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The Onset of Dental Erosions Caused by Acidic Foods and Drinks and its Prevention

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1. Summary

Dental erosion is a progressive lesion characterized by the loss of hard tissue of a tooth that is irreversible, resulting from a chemical process without the involvement of bacteria. The multifactorial aetiology of dental erosion involves intrinsic and extrinsic factors, including biological, chemical, and behavioural conditions, which contribute to its development.

Both enamel and dentin layers of teeth can be dissolved by acidic substances, making teeth more susceptible to decay and sensitivity. The severity of dental erosion is determined by the frequency and duration of exposure to acid, as well as various factors including nutrition, saliva, general health conditions, and mechanical stress. Certain habits, such as consuming acidic foods and drinks, exposure to acid in certain occupations, as well as medications or diseases that affect saliva flow rate, can increase the risk of dental hard tissue defects. Erosion caused by acidic beverages and food is influenced by its chemical parameters. The pH level, as well as the calcium, phosphate, and fluoride content of a drink or food, play crucial roles in this process.

Risk factors for erosion can be identified through a comprehensive clinical examination and detailed patient history, and strategies can be developed to reduce or eliminate these factors. Preventing dental erosion can be accomplished through a combination of dietary changes and proper dental care practices. Reducing consumption of acidic drinks and foods, using a straw to minimize contact with teeth, and rinsing the mouth with water after consuming these items are all effective preventative measures. In addition, maintaining good oral hygiene practices, including regular brushing and flossing, using fluoride toothpaste and mouthwash, and scheduling regular dental check-ups and cleanings can help to minimize the risk of dental erosion. The severity of the situation will determine whether additional preventive measures or treatments, such as fluoride application, dental bonding, or prosthetic treatment, are required.

Key words: dental erosion, acid erosion, erosive tooth wear, acid wear, chemical wear, non-carious cervical tooth wear, dental enamel, dental surface loss, dentin sensitivity, erosion prevention, erosion treatment

2. Introduction

The issue of dental erosion caused by acidic drinks and foods has become a growing concern in recent years. This condition occurs when the enamel on the surface of the teeth wears away due to exposure to acids, leading to tooth sensitivity, discoloration, and even cavities. Acidic drinks and foods, such as citrus fruits, soft drinks, and sports drinks, have become increasingly popular in modern diets, making it crucial for individuals to be aware of the potential risks and take preventative measures to protect their teeth.

Dental erosion is a concern for all age groups, particularly for young children whose primary dentition has much thinner enamel and dentin layers than permanent teeth. In recent years, the prevalence of dental erosion has increased in industrialized countries due to changes in dietary habits and social environments. The promotion of acidic foods and drinks through appealing advertisements and the widespread consumption of these products in households are the main contributing factors. Even sugar-free alternatives are often highly acidic and can cause irreversible harm, particularly in younger generations who may not be aware of the consequences.

This thesis aims to investigate the prevalence, causes, and consequences of dental erosion. The research will explore how early diagnosis, prevention and management can help prevent further damage to permanent teeth.

3. Literature Search Strategy

The searches were conducted during December 2022 and January 2023 in the database of PubMed. The search strategy includes synonyms and related terms for dental erosion to ensure a comprehensive search. It also includes additional terms related to dental health and oral health to capture any potential overlap in the literature. Finally, the search is limited to English and German language articles to avoid any potential language barriers. The search generates a total of 5874 results and a total of 895 results remained after removing the duplicates. All articles were screened according to the inclusion and exclusion criteria. A total of 130 references were used.

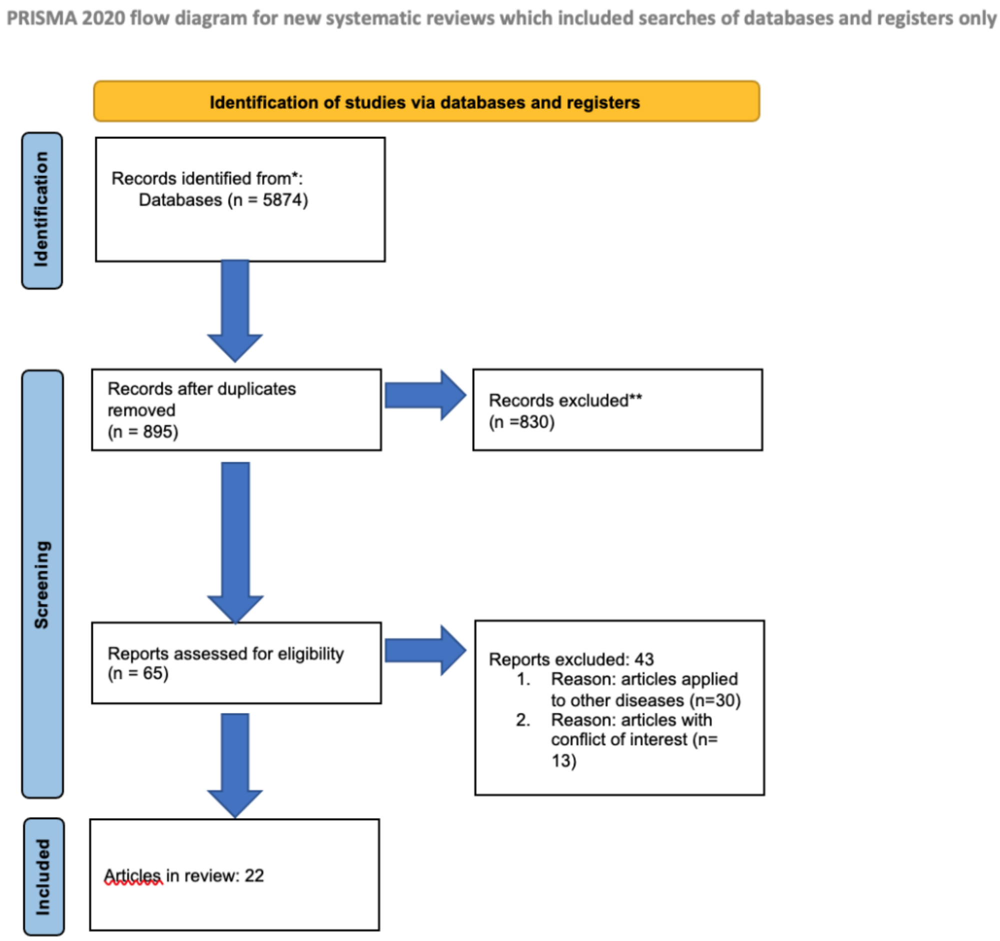
Inclusion criteria:

- Free full text
- Publication date not older than 10 years
- Article languages: English and German

Exclusion criteria:

- No full text available

- Other languages
- Articles with conflict of interest
- Articles based on other diseases



4. Erosion

4.1 Enamel

The human tooth is comprised of several layers, with the outermost layer covering the crown being referred to as enamel. Underneath the enamel, the much softer dentin layer is located. Enamel is actually the hardest substance found in the human body. It forms inside the jaw bone before the tooth emerges and undergoes several stages of development. The presecretory stage is followed by the secretory stage, a short transition, the maturation stage, and finally, apoptosis of ameloblasts leading to the tooth's eruption into the oral cavity.[1] During the presecretory stage, ameloblasts differentiate before the secretion of the mineralizing enamel matrix occurs in the secretory stage. The dentin-enamel junction is formed during this stage, separating the enamel from the dentin. The consistency of the enamel is soft, cheesy-like at this point due to the high amount of enamel matrix proteins and incomplete differentiation of ameloblasts. Once the enamel reaches full thickness, the ameloblasts change their morphology in the transition stage, leading to the maturation stage. In this stage, the ameloblasts alter their cell morphology, leading to cyclical transition between smooth and ruffle-ended cells. This process causes a fluctuation in enamel pH and ion transport, leading to the massive growth of crystals. The enamel matrix proteins are taken up by the cells, allowing for the expansion of mineral crystals while decreasing the amount of protein and increasing the content of mineral. Enamel formation is completed once the enamel crystals mature and grow, interlocking within bundles.[2] Enamel is primarily composed of inorganic substances (95%), with only a small number of organic substances (1%) and water (4%). The main constituents are calcium and phosphorus, although other minerals like sodium, magnesium, and chlorine can also be found. Enamel is organized in a hierarchical structure, built from a crystalline arrangement determined by the arrangement of hydroxyapatite and mixed apatite as fluoridated Hydroxyapatites, fluorapatites or carbonated apatite. Enamel's hardness is crucial to protect the tooth structure from external damage and withstands extreme chemical and temperature variation, and chewing forces, allowing it to last a lifetime. However, tooth enamel still cannot withstand all external influences.

