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ORIGINAL RESEARCH

Dissolution of Enamel on Exposure to Various Commercial Beverages Available in India

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ABSTRACT

Aim: The study was aimed to estimate the pH of the commonly available soft drinks in the Indian market and to assess the detrimental effects of the juices and beverages on the tooth surface by measuring the weight loss of the tooth sample.

Materials and methods: The study was done with eight different types of commercially available carbonated drink and fruit juices available in the Indian market among which six were carbonated drinks and two were juices. Carbonated drinks experimented were Coca-Cola, Pepsi, Fanta, Mirinda, 7Up and Sprite, and two fruit juices were Tropicana orange juice and real orange juice. Ten different bottles from each category were obtained, and the pH was estimated. Each of the beverages was divided into batch of 10 containers containing the tooth sample. Weight of all samples was measured at 24, 48, 72, 96, and 120 hours with subsequently changing each solution at an interval of 24 hours.

Results: The mean pH of the beverages was found ranging from 2.13 ± 0.02 in Pepsi to 3.41 ± 0.02 in Tropicana on opening. The mean pH of water was found to be 6.98 ± 0.01. Among carbonated drinks, the mean weight loss after 24 hours was highest in Coca-Cola and least in 7Up. Tropicana fruit juice had a higher tooth loss than real orange juices. When compared with water, the tooth loss was significantly higher in Coca-Cola after all specified time (hours).

Conclusion: The pH of both carbonated drinks and fruit juices was below the critical pH. The weight loss was also seen after every 24 hours in all the carbonated drinks and beverages. The study showed that these commercial beverages are harmful to the tooth structures, and hence, the health professionals play a major role in educating the population about its effects and advising them to use these products precisely.

Clinical significance: The change in lifestyle has increased the demand of soft drinks and artificial juice in Indian market. The use of these carbonated drinks and fruit juices causes damage to the tooth structure in all ages, especially in young mass. Our study provides an idea about the deleterious effects of these commercial drinks on dental hard tissues.

Keywords: Artificial beverages, Carbonated drinks, Dental erosion, Enamel dissolution.

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INTRODUCTION

Over the past two decades, due to the drastic change of lifestyle in India, the consumption of carbonated soft drinks and canned fruit juices has increased substantially. This growth has been attributed to the new production companies and the expansion of the older ones. Moreover, the change in the lifestyle of the people has resulted in increased demand of such drinks. Unfortunately, this has led to an increase in the cases of dental erosion among the Indian population.[1] The increased consumption of carbonated soft drinks and juices that have high content of sugar has also resulted in an increased prevalence of different chronic diseases, such as hypertension, type II diabetes, and obesity.[2] Dental problems, such as dental erosion and dental caries are also in the rise because of the increased habit of drinking these commercial beverages.[3]

There is obvious fall in the salivary pH noted after consuming soft drinks, which attributes to the intrinsic pH of the drinks as well as its buffering capacity. For enamel dissolution to occur, a pH of 5.5 is required which

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is considered to be the critical pH. Moreover, the concentration of acids as well as its quantity, mineral chelating properties, exposure time, and temperature also proves to be important in enamel dissolution. Saliva and its content, flow rate, and buffering capacity also play a key role in the process of enamel dissolution.[4]

Low pH and titrability of carbonated soft drinks and juices can damage the teeth by causing erosion on the enamel surface. In addition to this, the fermentable carbohydrates in these drinks are metabolized by microorganisms found in the plaque, producing organic acids. This results in demineralization and further leads to dental caries.[1] In newly erupted teeth, the enamel is porous; thus, it dissolves more easily in comparison with adult enamel.[5] A drop in the pH of dental plaque occurs after consuming carbonated drinks, which takes 20 to 30 minutes to get neutralized by saliva. Although a few attacks may not be harmful, a frequent consumption may lead to deleterious effect.[1]

When the dentition comes in frequent contact with exogenous acids of acidic food and beverages, it can get eroded.[6-11] Such erosions can be prevented by reduction in the amount and frequency of carbonated soft drink consumption.[9,12] Erosion capacity of any food article or beverage can be related with their acidity as well as phosphate and fluoride content. Surface characteristics, such as surface hardness and iodide permeability of enamel also regulate the surface erosion.[13] Similarly, drinks with high calcium, phosphate, fluoride concentration; higher pH; and lower titratable acidity will have less erosing affects.[14] The pathogenesis behind the erosion is high-frequency capacity of drinks which dissolves more number of mineral ions from the tooth surface.[13] With this in the background, the purpose of this study was to estimate the pH of the commonly available soft drinks in the Indian market and to assess the detrimental effects of the juices and beverages on the tooth surface by measuring the weight loss of the tooth sample.

