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Influence of Non-alcoholic Beverages on Micromechanical Properties of Human Enamel

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Abstract. Human enamel is a part of tooth which protects dentin and pulp against excessive mechanical stress during mastication and other outer stimuli (chemical, thermal etc.). If the enamel is damaged, as a result of change in mineral content and consequent decrease of mechanical resistance, cavities can initiate easier and it can lead to extraction of the whole tooth. Aim of the study is to show negative impact of beverages with a high content of sugar and a low pH value on micromechanical properties and thickness of the human enamel. The study points out that even short-term contamination (10 s) by the selected beverage causes decrease of surface hardness (H_{it}) and reduced modulus (E_r) of the enamel. The contamination for 5 min by coke caused decrease of the enamel thickness ~ 400 μm and decrease of the hardness ~ 22 %.

Introduction

Enamel is the hardest tissue in a human body. The hardness of enamel is a result of its composition – 96 % inorganic mineral in the form of hydroxyapatit and 4 % water and organic matter [1]. The enamel's primary purpose is to protect dentin and pulp against exposure to the outer stimuli. Among the most common stimuli are mechanical stress during mastication and exposure to the chemical processes during consumption of foods and beverages. Damage to the brittle enamel may then cause easier initiation of cavities and subsequent damage to the whole tooth and need of extraction.

Generally known fact is that excessive consumption of food and beverages with a high content of sugar has negative impact on oral health. In recent years, authors [2, 3] dealt with influence of coke on dental erosion and hardness of the enamel because the coke is favourite drink of adults and kids, despite the fact that contains much sugar and has a low pH value. The authors [3, 4] warn that contamination by the coke causes demineralization and softening of the enamel, although saliva slows down this action. People, who want to live healthy, can be threatened by damage of the enamel caused by consumption of drinks too. Consequences of sport drinks, fruit juices [4, 5], black and herbal tea [6] are often discussed.

This work is dedicated to evaluation of the influence of different common beverages that humans consume on the values of micromechanical properties and thickness of the enamel. Some of the analysed beverages are coke, orange juice, tea with honey or water. Due to the low volume of analysed material, we chose the nanoindentation method to determine the values of micromechanical properties. The analysed properties are hardness (H_{it}) and reduced modulus (E_r).

Methods

Micromechanical tests were carried out on a series of molars extracted due to paradontal reasons. The test specimens were carefully chosen so as to contain minimal visible damage to the enamel layer. The chosen molars were embedded in epoxy resin and subsequently cut into specimens 1 cm thick. The specimens were then grounded and polished in order to reach the occlusal surface. The complex morphology of the occlusal surface does not enable for direct indentation on the outer rim of enamel, but the tooth rather needs to be polished into a flat area. The specimen preparation is based on previous experiences in nanoindentation of teeth and materials of dental implants [7, 8].

The indentation was split into three parts. The first measurement was made on a clean specimen. The second measurement was made after contaminating the specimen for 10 seconds. The third measurement was made after 5 minutes of contamination. All specimens were individually contaminated by 20 µl of the liquid. For the purpose of this study, the most basic liquids (tap water, coca-cola, orange juice and tea+honey) were chosen. The values of pH (Tab. 1) were determined by pH meter (Hanna Instruments, USA). The contents of sugar (Tab. 1) were determined by nutrition labels, the only exception was a sugar content in the tea+honey which had to be calculated from the ratio tea/honey and the sugar content in the honey itself.

Tab. 2 The values of pH and sugar contents of the selected beverages

Beverage	pH	Sugar content [g/100 ml]
coke	2.74	11.20
orange Juice	3.97	10.00
tea+honey	4.58	8.90
H_2O	7.74	0.00

The measurements were performed on the CSM Instruments Nano Hardness Tester (CSM Instruments SA, Switzerland) equipped with a cube corner indentation tip. We used the mode of directed force with maximum force of 15 mN and loading speed of 90 mN/min. Evaluation of results was made in accordance with the standard Oliver&Pharr method [9].

