Managing Dental Erosion: Current Understanding and Future Directions

Course Author(s): Nicola West, BDS PhD FDS RCS (Eng) FDS (Rest Dent) FDS RCS Ed FHEA; Warden H. Noble, DDS, MS, MSEd; Donald J. White, PhD; Natasha West, BDS, MFDS RCSEd
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Conflict of Interest Disclosure Statement
- Prof. West has undertaken consulting work and given scientific lectures on behalf of P&G. She has no relevant financial relationships to disclose.
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Introduction – Dental Erosion
The purpose of this course is to provide information on the dental erosive tooth wear process, highlight key similarities and differences between erosive tooth wear and caries, provide effective strategies to help educate patients who are at risk for developing erosive tooth wear and manage patients who are already experiencing the condition to minimize its effects.

Course Contents

Overview

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Learning Objectives

Upon completion of this course, the dental professional should be able to:

- Discuss trends related to the prevalence of dental erosive tooth wear.
- Understand similarities and differences between dental erosive tooth wear and dental caries.
- Explain the etiology of dental erosive tooth wear to patients.
- Discuss the long-term effects of dental erosion.
- Explain strategies for diagnosing and managing patients at risk for dental erosion.

Background

The dental research community has made great strides in preventive dentistry over the past several decades, with breakthroughs such as the introduction of fluoride and tartar control dentifrices, enhanced dentin hypersensitivity reduction approaches and fluoride varnishes. In spite of these advances, dental erosive tooth wear has become a major new challenge for dental professionals. First identified as an emerging issue approximately 30 years ago, the prevalence of erosive tooth wear is increasing, the current estimated global prevalence in children and adolescents is 30-50%, and 20-45% among adults.[1] This is of particular concern since the enamel and dentin loss associated with this multifactorial condition is irreversible.

Historically there has been confusion between dental caries and erosive toothwear in the primary dentition as early clinical lesions can look alike. Despite some similarities between dental erosive toothwear and dental caries they are two unique processes with critical differences related to the etiological factors, the long-term effects, and the best ways to help manage these issues for each patient. They are both however, noncommunicable diseases (NCDs) and are highlighted by the World Health Organization to have major impact on health, well-being, health care systems and economies, adding to the increasing burden of NCDs. Challenges across all countries are related to inequalities, linked to exposure to risk factors like high sugar consumption and tobacco or alcohol use as well as to wider social, commercial and political determinants of oral health. Recognition of oral diseases as a global public health problem will continue to generate momentum, and action with ambitious targets to be achieved by 2030 through primary health care, there is hope that substantial progress will be made globally to close the gaps in oral health.[2]

Dental erosion is a condition that results from an excessive exposure to erosive acids, either of extrinsic (dietary) or intrinsic (gastric) origin. First quantified on a wide scale basis in the United Kingdom,[3,4] and also throughout Europe,[5-9] this problem later gained significant interest on a more global scale.[10,11] This condition is highly relevant to oral health professionals, and it presents these professionals with challenges regarding its detection, prevention and management. From a patient's point of view, dental erosive tooth wear can be associated with esthetic problems and pain from dentin hypersensitivity. It can also impact long-term tooth function. From the oral health care professional's point of view, it can be very difficult to manage; frequently requiring patient behavior change which can present a significant hurdle along with complex restorative treatment and long term monitoring and maintenance.

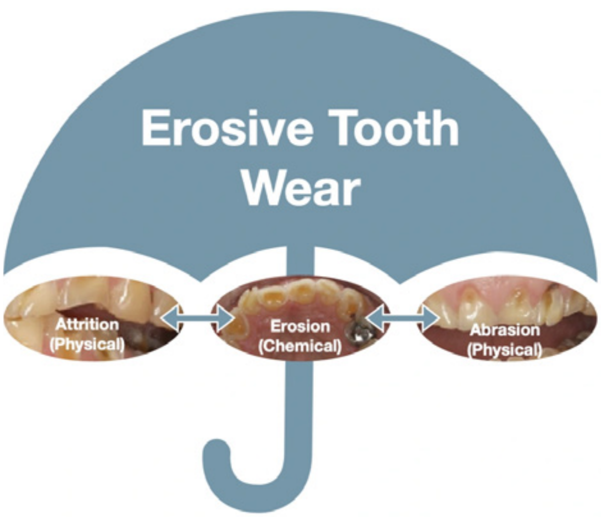


Figure 1. Erosive Tooth Wear (ETW) is an umbrella term that includes dental erosion, attrition and abrasion, alone or in combination.

