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Review

CONSEQUENCES OF CARBONATED BEVERAGES ON TOOTH ENAMEL: A SYSTEMATIC REVIEW

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ABSTRACT

The purpose of the current study was to assess the potential erosive effects of rising fizzy drink consumption on tooth surfaces. The study employed a rigorous methodology, using the Boolean keywords "soft drinks" AND "tooth" to conduct a detailed investigation in PubMed, Scopus, and Web of Science during the last five years (2018-2023). Of the initial 407 discovered publications, 18 studies were included, consisting of 12 *in vitro* and 7 *in vivo* research. The findings suggest that overindulgence in acidic carbonated beverages raises the possibility of dental erosion, which results in enamel deterioration and loss of its mechanical and physical qualities. Rougher surfaces, as a result of erosion, encourage more bacterial adherence and a higher possibility of cavities. Most commercial carbonated drinks have a pH lower than what is necessary for the demineralization of enamel. The length of exposure to these beverages and their acidity have different negative effects on enamel.

KEYWORDS: *nutrition, carbonated drink, demineralization, tooth, enamel erosion, dental hypersensitivity, oral pH, tooth decay, soft drinks, bacterial colonization*

INTRODUCTION

One of the most common diseases in both developed and developing countries is tooth decay, which is caused by various socioeconomic, behavioral, genetic, and environmental factors (1, 2). Acids, intrinsic and extrinsic, are among the leading causes of tooth erosion, with the pH of food and beverages playing an important role. However, other factors, such as saliva composition, eating habits, and lifestyle, can influence the erosive process (3-5). Children drank more carbonated drinks (CDs) as a result of the COVID-19 pandemic's alteration in dietary habits. Dental caries rates have increased due to this (6, 7).

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Optimizing public health during this epidemic requires knowledge from social and behavioral studies, lifestyle, and all human sciences relevant to diet and lifestyle, in addition to knowledge from the biological and medical sciences (8).

Several studies on the subject found that the growing habit of drinking CDs, sometimes instead of water, increases the risk of erosion of dental hard tissue (9, 10).

Due to the presence of acids such as carbonic, citric, phosphoric, and tartaric acid, the pH of CD is highly acidic, with values as high as 2.5 (11-14). These acids can erode tooth enamel (Fig. 1, 2), causing pain and hypersensitivity (15). Many factors, including the amount and type of acids in drinks, buffering capacity, temperature, and morphology of tooth enamel, influence the chemical-mechanical process known as tooth erosion (16, 17). In addition, the Faurier infrared spectrum has been used to study the effects of erosion at the chemical level (18-20).

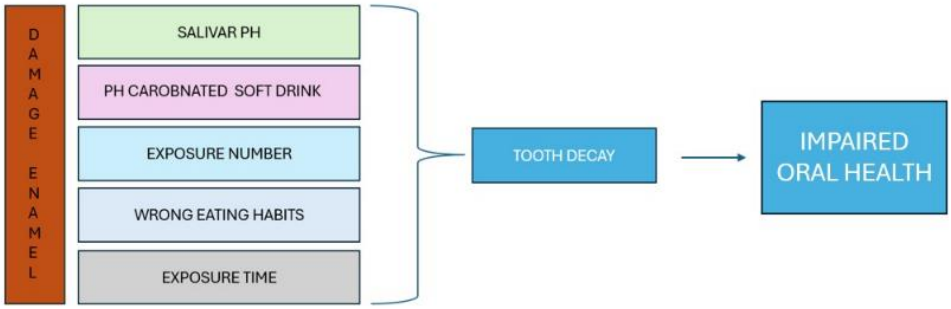

Fig. 1. *The causes of enamel damage.*

Fig. 2. *Example of the consequences of carbonated beverages on tooth enamel.*

MATERIALS AND METHODS

Registration and protocol

The current systematic review followed the PRISMA and International Prospective Register of Systematic Review Registry procedures (full ID:549705). The following databases, PubMed, Web of Science (WOS), and Scopus, were examined from January 1, 2018, to November 11, 2023, to search articles of the last 6 years. The search strategy was created by combining terms relevant to the study's purpose (Fig. 3).

