Nano-indentation of a King Cobra Fang

Michelle L. Oyen
Dehua Yang, Ph.D.

Figure 1: King Cobra, *Ophiophagus hannah.*

Nanoindentation techniques have been used to explore the mechanical properties of human teeth. Enamel, the hard outer covering of the tooth, is both harder and stiffer than the interior dentin.

Snake fangs are also teeth, and are also covered with an exterior enamel surface. The current study was undertaken to compare the mechanical response of snake fang enamel to human tooth enamel.

The snake fang tested in this study was from a King Cobra (Figure 1), a venomous snake. The fang is shown mounted on a sample puck in Figure 2, along with a schematic of the fang structure. The indentation tests were performed between the venom inlet and outlet sites.

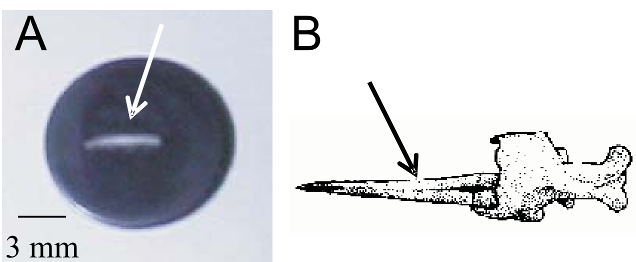

Figure 2: (A) King Cobra fang mounted on sample puck, with arrow indicating indentation site (B) Schematic of fang in similar orientation to mounted sample.

Nanoindentation experiments were performed with a Hysitron TriboIndenter®, an instrument with combined indentation and scanning probe microscopy capability. Indents were placed on the unpolished tooth surface. Four different peak loads were used, 200, 550, 1500, and 4100 μN. Figure 3 shows a scanning probe image of an indent array on the surface of the fang. Since the surface was slightly rough, values were averaged for the sixteen indents at each peak force level.

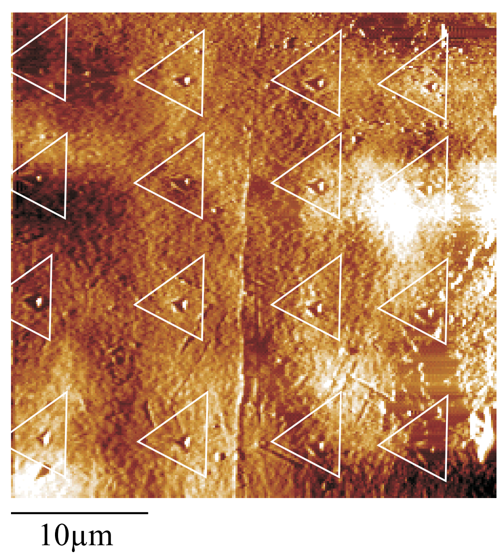

Figure 3: Scanning probe image of a 4x4 indent array on the surface of a King Cobra fang. Indents were spaced 10 μm apart, peak load was 1500 μN.

Nanoindentation load-displacement traces are shown in Figure 4 for the four different peak loads. There is some scatter in the responses, likely due to the surface roughness. Modulus and hardness values were calculated for each trace, and averages were computed for each peak load value. These results are shown in Table 1 below. Modulus decreased with increasing peak load, corresponding to increasing depth into the tissue. Hardness was approximately constant with depth. Standard deviations were larger for the small indents and decreased with larger indents, likely due to surface height variations in the local indent zones.

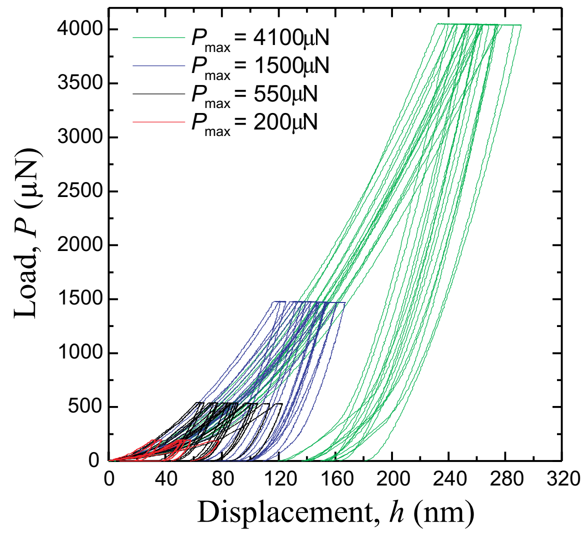

Figure 4: Indentation load-displacement traces for the exterior enamel of a King Cobra fang.

Indent Peak Load	Reduced Modulus E_r (GPa)	Hardness H (GPa)
200 μN	73.6 ± 19.9	2.3 ± 1.3
550 μN	64.3 ± 9.0	2.5 ± 0.9
1500 μN	54.6 ± 7.8	2.6 ± 0.6
4100 μN	46.1 ± 4.3	2.7 ± 0.3

Table 1: Means and standard deviations of mechanical property values for the surface of a King Cobra fang.

Modulus and hardness values for snake fang enamel were comparable to values previously quoted for nanoindentation of human enamel (E_r = 60-90 GPa, H = 3.1-3.4 GPa). The slightly lower hardness values for snake fang are likely related to the lack of surface polishing in this study. The decreasing modulus values with depth for snake fang may be related to differences in tissue layers or due to increased compliance from indenting a hollow structure.

References:

Habelitz S, Marshall SJ, Marshall GW, Balooch M: Mechanical properties of human dental enamel on the nanometre scale. *Arch Oral Biol* 46 (2001) 173-183.

Marshall GW, Balooch M, Gallagher RR, Gansky SA, Marshall SJ: Mechanical properties of the dentinoenamel junction: AFM studies of nanohardness, elastic modulus, and fracture. *J Biomed Mater Res* 54 (2001) 87-95.

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10025 Valley View Road
Minneapolis MN 55344
Tel: (1) 952-835-6366
Fax: (1) 952-835-6166
info@hysitron.com
www.hysitron.com

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