

Assessment Of The Effect Of Carbonated Drinks On The Surface Of Enamel Using A Scanning Electron Microscope

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ABSTRACT

Background: Soft drink consumption has recently increased significantly. According to studies, drinking beverages with added sugar increases calorie intake, which in turn causes obesity. The findings of research reports indicated that the majority of beverages have acidic properties. As a result, prolonged exposure to such a solution may cause erosion, which would erode the hard tissues of the teeth. This study aimed to determine how carbonated beverages affect the enamel's surface.

Methods: The sound teeth were collected and divided into three groups based on exposure (Group I - Pepsi + Bisleri (n=6), Group II - Coca-Cola (n=6), Group III - Controlled (n=3)). Teeth were sterilised with 1% Hypochlorite solution and cleaned with double-distilled water using a bath sonicator. The teeth were incubated with Coca-Cola (15 mL), Pepsi (15 mL), and Bisleri (15 mL) for 7 days and 14 days. SEM and EDS analyses were performed at 7 and 14 days.

Result: Compared to the Control (unexposed) group, exposed groups had more damage and loss of enamel surface at 7 days, as well as 14 days, tooth damage was more serious. In addition, compared to a single drink, combined exposure to two or more soft drinks at a particular time caused the loss of enamel structure. EDS analysis showed differences in Ca, P, O, and C wt % between the three groups. Exposed groups had less Ca, P and more C wt % compared to unexposed. This clearly suggests the detrimental effect of soft drinks on the enamel surface with longer exposure.

Conclusion:

Conclusively, the effect of carbonated drinks on the surface of enamel can be assessed by scanning electron microscope (SEM). Consuming two or more soft drinks at a particular time causes more damage to the enamel surface

Keywords: Bisleri, Coca-Cola, Erosion, Obesity, Pepsi and SEM

INTRODUCTION

Dental enamel serves as the primary protective barrier of the tooth against chemical, mechanical, and microbial challenges. Due to its acellular and non-vital nature, enamel cannot regenerate after formation, making it highly susceptible to cumulative wear and irreversible structural damage over time. Its integrity is influenced by a variety of intrinsic and extrinsic factors, including dietary habits, ageing, and clinical procedures(1). Previous studies have demonstrated that environmental influences can alter enamel mineral density and crystalline structure(2), while localised loss of enamel, particularly in interproximal regions(3), may result in surface irregularities of varying depths. Additionally, bioactive glass-based sealants have shown potential in reducing enamel demineralisation (4). These findings collectively highlight the multifactorial nature of enamel degradation.

Dietary behaviour plays a crucial role in maintaining enamel integrity. Frequent consumption of acidic foods and beverages

is a major factor contributing to dental erosion, as low pH environments facilitate the dissolution of hydroxyapatite crystals. This effect is further enhanced by sugars and organic acids, which promote demineralisation. Although remineralisation strategies such as casein phosphopeptide–amorphous calcium phosphate (CPP–ACP) complexes and fluoride-based agents(5) have shown effectiveness in restoring mineral loss, these approaches are beyond the scope of the present in vitro study. It is important to note that the erosive potential of beverages depends not only on pH but also on other physicochemical factors, including titratable acidity, buffering capacity, mineral content, and the presence of chelating agents

Soft drink consumption has increased significantly recently. According to studies, drinking beverages with added sugar increases calorie intake, which in turn causes obesity. The studies' findings indicated that the majority of beverages have an acidic character(6). As a result, prolonged exposure to such a solution may cause erosion, which would erode the hard tissues of the teeth. Energy drink consumption has significantly increased recently among the variety of processed beverages on the market, surpassing 5.8 billion litres in 160 countries in 2013. They have been developed to increase energy, due to the presence of taurine, caffeine and sugar in these drinks. Young people, especially university students, are more drawn to and more likely to consume soft drinks because of their appealing flavours and the possibility that they may keep them awake. According to studies, soft drinks are acidic drinks because of their low pH levels. Gambon et al. claim that recent changes in dietary practices, including a rise in the use of acidic beverages, are linked to an increased prevalence of tooth erosion. (7) Epidemiological studies show that teenagers and young adults are severely impacted, with men twice as likely to experience enamel loss. According to this data, tooth erosion has emerged as a significant public health issue in recent years, prompting the need for prompt and effective treatment.