MATERIALS AND METHODS

This study was conducted in the Department of Oral and Maxillofacial Pathology, Kalinga Institute of Dental Sciences, KIIT University, Bhubneshwar, India. Ethical clearance was obtained from the Institutional Ethics Committee Kalinga Institute of Medical Sciences, KIIT University with Letter No. KIMS/KIIT/IEC/003/2017 Dated: 05.01.2017. Eight different types of commercially available carbonated drinks and fruit juices available in the Indian market were obtained and evaluated. Among them, six were carbonated drinks and two were juices. Carbonated drinks experimented were Coca-Cola, Pepsi, Fanta, Mirinda, 7Up, and Sprite. The two fruit juices were Tropicana orange juice and real orange juice. Ten different bottles of carbonated drinks and tetra packs of fruit juices from each category were obtained, and the pH was estimated using a digital pH meter (Systronics digital pH meter 335).

For estimation of mineral weight loss, 90 freshly extracted permanent teeth for orthodontic reasons were collected and stored in 10% formalin. Before storage, the teeth were sterilized in 5% sodium hypochlorite solution. The stored tooth was segmented at cervix using a carborundum disk. Only the crown portion of the teeth was used in the experiment.

The weight of the crown portion of the sectioned teeth was measured using a microbalance (COHETECH digital weighing machine). Each of the beverages was divided into batch of 10 containers containing the tooth sample. Ten tooth samples were immersed in 10 different containers containing distilled water and were considered as control. Weight of all 90 samples was measured at 24, 48, 72, 96, and 120 hours with subsequently changing each solution at an interval of 24 hours. Data were entered into Excel sheet, and statistical analysis was performed using Statistical Package for the Social Sciences software version 21.

RESULTS

The mean pH of the beverages ranged from 2.13 ± 0.02 in Pepsi to 3.41 ± 0.02 in Tropicana on opening. The mean pH of water was found to be 6.98 ± 0.01 (Table 1). Among aerated drinks, the mean weight loss after 24 hours was highest in Coca-Cola, i.e., 0.099 gm ± 0.182 and least in 7Up, i.e., −0.21 ± 0.086. Tropicana fruit juice had a higher tooth loss than real orange juices (Table 2). Graph 1 shows that there was considerable amount of mineral loss of tooth in each beverage after every 24 hours. The graph depicts that the weight loss was mostly in the Coca-Cola and Pepsi. When compared with water, the tooth loss was significantly higher in Coca-Cola after 24, 48, 72, 96, and 120 hours. Although other beverages showed a higher tooth loss in comparison with water, their values were not statistically significant (Table 3).

Table 1: Mean pH of all the beverages with their respective SD

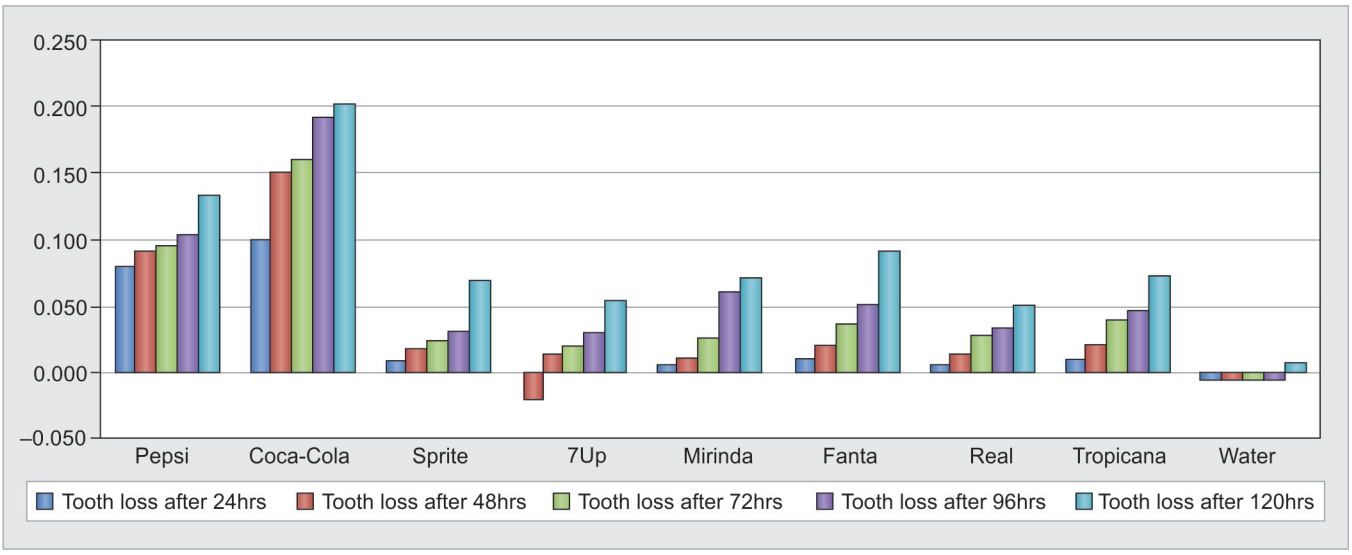
Type of solution	*Mean pH*	*SD*
Pepsi	2.13	0.02
Coca-Cola	2.24	0.03
Sprite	3.09	0.06
7Up	3.14	0.02
Mirinda	2.53	0.02
Fanta	2.51	0.02
Real	3.08	0.02
Tropicana	3.41	0.02
Water	6.98	0.01

