International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Microroughness Changes in Primary Tooth Enamel Following Exposure to Common Beverages

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Abstract: ***This in vitro study investigates how different commonly consumed beverages affect enamel microroughness in primary molars. Sixty caries-free primary molars were sectioned, polished, and randomly assigned to five groups exposed to either distilled water, bottled orange juice, freshly prepared orange juice, fluoridated mouth rinse, or Coca-Cola over a 30-day period. Enamel microroughness was measured before and after treatment using a surface roughness tester. The results revealed significant increases in microroughness for the orange juice and Coca-Cola groups, indicating enamel erosion, while the fluoridated mouth rinse slightly reduced roughness. These findings highlight the importance of moderating acidic beverage consumption and promoting fluoride use in dental care for children.***

Keywords: Primary teeth, enamel erosion, microroughness, acidic beverages, fluoride treatment

1. Introduction

Dental enamel in primary teeth is less mineralized and thinner than in permanent teeth, which makes it more vulnerable to both chemical and mechanical challenges [1]. Demineralization is a process that occurs when acids in dental plaque dissolve the organic and inorganic minerals that make up the basic calcium, phosphate, and hydroxyl crystals found in enamel, dentin, and cementum [2]. This process leads to a reduction in mineral content, which decreases the hardness of the tooth and indicates a need for remineralization [3]. Remineralization involves restoring the missing or damaged minerals in the tooth, and it ideally requires the presence of the same ions, with fluoride acting as a catalyst to facilitate this restoration [4]. Dental erosion, characterized by the irreversible loss of enamel due to acid exposure without bacterial involvement, is a growing concern due to the increased consumption of acidic beverages such as soft drinks and fruit juices. Enamel erosion compromises structural integrity, leading to reduced microhardness and increased surface roughness, which can exacerbate sensitivity and susceptibility to further damage [5, 6, 7].

Enamel microroughness (measured as Ra, the arithmetic average of surface height deviations) indicates surface texture changes that may promote plaque retention or aesthetic degradation. This property is important because it can influence susceptibility to cavities and the outcomes of restorative treatments, especially in children [8, 9]. Exposure to acidic environments, such as soft drinks or demineralizing solutions, can weaken enamel, increasing its microroughness [10, 11]. In contrast, fluoride-based treatments are known to promote remineralization [12]. Understanding how various solutions impact these properties in primary teeth is crucial for developing effective preventive dental strategies.

Previous studies have shown that beverages like Coca-Cola (pH ~2.5, containing phosphoric acid) and orange juice (pH ~3.5, containing citric acid) cause significant enamel demineralization, with citric acid being more erosive than phosphoric acid due to its chelating properties [13, 14, 15]. However, differences between bottled and freshly prepared orange juice, which may vary in acidity and additive content, remain underexplored. Conversely, fluoridated mouth rinses are hypothesized to promote remineralization and mitigate erosive damage. Distilled water, with a neutral pH, serves as a control to assess baseline enamel stability.

Aim: The aim of this study was to evaluate and compare how bottled orange juice, freshly prepared orange juice, Coca-Cola, and fluoridated mouth rinse influence enamel microroughness in primary teeth. The null hypothesis was that no significant differences would be observed in enamel properties before and after exposure to these solutions.

This research is significant because it addresses the real-world implications of dietary habits in children and the preventive role of fluoride. Understanding how commonly consumed beverages affect enamel microroughness can guide clinical recommendations and parental counseling on oral health.

2. Materials and Methods

Sixty caries-free primary molars, extracted prior to their natural exfoliation, were obtained with informed consent from the parents. Teeth were cleaned, disinfected and stored in distilled water at 4°C prior to the study. Then the teeth were sectioned to expose a 5x5x1 mm enamel surface. Samples were polished with 600-, 800-, and 1200-grit silicon carbide burs under water cooling to achieve a flat surface, and cleaned with non-fluoridated pumice. After that they were examined under an operating microscope (Semorr 3000E, Semorr Medical Tech Co., Jiangsu, China) for carious lesions, cracks or defects. Only teeth with sound structures and without caries lesions or other defects were used for the study.

The samples were then randomly assigned to five groups (n=12 each):

- **Group 1 (Control):** Distilled water (pH~7.0).
- **Group 2**: Bottled orange juice (pH~3.5)
- **Group 3**: Freshly prepared orange juice (hand-squeezed from navel oranges, pH~3.5)
- **Group 4:** Fluoridated mouthrinse with sodium Fluoride 0.05%-225 ppm fluoride (pH~6.0, Aquafresh Kids Big Teeth Mouthwash Fruity Flavour)
- **Group 5**: Cola beverage (pH~2.5).

Specimens were immersed in 50 mL of the respective solutions for 30 minutes, three times daily, over 30 days, with 1-hour intervals between immersions, simulating frequent beverage consumption. Solutions were refreshed daily, and exposures occurred at room temperature (20-22°C) with gentle agitation.

