Effect of coffee, tea, and milk consumption on tooth surface hardness (In vitro study)

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ABSTRACT

Background: Dental erosion is considered as the primary factor of hard tissue tooth loss. The etiology of dental erosion is the source of acid acting on tooth surface, which may be intrinsic through the backflow of gastric contents or extrinsic from dietary components. Coffee, tea, and milk are types of beverages with the largest consumption among Indonesian society. Their acidity and chemical properties are considered to play a role in the process of dental erosion and cause the change of tooth surface hardness.

Purpose: The aim of this research is to determine the effect of coffee, tea, and milk consumption on tooth surface hardness.

Methods: This research was started by measuring the baseline tooth surface hardness of 24 specimens using Micro Vickers Hardness Tester. The specimens were alternately immersed for 5 s in 20 mL test beverages (aquadest, coffee, tea, milk) and 20 mL artificial saliva for 10 cycles at room temperature. Total immersion time was 100 s. After the immersion sequence was completed, all specimens were conducted to post-immersion tooth surface hardness measurements. The baseline and post-immersion tooth surface hardness were analyzed using Paired T-test. The mean of tooth surface hardness changes were analyzed by one way ANOVA followed by LSD test.

Results: The result showed that there were statistically significant changes in tooth surface hardness (p<0.05) in coffee, tea, and milk group compared to control group.

Conclusion: The conclusion of this study is coffee, tea, and milk affects the tooth surface hardness.

Key words: Dental erosion, tooth surface hardness, beverages.

INTRODUCTION

Dental erosion is considered as the main factor of hard tissue loss. Its prevalence reached 80% in children and 43% in adults.1 Dental erosion is a condition of tooth structure loss as a result of acid dissolution without any direct bacterial involvement.2 Erosion process induces substantial loss of enamel elements subsequent exposure of the underlying dentine which leads to dentine sensitivity and tooth pain, vertical height reduction, and esthetic problem.3 Erosive demineralization also generates significant reduction of tooth surface hardness, causing the tooth surface vulnerable to mechanical impacts.2

Tooth surface is formed by enamel which is the hardest tissue of human body regarding its high mineral content, 95-98% inorganic materials in the form of hydroxyapatite crystals [[Ca₁₀(PO₄)₆(OH)₂]]. In spite of its hard and dense structure, enamel is permeable to certain ions and molecules. This permeability enables the penetration of ions and molecules from dietary components into tooth enamel which then dissolve the enamel and cause dental erosion.4,5

The underlying etiology of erosion is the exposure of acid on tooth surface, which may be intrinsic through the backflow of gastric contents or extrinsic from dietary components.2 Consumption behavior of
acidic beverages is the most common extrinsic factor causing dental erosion. Beverage-induced erosion is regard to the frequency of consumption and chemical composition.6

There are various types of beverages consumed among society, including coffee, tea, and milk. According to THIRST (The Indonesian Regional Hydration Study), coffee, tea, and milk are types of beverages with the largest consumption among Indonesian society.7 Their acidity and chemical properties are considered to play a role in the process of dental erosion and cause the change of tooth surface hardness. The aim of this research is to determine the effect of coffee, tea, and milk consumption on tooth surface hardness.

MATERIALS AND METHODS

Micro Vickers Hardness Tester MM 0054 (Buehler, Japan), pH meter TOA DKK IM-55G, immersion container, Beaker glass, calculator, micromotor, thermometer, maxillary first premolars, aquadest, artificial saliva, coffee, tea, milk, resin and catalyst, mask, gloves.

The research specimens were 12 sound human maxillary first premolars extracted for orthodontic reasons and were cut out of the roots. The crown parts were sectioned longitudinally into buccal crowns and palatal crowns. All specimens were randomly divided into 4 groups: control (aquadest), coffee, tea, and milk group. Each group consists of 3 buccal crowns and 3 palatal crowns. Each specimen was placed into a cylindrical resin mould with the enamel surface on the upper side and kept in distilled water for 2 x 24 hours before testing to equalize the water contents.

