Enamel demineralisation: impact of cola

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Dental erosion is defined as the irreversible chemical dissolution of dental hard tissues, including enamel and dentine, through a chemical process. This erosion occurs independently of bacterial or biofilm factors and is associated with an acidic oral environment, characterised by a pH level below 4.0 (Reddy et al, 2016).

The prevalence of dental erosion shows significant variation among different countries and age groups. However, a study conducted by Schlueter and Luka in 2018 revealed estimated rates of 30 to 50% in children and 20 to 45% in adults.

This issue is of concern for all dental professionals, as Al-Omiri and colleagues (2006), have observed that patients with enamel wear are nine times more likely to report discontent with their teeth when compared to the control group (Mehta et al, 2023). Furthermore, higher levels of enamel wear have also been associated with a lower oral health related quality of life and satisfaction (Mehta et al, 2020). As a result, it is vital that the dental team can appropriately manage tooth wear, particularly dental erosion. Through such efforts, they can help to minimise its extensive impact and prevent its progression.

Dental erosion is manifested by the demineralisation of enamel; acids are the primary agents that result in a softened enamel. Exposure to the acid alters the ability of saliva to remineralise the surfaces of enamel that have undergone demineralisation. When the exposure to acid is short, saliva can remineralise the enamel while naturally increasing the pH back to 7.0.

In contrast, when the exposure to acid is continuous, saliva's ability to remineralise enamel is insufficient to mitigate the damage, leading to loss of tooth structure (Cardoso et al, 2019). Therefore, the role of saliva in regulating acid attacks is significant, as it can aid in the remineralisation of dental hard tissue.

Aetiology

The aetiology of dental erosion is complex, typically categorised into extrinsic and intrinsic factors.

Extrinsic factors are largely influenced by dietary choices, particularly the consumption of acidic foods and beverages, which play a pivotal role in the erosion process. In contrast, intrinsic factors include various diseases and habits that elevate the presence of gastric acidic content in the oral cavity, further contributing to the exacerbation dental erosion. Conditions such as gastrointestinal eating disorders are common examples of this intrinsic factor (ten Cate and Imfeld, 1996).

Soft drinks are primarily characterised by their low pH levels resulting from high acidic content. In recent decades, the consumption of soft drinks has surged. Public interest reports that in 2004, approximately 37 gallons of soft drinks were manufactured for every man, woman, and child (Jacobson, 2004).

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Figure 1A: Dental erosion in anterior teeth, front view

Figure 1B: Dental erosion in anterior teeth, lateral view

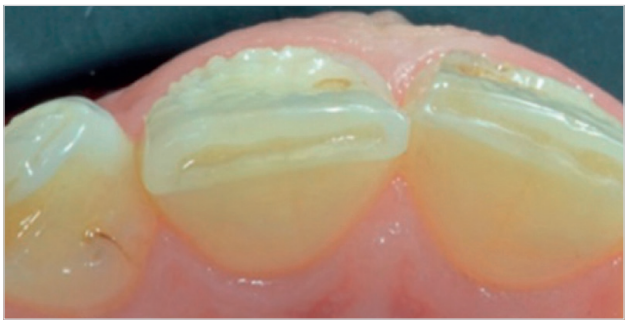

Figure 1C: Dental erosion in anterior teeth, occlusal view

Another study found that in the past three decades almost 66% of children and 77% of adolescents choose to consume sugary beverages daily (Lutovac et al, 2017). Therefore, the considerable increase in the consumption of these acidic soft drinks has now emerged as a principal cause of dental erosion (Reddy et al, 2016). Furthermore, it is also associated with weight gain, obesity, and type 2 diabetes, affecting adults more (Lutovac et al, 2017).

However, it is essential to identify that the presence of saliva in the oral cavity influences the overall impact of cola's acidic contents on enamel. In cases where saliva is deficient, the erosive process intensifies as the protective mechanisms, such as hydrogen ion dilution and buffering, become compromised (Reddy et al, 2016).

Comparing the effect of regular and diet cola on enamel

Tooth enamel is the hardest structure in the human body, made up of highly organised crystals arranged in 3D prisms, starting from the amelo-dentine junction towards the outer tooth surface. The unique morphology of enamel prisms is coordinated by ameloblasts cells, where each enamel prism is a product of a single ameloblast.

