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Correlation of ultrasound microscopy and Vickers hardness measurements of human dentin and enamel — A pilot study

Mareike Warkentin[a], *Cora Freyse*[b], *Olaf Specht*[c], *Detlef Behrend*[a], *Reinhard Maletz*[a], *Ralf Janda*[d,*], *Peter Ottl*[b]

[a] *Department of Materials Science and Medical Engineering, Friedrich-Barnewitz-Strasse 4, 18119 Rostock, University of Rostock, Germany*

[b] *Department of Prosthodontics and Materials Science, Strempelstrasse 13, 18057 Rostock, University of Rostock, Germany*

[c] *Institute of ImplantTechnology and Biomaterials e.V., Rostock, Friedrich-Barnewitz-Strasse 4, 18119 Rostock, Germany*

[d] *Dept. of Operative and Preventive Dentistry and Endodontics, Centre of Dentistry, Medical Faculty, Heinrich-Heine-University, Moorenstraße 5, Geb. 18.13, D-40225 Düsseldorf, Germany*

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ABSTRACT

Objective. To investigate if Vickers microhardness of dentin and enamel correlated with acoustic velocity c(l) or acoustic reflection from the sample's top (amplitude).

Methods. Eight transversal sections of a sound human tooth were investigated with scanning acoustic microscopy (SAM) and Vickers microhardness measurements. Longitudinal acoustic velocity c(l), amplitude and microhardness MHV were evaluated and for each c(l) test point corresponding amplitude and MHV were linearly interpolated and graphically analyzed. Spearman rank order correlation (r_S) was calculated ($p < 0.05$).

Results. c(l) was predominantly 6100–7000 ms^{-1} in enamel and 3800–4600 ms^{-1} in dentin and correlated significantly with MHV with 27–420 in enamel and 20–90 in dentin ($r_s = 0{,}57$). Amplitudes significantly correlated with MHV, too, but even better ($r_s = 0{,}77$).

Significance. Acoustic velocity and amplitudes were appropriate to detect microhardness differences of dentin and enamel and certain value ranges of both could be assigned to certain MHV ranges. Further research is needed to differentiate more precisely between the different hard tooth tissues.

1. Introduction

Scanning acoustic microscopy (SAM) also known as acoustic micro imaging (AMI) of dental hard tooth tissues had already started in the early fiftieth of the 20th century [1] and up to now a broad experience exists with this method to investigate all parts and properties of the hard tooth tissues [2–15]. SAM is also appropriate to detect caries [16], to judge the mechanical properties of enamel and dentin [17–22] or to investigate interfaces between tooth and restorative materials [23,24]. The big advantage of SAM is its accurate and nondestructive character.

* *Corresponding author.*
E-mail address: Ralf.Janda@uni-duesseldorf.de (R. Janda).

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In material science all types of hardness measuring methods are broadly used standard methods to judge the mechanical properties of all kinds of materials not only in dentistry but in all fields of technology and industries. The microhardness, one of the various methods, is easy to perform and appropriate to evaluate also the hard tooth tissues or even tiny parts of them [7,8,25–31]. Based on microhardness measurements Young's modulus of human dentin and enamel was calculated [7,8] and also the effect of bleaching on enamel was tested accordingly [26].

The goal of the present pilot study was to ascertain if there is a correlation of microhardness and SAM measurements when performed on human hard tooth tissues. No such study was found in the literature. If SAM indicated hardness differences between the different hard tooth tissues, this might be of importance in material development and research for nondestructive testing of restored teeth with varying materials. Especially when interfaces are examined, as for instance restorative-enamel [24] or restorative-dentin [23] interfacial bonding or debonding processes, a nondestructive and contactless research method might be advantageous. The null hypothesis of the present investigation was that there is no correlation of Vickers microhardness with acoustic velocity or acoustic reflection from the samples' tops (amplitude).

2. Materials and methods

2.1. Sample preparation

An intact upper second molar of a 48-year old patient without general diseases was extracted due to advanced periodontal attachment loss. The study was approved by the Ethics Committee of the University of Rostock (registration number: A 2010 26). Prior to preparation the tooth was stored in artificial saliva (according to DAC/NRF 7.5 Germany) at 4 °C and a three-dimensional X-ray (micro CT, Sky Scan 1172^{TM}, Bruker Inc., Billerica MA, USA) was performed (80 kV, 100 μA, filter Al 0.5 mm). Two corresponding datasets with a final image voxel size of about 34 μm were obtained. Prior to embedding in epoxy resin (Epothin, Buehler GmbH, Duesseldorf, Germany) the tooth was wrapped in Parafilm M (Bemis Inc., Neenah, WI, USA) to avoid contamination and cut into eight horizontal cross sections of equal thickness (2 mm) with a diamond-wire-saw (wire diameter 0.3 mm, HistoSaw DDM-P 216, Medim, Gießen, Germany) under permanent water cooling (Fig. 1).