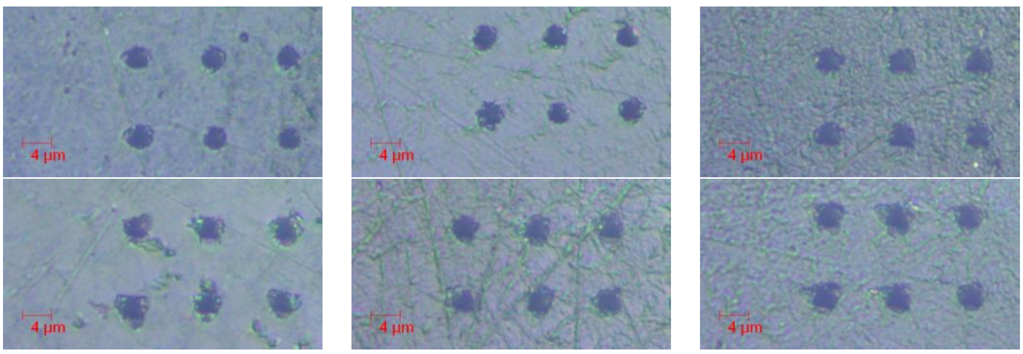
Results

Individual measurements were made in matrices of 5x5 indents. Subsequently, the changes in values of the micromechanical properties (the hardness, the reduced modulus) caused by chemical impact of the different commonly consumed beverages were evaluated. Impact of the beverages on degradation of specimen surface and enamel thickness was compared as well. The degradation of the surface was analyzed by an optical microscopy (1000x magnification) and an atomic force microscope (AFM). Fig. 1 shows obvious difference in roughness of the polished specimens.

without contamination | 10 s | 5 min

01 coke

02 orange juice



03
H_2O

04
tea+honey

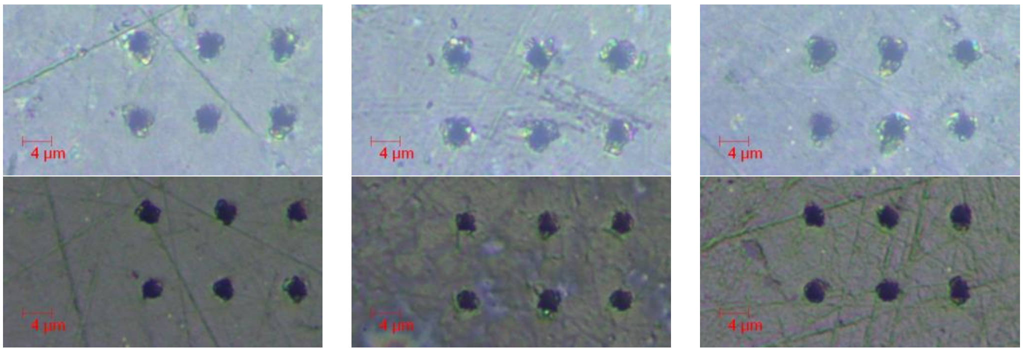


Fig.1 Degradation of the specimen surfaces caused by chemical impact of the different commonly consumed beverages. The degradation is compared for the specimen surfaces without contamination and contaminated for 10 s or 5 min

The determination of decrease in thickness of the enamel which is part of the specimen embedded in epoxy resin was a difficult task. Therefore, the nanoindentation was used for approximate evaluation. A matrix of indents with depths ~ 1240, 1040, 810, 730, 680, 550 and 400 nm was performed by different maximum loading forces – 25, 15, 10, 8, 6, 4 and 2 mN. Based on observability of the indents after 5 min of the contamination was possible to estimate decrease in the enamel thickness. Fig. 2 shows that the indent with depth of 400 nm (2 mN) is almost invisible which was caused by etching. The greatest decrease in thickness ~ 300–500 nm and the most degraded surface was observed after contamination by the coke and the juice for 5 min. On the contrary, after contamination by the water no degradation of the surface was observed. The change in smoothness of the specimen surface caused by short-term contamination (10 s) was the most obvious for the juice (Fig. 1).