The enamel surface isn't flat; instead, it exhibits a wavy structure with shallow grooves known as perikymata.

Yet under the influence of acidic beverages like cola, after five minutes, there is statistically significant disorder of the integrity of enamel crystal structure. Therefore, the erosion of this surface anatomy, accompanied with sensitivity are distinctive inductions of dental erosion linked to regular consumption of cola (Lutovac et al, 2017).

Individuals consuming soft drinks more than twice a day are four times more likely to develop a lesion through erosion, which could be as much as 1 µm per day (Lutovac et al, 2017). Moreover, if enamel erosion is not effectively managed and controlled it can lead to dentinal hypersensitivity, which will result in unpleasant pain (Alcântara et al, 2019).

Carbonated acidic substances, such as cola, induce changes in the mineral structure of enamel, leading to a subsequent fall in enamel's physical and mechanical properties (Inchingolo et al, 2023).

The acidity of cola primarily is derived from the presence of phosphoric acid, which is an additive used to enhance flavour and extend shelf life. Additionally, citric acid can also be included to create a tangy flavour profile while also serving as a preservative (Khamverdi et al, 2013).

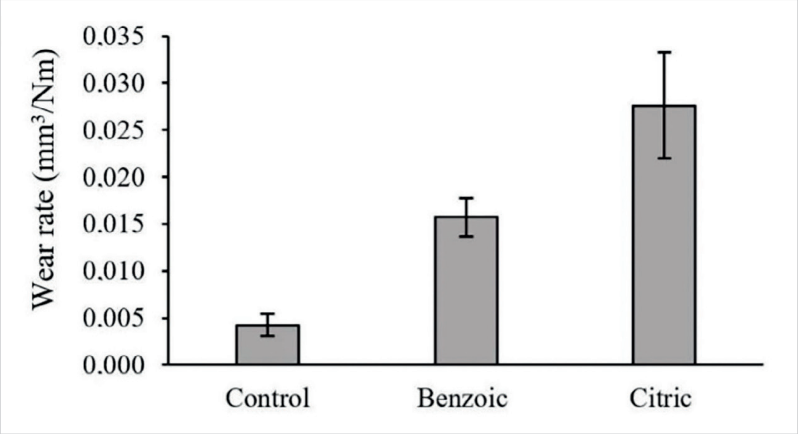

Figure 2: Enamel wear rate after exposure to the three condition (Cardoso et al, 2019)