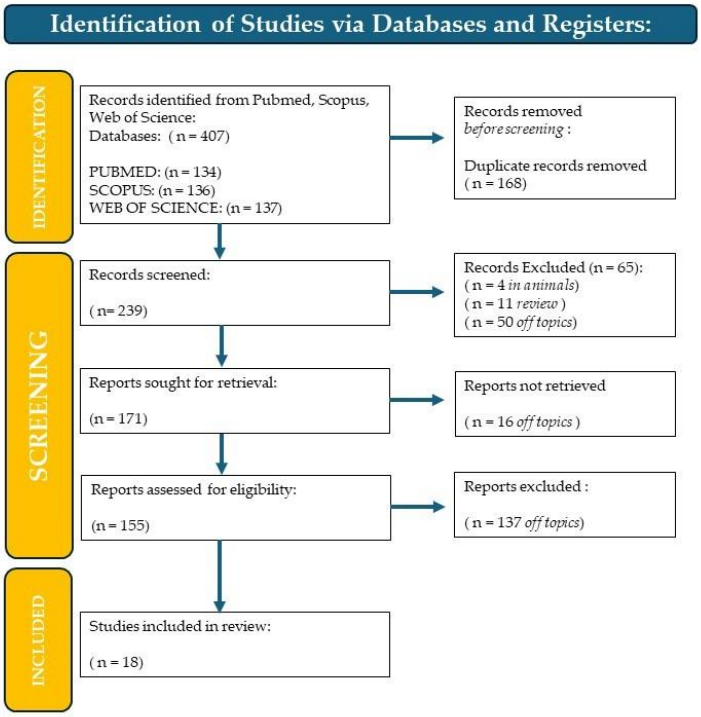

Fig. 3. *PRISMA flowchart.*

The process of searching

Scopus, PubMed, and WOS were searched with an English language restriction to find papers that fit the topics published between January 1, 2018, and November 11, 2023. Because they were a combination of words that matched the objective of our analysis, the following Boolean keywords were added to the search strategy: "teeth" AND "soft drinks".

Eligibility criteria

Inclusion criteria:

(1) human subjects' *in vivo* and *in vitro* studies;
(2) linguistic studies;
(3) open-access studies;
(4) randomized clinical trials;
(5) studies on the impact of carbonated beverages on dentin enamel comprise the remaining body of research.

Exclusion criteria:

(1) research involving animals;
(2) research conducted in languages other than English;
(3) research with restricted access;
(4) case studies, series, reviews, editorials, and book chapters.

The PICOS criteria were used to conduct the review:

• Participants: adult and pediatric teeth, both *in vivo* and *in vitro*, were used.
• Steps taken: consuming a lot of fizzy beverages.
• Comparisons: CDs are not used very often.
• The outcome is damaged dental enamel.

Research: human teeth subjected to *in vitro* and *in vivo* clinical testing.

Risk of bias measurement

RevMan 5.5 software was used to evaluate the risk of bias in the selected studies. The evaluation followed the Oral Health Assessment Tool (OHAT) criteria, which covered aspects like performance and detection blinding, partial reporting, allocation concealment, and randomization. Seven *in vivo* studies were analyzed to determine the risk of bias.

The risks were divided into three categories: adequate, ambiguous, and inadequate. Studies were considered to have a low risk of bias if they met at least five to seven positive criteria without adverse outcomes. *In vitro* studies were excluded from the report (Fig. 4.)