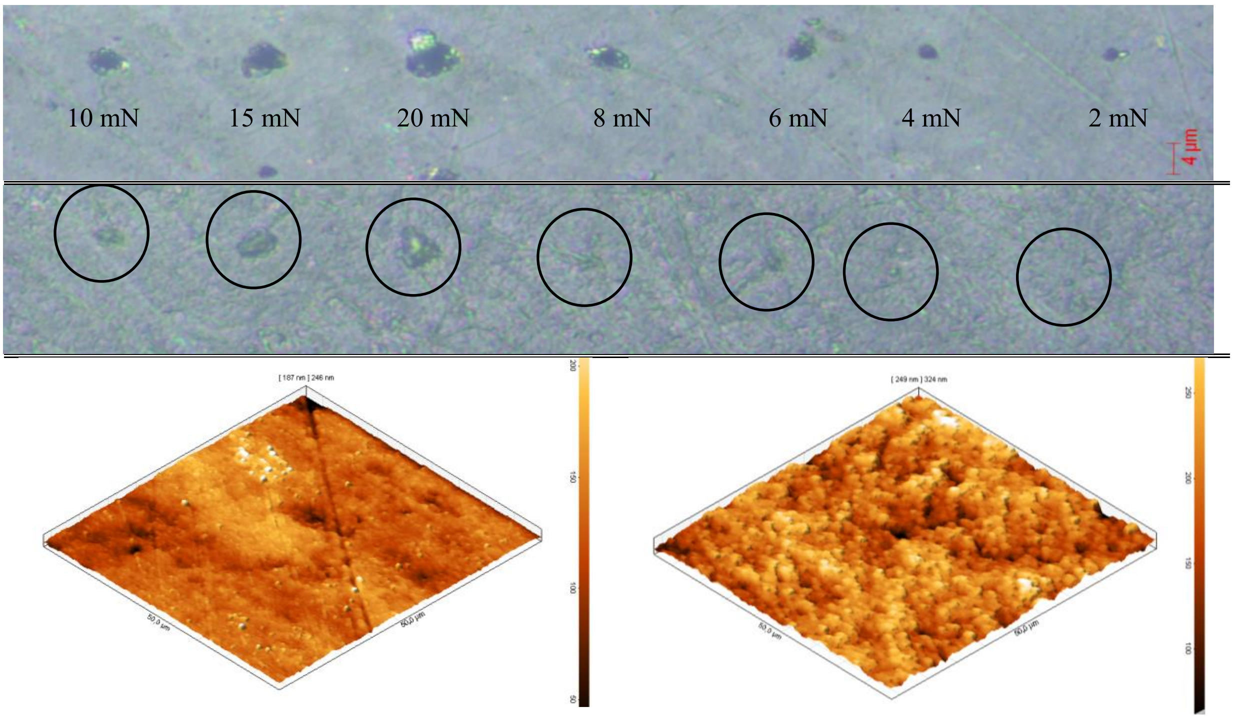


Fig.2 Comparison of observability of the indents before (at the top) and after 5 min contamination by the coke (in the middle). The figures were performed by optical microscope (1000x magnification). Based on the observability it was possible to estimate decrease in the enamel thickness ~ 300–500 nm. Pictures performed by AFM (at the bottom) show difference in surface roughness before (on the left) and after (on the right) contamination

The measurements of the micromechanical parameters, such as the hardness (H_{it}), the reduced modulus (E_r) and a contact depth (h_c), were statistically determined and overall results are showed in Tab. 2. The obvious changes were observed for every parameter but the difference in hardness (Fig. 3) was dominant. The hardness of enamel decreased ~ 10–20 % for specimens 01 and 02 (the coke and the juice) after 5 min of contamination. Short-term contamination (10 s) caused decrease ~ 3% for the same specimens.