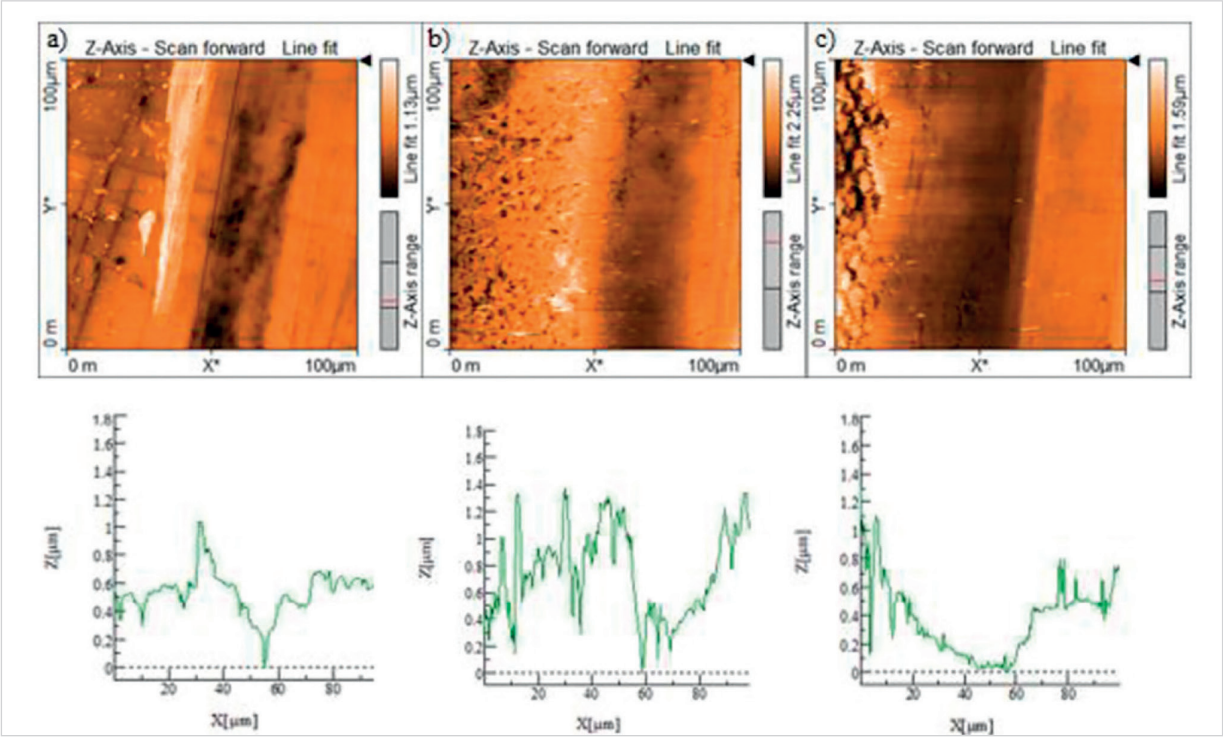

Figure 3: AFM images (100×100µm²) and the corresponding profiles of the wear tracks: a) control; b) benzoic acid; c) citric acid (Cardoso et al, 2019)

Both regular and diet cola share a similar pH range of approximately 2.7 to 3, well below the critical pH threshold of 4.0 (Khamverdi et al, 2013).

Diet cola contains both phosphoric acid and citric acid, unlike regular cola, which only contains phosphoric acid (Lutovac et al, 2017).

Earlier studies using atomic force microscopy (AFM) have shown that beverages with citric acid can cause more extensive enamel erosion than drinks like regular cola, which only contain phosphoric acid (Sigusch et al, 2008).

This distinction becomes apparent when considering a study by Khamverdi and colleagues (2013) that compared the effects of cola and diet cola on enamel, revealing that 'Diet Coca-Cola is more erosive than the regular type'. They further observed that the erosive potential of diet cola is more pronounced due to the presence of additional citric acid.

The consumption of beverages with a pH value below 4.0 poses a significant risk to dental health. The presence of

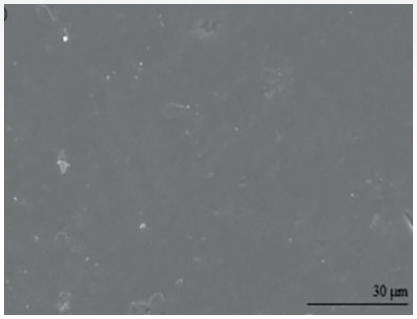

Figure 4A: SEM image (x1000) of the enamel surface: control (Cardoso et al, 2019)

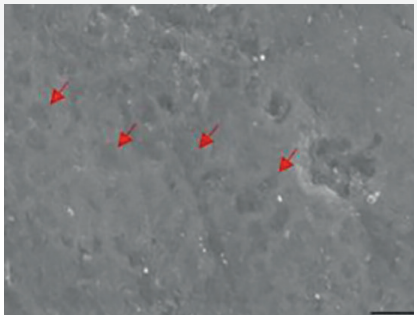

Figure 4B: SEM image (x1000) of the enamel surface: benzoic acid (Cardoso et al, 2019)

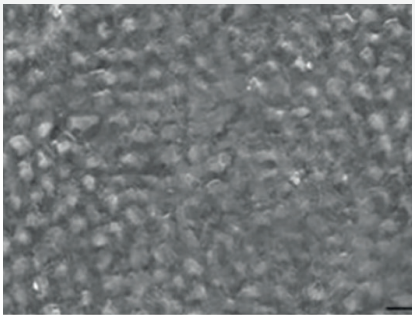

Figure 4C: SEM image (x1000) of the enamel surface: citric acid (Cardoso et al, 2019)

acidic flavourings in these beverages reduces the solubility product of enamel, shifting it into a more soluble phase.