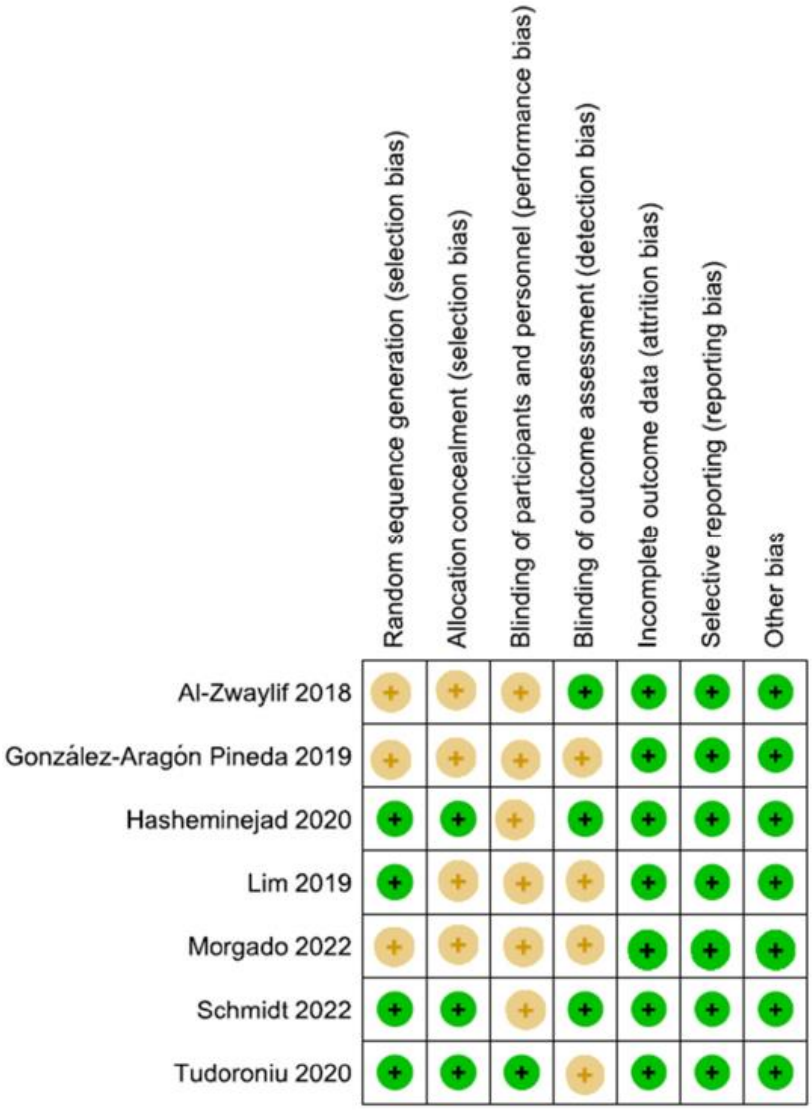

Fig. 4. *Bias risk graphs.*

RESULTS

Four hundred and seven articles (PubMed n = 134, Scopus n = 136, and WOS n = 137) remained from the original search after 168 duplicates were removed. Therefore, 239 articles remained. A total of 156 articles advanced to the screening phase; however, 83 were disqualified for the reasons listed below: 11 were reviews, 16 had no free complete text, 3 had animal-related content, and 53 were off-topic. Nineteen recordings, 12 *in vitro* and 7 *in vivo* were eventually included in the inclusion phase after an additional 137 articles were removed from these products since the supplied data did not pique their attention. The results of each experiment are displayed in Table I (21-36).