The first and the last slice of approx. 1 mm thickness were discarded. The slices were deburred and ground from both sides under constant water cooling by changing their orientation by 90° every 20 s (device Tegra-Pol-15, Stuers GmbH, Willich, Germany, silicon carbide paper P-800, P-1200, P-2500 and P-4000, Buehler GmbH, Duesseldorf, Germany). A Cartesian coordinate system was scratched on the coronal side of each slice to assign the points for the following measurements. The average thickness of each slice was obtained by measuring its thickness in 1 mm steps (x- and y-direction, measuring error 1.54%) with a caliper gauge (Mitutoyo Inc., Kawasaki, Japan). This resulted in values between 1.46 and 1.74 mm (Fig. 1).

2.2. Acoustic measurements

Ultrasound C-scans were taken from the top of each slice (scanning electron microscope SAM 300, PVA TePla GmbH, Wettenberg, Germany, single element 50 MHz ultrasound transducer). The slices were positioned in a water-filled hole of a brass block and the whole assembly was put in a water bath (aqua dest.) so that the impedance difference of the sample to the surrounding was the same from its front and back and the echo could not be falsified by a further interface. The sample holder was put in such position that the movements of the SAM-transducer corresponded with the axes of the coordinate system on the samples' tops. The subsequent C-scan (200 ns, 320 V, 11 dB) served as orientation to position the trans-

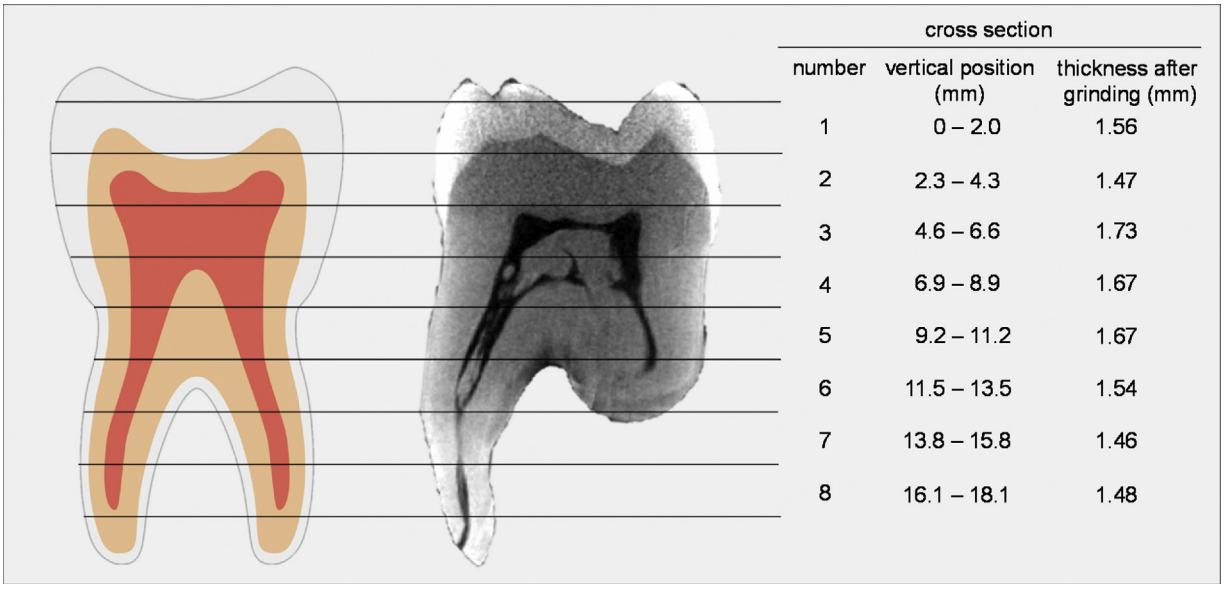

Fig. 1 – μCT of the tooth' palatinal-vestibular plane, vertical positions of the preparations, slice thicknesses after grinding (mm).

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