Microroughness Assessment

The surface roughness of all samples was measured using a Surface roughness tester (model – SRT-6210S, Shenzhen Graigar Technology Co, Shenzhen, China). It has a five µm radius needle tip with a cutoff value of 0.08 mm (λc), a transverse length of 0.25 mm, a measurement speed of 0.25 mm/sec, and a Gaussian Filter. Measurements were taken before and after immersion.

The diamond tip of the measuring device was positioned at the center of the prepared enamel surface, and the device was activated. During operation, the diamond tip moved horizontally across the tooth surface, back and forth, covering a linear displacement of 1.2 mm. For each sample, the average value of the Ra parameter, measured in micrometers was displayed on the device screen. Five measurements were taken for each tooth to calculate the average Ra value.

Statistical Analysis

Data were analyzed using SPSS (Version 26.0). Normality was assessed with the Shapiro-Wilk test. Pre- and post-immersion microroughness were compared within groups using paired t-tests and between groups using one-way ANOVA with Tukey's post-hoc test. Significance was set at $p<0.05$.

3. Results

The results from the microrouphness tests are presented in table 1.

Table 1: Microroughness (Ra, µm) before and after Treatment

Group	Baseline (Mean ± SD)	Post-Treatment (Mean ± SD)	Change (%)
Bottled Orange Juice (1)	1.890 ± 0.540	2.455 ± 0.530*	+35%
Fresh Orange Juice (2)	1.760 ± 0.630	2.323 ± 0.410*	+32%
Coca-Cola (3)	1.980 ± 0.440	2.475 ± 0.740*	+25%
Fluoride Mouth Rinse (4)	1.880 ± 0.740	1.786 ± 0.230	-5%
Distilled Water (5)	1.860 ± 0.610	1.858 ± 0.545	0%
*Significant difference from baseline (p<0.05)			

Baseline Ra values were consistent and showed no statistically significant differences among the groups. After treatment, Ra levels increased significantly in Groups 1–3 ($p<0.05$). Bottled orange juice caused the highest increase in microroughness (35%), followed by fresh orange juice (32%) and Coca-Cola (25%). Aquafresh mouth rinse resulted in a slight reduction in Ra, while distilled water showed no change.

4. Discussion

The results of our study reject the null hypothesis, demonstrating significant differences in enamel microroughness after exposure to the tested solutions. Bottled and freshly prepared orange juice exhibited the most pronounced erosive effects, increasing microroughness by 30-32% (table 1). This suggests that citric acid's ability to chelate calcium ions contributes significantly to hydroxyapatite destabilization, consistent with previous research [16]. The similar effects of bottled and freshly prepared orange juice suggest that differences in processing or additives (e. g., preservatives in bottled juice) have minimal impact on erosivity, likely because both have comparable pH (~3.5) and citric acid content.

Coca-Cola caused moderate erosion. Cola's lower pH (~2.5) likely exacerbated enamel erosion, leading to microroughness increase (table 1). This aligns with studies reporting severe enamel wear in children consuming acidic soft drinks [17, 18]. However, cola's erosive effect was less severe than orange juice, supporting evidence that phosphoric acid is less erosive than citric acid (table 1). The observed increase in microroughness reflects initial demineralization.

Aquafresh mouth rinse, containing 225 ppm fluoride, effectively restored enamel properties to near-baseline levels in primary teeth by promoting remineralization through fluorapatite formation, a highly acid-resistant mineral. The minimal increase in microroughness in this group indicates fluoride's role in preserving enamel surface integrity (table 1). This supports the use of fluoridated products to enhance enamel resilience in primary teeth, given their natural susceptibility to demineralization. Fluoride varnishes further enhance enamel hardness by forming a surface reservoir that slowly releases fluoride ions, fostering a stable fluorapatite complex that inhibits crystalline dissolution [19]. This process reduces demineralization rates and increases calcium fluoride deposits, with efficacy depending on the type and concentration of fluoride compounds formed on the enamel surface [19].

Microroughness changes are clinically relevant, as increased surface roughness can enhance bacterial adhesion and plaque retention, increasing caries risk [20]. The pronounced roughness in the cola group underscores the need for dietary counseling to limit acidic beverage consumption in children.

5. Conclusion

Bottled and freshly prepared orange juice exhibited the greatest erosive effects on primary tooth enamel, followed by Coca-Cola. The fluoridated mouth rinse helped maintain enamel integrity, while distilled water had no adverse effect. These results emphasize the need for dietary moderation of acidic beverages in children and advocate for the regular use of fluoride products to prevent enamel erosion. Further in vivo studies are recommended to validate these findings under natural oral conditions.

Funding: None

Conflict of Interest: The author declare no conflicts of interest.

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