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ORIGINAL ARTICLE

Erosive potential of soft drinks on human enamel: An *in vitro* study

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Background/Purpose: Most soft drinks are acidic in nature. Regular consumption of these drinks may result in dental erosion. The aim of this *in vitro* study was to evaluate the erosive potential of different soft drinks in Taiwan by a novel multiple erosive method.
Methods: Four commercially available soft drinks in Taiwan were selected for this study. The properties of each product were analyzed to measure their pH, titratable acidity, and ion contents. The erosive potential of the soft drinks was measured based on the amount of loss of human enamel surface following its exposure to the soft drinks tested for different periods (20 minutes, 60 minutes, and 180 minutes). The enamel loss was measured using a confocal laser scanning microscope.
Results: The pH values of the soft drinks were below the critical pH value (5.5) for enamel demineralization, and ranged from 2.42 to 3.46. The drink with ingredients of citric acid and ascorbic acid had the highest titratable acidity (33.96 mmol OH^-/L to pH 5.5 and 71.9 mmol OH^-/L to pH 7). Exposure to all the soft drinks resulted in loss of human enamel surface (7.28–34.07 μm for 180-minute exposure). The beverage with the highest calcium content had the lowest erosive potential.
Conclusion: All tested soft drinks were found to be erosive. Soft drinks with high calcium contents have significantly lower erosive potential. Low pH value and high citrate content may cause more surface enamel loss. As the erosive time increased, the titratable acidity to pH

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7 may be a predictor of the erosive potential for acidic soft drinks. The erosive potential of the soft drinks may be predicted based on the types of acid content, pH value, titratable acidity, and ion concentration.

Introduction

Consumption of soft drinks has become very popular in Taiwan recently.[1] Previous studies have suggested that consumption of sugar-sweetened beverages leads to higher calorie intake, which subsequently leads to the problem of obesity.[2] Results of various studies have shown that nonalcoholic beverages are mostly acidic in nature.[3] Therefore, prolonged contact with such a solution may destroy the hard tissues of the teeth by erosion.[4] Dental erosion is the chemical loss of tooth structure due to the action of acids that are not produced by bacteria.[5] Dental erosion is an important clinical problem in Taiwan. Previous studies have shown that the prevalence of dental erosion is on the rise. Deery et al[6] examined 11–13-year-old adolescents from the United States and the United Kingdom, and reported dental erosion in 41% and 37% of adolescents, respectively.

Among children, dental erosions are mainly caused by excessive consumption of erosive soft drinks.[7] Growing evidence suggests a considerable increase in consumption of potentially erosive drinks.[8] Reports have also been published regarding significant associations between soft drink consumption and dental erosion. A report by the Health Promotion Administration, Ministry of Health and Welfare Studies (Taipei, Taiwan) showed that the prevalence of dental caries in children and adolescents has declined over the past 20 years in Taiwan. However, the survey also reported that there is a rapid increase in the consumption of sugar-containing beverages among children and adolescents.[9] This practice may lead to other health-related problems. To analyze various chemical properties of soft drinks and their effects on human enamel, the erosive potential of four commercially available soft drinks in Taiwan was investigated in this *in vitro* study by a novel multiple erosive method. The null hypothesis tested was that there was no difference in the erosive potential of any of the soft drinks.

Table 1 Ingredients of soft drinks selected for analyses.

Brand	Ingredients (as listed by the manufacturers)	Volume (mL)
A	Carbonated purified water, high-fructose syrup, sucrose, cane sugar, phosphoric acid, nature flavorings, caffeine	600
B	Carbonated purified water, high-fructose syrup, granulated sugar, citric acid, cane sugar, flavor	600
C	Water, diluted fermented milk, skimmed milk powder, citric acid, flavor, soybean polysaccharides, sodium citrate, sucralose, acesulfame potassium	500
D	Water, granulated sugar, lemon juice, citric acid, flavor, sodium citrate, ascorbic acid, safflor yellow, calcium pantothenate, vitamin B_6, carotene	500

Materials and methods

Soft drink preparation and analyses

Four commercially popular bottle drinks were selected and purchased for analyses (Table 1). Freshly opened beverages were analyzed in triplicate to determine their pH values and titratable acidity at room temperature. The pH values of the experimental drinks were measured with a previously calibrated pH meter (Suntex Instruments Co., Ltd, Taipei, Taiwan). Values for titratable acidity were determined as the volumes of 0.1 M NaOH required to increase the pH of 50 mL of the beverages to 5.5 and 7.0. The values were then converted to mmol of OH^- per liter to the pH of soft drinks. The calcium, inorganic phosphate, and fluoride contents of the beverages were determined using an automatic ion chromatography system (861 Advanced Compact IC; Metrohm Ltd, Herisau, Switzerland). The concentrations of ions were used in an iterative computational procedure with the modified Debye–Hückel equation to determine ion activity product (Iap) for hydroxyapatite.[10] The solubility product (Ksp) for hydroxyapatite was based on the research of McDowell et al.[11] The degree of saturation with respect to hydroxyapatite (DSHA) was determined using the following equation:

$$DSHA = (Iap/Ksp)^{1/n}$$, where n equals the number of ions in a unit cell.[10] [1]

Preparation of enamel samples and erosive challenge

Human molar teeth used in the study experiment were collected from the dental clinic of the National Taiwan University Hospital (NTUH; Taipei, Taiwan). This study was approved by the Institutional Review Board of NTUH (Approval Number: 200806002R). The teeth were carefully examined for evidence of caries, enamel hypoplasia, and other defects. Only sound teeth were included for analysis.