Baseline microhardness measurements were tested using Micro Vickers Hardness Tester with 100 grams load for 30 seconds. Indentation using Vickers diamond produced rhombic shaped with two diagonal lengths (d1 and d2). The mean of two diagonal length results was then inserted into Vickers Hardness formula:8

\[ \text{VHN} = \frac{1.854 \times \text{P}}{\text{d}^2} \]

VHN : Vickers Hardness Number (kg/mm²)
P : load weight (100 grams)
d : diagonal length (1/1000 mm)

Following the measurement of baseline microhardness, all specimens were immersed in test beverages in accordance to each group (control, coffee, tea, and milk) and in artificial saliva. The immersion method was performed as follows: all specimens were alternately immersed for 5 s in 20 mL test beverages (aquadest, coffee, tea, milk) and 20 mL artificial saliva for 10 cycles at room temperature. Total immersion time was 100 s.9 After the immersion sequence was completed, all specimens were conducted to post-immersion tooth surface hardness measurements.

The baseline and post-immersion tooth surface hardness were analyzed using Paired T-test. The mean of tooth surface hardness changes were analyzed by one way ANOVA followed by LSD test.

RESULTS

The baseline and post-immersion Vickers Hardness Number of four experiment groups are shown in figure 1 and table 1. Immersion of specimens in coffee causing a significant reduction of tooth surface hardness (p<0.05). Tooth surface hardness increased significantly (p<0.05) in tea and milk group.

Figure 2 shows the reduction of tooth surface hardness in coffee group (78.127 ± 3.249 VHN) as well as the rise of tooth surface hardness in tea (56.054 ± 11.061 VHN) and milk (73.944 ± 11.589 VHN) group.

![Figure 1. Graphic of tooth surface hardness pre- and post-immersion in control (aquadest), coffee, tea, and milk group.](image1)

![Figure 2. Graphic of tooth surface hardness changes in control (aquadest), coffee, tea, and milk group.](image2)
One way ANOVA analysis indicates that there were significant differences (p<0.05) between four test beverages groups with p-value=0.001. Table II shows post hoc analysis using LSD test. The significant differences of tooth surface hardness changes occurred in control group compared to coffee, tea, and milk group, as well as coffee group compared to tea and milk group. There was no significant difference of tooth surface hardness changes between tea and milk group (p>0.05).

<table>
<thead>
<tr>
<th>GROUP</th>
<th>n</th>
<th>Tooth Surface Hardness (VHN)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (Aquadest)</td>
<td>6</td>
<td>Pre-Immersion: 262.212 ± 27.575</td>
<td>Post-Immersion: 262.996 ± 27.206</td>
</tr>
<tr>
<td>Coffee</td>
<td>6</td>
<td>283.842 ± 17.892</td>
<td>205.715 ± 16.431</td>
</tr>
<tr>
<td>Tea</td>
<td>6</td>
<td>271.518 ± 11.308</td>
<td>327.572 ± 13.702</td>
</tr>
<tr>
<td>Milk</td>
<td>6</td>
<td>279.030 ± 22.811</td>
<td>352.974 ± 24.814</td>
</tr>
</tbody>
</table>

* = significant difference (p<0.05)

The significant decrease of tooth surface hardness occurred in coffee group, as showed in Paired T-test analysis, indicated the erosion of tooth specimens immersed in coffee. This phenomenon caused by the acidic nature of coffee drinks. The coffee used in this experiment has relatively low pH value (Table 3). Low or acid pH value is one of tooth erosion factors. Previous studied suggested that the degree of acidity (pH) is a major factor in determining the erosive potential of dietary components. Another supporting statement said that pH is an accurate indicator of tooth erosion. Furthermore, malic acid contained in coffee also involved in the process of erosion due to its chelating properties. This acid is able to bind tooth calcium and induce enamel crystal porosity effecting in tooth erosion, hence decreasing tooth surface hardness.