4.2 Definition and Principles of Tooth Erosion Formation

Tooth erosion is a type of non-caries induced dental lesions. It occurs when tooth structure is lost due to chemical influences of acids or calcium-chelates, without the influence of microorganisms. These acids may come from either intrinsic or extrinsic sources, and the location and occurrence of dental erosions can vary. Typically, the erosive process begins on the outer surface of the tooth and progresses downwards in layers. Initially, the erosion is not visible or painful, but as it reaches the dentin, it can cause hypersensitivity, discoloration, and visible defects.[3] Tooth erosion is irreversible, meaning that lost tooth structure cannot be regained, and if the causative factors are not reduced, erosion will continue until the entire tooth structure is lost.[4] Early signs of erosion include a smooth, dull surface on the tooth crown, which progresses to concavities visible on vestibule and oral smooth surfaces.[5] These concavities grow wider, but not deeper, and smoothen the adjacent edges. Erosion is most commonly observed on the incisal and approximal surfaces of anterior teeth, where it appears as translucency. Marginal regions of teeth next to the gingiva tend to have less erosive tissue due to the higher amount of neutralizing saliva from the dental papillae. Advanced erosion can cause synclinal reduction on vestibule surfaces and ultimately lead to the loss of occlusal morphology and anatomy. Complications can include the exposure of the pulp chamber, loss of the entire tooth crown, loss of vertical dimension, and temporo-mandibular joint dysfunctions. Tooth erosion is a multifactorial process that is influenced not only by the pH of the acids but also by other factors such as the composition of saliva, salivation rate, saturation of calcium and phosphates, and buffer capacity. [6] In addition to erosion, abrasion, attrition, and abfraction are also non-carious induced dental tooth losses that can occur in isolation or combination and can easily be confused with erosion.[7] Early diagnosis of tooth erosion is crucial as it is irreversible, and it is difficult to detect early due to late showing clinical signs and potential for differential diagnoses.

4.3 Pathogenesis

The pathogenesis of dental erosion is initiated by a disruption of the balance between hydroxide apatite crystals in the dental enamel and the phosphate and calcium ions in saliva, which is typically a saturated solution of hydroxyapatite at neutral pH levels. Any acidic substance that alters the pH value can disturb this equilibrium, leading to unsaturation in terms of hydroxide ions when the acidity level in relation to dental enamel is high. The process of dental erosion varies in severity depending on the duration and frequency of acid exposure. Once the pH value falls below the critical range of 5.3 to 5.5, the saliva becomes unsaturated in terms of hydroxide ions, causing the dental enamel to release phosphate and calcium ions due to a diffusion gradient.[8] Calcium ions can also bond with complex-forming chelators, such as citric acid, further exacerbating the demineralization and erosion process. The dissolution of the enamel follows a distinct pattern, starting with the prism sheaths, then the prism core, and finally the interprismatic substance. The erosion process continues onto the dentin, where the peri- and intratubular dentin are successively destroyed, causing the gradual removal of hard tooth substance layer by layer. The speed of neutralization of the acid depends on the buffer capacity or pH stability of the acid, as well as the salivation rate and saliva content. In cases where the salivation rate is reduced, as may occur due to other illnesses, the neutralization process takes longer. Some saliva components, such as Statherin proteins and the pellicle forming on the dental surface, have a preventive effect on dental erosion by adsorbing onto the tooth surface and shielding it from surrounding acids.[9]

The characteristics of the acid itself, such as its strength, protonation, and adhesiveness, also play a crucial role in the erosive process.

4.4 Etiology and Location

The development of dental erosion can be attributed to a multifactorial process including three groups being classified. A distinction is made between extrinsic, intrinsic and biological influences[10], which will be described below.

4.4.1 Intrinsic Factors

Dental erosions can be caused by intrinsic factors including diseases as gastroesophageal reflux, bulimia nervosa and anorexia. Often, the dentist is the first to diagnose such illnesses based on the clinical manifestations seen in the oral cavity. At the beginning, erosions can be observed especially on the palatal surfaces of the maxillary anterior teeth. Afterwards those extend to the palatal areas of the lateral maxillary teeth and later, in advanced stages, to the lingual and occlusal surfaces of the mandibular teeth.[11] The causative factors are the gastric acid and the acidic contents of the stomach. All three diseases mentioned before have in common to lead to gastric juice repeatedly entering the oral cavity. The pH of gastric acid counts 1,0 to 1,5 which falls widely beneath the critical range of dental enamel. Since gastric acid has a lower pH compared to acidic drinks, it is even more acidic and has an increased erosive potential. Moreover, it dissolves higher amounts of calcium from the dental enamel in a shorter time.[12]

In healthy condition, the pH of the esophagus can be measured between five and seven. However, in cases of gastroesophageal reflux the pH of the esophagus decreases to a value lower than four. Typical symptoms are heartburn, epigastric pain, acid regurgitation and dysphagia. The prevalence of gastroesophageal reflux has been reported to be about 10 to 20% in Europe as well as in North America and only 5% in Asia.[13] Furthermore, the disease affects all age groups. First, the refluxed acid attacks the palatal surface of the upper incisors. If the condition continues, erosion of the occlusal surfaces of the posterior teeth in both arches occurs. In general, the labial or buccal surfaces are only affected if acid reflux persist for an extended period of time. The primary explanation for why the palatal surfaces of the maxillary teeth are the first to experience erosion is that they are shielded from the major salivary glands, and the tongue remains in frequent contact with the acidic substances.[14] Notably increased is the likelihood of dental erosion when chronic vomiting coincides with gastroesophageal reflux. Patients, who suffer from gastroesophageal reflux can show especially at night a unilateral variation regarding dental erosion. Here, all teeth of the relevant half of the face can be damaged, which can be attributed to laying on one side while sleeping. The erosive potential is further increased due to reduced salivary flow at night.[15] Most affected patients are not aware of having rather gastroesophageal reflux nor dental erosion.

Another intrinsic factor causing dental erosion are eating disorders. Young women between the ages 12 and 35 years are particularly affected. It is estimated that about 5% of young women between the ages 18 and 35 years suffer from bulimia and about 2% of the female age group between 12 and 20 years suffer from anorexia.[16] Anorexia nervosa is an eating disorder characterized by an abnormally low body weight, an intense fear of gaining weight as well as a distorted perception of body image. In general, more women than men are affected.[17] The prevalence is reported to be 1,1% women and 0,3% men of the age range 18-79 years in Germany.[18] The disease can be further differentiated in several sub-types. On the one hand there is the type of nourishment refusal or reduction and on the other hand there is the type which additionally loses weight through vomiting. Most affected people can be recognized by their outer, underweight appearance.[19] Typical behavioral patterns are strict fasting and increased physical activity.