Table I. *Descriptive summary of in vitro and in vivo investigations.*

Authors (years)	Type of Study	Aim of study	Materials	Results
Gotouda et al. (2017) (21)	Study *in vitro*	Examine how different beverages and enamel respond to CD.	X-ray microdiffraction examination demonstrated varying levels of enamel white spots, ranging from slight to significant deterioration.	Important crystallographic information from this study will support preventive dentistry.
Shroff et al. (2018) (22)	Study *in vitro*	Assess the potential erosive impact of 20 drinks.	Six milliliters of fluid had to be dispensed. Saliva was utilized to prepare enamel samples, and 5 g or 7 g of the experimental beverages were used to measure their acidity. Each drink's cumulative weight reduction was calculated across various time intervals.	The weight loss of the experimental beverages significantly differed from that of the packaged fruit juices after 24-hour immersion in CD due to their higher acidity values.
Al-Zwaylif et al. (2018) (23)	*In vivo* study	Examine the connection between tooth wear and dietary acid consumption and timing.	Three thousand five hundred and eighty-six individuals took part. Information was acquired regarding the four types of acidic meals, when they should be consumed, how tooth wear affects the surface area of teeth, and how to consume acidic foods.	Regular consumption of soft drinks is associated with tooth erosion. Soft beverages and meals are linked to moderate to severe deterioration. Other acidic foods are not connected to the decline.
González-Aragón Pined et al. (2019) (24)	*In vivo* cross-sectional study	Examine the connection between various beverages and erosive toothwear (ETW).	A questionnaire will be used to monitor the frequency of consumption of various beverages such as milk, water, fruit juices, hot beverages, and soft drinks.	To avoid ETW, milk and milk products could be a decent substitute for sugary beverages.
Lim et al. (2019) (25)	*In vivo* study	Analyze the long-term impact of soda consumption on children's dental cavities.	Nine hundred ninety-five pairs of carer and child. Keeping an eye on kids' dental surfaces was the task. Caregiver smoking, oral health fatalism, and social support were among the variables.	Those who drank a lot of soda had a higher rate of cavities than those who didn't. The work emphasizes how modeling problems in longitudinal research can be addressed with focused maximum likelihood estimates.
Charpe et al. (2019) (26)	*In vitro* study	Examine the differences in dental enamel's solubility following different durations of alcohol exposure.	Using extracted teeth, three distinct beverages were examined for their ability to dissolve enamel at various intervals. The Calcium Reagent Set and a semi-automatic analyzer were used to analyze calcium release.	Significant calcium loss was seen in relation to beer, whiskey, soft drinks, and hard beverages.
Kono et al. (2019)(27)	*In vivo* study	Teeth sections were subjected to micro-FTIR spectroscopy to elucidate the chemical mechanisms involved in dental caries.	According to X-ray microdiffraction research, the enamel contained a wide range of white stain areas, from almost undetectable to almost completely decayed.	This study demonstrated the range and normalcy of tooth enamel properties.
Panic et al. (2019) (28)	*In vitro* study	Find out how CD affected dentin and enamel over time.	Twenty samples were evaluated and photographed using SEM at 60 minutes, 24 hours, and 7 days after exposure to drinks. The results were examined using ANOVA.	The drinks' pH values were lower than the enamel's critical pH, and degradation started to show after just 60 minutes of exposure.
Paula et al. (2019) (29)	*In vitro* study	Juices' pH, acidity, and erosive potential are assessed.	After being surgically extracted, fifteen third molars were immersed in a juice and citric acid solution for four days. The microhardness and roughness of the samples were measured both before and after the erosive cycles. To examine variance, ANOVA was employed.	Juices can be erosive due to their acidic pH.
Ramya et al. (2020) (30)	*In vitro* study	Examine the impact of soft drinks on the demineralization of extracted teeth.	Teeth that have been removed. Their mass was ascertained using a computerized balance. Ten teeth were inserted into every soft drink serving over a specific period. Again, their weight was analyzed. The weight shift was observed, and the outcomes were explained. The study found that the teeth exposed to fizzy beverages lost weight due to the chemicals in the drinks degrading their mineral makeup.	The effects of CD and non-CD on tooth structure are not the same.