In most cases, dental erosion does not present as a single condition. It is one part of a broader, multi-factorial 'umbrella' condition referred to as *erosive tooth wear* (ETW) (Figure 1). ETW is a growing problem, seen day to day in general practice (Figure 2). It includes different factors, including dental erosive tooth wear, abrasion and attrition, alone or in combination. Generally, ETW is classified according to the specific mechanism that is responsible for the wear. While the mechanism for tooth wear resulting from erosion is chemical, abrasion and attrition are the result of physical forces. Abfraction, a theoretical term cited in the literature as a fourth type of tooth wear etiology, has been discouraged as a used term, recent consensus meetings and publications determined that there is not enough evidence to support this as a separate process.[12,13]

In the past, particularly in the US, dental professionals often associated tooth wear with occlusion and bruxism. But the fact is it probably has more to do with acid impact on teeth. Changes on the lingual surfaces of eroded teeth, for example, are likely the result of a combination of acid and repetitive, frictional forces from the tongue.[14] It is not from occlusion or any type of a bruxism-type movement. There are two distinct processes at work, which highlights the complexity of the problem. Regardless of which forces are at play in an individual patient, the net clinical outcome is tooth surface loss.

- Dental erosion is an outcome resulting from the dissolution of dental hard tissue by either intrinsic or extrinsic acids that are not of biological origin.
- Abrasion is a form of physical wear that is the result of mechanical interactions, such

Figure 2. Severe erosion on a patient consuming 1.5 gallons of Kombucha tea, a low pH fermented drink, daily.

as tooth brushing or repetitive contact of a foreign object, with opposing tooth surfaces.
- Attrition is a form of physical wear that occurs as the result of one tooth coming into contact with another and is often associated with bruxism (unconscious tooth grinding or clenching).

Clinically, ETW is often associated with a combination of tooth wear processes, with dental erosion being the most common component. In addition, dental hygiene habits, such as brushing with a hard-bristled toothbrush or brushing too soon after taking in acid-containing food or beverages, can have an impact on tooth wear. Excessive tooth brushing can also remove significant portions of the acquired dental pellicle. Pellicle serves as a natural protection against both erosive acids and frictional wear. When teeth are brushed directly before eating or drinking, the thickness of the pellicle, and therefore its ability to protect exposed tooth surfaces, is reduced. Soon after brushing, the pellicle begins to be restored. Many dental professionals now suggest waiting for 1-2 hours after brushing before consuming acid-containing foods and beverages,[15] giving the pellicle sufficient time to regain a reasonable level of defense.

As we are all aware, people are living longer, and the increasing prevalence of dental erosive tooth wear can have multiple contributing factors. Diet recommendations from our medical colleagues to combat certain diseases such as diabetes and cardiovascular disease, can include increase consumption of healthier but more erosive fresh fruits and acid containing vegetables. In addition, our consumption of acidic beverages (e.g., soft drinks, juice, sports drinks) is increasing dramatically year-on-year. Data comparing populations in both the UK and US suggest we can anticipate finding a significant level of dental erosion in the general population,[16] with even higher numbers anticipated for specific high risk groups.[4,6,17] The evidence suggests the presence of erosion is growing steadily.[5,18] A recent 7 year study involving over 3500 people across 7 European countries showed that the maximum BEWE 1 score is particularly high in young adults indicating ETW is initiated in adolescence or younger. Patients presenting with ETW should have their dietary habits assessed by recording their complete dietary intake in a diet record, from which clinicians can assess the erosive potential of the different beverages and foods, as well as the frequency of ingestion, to provide individually tailored prevention and intervention.[19]

There has been a significant decline in the prevalence of edentulism reported at global, regional and country levels. The global estimated prevalence of edentulism was 22%, with 11% (North America), 28% (Europe), and 37% (South America).[20] A growing older population who are retaining more teeth present additional challenges for clinicians as many of these patients are aesthetically sensitive. In the past, people in this cohort had a greater acceptance of extractions and dentures however this is changing, and we have far more teeth needing attention than we did several years ago. The change in appearance of worn teeth does not necessitate the need for restorative intervention, but for some the rate of wear or severity becomes so pronounced that treatment should be considered,[21] this needs to be acknowledged and properly managed.