Dental erosion is usually treated with the help of resin bonding and veneers or, in severe conditions, with crown restoration. However, these methods involve excessive removal of natural enamel structure. Hence, the best way to prevent unnecessary loss of tooth structure is early prevention of demineralisation of tooth surfaces using remineralisation agents or toothpaste (8). Several available remineralisation agents have been developed to prevent dental erosion. These agents remineralise the enamel by providing the calcium and phosphorus ions for the formation of hydroxyapatite crystals. These crystals fill the gaps formed by demineralisation. However, these hydroxyapatite crystal sizes vary among the remineralising agents, especially those synthesised using the nanoparticle technology. Even after that, studies have shown that full mineralisation can not be achieved even with additional fluoride or other minerals (9). This could be attributed to the underlying mechanism or structural change produced by a different acidic environment created and the time of exposure (10–14). Further, studies have observed differences in morphological changes produced by soft drinks compared to acidic dental materials (15). These soft drinks and dental materials have an impact on enamel pore size after the demineralisation, as well as size increase or alteration depending upon the time of exposure (15). Hence, the use of remineralising agents with different crystal sizes may not be efficient to fill the pores of different sizes formed by soft drinks or dental agents. The extent of erosion has been assessed using a range of techniques, including profilometry, atomic force microscopy, scanning electron microscopy (SEM), microradiography, iodide permeability testing, confocal laser scanning microscopy, and microhardness testing, all of which help evaluate the loss of dental hard tissues and the softening effects caused by erosive processes(16).

Currently, there is limited information about the surface structural properties of enamel exposed to different soft drinks. Increasing our understanding of the process of demineralisation caused by soft drinks will help in improving the remineralisation capacity or development of anti-erosive agents.

2. MATERIALS AND METHODS:

2.1 Materials used in this study

Three different beverages were used in this study. It included Pepsi (15 ml), Bisleri (15 ml), and Coca-Cola (15 ml).

2.2 Sample preparation

15 sound human teeth were collected and sterilised with 1 % Hypochlorite solution. These teeth were washed thrice with distilled water and dried in a hot air oven at 50 °C for 3 hours. Teeth were divided into three groups (Groups: Group I - Pepsi + Bisleri (n=6); Group II - Coca-Cola (n=6); Group III - Controlled (n=3) based on the type of soft drink exposure.

2.3 Soft drink exposure

Teeth were incubated with Coca-Cola (15 ml), Pepsi (15 ml), and Bisleri (15 ml) for 14 consecutive days to analyse the erosion rate on the superficial layer of the tooth. FE-SEM analysis was performed at Days 7 and 14. Further, EDX analysis was performed to analyse the mineral composition of the enamel surface.

2.4 FE-SEM and EDS analysis

Before SEM and EDX analysis, specimens were coated with platinum for 30 sec and examined in the SEM microscope at

different magnifications for morphological changes and images were recorded. EDX analysis was performed using SEM images. Image and EDS data were stored and analysed by experts. Parametric data was analysed using the one-way ANOVA with Post-Hoc test.

3. RESULTS:

3.1 Result of morphology evaluation using SEM

Exposed enamel surfaces were examined for damage in soft drink-treated tooth surfaces at 7 days and 14 days. The result proves the detrimental effects on enamel surfaces. Group I teeth showed pronounced loss of enamel structure as well as roughness compared to group II and group III. The effects are even more pronounced after 14 days in both groups I and II.