In contrary, bulimia cannot be recognized by an outer, thin appearance as in anorexia cases, moreover bulimia affected people can maintain their normal weight which leads mostly to late diagnosis. Typical behavioral patterns of bulimia are repeated binge eating attacks where huge amounts of food are eaten in a short time followed by loosening the eaten food by self-induced vomiting. Often, the disease occurs in combination with the intake of laxatives as well as diuretics and excessive tooth brushing. Bulimia can be diagnosed as illness as soon as the binge eating attacks followed by self-induced vomiting have occurred at least twice a week in the past three months. Since the disease is linked to self-induced vomiting, the affected patients are at higher risk to get dental erosion.[20] After Johansson et al., patients who vomit voluntary are 5.5 times more likely to experience dental erosion than healthy controls.[21] It results from regularly vomiting and with that bringing the teeth in contact with the highly acid gastric juices, which affect the teeth severely. Erosive changes can be detected on all tooth surfaces of patients affected by bulimia. Uhlen et. Al reported, irrespective of the duration of self-induced vomiting, lesions, be they enamel or dentine lesions, were found on palatal surfaces of bulimics (46%) followed by occlusal surfaces (36.6%) and buccal surfaces (21.8%).[22] Commonly, dental erosions are observed on the palatal surfaces of the upper incisors because this area comes into contact with gastric acid initially during vomiting. Furthermore, the coarse texture of the tongue frequently touches the palatal surfaces of the upper front teeth, causing a rubbing effect that exacerbates the tissue loss after vomiting. Additionally, excessive tooth brushing after vomiting can lead to further loss of dental hard tissue. Patients who have bulimia typically experience a decrease in salivary flow rate, which reduces the remineralization of the teeth and, in turn, contributes to the dental erosion process.[23] In addition to the intrinsic factors previously mentioned, dental erosions are frequently associated with extrinsic factors. Bulimic patients, in particular, often consume significant amounts of herb tea, soft drinks, and apple cider vinegar, which increases their risk of dental erosion. In a study comparing 20 bulimics with 20 controls, 13 of the bulimics drank carbonated drinks more than four times a week, while only four of the controls did so. [24]

Another intrinsic factor that can contribute to dental erosion is chronic alcoholism. Alcoholics frequently consume acidic beverages and, in most cases, vomit thereafter. [25]

4.4.2 Extrinsic Factors

Extrinsic factors are the primary contributors to dental erosion. [26] These include acids that originate from external sources such as beverages, food, environmental factors, and medication. Among these, dietary habits have been extensively studied as the most significant influencing factor. Dental erosion caused by extrinsic factors is typically limited to the labial and occlusal tooth surfaces.

Scientific research has demonstrated that the habitual intake of soft drinks, including cola, energy drinks, and flavored beverages, as well as alcoholic beverages such as alcopops and wine, and acidic fruits like apples, kiwis, pineapples, nectarines, and lemons, as well as acetic and lactic-acid fermented foods like mixed pickles or balsamic vinegar, can result in dental erosion.[27] Herbal teas like rosehip, mallow, and flavored teas with citric acid are considered acidic with a pH range of 2.6 to 3.9, which falls below the critical range for dental enamel.[28] Additionally, these teas possess a high buffering capacity and a low fluoride content, rendering them more erosive than even orange juice. Therefore, their regular consumption can lead to dental erosion. [29] After Lussi et al. soft drinks and fruit juices account for 50% of total non-alcoholic beverage consumption in Europe.[30] As mentioned earlier, the critical aspect is the pH value of a product, which must fall below the critical pH value of dental enamel to be classified as having potential erosive properties. The erosivity of an acidic product depends on its pKs value, which measures the proton release during chemical reaction. As a result, food and drinks with similar or even the same pH value can be differently erosive. Furthermore, the erosive potential of food depends not only on the pH value, but on other factors as the buffering capacity, the mineral content, especially regarding calcium and phosphate, the chelating properties and, above all, the frequency of consumption.[31] Although, edibles as yogurt account a pH value of 3.8, which falls below the critical value of 5.3[32] of dental enamel, it does not cause erosion due to its high contents of calcium and phosphate.[33] Calcium and phosphate saturation can help to mitigate the acidic nature of a substance, thereby providing a protective effect.[34] Carbonated water does not fall under the category of erosive beverages. In fact, previous experiments have shown that carbonated water has an erosive potential that is up to 100 times weaker than that of soft drinks.[35] The consumption of soft drinks has risen highly in recent decades. In the US, the consumption of soft drinks among boys tripled between 1965 and 1966. According to Lussi and Carvalho, the global consumption of soft drinks in 2007 was 552 billion liters. That corresponds to 83 liters per person. Soft drinks differ in pH as well as in erosive potential. Despite a low pH of 2.6, cola shows a lower erosive potential than light sprite (pH 2.9), ice tea (pH 3) or red bull (pH 3.4). Next to soft drinks, even supposedly healthy fruit juice can damage the tooth structure. The effect is intensified when fruit juice is consumed just before bedtime or during the night when the salivary flow decreases.[36]

In today's modern, industrialized society, people often have a shortage of time for regular meals. Irregular eating habits, frequently drinking erosive beverages and deviant swallowing behavior have become commonplace and thus representing another extrinsic risk factor. Moreover, there has been a steady rise in dental erosion among children, which can be attributed to the heightened consumption of acidic juices, fruit juices, and various other soft drinks. Individual food as well as lifestyle habits are highly influenced by the socio-economic status of an individual. In contemporary times, individuals are driven by a desire for self-optimization, which involves adopting a healthy lifestyle comprising of high consumption of fruits and vegetables, and exercising extensively. However, eating excessive amounts of fruits increases the acid content in the diet, while intense exercise results in reduced salivation and loss of body water. Furthermore, some individuals prefer consuming sports drinks, which are typically high in acids, while exercising. In general, when the protective rate of saliva decreases and acidic beverages are ingested, the risk of dental erosion is heightened. Typically, a health-conscious lifestyle is associated with excellent oral hygiene. However, certain oral hygiene products, such as Listerine and hexetidine mouthwashes that contain ethylenediaminetetraacetic acid or have a low pH level, can actually contribute to dental erosion. Nevertheless, the low pH of fluoride contained in mouthwashes is an exceptional case. The caries-preventive characteristic of fluoride is based on the production of a calcium and fluoride rich layer. In that relation, the buildup of calcium fluoride is dependent on the availability of calcium. The more acidic the mouthwash, the more calcium can be dissolved away of the dental tissue or the saliva and used for the buildup of calcium-fluoride which protects from erosion.[37] Same as mouthwashes, toothpastes containing fluoride have a low pH level too. On the one hand, it ensures a chemical balance regarding fluoride components and on the other hand, it favors the integration of fluoride ions into the hydroxyapatite and therefore the buildup of fluorapatite. Toothpastes, containing citric acid or citrate, having a low pH and do not contain fluoride can cause erosion. In this regard, an in-vitro study conducted on cow teeth demonstrated a reduction in dental structure hardness.[38] Apart from the aforementioned lifestyle, there are individuals who adhere to a plant-based vegetarian or vegan diet. While some people follow a vegetarian or vegan diet for religious or ethnic reasons, it has become increasingly popular among younger generations. While vegetarian only abstain from meat, abstain vegans from all animal products. A vegetarian same as vegan diet contains mostly an increased number of acids due to a higher consume of fruits as well as high fiber foods, which causes erosion. In addition, a vegan diet prohibits the consumption of any milk products, which reduces the intake of protective calcium and places individuals who follow a vegan diet at a higher risk of developing dental erosion.