Tab. 2 Reduced modulus (E_r), hardness (H_{it}) and contact depth (h_c) without and with contamination for 5 min

		01 – cola		02 – orange juice		03 – H_2O		04 – tea+honey	
		0 s	5 min	0 s	5 min	0 s	5 min	0 s	5 min
H_{it} [MPa]	Mean	3378	2645	2907	2603	2918	2926	3508	3379
	Std Dev	182	167	283	185	146	252	170	133
[%]	Decrease	21.70		10.46		–			3.68
E_r [Gpa]	Mean	96.13	91.36	89.25	88.29	89.56	87.94	101.75	94.82
	Std Dev	6.6	7.6	7.7	4.5	5.3	4.9	8.1	3.8
[%]	Decrease	4.97		1.08		–		6.81	
h_c [nm]	Mean	1030	1169	1115	1179	1110	1107	1010	1031
	Std Dev	29	37	55	43	29	50	25	21

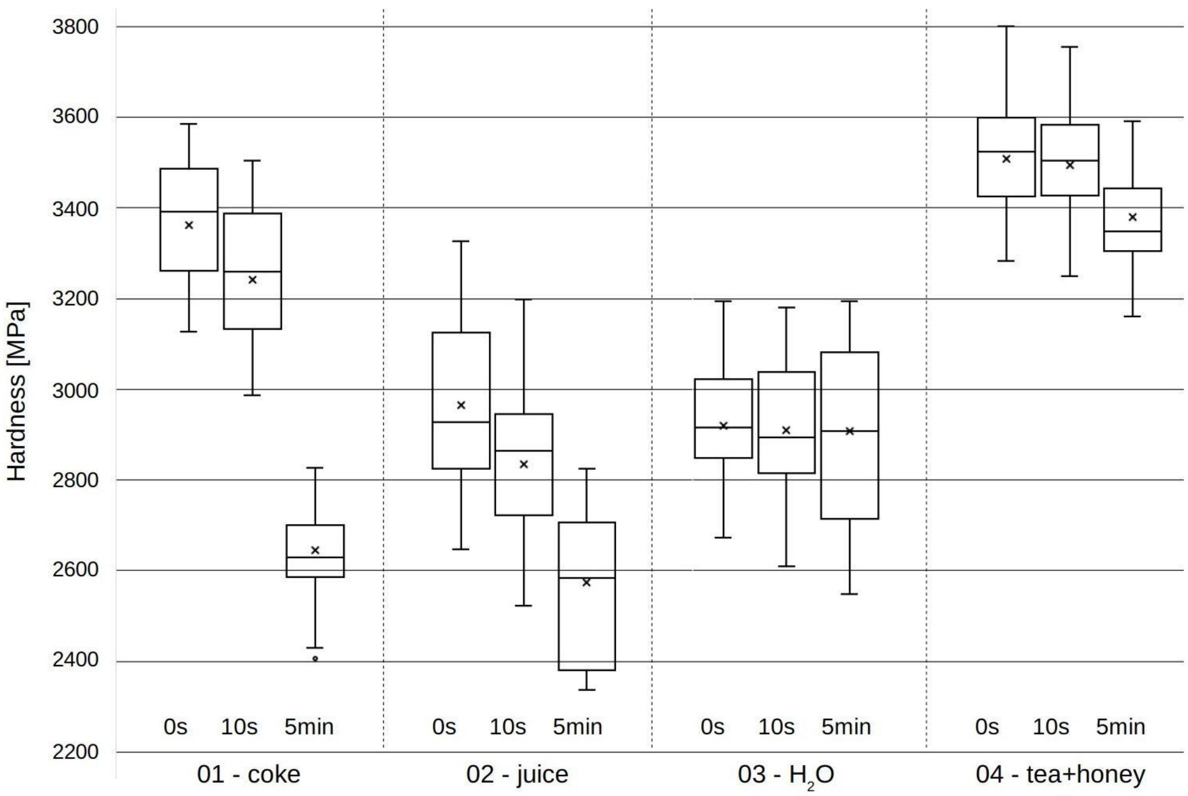


Fig.3 The statistically determined values of the hardness (H_{it}) before and after contamination (10 s, 5 min) by the coke, the juice, the H_2O and the tea+honey

Conclusions

The measurements proved that contamination by the commonly consumed beverages (the coke, the orange juice) can negatively affect the human enamel. The contamination by H_2O was observed as well for verification of the measurements. As expected, the water had no effect on the micromechanical parameters and the degradation of specimen surface. The analysis showed that drinks with low values of pH can cause significant decrease in enamel thickness and degrade surface of the enamel. As a result, quality of teeth and resistance to cavities can be lowered. The question is how much the degradation depends on the high sugar content of the observed beverages.

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