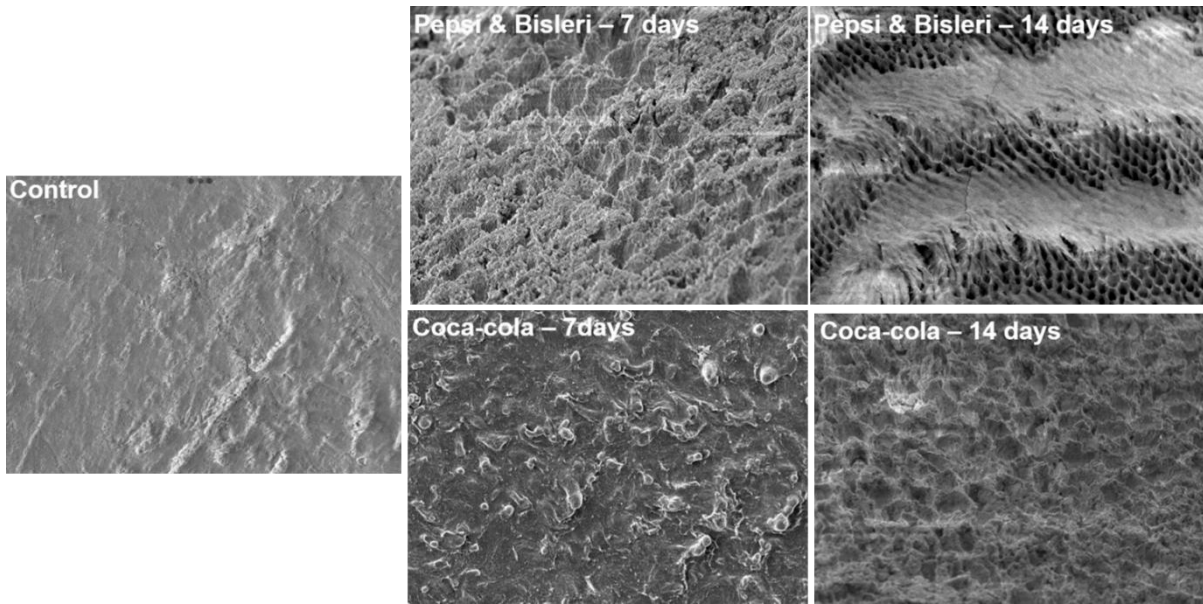


Fig. 1. Representative SEM micrographs of the teeth surface. In the control group (Group III), the enamel showed a smooth surface (a); whereas there was demineralisation of the enamel surface at day 7 (B) and day 14 (C) in groups I and II, which was evident by loss of prism and interprismatic substance resulting in fish scale appearance of the enamel surface. When comparing Group I and Group II at 7 days and 14 days, the changes were more pronounced in Group II. After 7 days (D), Coca-Cola alone had demineralised the surface, showing the dental surfaces with partially demineralised dental tubules, whereas at 14 days the surface was rougher and more irregular (E).

3.2 Results of EDS (Energy-Dispersive X-ray Spectroscopy) analysis :

The percentage of elements present in the control sample, Pepsi and Bisleri treated sample, and Coca-Cola sample was analysed with the help of energy-dispersive X-ray spectrometry. There was a difference in calcium, phosphate, and carbon content in tooth enamel between the three groups, especially calcium and phosphate (Table 1). The control sample showed fewer levels of Ca and P when compared with the treated tooth sample. Comparing both the treated teeth, we infer that the one treated with Pepsi and Bisleri had higher mineral levels than the Coca-Cola-treated tooth.

Table 1:

	PEPSI AND BISLERI (GROUP A)		COCA-COLA (GROUP B)		CONTROL (GROUP C)		p Value
	Mean	SD	Mean	SD	Mean	SD	
O	48.2	0.1581	45.1	0.1581	36.5	0.505	<0.001
Ca	23.9	0.128	20.7	0.1098	30.24	0.0872	<0.001
C	14.64	0.2074	22.9	0.1581	18.2	0.1467	<0.001
P	11.2	0.1581	10.2	0.0997	13.7	0.1563	<0.001
Cl	0.4	0.1589	0.318	0.1289	0.388	0.0179	0.515
Na	0.381	0.1127	0.465	0.0256	0.3	0.0098	0.453

Figure 2: EDS of the control sample, Pepsi, Bisleri and Coca-Cola treated samples.