The intake of certain medications can also be associated with dental erosion. For instance, chewing acetylsalicylic acid or vitamin C supplements can lead to erosion on the occlusal tooth surfaces. Medications, as for example antihistamine, diuretic, tranquilizer, anti-Parkinson medication, anti-HIV medication, anti-migraine medication, anti-depressives, bronchodilators or muscle relaxants; decrease the salivation rate and therefore favor erosion.[39]

Additionally, professions that involve exposure to high levels of acid in the environment pose an increased risk for erosive dental changes. Individuals working in the chemical industry are particularly susceptible due to their exposure to inorganic acids, which often affect the incisal edges of the upper anterior incisors and posterior teeth. Mouth breathing can further exacerbate the risk of erosion.[40] The higher the acidic amount on the working place, the more erosive changes can be recognized.

Furthermore, professional wine tasters are at a higher risk of developing dental erosion. One reason for wine's erosive potential is its low pH level, typically ranging from 3 to 3.6. Additionally, wine tends to have reduced mineral content, particularly in terms of calcium and phosphate. In a study of Chikte et al.[41], several winery owners, who drink wine regularly, were compared with their marriage partners, who do not. Aim was to prove whether the winery owners show an increased erosive tooth loss than their partners. All of the participants were clinically examined and the condition of their teeth reported. Additionally, the existence of previous dental tissue loss including grade and location, as well as previous fluoridation and prosthetic works were noted. The salivation rate, the buffer capacity and the pH value of the saliva was measured as well. All in all, the study involved 36 participants, 21 of whom were wine tasters and 15 were their spouses. The results indicated that the wine tasters experienced greater dental tissue loss compared to the control group, highlighting the increased risk of dental erosion associated with regular wine consumption.

4.4.3 Biologic Factors

Biological factors that contribute to erosion include the anatomy of teeth and soft tissues in the oral cavity, the composition of tooth structure, and saliva. Among them, saliva is the most critical biological factor in reducing the risk of erosion. Saliva directly affects the erosivity of substances by diluting, washing away, and neutralizing them, as well as by buffering their effects. Also, saliva plays a significant role in protecting tooth surfaces by forming pellicles that act as a protective membrane and aid in remineralization. However, once tooth surfaces are fully dissolved, saliva can only remineralize the thin demineralized layer that remains.[42] The protective properties of saliva are evident even before an acid attack, as external stimuli such as the sight or scent of acidic foods can trigger an increase in salivation. Similarly, just prior to vomiting, the brain's vomiting center prompts a rise in salivation, which is often noticeable in patients with chronic alcoholism or bulimia nervosa. However, in patients with chronic reflux, the autonomic nervous system does not stimulate salivation, and the vomiting center in the brain remains inactive.[43] Next to the secretion of carbon dioxide, the secretion of several ions as hydrogen carbonate, dihydrogen phosphate, hydrogen phosphate, calcium and fluoride count to the protective characteristics of the saliva.[44] [45] As soon as acidic drinks or food enter the oral cavity, various protective mechanisms are set in motion to protect the teeth from erosion. According to Engelen, only three drops of 4% citric acid placed on the tongue, every 30 seconds, five minutes apart, can increase the salivary flow rate from 0.38 ml/min to an average of 1.87 ml/min.[46] Furthermore, chewing can increase the salivary flow as well.[47] The quantity and composition of saliva released from various salivary glands depend on the type of stimulus.[48] When salivation increases, the concentration of hydrogen carbonate in saliva also rises, leading to a neutralizing effect. This, in turn, enhances the buffering capacity and rinsing action of saliva.[49] Beyond that, the protective mechanism of saliva is influenced by the consistency of food and the anatomy of the oral cavity. Teeth surfaces that are in contact with serous saliva are considered to be better protected than those in contact with mucous saliva. Accordingly, the labial surfaces of the upper incisors are more prone to acidic attacks than the lingual surfaces of the lower jaw teeth.[50] The serous salvia of the parotid gland features a greater buffer capacity and a higher remineralization potential than the sero-mucosal saliva of the submandibular gland and the mucosal saliva of the sublingual gland.[51] Clinically, there is a connection between a low salivary flow rate, reduced buffer capacity and the development of dental erosion.[52] As previously mentioned, the saliva is involved in pellicle formation, which contain salivary proteins and form on the teeth surfaces immediately after the teeth have been cleaned. In addition to salivary proteins, pellicles contain proteins of the gingival sulcus fluid, blood, food and bacteria.[53] Studies have shown the ability of pellicles to protect the teeth from acidic attacks, dependent on their thickness and maturation time.[54] To prevent erosion, the pellicle acts as a semi-permeable diffusion barrier, obstructing direct contact between tooth surfaces and acidic substances. Hanning and Balz conducted a study demonstrating that the pellicles on the palatal side of enamel specimens were thinner than those on the buccal or lingual surfaces of the teeth.[55] Similarly, Young and Kahn observed that teeth surfaces with thicker pellicle layers had fewer erosive defects.[56] Within around two hours, the pellicle reaches its maximum thickness, followed by a conversion and maturation process that increases its resistance to acids. The extent of protection against erosive attacks on tooth enamel varies based on the composition and level of maturation of the pellicle. Hara et al. conducted a study revealing that a pellicle matured for two hours could decrease the demineralization caused by orange juice acid over a period of 10 minutes.[57] However, the saliva cannot fully protect the teeth from acids, only from occasional, weak acidic attacks.[58] The composition and anatomy of teeth is another factor that can influence the development of erosion. Whereas enamel consists of 2% organic and 96% inorganic minerals, build in a hexagonal hydroxyapatite prism, consists dentin of only 20% organic and 70% inorganic minerals.[59] Furthermore, the crystals of the dentinal inorganic matrix are looser as well as smaller compared to enamel. In addition, the dentinal inorganic matrix features more impureness shown in form of carbonate-, magnesium- and sodium-ions as the inorganic matrix of the enamel. Consequently, dentin is more susceptible to acid solubility than enamel.[60] On the other hand, dentin contains collagen fibers that remain intact after demineralization by acids, providing some protection against erosion for a certain period. As long as the exposed collagen fibers stay hydrated and vital, those act as diffusion barrier for acids and prohibit the dissolution of further minerals form the still intact dentin.[61] [62] In comparison to permanent teeth, deciduous teeth are smaller and have a thinner enamel layer.[63] [64] Additionally, the prisms of milk teeth are smaller and less connected, resulting in a more porous structure. While the organic component of the enamel in permanent teeth varies between 0.4% and 0.8%, falls the organic component of enamel in deciduous teeth between 0.7% and 12% and shows therefore a bigger range. Overall, the enamel of primary teeth is less mineralized and softer than that of permanent teeth.[65] [66] [67] In a study by Hunter et al., it was found that the erosion process in primary teeth progresses more quickly, reaching the dentin faster than in permanent teeth.[68]

4.5 Epidemiology

According to a study conducted from 2004 to 2005, dental erosion was prevalent in children aged 3 to 6 years in Göttingen, with a prevalence rate of 22% among 3-year-olds and 38% among 6-year-olds.[69] Ten years later in 2014 to 2015, another study was carried out under the same study management and a prevalence of 14% to 71% was observed in 3- to 6-year-old children.[70] Within a decade, there was a significant increase in the prevalence, particularly among older children.

During the late 1980s and early 1990s, adults aged 26 to 30 had a prevalence of approximately 30%, while those aged 46 to 50 had a prevalence of 43%.[71] In the IV.