### DISCUSSION

In recent years, dental hard tissue damage problems among children and adults are considered as the result of the rising dental erosion incident. High consumption of acidic beverages is believed to play a major role in its erosive process. The acid of beverages acting on tooth surface will release H+ ions which will bind to the hydroxyl groups (OH) and phosphate groups (PO₄) of hydroxyapatite crystals (Ca₁₀(PO₄)₆(OH)₂) to form H₂O, HPO₄²⁻, dan H₂PO₄⁻. This process leads to the depression amount of OH⁻ and PO₄³⁻ causing the dense hydroxyapatite crystals (solid) to be dissolved (solution). The continually demineralization process will create small pores in tooth enamel, which is called porosity, resulting in the reduction of enamel surface hardness.

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Beside coffee, tea is also classified as acidic beverage because of its low pH. The pH value of tea used in this experiment is even lower than the coffee (Table 3), nevertheless there was no erosion or reduction of tooth surface hardness in all specimens immersed in tea. However, pH is not the only factor provoking dental erosion. Several other factors...

### Table 3. pH value of test beverages: aquadest (control), coffee, tea, and milk

<table>
<thead>
<tr>
<th>Test Beverages</th>
<th>Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.001*</td>
</tr>
<tr>
<td>Coffee</td>
<td>0.001*</td>
</tr>
<tr>
<td>Tea</td>
<td>0.153*</td>
</tr>
<tr>
<td>Milk</td>
<td>0.153*</td>
</tr>
</tbody>
</table>
factors may contribute in the process of dental erosion, including the concentration of chemical ions in beverages. Tea contains a number of calcium, phosphate, and fluor.\textsuperscript{16} Calcium and phosphate are chemical compounds constructing the composition of enamel hydroxyapatite crystals, therefore increased concentration of these compounds on tooth surface layer may form a saturated atmosphere which preventing the dissolution of hydroxyapatite crystals, hence inhibits erosion process.\textsuperscript{14,15} Nonetheless, calcium in tea doesn’t effectively restrain tooth erosion due to its bond with the oxalate in tea forming calcium oxalate complex (CaC\textsubscript{2}O\textsubscript{4}) which has low solubility.\textsuperscript{16} This prevents the release of calcium into tooth surface to form hydroxyapatite crystals. In addition, fluor in tea complex the hydroxyapatite crystals to form a more acid-resistant fluorapatite crystals. Fluorapatite can stimulate enamel remineralization, hence increasing tooth surface hardness.\textsuperscript{17}

Paired T-test results in milk group showed a significant increase in tooth surface hardness. This may be related to pH value of the milk (6.73) which is nearly consistent with the pH of aquadest (7.02). According to study of Ren (2011), tooth enamel will undergo erosive demineralization when pH of oral environment reaches a critical threshold of 5.5.\textsuperscript{3} Based on this theory, milk’s pH value in this research was insufficient to initiate the erosion process so that the demineralization did not occur. Calcium and phosphate are also found in milk in the form of complex casein phosphopeptide-amorphous calcium phosphate (CPP-ACP).\textsuperscript{18} CPP-ACP prevents tooth erosion by localizing ACP onto tooth surface, which buffers free calcium and phosphate ions activities, thereby helping maintain a state of supersaturation by suppressing demineralization and enhancing remineralization.\textsuperscript{19} The calcium bind to casein in milk is easier to release so it can be stated that milk calcium has a high bioavailability.\textsuperscript{20} Milk also contain fluoride that has protective effect through the formation of fluorhydroxyapatite or fluorapatite which is known to have a lower solubility degree than hydroxyapatite.\textsuperscript{16}

This research used periodically immersion method of specimens in test beverages and artificial saliva as a simulation of oral physiological condition. Saliva is a very important biological parameter related to dental erosion development. Several salivary protective mechanisms against dental erosion include the neutralization of acidic condition (buffer), the formation of a protective layer (pellicle) on enamel surface, and remineralization of apatite crystals due to the content of calcium and phosphate ions.\textsuperscript{21,22} The designed method in this research was developed from the previous studies which merely immersed the specimens in beverages without considering the role of saliva.\textsuperscript{5,10,11}

It can be concluded from this study that coffee consumption may reduce tooth surface hardness and cause tooth erosion, while tea and milk consumption can increase tooth surface hardness and prevent tooth erosion.

REFERENCES
3. Ren Y. Dental erosion: etiology, diagnosis, and prevention. ADA CERP 2011; 76-84.