Hasheminejad et al. (2020) (31)	*In vivo* study	Examine the relationship between drinking habits, tooth erosion, and dental caries.	Survey on the usual drinking patterns of 600 teenagers.	Teenagers often drink dangerous drinks. Soft drinks have been related to increased erosion and caries, but milk has been demonstrated to protect against caries.
Chandrasekhar et al. (2020) (32)	*In vitro* study	Compare the surface microhardness and mineral loss of enamel exposed to CD 1 with and without calcium glycerophosphate (CaGP).	The surface microhardness of forty enamel samples was evaluated to quantify mineral loss using spectrophotometric analysis and four cycles of intermittent blotting.	The enamel's mineral loss and deterioration in surface microhardness were significantly halted by adding CaGP to the CD.
Tudoroniu et al. (2020) (10)	*In vivo* study	Assess the incidence of dental caries in teenagers and examine the connection between sugary food intake and dental care habits.	A survey of 650 teenagers examined the relationship between the DMFT index, dental cleanliness, and eating behaviors.	Teenagers still have a high prevalence of caries, influenced by their dietary patterns.
Al-Amri et al. (2021) (33)	*In vitro* study	The enamel is subjected to minute alterations as a result of the beverages' other contents, pH, and duration of display.	Three sets of removed teeth were submerged in sweet beverages and saliva, and changes in tooth surface roughness were measured using a profilometer.	Teeth's surface roughness increased after being exposed to sugary beverages.
Sooksompien et al. (2022) (34)	*In vitro* study	This study evaluated morphological and atomic percentage (at.%) changes in primary teeth's enamel surfaces after they were exposed to carbonated soft drinks using energy dispersive spectroscopy (EDS) and scanning electron microscopy (SEM).	1. Children had the extraction of their 45 first molars; 2. they were immersed in commercial soft drinks or deionized water; 3. the enamel surface underwent morphological changes.	The acidic pH of soft drinks changed the enamel's surface.
Arafa et al. (2022) (35)	*In vitro* study	Carbonated soft drinks cause reactions in dental dentin and enamel.	Teeth displayed a wide spectrum of enamel deterioration, both microscopic and by X-ray microdiffraction studies following a week of exposure to fizzy drinks.	Compared to saliva, milk did not exhibit any erosive effects on the enamel surface, while soft beverages did.
Schmidt et al. (2022) (36)	*In vivo* study	By measuring the awareness of dental erosion, one can ascertain the relationships between sociodemographic traits, awareness and knowledge of tooth erosion, and beverage drinking patterns.	Four hundred eighteen students completed an online survey.	Fruit juices and soft drinks were the most commonly consumed acidic beverages. Students who were aware of the risk of tooth erosion drank fewer acidic beverages regularly. The majority of overseas students had less knowledge regarding dental degeneration. Older students studying health-related subjects correctly identified a greater number of varieties of acidic beverages.
Morgado et al. (2022) (2)	*In vivo* study	Educate patients and healthcare providers about the erosive potential of bottled water and analyze its pH levels to address the growing problem of dental erosion, particularly in high-risk populations.	pH analysis of 105 bottled water samples: -32 were carbonated; -73 were non-carbonated.	Bottled water in Portugal varies in pH values. Some brands have pH values below the critical threshold for enamel and dentin, indicating a higher risk of dental erosion based solely on the pH parameter.

DISCUSSION

The article focuses on the harmful effect of CDs on enamel. CDs are becoming increasingly popular in contemporary society and can replace water as the main beverage; however, these types of drinks expose teeth to the acids that are present in these drinks (2, 21, 36). Citric, phosphoric, and carbonic acids lower the oral pH, promoting enamel erosion(10, 37, 38).

Although dental enamel is the hardest part of the human body, the chemicals in CD can affect it (33, 39, 40). The hardness and roughness of the enamel surface are evaluated, and parameters show how severe the damage caused by the acids in CD is (22, 41, 42). Research indicates that consuming these drinks on a daily basis dramatically raises the risk of tooth erosion (35, 43).