SD: Standard deviation

Table 2: Comparison of mean tooth loss after immersion into each beverage in an interval of 24, 48, 72, 96, and 120 hours

Type of solution		*Tooth loss after 24 hours (in gm)*	*Tooth loss after 48 hours (in gm)*	*Tooth loss after 72 hours (in gm)*	*Tooth loss after 96 hours (in gm)*	*Tooth loss after 120 hours (in gm)*
Pepsi	Mean ± SD	0.081 ± 0.214	0.091 ± 0.213	0.096 ± 0.213	0.104 ± 0.213	0.132 ± 0.216
Coca-Cola	Mean ± SD	0.099 ± 0.182	0.151 ± 0.312	0.161 ± 0.312	0.192 ± 0.306	0.203 ± 0.305
Sprite	Mean ± SD	0.009 ± 0.014	0.019 ± 0.032	0.025 ± 0.062	0.031 ± 0.070	0.070 ± 0.107
7Up	Mean ± SD	−0.021 ± 0.086	0.014 ± 0.020	0.021 ± 0.028	0.030 ± 0.046	0.054 ± 0.083
Mirinda	Mean ± SD	0.006 ± 0.008	0.012 ± 0.017	0.026 ± 0.037	0.060 ± 0.098	0.072 ± 0.116
Fanta	Mean ± SD	0.010 ± 0.014	0.021 ± 0.028	0.036 ± 0.049	0.051 ± 0.069	0.092 ± 0.121
Real	Mean ± SD	0.007 ± 0.012	0.015 ± 0.026	0.029 ± 0.046	0.034 ± 0.051	0.051 ± 0.088
Tropicana	Mean ± SD	0.010 ± 0.014	0.022 ± 0.029	0.040 ± 0.061	0.047 ± 0.065	0.073 ± 0.097
Water	Mean ± SD	−0.001 ± 0.003	−0.002 ± 0.007	−0.004 ± 0.006	−0.006 ± 0.009	0.009 ± 0.015

SD: Standard deviation



Graph 1: Tooth loss after immersion into each beverage in an interval of 24, 48, 72, 96, and 120 hours

Table 3: Comparison of tooth loss among various solutions when compared with water

	After 24 hours		*After 48 hours*		*After 72 hours*		*After 96 hours*		*After 120 hours*	
Beverages	*Mean difference (water vs type of solution)*	*p-value*	*Mean difference (water vs type of solution)*	*p-value*	*Mean difference (water vs type of solution)*	*p-value*	*Mean difference (water vs type of solution)*	*p-value*	*Mean difference (water vs type of solution)*	*p-value*
Pepsi	0.83	0.065	0.93	0.115	0.100	0.100	0.110	0.081	0.124	0.075
Coca-Cola	0.100	0.022*	0.153	0.008*	0.154	0.006*	0.190	0.002*	0.194	0.005*
Sprite	0.010	0.811	0.021	0.711	0.029	0.623	0.037	0.540	0.061	0.362
7Up	0.019	0.653	0.016	0.777	0.024	0.677	0.035	0.560	0.046	0.498
Mirinda	0.007	0.865	0.014	0.802	0.030	0.614	0.066	0.278	0.063	0.350
Fanta	0.011	0.797	0.023	0.683	0.040	0.501	0.057	0.349	0.083	0.216
Real	0.008	0.849	0.017	0.762	0.033	0.576	0.040	0.509	0.042	0.529
Tropicana	0.011	0.759	0.024	0.671	0.043	0.461	0.053	0.382	0.064	0.342

*p ≤ 0.05

DISCUSSION

Fruit juices and carbonated drinks are commonly consumed in India especially among children and adolescents. This increasing trend in consumption of these commercially available drinks has a capability to erode the dental hard tissues. Hence, the aim of the study was to evaluate the mineral loss from the tooth structure and erosive potential of juices and soft drinks widely available in India. In this study, eight drinks were experimented among which six were aerated drinks and two were artificial fruit juices.