German Oral Health study in 2006, the prevalence of non-carious tooth tissue lost, including dental erosion, was observed to be 17% for men and women aged 35 to 44 years and 32% in men and 26% in women of the ages 65 to 74.[72] Another decade later, the V. German Oral Health Study conducted in 2016 found that the prevalence had increased to 47% in 35- to 44-year-old men and to 42% in women. A prevalence of 65% was determined for men aged 65 to 74 years and 52% for women of the same age.[73] Comparing the last two studies from 2006 to 2016, the prevalence has doubled in a period of 10 years for both younger and older men and women. On the one hand, the prevalence for men is higher than for women and on the other hand the prevalence increases with age. The incidence of erosion is steadily rising in both children and in adults. Furthermore, the prevalence is even higher in individuals affected by extrinsic and intrinsic factors. In individuals with gastroesophageal reflux, a study found a dental erosion prevalence of 98% in children, while the corresponding age-matched control group had a prevalence of only about 19%.[74] The prevalence of the risk group for adults was approximately 75%, whereas the age-matched control group had a prevalence of only 17%.[75] Patients with eating disorders such as anorexia nervosa or bulimia nervosa were found to have a prevalence rate ranging between 45% and 98%.[76] Irrespective of the type of eating disorder, the risk of dental erosion was determined to be 8.5-fold higher.[77] A study conducted in Sweden focused on erosion prevalence among wine tasters and found that almost two-thirds of all examined individuals experienced tooth hard tissue loss due to erosion.[78] The cause was attributed not only to the low pH value of wine but also to the prolonged holding and rinsing of the mouth with the wine being tested.

4.6 Diagnosis and Indexes

The diagnosis of dental erosion relies on a combination of clinical examination and the patient's medical history. Clinically, dental erosion is only visible after a certain loss of substance[79], as in advanced stages, when the dentin exposes or after the formation of dents on the occlusal surfaces. Patients often realize they have experienced tooth structure loss, when they notice their teeth have turned yellowish in color, lost vertical dimension, and become more sensitive.[80] Currently, there are no technological tools available to diagnose early tooth erosion, and therefore a diagnosis is typically based on the clinical appearance.[81] To classify a disorder related to tooth structure loss, it is important to first record and analyze the signs and symptoms. Next, a comparison should

be made between the current condition and the natural anatomy and morphology of the teeth. Different chemical and physical influences on the tooth tissue can result in a characteristic appearance. Typically, the classification of tooth structure loss is based on observable morphological features. There are also various indices available that can provide information on the cause of the loss, such as attrition, abrasion, and erosion.[82]
The surface of initial tooth erosion is typically smooth and glossy, although in rare cases it may appear dull.[83] [84] Here, the perikymata is no longer visible. Tooth structure loss typically occurs above the cemento-enamel junction, while the area around the gingival sulcus remains intact. Plaque buildup may act as a diffusion barrier, or the neutralizing effect of the sulcus fluid could be a contributing factor.[85] According to measurements of Stephen et al., the pH value of the sulcus fluid is 7.5-8.[86] As the dental erosion progresses, the cusp tips of molars gradually become rounded, resulting in a loss of their characteristic morphology. The incisal edges of incisors shorten[87] and existing fillings appear higher than the tooth structure.[88] Furthermore, the dentin becomes more visible as erosion progresses, especially in areas where the enamel is naturally thinner as for example at the neck of the tooth.[89] In severe cases, the entire occlusal surface of the tooth may be lost.[90] Extensive decalcification on the palatal surfaces is also a typical characteristic.[91]
Currently, there is no standardized index for recording dental erosion, whether for use in scientific research or dental practices. Classification of dental erosion should take into account the extent and severity of the changes observed. In 2009, Bartlett et al. introduced the Basic Erosive Wear Examination (BEWE), a method for evaluating acid damage to dental tissue. This method assesses four grades of erosive damage on the vestibular, oral, and occlusal surfaces of all teeth, except for wisdom teeth. The dentition is divided into sextants, and the highest level of erosive damage in each sextant is recorded.

Table 1

BEWE Index assessment (score and description)

Score	Description
0	No erosive tooth wear
1	Initial loss of surface texture (brightness loss, opaque surface or 'frosted glass' appearance)
2	Distinct defect, hard tissue loss, less than 50% of the surface area. Dentin could be involved
3	Hard tissue loss in more than 50% of the surface area. Dentin could be involved

BEWE index assesses the damage according to the tooth affected surface regardless its depth in dentin.[2]

Sextants' cumulative assessment (maximum 18) defines the BEWE index value per assessed subject, allowing the clinical management actions according to risk.

[92]

In the end, the total value obtained from BEWE determines the severity of dental erosion and helps guide recommendations for further treatment.

Risk level	Cumulative score of all sextants	Management
None	≤ 2	Routine maintenance and observation. Repeat at 3-year intervals.
Low	3 to 8	Oral hygiene, dietary assessment and advice, routine maintenance and observation. Repeat at 2-year intervals.
Medium	9 to 13	Oral hygiene, dietary assessment and advice, identify the main etiological factor(s) for tissue loss and develop strategies to eliminate respective impacts. Consider fluoridation measures or other strategies to increase the resistance of tooth surfaces. Ideally, avoid restorations and monitor erosive wear with study casts, photographs, or silicone impressions. Repeat at 6- to 12-month intervals.
High	14 and over	Oral hygiene, dietary assessment and advice, identify the main etiological factor(s) for tissue loss and develop strategies to eliminate respective impacts. Consider fluoridation measures or other strategies to increase the resistance of tooth surfaces. Ideally, avoid restorations and monitor erosive wear with study casts, photographs, or silicone impressions. Especially in cases of severe progression, consider special care that may involve restorations. Repeat at 6- to 12-month intervals.

[93]

5 Acidic Stimulants

The chemical erosive process occurs when strong or weak acid H+ ions or anions are present and bind to calcium ions or form complexes. Although hydrochloric acid is not commonly found in the oral cavity, weaker acids such as acetic or citric acid are more prevalent. H+ ions are produced when acids dissociate in water and can vary in quantity. For instance, citric acid can dissociate into three H+ ions, while acetic acid produces only one H+ ion. The H+ ion can bind to carbonate or phosphate and directly dissolve the minerals in the tooth structure.[94]

$$Ca_{10-x}Na_x(PO_4)_{6-y}(CO_3)_z(OH)_{2-u}F_u + 3H^+ \Rightarrow (10-x)Ca^{2+} + xNa^+ + (6-y)(HPO_4^{2-}) + z(HCO_3^-) + H_2O + uF^-$$

When the H+ ion from acid binds to a carbonate or phosphate ion, it causes direct acid attack and dislodges the ions from the tooth's crystalline structure. The potency of the acid is crucial in this process. Hydrochloric acid, for example, is a strong acid that fully dissociates in water, resulting in rapid and direct demineralization of the tooth surface.[95] In the following table of Featherstone and Lussi[96], the acid and calcium dissociation constant are presented. The calcium bonding force becomes stronger with higher values of the dissociation constant.