It is not unreasonable to surmise that the increasing life expectancy, coupled with maintaining a healthier lifestyle involving a more acidic diet, may well lead to more and more cases of dental erosion. That is, of course, unless we put preventative measures in place to help address these concerns before significant damage is caused. Dental professionals need to be far more proactive at looking for erosion, particularly at the earliest stages of the condition, and recommending the use of products that have been demonstrated to be effective at helping to prevent its initiation and progression.

Etiological Factors

Acid erosion involves a chemical process, a dissolution of hard tissue structures, without bacterial involvement. The erosive process is not necessarily a simple one. One way to think about it is by focusing on changes occurring in the saliva. When the pH drops in the saliva, it then drops in the acquired, or salivary, pellicle. After that, acidic changes occur on the tooth surface, which initiates the series of events that lead to tooth surface loss. In reality, nothing

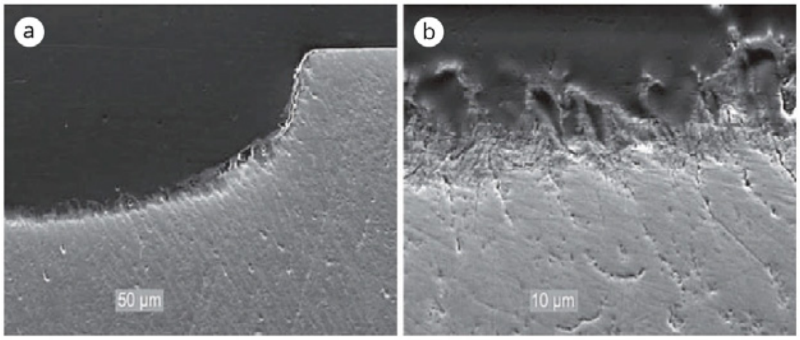


Figure 3. (a) SEM showing loss of enamel and, (b) at greater magnification, the softened layer at the advancing front of the lesion.
Images courtesy of Karger.[24]

Table 1. Composition of Enamel and Dentin.

Component	Enamel	Dentin
Inorganic Material	85%	45%
Organic Material	2%	34%
Water	11%	21%

happens on the tooth until it happens first in the saliva. As such, saliva has become a primary area of interest to monitor.

Poor salivary flow impacts clearance of acids and buffering, and therefore delays a return to the resting pH. The saliva also supplies the pellicle; pellicle helps prevent and stop progressive erosion unless overwhelmed by a strong acid challenge. Synergistic wear may occur, for example, by the tongue abrading softened enamel palatally and lingually.[14]

An excellent technical description of dental erosion has been offered by Ganss: "Dental erosion can be defined as dissolution of tooth by acids when the surrounding aqueous phase is undersaturated with respect to tooth mineral. When the acidic challenge is acting for long enough, a clinically visible defect occurs. On smooth surfaces, the original luster of the tooth dulls. Later, the convex areas flatten or shallow concavities become present which are mostly located coronal to the enamel-cementum junction. On the occlusal surfaces, cusps become rounded or cupped and edges of restorations appear to rise above the level of the adjacent tooth surfaces. In severe cases, the whole tooth morphologically disappears and the vertical crown height can be significantly reduced. The result of continuing acid exposure, however, is not only a clinically visible defect, but also a change in the physical properties of the remaining tooth surface. It is recognized that erosive demineralization results in a significant reduction in microhardness, making the softened surface more prone to mechanical impacts. Although independent in origin, erosion is linked to other forms of wear not only because it contributes to the individual overall rate of tooth tissue loss, but also by enhancing physical wear."[23]

In terms of acid erosion, the process begins with a surface softening, followed by surface loss, as depicted in Figure 3. Surface loss occurs as a result of frictional forces impacting the softened tooth mineral, followed by the

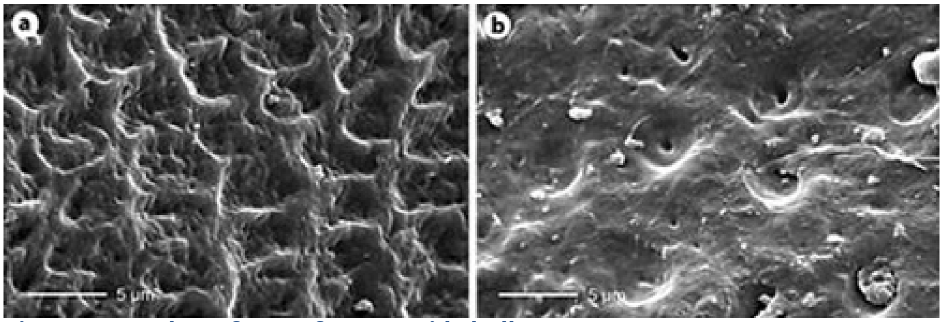


Figure 4. Tooth surfaces after an acid challenge.
(a) Erosive demineralization of the enamel shows loss of surface between enamel prisms, with the prisms themselves remaining intact. These areas are susceptible to loss due to subsequent frictional forces. (b) Dentin surface subjected to the same erosive challenge reveals a surface that is much different from enamel. Demineralization of the intertubular matrix has occurred, and some of the dentinal tubules become opened, which can lead to sensitivity.
Images courtesy of Karger.[24]