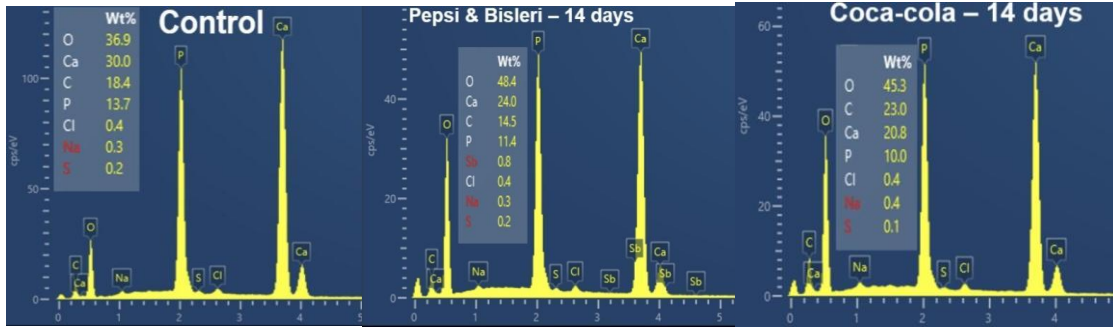
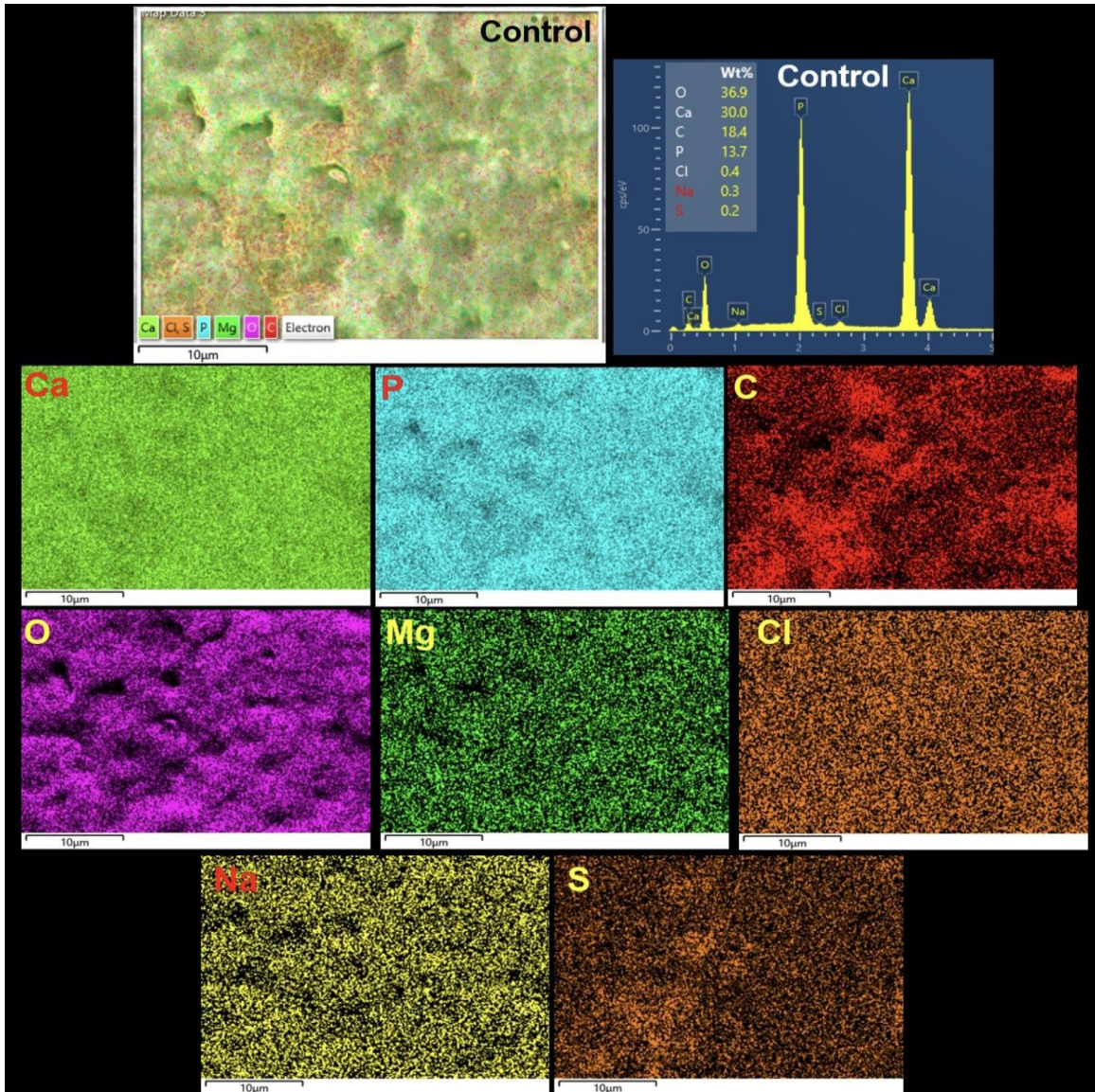