Acid	pK 1	pK 2	pK 3	logK Ca (1)	logK Ca (2)	logK Ca (3)
Acetic acid	4,76			1,18		
Lactic acid	3,86			1,45		
Citric	3,13	4,76	6,40	1,10	3,09	4,68
Phosphoric acid	2,15	7,20	12,35	1,40	2,74	6,46

[97]

Since citric acid exists in water as a mixture of H+ ions, acid ions and undissociated acid molecules, it has a greater ability to form complexes, which is shown in the table. The amount depends on the one hand on the dissociation constant and on the other hand on the pH value of the solution. While the H+ ion demineralizes the tooth enamel, the citrate ion complexes the dissolved calcium ion. Depending on its molecular structure and electronegativity, each acid anion can bind calcium ions in complexes of different strengths. Citric acid is known for its potent demineralizing effect on tooth enamel due to its ability to bind calcium in complexes and three available H+ ions.[98][99][100] The pKa value of an acid determines its strength. When the pH of a solution of weak acid is equal to its pKa value, 50% of H+ ions dissociate and go into the solution while the remaining 50% remain as undissociated acid. The stability constant K represents the anion-calcium interaction and measures its binding strength. Higher values of logK indicates stronger binding strengths. In this relation, citric acid causes more harm to tooth enamel than acetic acid due to its stronger binding property. It forms a stronger bond with calcium than the bond between calcium and the apatite mineral, resulting in the calcium staying in the solution and demineralizing the tooth surface.[101] In case of a weak acid, as for example acetic acid, the H+ ions are as long provided and consumed during the interaction with the apatite mineral until the equilibrium constant of the acid is reached. Frequent consumption of balsamic salad dressing can lead to this type of erosion. However, the case with lactic acid is entirely different. Lactic acid has a laterally attached OH- group that has a potent calcium-binding property. Additionally, it has a stronger acidity constant than acetic acid, resulting in a higher concentration of H+ ions in a shorter time and causing the solution's pH to drop. Lactic acid and acetic acid exhibit similar behavior when it comes to neutralization. However, lactic acid can demineralize tooth enamel even at a pH range of six to seven, where demineralization by H+ ions is not usually possible, due to its potent calcium-binding properties. On the other hand, citric acid has more complex calcium-binding properties because it is a triprotic acid, with three pKa values, one for each proton that is reversibly bound to the citrate anion. When all three protons are separated from the citric acid molecule, the calcium is bound in a three-dimensional complex through an electrostatic interaction of COO- groups that act as a chelator. At lower pH values, citric acid directly attacks the tooth structure, while at higher pH values, it dissolves calcium from the apatite structure. This property of citric acid is particularly relevant in the context of fruit juices and soft drinks. Some fruit preparations, such as orange juice, add calcium to saturate the citrate. This reduces the amount of calcium from the tooth structure bound to citrate and, therefore, decreases the erosive effect of the drink.[102]

5.1 Acidic Drinks and Foods

In order to investigate the erosive potential of different drinks and foods, a study of Adrian Lussi, Samira H. Joao-Souza, Brigitte Megert, Thiago S. Carvalho and Tommy Baumann was conducted in 2019.[103] The study tested the erosive potential of specific drinks and foods on premolars without caries. The enamel hardness of the teeth was measured before and two minutes after exposure to an acidic product. The study also determined the following values for the drinks and foods: pH, erosive potential, titratable acidity, calcium content, inorganic phosphorus content, fluoride content, and degree of saturation in relation to hydroxyapatite.

Products	Tooth	pH	% after 2 min	Erosive potential	mmol OH-/l until pH 7	[C] mmol/l	[P] mmol/l	[F] ppm	(pK-pl) HAP

Coca-Cola	Permanent	2,4	-30,7	↓↓	17,5	1,08	5,04	0,22	-20,0
Coca-Cola light	Permanent	2,6	-46,1	↓↓	19,0	0,82	4,85	0,22	-19,4
Coca-Cola zero	Permanent	2,6	-18,5	↓↓	32,6	0,26	4,88	<0,01	-22,2
Fanta	Permanent	2,7	-47,7	↓↓	52,5	0,48	0,08	0,04	-25,2
Sprite	Permanent	2,5	-37,6	↓↓	39,0	0,30	0,02	0,02	-28,8
Sprite zero	Permanent	2,9	-35,6	↓↓	57,3	0,30	<0,01	<0,01	-33,1
Monster Energy Drink	Permanent	3,4	-11,6	↓	95,5	0,04	<0,01	0,01	-30,6
Red Bull Energy Drink	Permanent	3,3	-16,6	↓	98,0	1,94	<0,01	0,11	-26,4
Apple Juice	Permanent	3,4	-25,9	↓↓	72,0	1,96	1,66	0,06	-13,0
Orange Juice	Permanent	3,6	-10,1	↓	121,0	1,98	2,57	0,03	-11,3
Milk	Permanent	4,1	<0,01	→	4,0	29,50	18,90	0,01	16,3
Ice Tea	Permanent	3,0	-16,8	↓↓	24,0	0,18	0,12	0,58	-24,0
Espresso	Permanent	5,8	0,7	→	3,0	0,69	0,63	0,07	0,6
Red Wine	Permanent	3,4	-5,7	↓	76,0	1,25	4,69	0,07	-12,5
White Wine	Permanent	3,6	-4,9	↓	53,0	1,30	4,42	0,27	-11,3

The pH levels of various drinks were measured, with espresso having the highest pH of 5.8 and Coca-Cola having the lowest at 2.4. After two minutes of incubation, the greatest decrease in hardness was observed in Fanta (-47.7%), while exposure to milk had no effect. Erosive potential ratings showed that Coca-Cola, Coca-Cola light, Coca-Cola zero, Fanta, Sprite, Sprite zero, apple juice, and iced tea had the highest potential, while milk and espresso had the lowest. Espresso had a buffering capacity of 3.0 mmol OH-/l, while orange juice had 121.0 mmol OH-/l. The drink with the highest calcium content was milk (29.50 mmol/l), and the lowest was Monster Energy Drink (0.04 mmol/l). Milk also had the highest phosphorus content (18.90 mmol/l), while Monster Energy Drink and Red Bull Energy Drink had the lowest (<0.01 mmol/l). The lowest fluoride content was measured in Coca-Cola zero, Sprite zero, Monster Energy Drink, Red Bull Energy Drink, milk, while the highest was in Ice tea (0.58 ppm). Milk achieved the highest degree of saturation in terms of hydroxyapatites, while Sprite had the lowest.

Products	Tooth	pH	% after 2 min	Erosive potential	mmol OH-/l until pH 7	[C] mmol/l	[P] mmol/l	[F] ppm	(pK-pl) HAP
Apricot	Permanent	3,3	-23,3	↓↓	317	1,20	5,95	0,02	-13,6
Kiwi	Permanent	3,2	-23,4	↓↓	206,5	3,35	4,47	0,02	-11,9
Orange	Permanent	3,6	-17,3	↓↓	113,0	2,18	1,27	0,03	-11,8
Yoghurt	Permanent	3,9	0,5	→	120,0	43,33	34,34	0,04	-0,6
Haribo Pommes yellow	Deciduous	2,5	-14,1	↓	104,5	0,07	0,12	0,02	-30,6
Apple Vinegar	Permanent	3,4	-27,2	↓↓	-	-	-	-	-
Honey	Permanent	3,6	-0,4	→	-	-	-	-	-
Salad dressing	Permanent	4,0	-3,9	↓	141,0	20,50	0,46	0,10	-6,1

The pH levels of different foods were measured, with salad dressing having the highest pH of 4.0 and Haribo Fries gummy bears having the lowest at 2.5. After two minutes of incubation, the largest decrease in hardness was observed in apple vinegar (-27.2%), while yogurt showed the least effect (0.5%). Apricots, kiwi, oranges, and apple vinegar were rated as having the highest erosive potential, while yogurt and honey were rated as having the lowest. Haribo Pommes gummy bears had the lowest buffer capacity (104.5 mmol OH-/l), while apricots had the highest (317 mmol OH-/l). The highest calcium content was found in yogurt (43.33 mmol/l), while the lowest was in Haribo Pommes gummy bears (0.07 mmol/l). Yogurt also had the highest phosphorus content (34.44 mmol/l), while Haribo Pommes gummy bears had the lowest (0.12 mmol/l). The salad dressing had the highest fluoride content (0.10 ppm), and apricots, kiwi, and Haribo Pommes gummy bears had the highest fluoride content. Yogurt (-0.6) had the highest degree of saturation with regard to hydroxyl apatite, while Haribo Pommes gummy bears (-30.6) had the lowest.