Figure 5. Typical etching pattern on teeth after use of a 37% phosphoric acid treatment.

initiation of a second softened layer, which is partly demineralized. The affected area of the tooth is susceptible to further frictional challenges, which leads to additional tooth surface loss.

Because of the interaction between frictional forces and acid, we have to consider tooth wear the result of a rather complicated process. In general, ETW is a multifactorial process that involves acid erosion and frictional forces of abrasion and attrition.

Differences Between Dentin and Enamel Erosion

One factor that complicates ETW even further is the composition of enamel and dentin, which are very different (Table 1). While enamel is approximately 85% mineral, combined with a small amount of collagen, organic material and water, dentin is highly organic. Dentin is comprised of about 45% mineral, with the remainder a combination of organic matter and water. Due to the difference in makeup, dentin reacts much differently to erosive activity and wear than enamel (Figure 4).

One way to think about the dental erosion process is to consider how adhesive bonding procedures, using 37% phosphoric acid, condition the tooth surface to enhance retention of the material. After placement of the acid, the result is typically a visibly chalky appearance (Figure 5). The surface has been

Figure 6. Image shows high level of ETW on the dentin surfaces, yet leaves some areas of enamel less affected.

Photo courtesy of Dr. Michael Nelson.

demineralized, or etched. That is the same thing that happens on a slightly different scale every time there's an acid challenge in someone's mouth, from whatever source. The primary difference is that one challenge is controlled, and limited to a single exposure, while the other can repeat over and over in the mouth, and happen over a prolonged period. After an erosive acid challenge on enamel, for example, enamel prisms remain (Figure 4a). Once these demineralized prisms of enamel are present, they are highly susceptible to abrasive forces. Micron by micron, the tongue, food, occlusal forces, etc., will break these susceptible areas off and begin a repetitive cycle of tooth surface softening and loss.

Although the same factors are at play on dentin, the overall process of dental erosion on dentin is somewhat different. When dentin is attacked by erosive acids, the result is a demineralized organic matrix. The mineral portion becomes highly demineralized (Figure 4b). This is very important, for example, in adhesive dentistry and when doing bonding type techniques. It is not hard to imagine how erosive acids predispose the dentin to surface loss and wear. These processes also expose open dentinal tubules, which can then lead to tooth sensitivity.

Dentin is subject to degradation by proteolytic enzymes, the MMPs, among other things.[25] As we try to understand these processes, we have to include this as one of the risk factors in the degradation, or changes, that occur in dentin erosion. If the dentin becomes soft and liquefied, this will have a significant effect on the magnitude, the extent and the rapidity of tooth surface loss.

In summary, in the case of enamel erosion, we see more demineralization and bulk tissue loss, which is primarily due to the higher mineral content in enamel. Importantly, many of these changes occur at a pH of less than 4. Dentin, on the other hand, has overall less demineralization and bulk tissue loss under an acid challenge, has a softer matrix and is more susceptible to surface loss due to frictional forces. Changes in dentin typically occur at somewhat higher pH, usually above pH 4.

From a clinical standpoint, erosive processes can appear to be contradictory (Figure 6). In reviewing this figure, one might question how there is so much dentin loss, while the enamel appears to be much less affected. Relating this image to the discussion above, it is likely that in this patient the erosive challenge wasn't at a very low pH. It may have been a higher pH, still under 5.5 or so, but at a pH that didn't have a significant impact on the enamel. Because it wasn't a low enough pH, there was a much greater erosive effect on dentin than enamel.