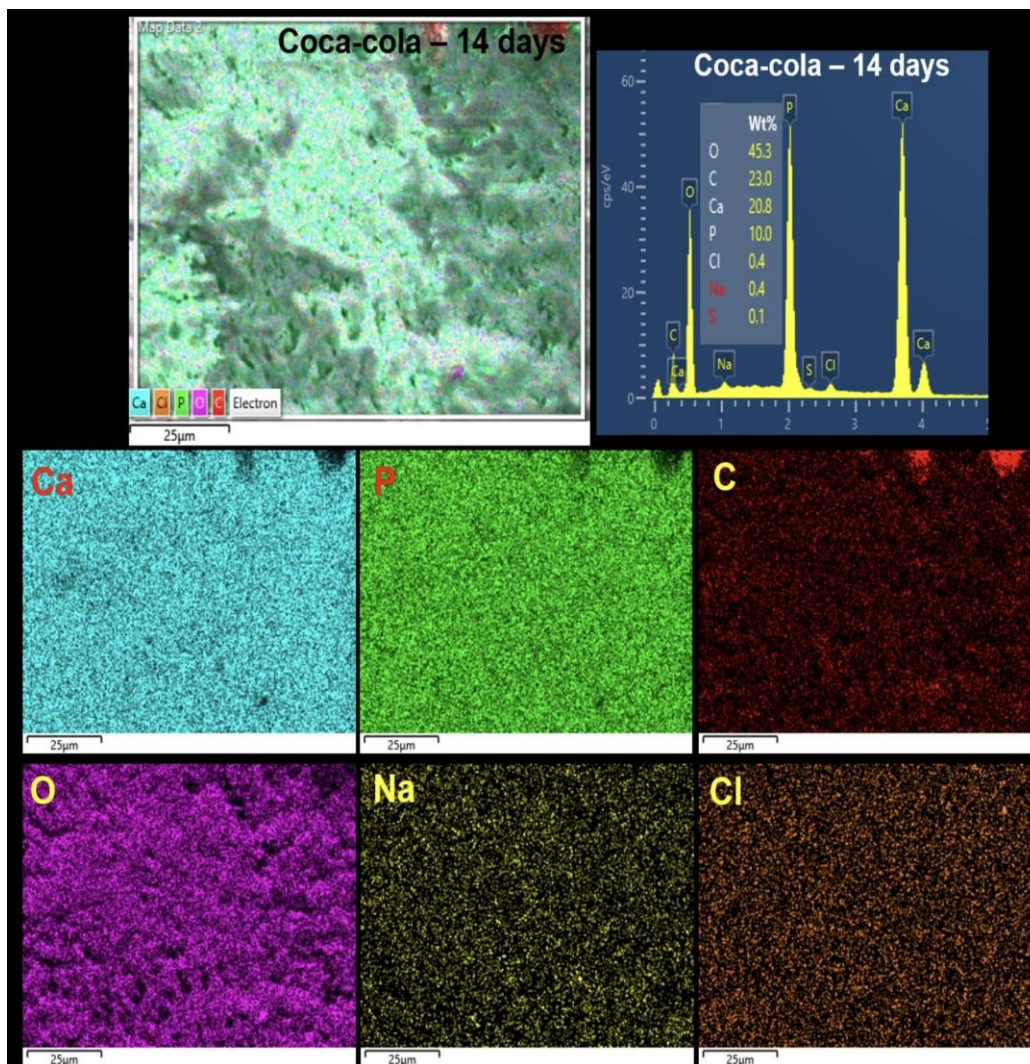