In summary, the study findings indicate that the pH value alone does not determine whether demineralization of teeth occurs. The crucial factor is the degree of saturation of dissolved substances in the liquid that comes into contact with teeth at a given pH value. As the drinks and foods examined contained varying concentrations of dissolved substances, there is no specific critical pH value. If the amount of certain dissolved substances in a drink or food is too small, it leads to undersaturation and demineralization of teeth until equilibrium is reached and the liquid becomes saturated. However, if the number of dissolved substances in the liquid is already equal to or greater than that in dental hard tissue, the liquid is already saturated or oversaturated, and demineralization will not occur. The saturation of the liquid in relation to dental hard tissue is primarily determined by the calcium content, and to a lesser extent by the phosphate and fluoride contents of the drinks and foods at a given pH value. Hence, a low-pH drink or food with high concentrations of these substances may counteract erosion because the liquid is already saturated or oversaturated in comparison to dental hard tissue. Conversely, erosion may occur at a higher pH value if these substances are absent or present in low concentrations, since the liquid is undersaturated with respect to dental hard tissue. The degree of saturation of dissolved substances determines the erosive potential, which can be altered. For instance, adding calcium to orange juice can reduce its high erosive potential.[104] Since the erosive potential depends on the saturation gradient, which is based on the contents of calcium, phosphate and fluoride, it can be changed. For example, the high erosive potential of orange juice can be decreased by adding calcium.[105] Yogurt, which naturally has a low pH too, has no erosive potential due to its high calcium and phosphate contents. Further, the erosive potential of salad dressings or fruit salads can be minimized by adding yogurt. Besides adding calcium and phosphorus, it is not recommended to add fluoride at high concentrations due to its potential side effects.[106] Diluting drinks with water is another way to reduce their erosive potential, as it decreases the concentration of H+ acid. Apart from the degree of saturation, the buffering capacity of a substance also affects its erosive potential. A substance with high buffering capacity takes longer to neutralize by saliva.[107]

5.2 Chemical Parameters

Chemical parameters play a significant role in the erosion caused by beverages, food, and other products. After examining various in-vitro and in-situ studies, Lussi and Jaeggi concluded that the erosive potential of acidic drinks is not solely dependent on pH but also on the mineral concentration and titratable acid. The buffer capacity and the ability to complex calcium ions are crucial factors that determine the degree of mineral saturation and demineralization concerning dental enamel minerals. The pH level, as well as the calcium, phosphate, and fluoride content of a drink or food, are key determinants of this process.

5.2.1 PH

An aqueous solution's acidity or basicity is measured by its pH value. A pH value less than seven indicates an acidic solution, while a value greater than seven indicates an alkaline solution. A pH of seven represents a neutral solution. When acids are dissolved in water, they release hydrogen ions, causing a decrease in the pH value. On the other hand, bases either release hydroxyl ions that bind with hydrogen ions from water dissociation or directly bind to hydrogen ions, resulting in an increase in the pH value. Therefore, pH serves as an indicator of the presence of acids and bases in a solution, and the strength of an acid or base determines the extent of its dissociation and its impact on the pH value. Additionally, repeatedly rinsing an erosive drink in the mouth causes the neutralized layer on the tooth surface to erode continuously. Excessive erosive substances can cause demineralization, and pH is considered the most significant factor in this process.

5.2.2 Buffer Capacity

The buffer capacity displays the amount of strong acid or base that can be taken up by a buffer solution without a significant change in pH. This capacity is determined by the number of hydroxide ions or protons that need to be added to one liter of the solution to cause a significant change in pH. The unit used to measure buffering capacity is moles per liter, and it is dependent on the quantity of weak acid or base present in the solution. For instance, a basic solution can buffer H3O+ only if a weak base is present, while a weak acid can only buffer OH- ions if they are present. The greater the amount of weak acid or base in a solution, the greater its buffering capacity. In case of a minor acid attack, the buffering capacity of the liquid directly attached to the tooth structure is crucial. Additionally, the demineralization process is regulated by the ratio of saliva to the amount of liquid consumed in the mouth.[108] Moreover, citric acid's chelating characteristics can exacerbate the erosive procedure by reacting with the minerals in both saliva and tooth structure, resulting in the dissolution of the latter. As a consequence of the erosive process, Meurmann and ten Cate noted that citrate in typical fruit juices complexes up to 32% of the calcium present in saliva.[109] Thus, citric acid decreases the saturation of saliva with calcium and accelerates the demineralization of tooth structure. Moreover, calcium chelators can directly cause enamel demineralization. The length of time it takes for saliva to neutralize acid is determined by the buffering capacity of a beverage. As a result, some drinks may be more erosive than others, even if they have the same pH value.[110]

5.2.3 Titratable Acidity

The process of acid-base titration is an analytical method used to determine the concentration of either an acid and base in a solution. This involves gradually adding either an acid or a base to the solution until the concentration can be deduced. This process is known as titration. When examining beverages, titratable acids refer to the total amount of free acids present in the drink, excluding carbonic acid. Additionally, Lussi et al. discovered through further research that the erosivity of a substance is not solely determined by its pH value, but also by the titratable amount of NaOH until the pH value reaches 7.[111] Apple juice, orange juice, and grapefruit juice are recognized for their high erosive potential. Cairns et al. conducted experiments in which they diluted various juices with water and found that a 1:1 dilution required 50% less sodium hydroxide solution to reach a pH value of seven in comparison to undiluted juices.[112] Even with dilutions of 1:6, the addition of sodium hydroxide solution was necessary to achieve neutralization. Simply adding water could not achieve a neutral value.[113] However, it can be assumed that consumers will not accept greater dilutions, exceeding 1:1, as they desire the drink to maintain its taste and color.

5.2.4 Calcium, Phosphate and Fluoride Concentrations

The presence of calcium, phosphate, and fluoride in food and beverages has a notable impact on their ability to erode tooth enamel. According to Larsen and Nyvad, it is possible to gauge the erosive effect on hydroxyl and fluorapatite by analyzing the levels of pH, calcium, phosphate, and fluoride saturation in the food or drink.[114] A study conducted by Lussi revealed that no erosion was observed in enamel samples immersed in orange juice with a pH of 4 and a calcium concentration of 49.9 mmol/l over a period of seven days. [115] Furthermore, Barbour et al.'s research demonstrated that even slight adjustments in calcium and phosphate saturation, without any modifications to the pH level, resulted in a reduced erosive impact.[116] Attin and colleagues conducted a study to examine how the tooth structure is affected by 1% citric acid (pH 2.2) containing varying amounts of calcium, phosphate, and/or fluoride. [117] They discovered that the solution had a lower potential for causing erosion. Based on their findings, Attin and his team concluded that the best way to protect tooth enamel was to add either 1 mmol/l calcium or a combination of 0.5 mmol/l calcium, 0.5 mmol/l phosphate, and 0.031 mmol/l fluoride.[118] Yogurt is another example of a food with a low pH of approximately 4, but a high amount of calcium and phosphate. With a phosphate concentration of 21.4 mmol/l and a calcium concentration of 2.5 mmol/l, yogurt displays almost no reduction in surface microhardness when compared to light Sprite, apple or grapefruit juice, and salad dressing. These other foods contain considerably lower amounts of phosphate and calcium, with yogurt having a pH value of 3.84, Sprite light 2.88, apple juice 3.3, grapefruit juice 3.74, and salad dressing 3.6. Consequently, yogurt is deemed to be supersaturated based on the hydroxyapatite structure of enamel. Therefore, despite having a low pH, it is less erosive than foods with a similar pH but without high calcium and phosphate levels. The role of fluoride regarding prevention erosion is controversial.[119] Lussi et al.[120] [121], as well as Mahoney et al.[122], conducted studies that indicated the natural fluoride concentration found in beverages does not significantly reduce erosion. However, there may be a slight protective effect under conditions of low erosion. For instance, apple juice had a fluoride concentration of 0.22 ppm, salad dressing had 0.14 ppm, and yogurt only had 0.06 ppm of fluoride. As a result, the fluoride levels were too low to provide adequate protection.

