. The samples were mounted on a glass slide putting a flat tooth surface on the top in dry condition.

Results / Discussion: Figure 1a shows the load displacement curve from sea urchin tooth sample. Nanoindentation hardness results from human tooth sample show that decreasing gradient mechanical properties (both hardness and modulus) seems to be existed from enamel to dentin. Enamel has a hardness of 3.5 GPa which is much harder than dentine ~0.87 GPa. Young's modulus of human tooth enamel is also very high ~88 GPa in comparison to dentin modulus ~23 GPa. Most interestingly the sea urchin tooth has equal or higher hardness (Figure 1b) than human enamel. The hardness on the surface of sea urchin tooth was found ~3.7 GPa but lower modulus 55 GPa than human tooth enamel.

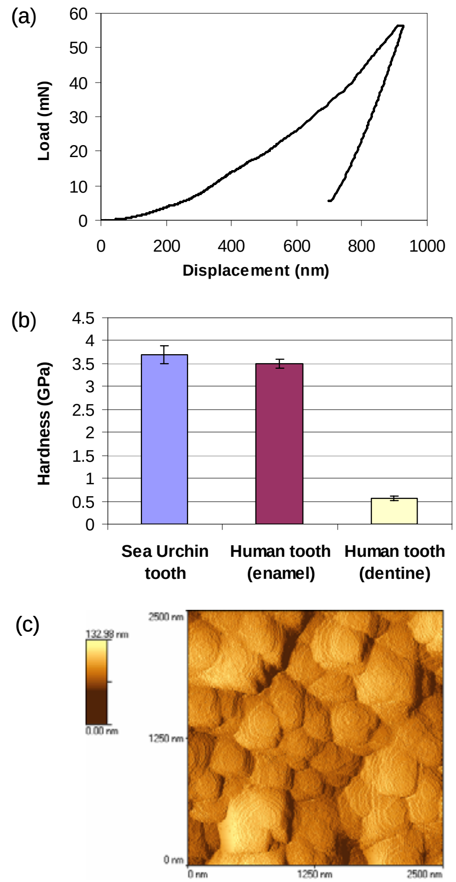

Fig 1: (a-b) Nanoindentation results on teeth samples. (c) AFM image showing the heads of enamel rod in the human tooth.

These results will help us to understand the mechanism of tooth reconstruction of both sea urchin and human. We will also get better understanding on how the diets influence the structural and mechanical properties of the teeth structure. The morphological structure of human enamel structure is shown in figure. 1c. AFM image is showing the heads of enamel rod in the human tooth.

Conclusions: We have investigated the mechanical and structural properties of sea urchin teeth and also human teeth. We also reveal the mechanical and morphological difference between the enamel and dentin structure of human teeth. Enamel has a hardness of 3.5 GPa which is much harder than dentine ~0.87 GPa. The sea urchin tooth has equal or higher hardness than human enamel. This research was supported by the Mississippi–Alabama SeaGrant Consortium, grant number NA86RG0039, We also acknowledge the support from the National Institute of Dental and Craniofacial Research (NIDCR), NIH under Grant No. R01 DE013952.

References: [1] B. W. Hammer, Marine Biology 145 (2004) 1143. [2] S. Chowdhury, Journal of Nanoscience and Nanotechnology, 5 (11) (2005) 1816.