Acute consumption of soft drinks will have negligible effect on tooth. A reduction of enamel microhardness has been seen on enamel when exposed to soft drinks even for

a very short duration.[15] The purpose of the study deals with mineral tooth loss when exposed to the beverages for prolonged period. It is well recognized that repeated consumption of soft drinks causes acid dissolution of enamel as most of these beverages have pH below the critical pH.[4] Moreover, exposure time for a beverage on the dentition is around 20 seconds before the salivary clearance.[16] Thus, if a person consumes 3 to 4 times a week, then the exposure time for a beverage in a year would be around 8 hours. In our study, a test period of 120 hours was used, which corresponds to a reasonable period of 15 years for calculating potential attack on enamel.

In addition to carbonic acid, i.e., used for aeration, citric acid and phosphoric acid are the main constituents of soft drinks.[4] The pH of various beverages used for the study was below the critical pH which is 5.5 for mineral dissolution, i.e., 2.13– to 3.41 (Table 1). When the acidity of the beverages is below the critical pH, the solution tends to be unsaturated and mineral loss from the tooth structure tends to dissolve until the solution becomes saturated.[4] In this study, the solution or the beverages were replenished after every 24 hours. Hence, the solution remains unsaturated as every time a person consumes an unsaturated beverage.

Apart from pH of the beverages, calcium, phosphate, and fluoride contents of the beverages are important factors in determining the degree of saturation with respect to the tooth mineral, which is the driving force for enamel dissolution.[17] We have considered distilled water in the study as a control to find out the significant difference in weight loss among various beverages. Its pH was found to be near neutral (6.98 ± 0.01). Distilled water had minimal effect on loss of tooth mineral content. This was in consonance with *in vitro* studies by Hughes et al.[18] In this study, Coca-Cola showed highest mean weight loss after 24, 48, 72, 96, and 120 hours among all the beverages. When compared with water, the same had a significantly higher tooth loss (Table 2). This was in contrast to a study by Attin et al[19] where they found Coca-Cola to be having the least erosive potential. Though insignificant, all the other beverages with an exception of 7Up showed a higher tooth loss in comparison with water. This was in consonance with *in vitro* studies by Larsen and Nyvad[3] and Hughes et al[18] where they found inverse association with pH of drinks and dental erosion.

On the contrary, 7Up showed an increase in weight in the first 24 hours. This may be attributed to the higher calcium, phosphate, and fluoride content of the drink which can prove less harmful on the dentition. Attin et al[19] observed a significant protective potential of the drinks when it was modified with a low concentration of calcium, or a combination of phosphate, calcium, and fluoride. He further speculated that a CaF_2-like layer is formed on the surface of enamel by rinsing enamel with fluoridated acidic solutions which may remineralize when exposed to saliva and protect against erosion. In this study, Mirinda and 7Up had the least erosive potential in comparision with other carbonated beverages.

Furthermore, the amount of tooth loss increased while the tooth was kept in these beverages for a longer period. This suggests the ill effects of increased consumption frequency. Tahmassebi et al[20] suggested the use of straw whenever possible, and reducing the frequency of soft drink consumption can go a long way in reducing dental erosion.

Many believe that readily available fruit juices are healthy, but it has been observed that it causes tooth erosion due to high buffering capacity (because of added preservatives) similar to carbonated beverages.[21] pH is not just important, but rather the titratable acidity that plays an active role in causing tooth erosion.[22] Although equal titratable acidity of both carbonated and fruit juices, the amount required to reach critical pH is less in fruit juices than in carbonated drinks. Thus, this suggests that to neutralize the saliva, large amount of buffering agents in saliva is required.[4,23,24] Moreover, due to high viscosity of the drinks, it is difficult to penetrate the capillary pores in the enamel.[25]

Other than pH, the buffering effect of the acidic solution is important to determine the dissolution of apatite. The higher the buffering effect, the more the apatite will be dissolved before achieving neutral pH, and dissolution process is stopped.[3] This poses a limitation to our study since buffering capacity of the drinks was not taken into consideration. The *in vitro* study design will not give the exact data of enamel erosion. Thus, this study cannot be generalized to *in vivo* clinical environment of oral cavity.

CLINICAL SIGNIFICANCE

In recent years, with a change in lifestyle, there has been an increase in demand of soft drinks and artificial juice in the Indian market. Extended use of carbonated drinks and fruit juices can cause irreversible damage to the tooth structure in children and young adults. Patients with reduced production of saliva and athletes (dehydration) are at a greater risk for dental erosion. Our study provides an idea about the deleterious effects of these commercial drinks on dental hard tissues. As dental professionals, efforts should be made to educate the general public about the ill effects of these drinks and encourage its sensible use.

CONCLUSION

The pH of all the beverages was below the critical pH. There was considerable amount of weight loss after every 24 hours in all the carbonated drinks and beverages.

Maximum mineral content loss was seen in Coca-Cola and least in Sprite. As dentists, an approach should be made to create awareness among the general population about the effects of these drinks on teeth. An emphasis should be made on modification of these commercial drinks and should standardize its recommended usage quantity.

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