6 Prevention and Therapy

Since the process of dental erosion is irreversible, the associated loss of tooth structure cannot be recovered. Therefore, it is crucial to quickly diagnose non-caries related lesions and investigate the underlying cause. The main treatment approach involves minimizing contact between the teeth and the causative agents to halt the progression of erosion. In addition to taking a general medical history, it is important to inquire about the patient's eating habits. Maintaining a food diary for several days can be useful in determining which foods and drinks are causing erosion. Patients often have difficulty distinguishing between foods that cause erosion and those that do not. When extrinsic erosion is present, it is important to provide patients with comprehensive education about appropriate dietary and oral hygiene practices.[123] It is important to avoid constantly sipping acidic drinks throughout the day. However, not all acidic drinks have erosive potential, so it is crucial to provide patients with appropriate education. Fruit juices that contain at least 1g/l of calcium as an additive do not cause erosion despite having a low pH.[124][125] In addition, patients should be advised to consume fruits only in combination with dairy products such as yogurt. If dental erosion is caused by intrinsic factors such as gastroesophageal reflux, anorexia nervosa, or bulimia nervosa, patients should be referred to specialists in the relevant fields to appropriately treat the underlying condition.[126] The primary goal of therapy is to minimize further dental tissue loss caused by constant exposure to acids. In this regard, preventing demineralization is more important than promoting remineralization. Oral hygiene practices can have both positive and negative impacts on the progression of erosion. Applying fluorides is recommended, as they not only prevent caries but also inhibit the erosive process. Fluorides like amine fluoride and sodium fluoride create a surface layer containing calcium fluoride that acts as a protective barrier against acids. If the pH level drops, fluoride ions are released, and the tooth is remineralized. This makes fluorides especially beneficial in preventing caries. However, since erosion occurs only in a low pH environment, the protective layer dissolves relatively quickly, and frequent or high-concentration application of fluorides is necessary to achieve optimal results.[127] Studies have shown that the use of sodium fluoride solutions can reduce enamel loss by 18-29% and dentine erosion by 23-29%. To enhance the effectiveness of these fluorides, they can be combined with specific ions such as tin chlorides or tin fluorides, which can be added to mouthwashes and toothpastes. In a study several dental tissue samples were demineralized and then remineralized before being placed in a test solution for a period of 10 days. The results demonstrated the positive effect of tin chloride. While the control group experienced a tissue loss of 48.8 µm, the group treated with tin chloride only lost 17.6 µm of tissue.[128] Tin chloride forms acid-resistant precipitates on the tooth surface and typically only needs to be used once or twice a day. Additionally, the effect of tin chloride in toothpastes can be enhanced by incorporating chitosan. Studies have shown that combining these two active ingredients results in less tooth structure loss compared to toothpastes containing only tin and sodium fluoride.[129] Moreover, providing proper guidance on individual oral hygiene practices is crucial. Following an erosive attack, the microhardness of enamel and dentine decreases, which reduces the abrasion resistance of the enamel. Using an abrasive toothpaste while brushing can partially remove the demineralized tooth enamel, so patients should always opt for a non-abrasive toothpaste that contains fluoride. Additionally, tooth brushing immediately after acidic exposure should be avoided to prevent further damage to the demineralized surface. For patients at high risk of erosion, it may be advisable to brush their teeth before consuming acidic food or drinks to significantly reduce the resulting erosive and abrasive loss of hard tooth tissue for both enamel and dentine. Moreover, the abrasion of eroded teeth is not only influenced by toothpaste but also by the contact pressure of the toothbrush. Tooth structure loss increases with greater contact pressure, as shown in a study where manual toothbrushes applied more pressure than ultrasonic or sonic toothbrushes, regardless of the brushing technique or the hardness of the oscillating toothbrush. Therefore, sonic toothbrushes are especially recommended for patients with erosion.[130] In addition to using non-abrasive fluoride toothpaste, patients should be advised to brush their teeth with less pressure to prevent tooth structure loss. After an erosive attack, patients should rinse their mouth with water or fluoride-containing mouthwash to neutralize the acids and stimulate saliva production. Furthermore, chewing sugar-free gum can boost saliva production, which enhances the protective function of saliva. By increasing saliva flow rate, the buffer capacity is raised, leading to increased acid clearance and pH levels in the oral cavity. If causal therapy is not feasible, patients with dry mouth may benefit from using saliva substitutes. When selecting a product, it is essential to ensure that it is fluoridated and has a neutral pH value; otherwise, it may exacerbate erosion. Ultimately, the effectiveness of these preventive measures' hinges on patient compliance, particularly with regular use of the recommended products and instructions. Prophylactic measures can only impede or prevent further deterioration, but they cannot restore lost tooth tissue. Typically, when an erosion lesion reaches the dentin, or even beforehand, it should be treated using minimally invasive methods. The initial step is to apply a suitable dentin bonding system to seal the area, which can minimize dentin hypersensitivity and slow down the lesion's progression. Tooth structure loss can lead to a loss of vertical dimension or compensatory growth, resulting in occlusal drift and shortened teeth. This can leave insufficient space for restoration. When interocclusal loss is less than 2mm, teeth can be directly restored with composite, which patients usually tolerate well even with slight bite elevation. However, when there is more than 2mm loss on multiple surfaces per tooth, and with significant reduction in vertical dimension, complex reconstruction with indirect restorations is usually necessary. Orthodontic correction can be useful, particularly when a specific group of teeth, typically the anterior of the upper jaw, is severely affected, while other teeth show only mild erosion. To avoid invasive restoration of all teeth, gaining interocclusal space can be more tooth-friendly and cost-effective. Fixed or removable appliances or the so-called Dahl appliance can be used for this purpose. After orthodontic treatment, eroded teeth can be restored with crowns or veneers. To commence prosthetic treatment, it is crucial to investigate and treat the causes of erosion, and the patient must be able and willing to control the causative factors.

7 Conclusion

Dental erosion is a prevalent condition in the community, with a high incidence among younger age groups. Despite its impact on oral health, there is a lack of awareness among patients regarding the condition and its risk factors. While dental erosion is a multifactorial condition, dietary habits, particularly the consumption of soft drinks and citric fruits, are the most common risk factors. Other factors, such as the composition of saliva, salivation rate, and buffer capacity, also contribute to the progression of dental erosion. To manage dental erosion effectively, it is crucial to establish early diagnosis and appropriate preventive methods. Patient compliance plays a crucial role in maintaining oral health, and therefore, patient education and awareness are crucial. Specific examples could be given to illustrate how changes in dietary habits, such as reducing the intake of acidic foods, can help prevent or manage the condition. Emerging research on dental erosion can provide new avenues for further research and impact current practices. Future research should focus on addressing potential limitations, such as the lack of objective diagnostic tools and understanding the social and psychological impacts of the condition on patients' quality of life. Overall, management of dental erosion includes identifying and eliminating causative factors, prevention and monitoring, and operative intervention. Individually adapting daily oral hygiene habits, in conjunction with patient compliance, can reduce the progression of tooth structure loss. By addressing the risk factors and establishing early diagnosis, dental erosion can be effectively managed, contributing to improved oral health and quality of life for patients.

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