Dental erosion is a non-carious lesion that results in the tooth's surface losing its dentine and enamel permanently (44). Various internal and external causes influence this illness, but lifestyle and food choices play a significant role. Younger age groups are more likely to experience dental issues (23, 24, 34).

According to epidemiological studies, CD and fruit juices are among the most acidic beverages consumed by children and young people (14, 25, 45). Dental erosion is increased by the increased consumption of acidic drinks, which is more common in young people (46). However, data on the prevalence of dental erosion show a tendency to be more severe in younger groups (27, 46).

Socio-economic consequences are evident, as people with a higher socioeconomic status will likely have better oral hygiene and more frequent dental check-ups (47). Furthermore, regular drinking of carbonated beverages has been shown to increase the risk of dental erosion, while those who avoid drinking these beverages have a significantly lower risk (28, 29).

Due to the different structural compositions of enamel and dentine, the erosive effects of CD vary. Dentin and enamel leak more quickly, but both are sensitive to the acids in CD. To avoid dental erosion, it is important to understand how regular consumption of CDs affects this problem. Tooth erosion can increase sensitivity and enamel wear, which can have a negative impact on overall dental health (10, 30, 32)

Studies highlight the significance of raising cognizance of the harmful impacts of CD and implementing proactive steps to safeguard oral health, particularly among youth. Promoting good oral hygiene, forbidding the consumption of CDs, and promoting the use of water and other wholesome substitutes (31).

Saliva normally increases in response to drinking and protects dental enamel from acidic beverages. However, individuals with reduced salivary flow are likelier to have eroded enamel. Dental erosion occurs when enamel components such as fluorapatite and enamel hydroxyapatite are exposed to a significantly lower pH than these substances, i.e., between 4.3 and 4.5 (33, 35).

Research has examined the erosive potential of CD and fruit juices based on their pH, mineral content, and capacity to chelate calcium from food and beverages. Research indicates that consuming CD regularly is associated with a higher risk of tooth degeneration, with a greater degree of severity for frequent consumers (48). On the other hand, phosphate, calcium, and fluoride added to beverages can decrease erosion and improve enamel solubility (10, 11, 27). Saliva removes acids from the tooth surface and acts as a protective barrier, which prevents erosion (17, 49, 50).

Although these tests did not simulate natural mouth conditions, they evaluated erosion on dental samples immersed in acidic beverages (22). However, mineral loss was significantly reduced when saliva was used to preserve dental samples (29, 34, 36).

In conclusion, preventing dental erosion brought on by acidic beverages requires an awareness of the function of saliva and restricting the consumption of carbonated beverages. Dental erosion can result in discomfort and hypersensitivity. Its health status can be determined by evaluating the enamel surface to determine the erosion risk (2, 25).

The increasing consumption of fizzy drinks among young people increases the likelihood of tooth decay and erosion(27, 51). Using X-ray microdiffractometry, studies examined how dentine and enamel reacted to CD. Incorporating buffering agents such as CaGP in carbonated beverages can reduce erosion, but the taste of the beverages prevents this (21, 27, 35). The risk of tooth damage is related to consumption during meals. Sports such as rugby increase the likelihood of erosion. Sports and fizzy drinks make enamel less hard. In contrast, milk reduces the formation of caries (24, 35).

CONCLUSIONS

Consumption of carbonated beverages has increased, raising concerns about oral health. The public should be actively educated about tooth erosion by dentists and medical professionals and encouraged to follow healthier lifestyles.

The quality of tooth enamel depends on the pH of saliva. People with little saliva and frequently drink acidic beverages are more vulnerable to enamel erosion. The first tip is to drink water and include fresh fruit in a balanced diet.

Healthcare providers must persuade individuals to abstain from acidic beverages, and policymakers should suggest ways to reduce sugar-filled beverages. There are numerous programs available to enhance general and dental health.

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Conflicts of Interest
The authors declare no conflicts of interest

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