Figure 3: E mapping of the control sample, Pepsi, Bisleri and Coca-Cola treated sample.





4. DISCUSSION:

The study observed the demineralising effects of soft drinks on the enamel surfaces, especially if they are exposed for a long duration. 30 to 40 years ago, the beverages were occasionally available to the younger generation for drinking; however, recently they have become common household drinks and available to young people (17). As a result, people often drink soft drinks, which expose the teeth, leading to erosive changes on the surface. Wang et al. observed that all soft drinks are erosive in nature. (6) Another study by Jain et al. observed (18) contrasting findings for Coca-Cola drinks. According to a study, non-cola drinks are more erosive than cola drinks. Similar observations were reported by von Fraunhofer JA et al. (19). Furthermore, the addition of sugar has a more erosive action than without sugar-containing Coca-Cola drinks. than their diet counterparts. To improve the flavour, drinks are usually modified with the addition of sweeteners such as aspartame. The addition of aspartame to Coca-Cola can cause enamel surface structure loss; however, the exact mechanism needs to be studied. Besides exposure to soft drinks, teeth are exposed to dental forces such as mastication or abrasion caused by the tooth brushing technique. Additional defects and damage to the enamel surface may worsen and accelerate the dental erosion (20) or vice versa (21). The study by Dixit et al(22) showed that packaged fruit juices exhibited greater erosive potential compared to fresh juices. This finding is consistent with the study by Halageri et al., which compared the oral clearance rate of packaged fruit drinks and fresh fruit juices among dental undergraduate students. Their results indicated that the packaged fruit drink group experienced the greatest immediate drop in pH following consumption. Marcel et al, Ready-to-drink (RTD) alcoholic beverages demonstrated considerable erosive capacity, leading to enamel softening, elevated surface roughness (Sa), and detectable surface loss (SL). Drinks characterised by higher titratable acidity (TA), greater buffering capacity (β), and the presence of organic acids such as citric and malic acids caused the most pronounced damage. While in vitro

conditions may represent a maximal estimate of erosion, the consistently large effect sizes suggest that beverage composition plays a dominant role in enamel degradation. In view of the increasing consumption of RTDs, it is important to raise awareness about their potential adverse effects on dental health(23).

In addition to soft drinks, consumption of flavoured water drinks such as bisleri, Aquafina are consumed daily and Aquafina is increasing exponentially. These water drinks have shown erosive potential (24). Brown et al. observed that these commercial water drinks have erosive potential similar to soft drinks. The Younger generation most of the time consumes both water and soft drinks together routinely. Hence, there may be a combinatorial erosive effect on enamel. However, this aspect has not been studied adequately. In the present study, we observed the combined effect on the tooth surface. There was lots of surface structure evidenced by roughness and a honeycomb pattern. Further, soft drinks have caused loss of Ca and P after exposure. This could be one of the reasons why water drinks might harm the remineralisation and/or adhesive capacity of dental materials (25). It also affects orthodontic treatment by interfering with altered enamel characteristics (26). The demineralising capacity is influenced by the time of exposure of the enamel surface to soft drinks. The time is proportional to the duration of exposure as well as the frequency of exposure (10). Studies have exposed teeth for a duration ranging from 5 minutes to 5 minutes to 48 hours. Pore volume and surface area increase with time. However, these have not considered the buffering effect of saliva in the oral cavity. Hence, the present study exposed teeth for a longer duration to give adequate exposure time that may mimic the in vivo exposure. Results were in line with the literature; longer duration of exposure had a pronounced effect on the enamel surface. This also impacts the remineralising capacity of the remineralising agents (27). This could be due to the different surface changes that are produced by different soft drinks, which in turn may affect the remineralising capacity of agents. In the study, Coca-Cola at 7 days almost causes more loss of enamel structure, leaving more organic substance, which is difficult to remineralise due to a lack of framework compared to a partially mineralised surface. Our study clearly shows that there is a need not only to prevent erosion due to excessive consumption but also to increase the understanding of these changes at the ultramicroscopic level to develop remineralising agents to improve their efficacy.

The present study has certain limitations in terms of the type of soft drinks tested and the time of exposure. There are plenty of soft drinks available, but we could analyse only three. Further, an exact oral environment could not be created to study the impact of demineralisation and soft drink demineralising capacity.

5. CONCLUSION:

Soft drinks and carbonated drinks have a demineralising capacity, which can cause dental erosion as well as affect the dental treatment outcome. Hence, there is a need to reduce the exposure of teeth with soft drinks. Further, as preventive measures, better remineralising agents should be developed to specifically target the erosion caused by specific aetiology agents such as soft drinks

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