Understanding the pH of these beverages empowers dental professionals to plan effective preventive strategies as part of treatment plans. This knowledge allows them to address dental erosion implications and guide patients in making dietary choices that avoid substances with a pH below four while favouring options above this threshold (Cardoso et al, 2019).

Effect of citric acid on crystal morphology

Citric acid is a weak acid, found in various citrus fruits such as lemon, grapefruit, tangerine and orange (Penniston et al, 2008). It is often used as an ingredient to modulate taste of beverages while serving as a natural preservative (Grigor, Johnson and Salminen, 2002).

The research by Khamverdi and colleagues (2013) demonstrated that while regular cola contains phosphoric acid, the increased erosive potential of diet cola can be linked to the presence of additional citric acid.

The pronounced erosive potential of citric acid stems from its role as a chelator, where it can effectively bind to the calcium ions within enamel's hydroxyapatite structure (Attin et al, 2003).

It was found that temperature had no effect on the erosive potential (Khamverdi et al, 2013).

In previous research, the impact of citric acid on enamel morphology and wear has been investigated (Cardoso et al, 2019).

Human enamel was cut and exposed to citric acid and benzoic acid, using conditions that mirror those that occur during a normal meal.

Cardoso and colleagues (2019) found that the wear resistance of enamel is found to be lowest when subjected to citric acid. This is primarily due to the distinct way citric acid interacts with enamel, inducing alterations in the enamel crystal morphology.

Specifically, citric acid's action is characterised by a selective, uneven modification of the enamel structure (Cardoso et al, 2019).

Enamel morphology was closely examined using atomic force microscopy (AFM) and scanning electron microscopy (SEM), before and after the acid exposure. It was found that citric acid selectively targets the interrod regions, resulting in the isolation of the individual enamel rods orientated perpendicularly.

In contrast, benzoic acid attacks the enamel uniformly, thus enamel has a higher wear resistance.

A similar result was also observed by Zhang and colleagues (2015), where it was concluded that in an acidic environment the mechanical and wear properties of enamel are influenced.

Based on SEM images, there are surface irregularities on citric exposed enamel, making it more susceptible to fractures (Cardoso et al, 2019). Therefore, this examination reveals the delicate balance between citric acid and the overall structural integrity of enamel, highlighting the underlying mechanisms that contribute to enamels poor wear resistance.

Conclusion

It can be concluded that the erosive potential of diet cola has shown that it poses a significant threat to the dental enamel, where the acidic content is the primary culprit. Dental erosion of the dental hard tissues, particularly the enamel, is a widespread issue affecting both children and adults.

Dental erosion significantly compromises dental health but also has a poor impact on an individual's quality of life, as observed through higher levels of dissatisfaction

and discomfort among patients who are affected. Thus, dental erosion remains as a cause for concern for dental professionals and a source of dissatisfaction among patients.

Studies have demonstrated that diet cola, which is often consumed as a healthier alternative to regular cola, paradoxically contributes to dental erosion the most, due to its acidic flavourings, specifically the addition of phosphoric acid and citric acid.

It is important to note that saliva plays a crucial role in buffering and remineralising the dental enamel. It aids to compensate the negative effects of the acidic flavourings, but its absence or insufficiency can exacerbate the erosion process.

As the consumption of soft drinks continuous to rise, it becomes increasingly essential to raise awareness about the erosive potential of diet cola.

Understanding the erosive potential of diet cola enables individuals to make informed choices regarding their consumption of beverages, as awareness is necessary for prevention.

Dental professionals can play a significant role by conducting dietary analysis, enabling them to promote preventive education and collaborate with patients in making informed choices. This approach empowers individuals to take control of their oral health.

By assisting patients in selecting beverages with a pH above four and advising to gradually eliminate acid consumption, we empower patients to make impactful dietary adjustments to help maintain the integrity of enamel.

It is then essential that individuals use this information and consider making the required dietary changes and seek dental advice to protect their oral health.

Further research into dental erosion and its impact on enamel will help to discover more effective preventive measures.

The erosive potential of diet cola is a topic of concern, and it serves as a reminder that an individual's dietary choices can impact their oral health with significant consequences.

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