Tooth attachment in a Narwhal *(Monodon monoceros)* compared to a Human *(Homo sapien)*

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Introduction: One of the current challenges in tissue engineering is attachment of the *in vitro* grown tissue to native tissue. The first step is to understand the natural attachment and this work focuses on the attachment of a human tooth and its relation to biomechanical function. Comparison studies of structure and mechanical properties at micro- and nano-scales were performed on teeth taken from narwhal (NW) (*Monodon monoceros*) and humans (*Homo sapiens*) to determine if the NW tooth is a valid experimental model to study macro-scale functional biomechanics between cementum (C) and root dentin (RD). It is known that the limited human cementum thickness [Fig.1] offers a challenge when performing macro-scale biomechanics study [1]. Hence, sections from NW tusk (tooth) and human tooth were obtained and the structure and mechanical properties were determined using histology, high resolution microscopy, and site-specific nanoindentation techniques. It is hypothesized that the NW tooth attachment is similar to a human involving micro-scale collagen fiber bundle (CFB) insertions into root dentin with similar mechanical properties. The results presented are site-specific properties of the CFB and cementum dentin junction (CDJ) which form the basis for tooth attachment.

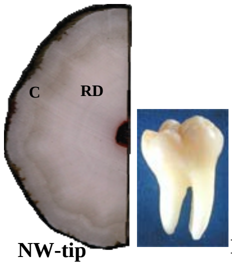

Figure 1: Size of ½ disc taken from the tip of a NW tusk compared to a human tooth. C- cementum (C); root dentin (RD).

Materials and Methods: 3 mm thick, 2 x 5 mm specimens were prepared from 6 mm thick discs sectioned ~ 12 cm from the tip of a 220 cm NW tusk. 2 mm thick, 2 x 3 mm specimens were sectioned from the apical third of human molars. The specimens were ultrasectioned [2] for high resolution structural analysis under dry and wet conditions using an AFM (Multimode, Veeco-DI, CA) followed by site-specific nanoindentation using an AFM-based nanoindenter (Triboscope, Hysitron, St. Paul, MN) with a 100 nm radius of curvature Berkovich diamond tip, the rate of loading equal to 333.3 μN/s. Histology specimens from NW and human were stained with Masson's trichrome after fixing and demineralizing in Cal EX – II solution [Fisher Scientific, Fair Lawn, NJ].

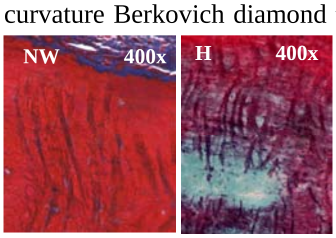

Figure 2: Representative histology micrographs

Results: Histologically CFB at the root surface and within cementum [dark bands in Fig. 2] were observed in both species. Complementing these results were AFM micrographs under wet conditions, which illustrated swollen CFB [Fig. 3a] within cementum connecting to RD in both species. Although fibers running parallel to the root surface were observed, no distinct lamellar pattern as observed in humans was seen in NW [Fig. 3]. A higher concentration of 2.5 – 11.5 μm wide NW-CFB was observed while human-CFB was 2-7 μm [Fig. 3a]. An increased swelling (CDJ) adjacent to RD limited to a width of 15 to 30 μm similar to human tissue [Fig. 3b] was observed. The following table provides a similar range in elastic moduli of wet CFB and CDJ across species. The higher elastic modulus values of human CDJ could be due to higher degree of mineralization.

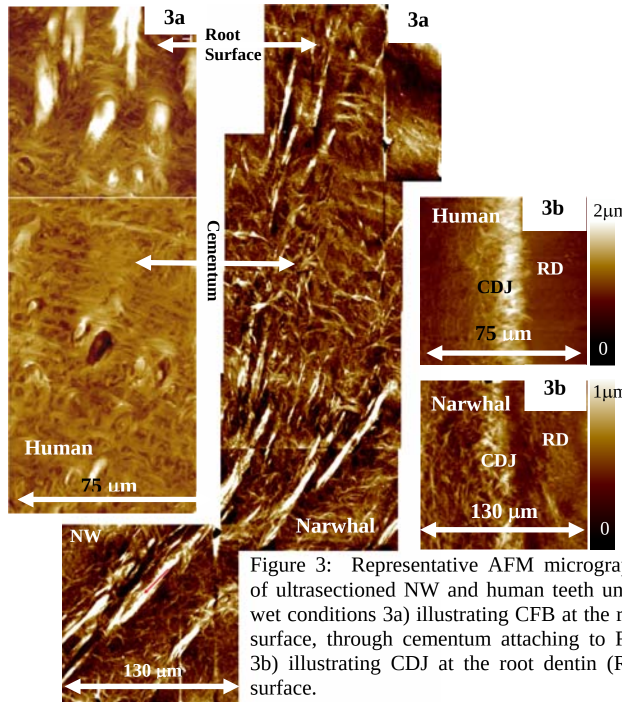

Figure 3: Representative AFM micrographs of ultrasectioned NW and human teeth under wet conditions 3a) illustrating CFB at the root surface, through cementum attaching to RD; 3b) illustrating CDJ at the root dentin (RD) surface.

Species	CFB (GPa)	CDJ (GPa)
Human	1.2 - 3.0	2.1 - 3.7
Narwhal	1.5 - 2.7	1.7 - 2.4

Conclusions: Despite the obvious size and tooth-function differences across species, amazingly the CDJ and tooth attachment structures, predominantly dependent on CFB, were found to be very similar. Additionally, the elastic modulus values and the swelling of these regions under wet conditions were similar potentially due to similar chemical composition including collagen fibers and glycosaminoglycans as observed in humans [3]. Thus, NW tooth specimens could serve as a valid experimental model to study macro-scale functional biomechanics between cementum and root dentin. Currently, detailed investigations of the chemical composition are being performed using Raman spectroscopy.

References & Acknowledgements: 1. Currey JD, Bones Structure and Mechanics, Princeton University Press, 2002, pg. 177; 2. Ho SP, Balooch M., Goodis HE., Marshall GW., Marshall SJ, JBMR., 68A, 343-351, 2004; 3. Ho SP, R Sulyanto, SJ Marshall, GW Marshall, JStruct. Biology, 151, 69-78, 2005. Support: NIH/NIDCR P01DE09859.