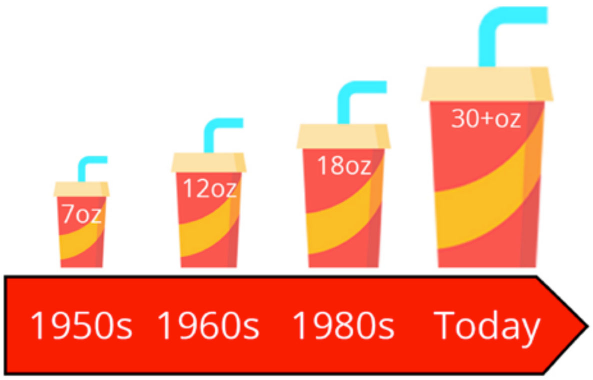


Figure 7. Beverage sizes have grown significantly. In the 1950's, the average cola drink in a US restaurant was 7 fl. ounces (207 mL). Serving sizes have increased steadily ever since; today, the average serving size is over 30 fl. ounces (887 mL), with individual "large" portions often providing 42-44 fl. ounces (1,242-1,301 mL), or more, of beverage.

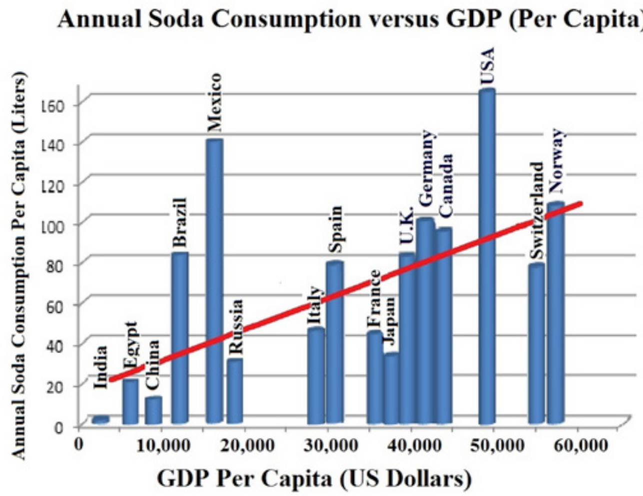


Figure 8. Annual global consumption of sodas vs. GDP per capita clearly demonstrate a much higher level of consumption in the US compared to other nations.
Adapted from Sugar, Consumption at a Crossroads. Credit Suisse.[32]

At the same time, the area identified by the green arrow shows a much different situation. This area likely involves actual frictional forces from the opposing teeth, which has resulted in more enamel loss. The question becomes: how do you have, in the same mouth, this level of discrepancy? This dilemma serves to highlight the complexity and the clinical challenges that dental professionals face in dealing with this problem. One answer is to make sure that dental professionals are trained to assess this condition from multiple perspectives.

One problem, from an epidemiologic standpoint, is that dental erosion is often not noted on a patient's chart, especially in the United States. This contrasts significantly with Europe, Australia and some South American countries, where the assessment of dental erosion has become a routine practice. In the past, unless there was pain or some type of cosmetic problem, patients did not seek treatment for erosion, and most dentists didn't offer care for it. As dental erosion has become more of an issue, it is hoped that all dental practitioners develop a greater awareness of the problem and become more equipped to help manage their patients that are either at risk, or are already experiencing some level, of dental erosion.

Dental Erosion and Diet

Frequent consumption of carbonated/soft drinks, natural fruit juices and acidic snacks or sweets along with Vitamin C are significantly associated with ETW; compared to protecting foods such as milk and yogurt.[26] Most researchers consider acid-containing soft drinks and beverages as primary culprits in the growing incidence of dental erosion.[10,13,21,22,27-29] Over the past several decades, serving sizes in the US have increased dramatically.[10,30] The average drink size, in the 1950's, was slightly less than seven (7) fluid (fl.) ounces (207 mL). By the 1960's, this average serving size had increased to twelve (12) fl. ounces (355 mL), and by the late 1990's had increased still further to twenty (20) fl. ounces (532 mL). (Figure 7) In many restaurants, the largest sizes that are sold often contain 42-44 fl. ounces (1,242-1,301 mL), and free refills are commonly available.[31] Between 56% and 85% of children at school have been reported to consume at least one (1) soft drink daily, with 20% consuming an average of four (4) or more servings every day.[10]

In the US, current caloric intake has been shown to be up to about 4,000 calories per day per person. Approximately 25% of this caloric consumption is in the form of sugar sweetened beverages or, at the very least, added sugars

Table 2. pH Values of Common Beverages.

Beverage	pH
Pure Water	7.0
Milk	6.6
Tea	6.2
Coffee and milk	5.3
Black Coffee	5
Tomato Juice	3.7
Sprite	3.29
Diet Pepsi	3.03
Gatorade	2.92
Dr. Pepper	2.90
Fruit Punch	2.82
Orange Juice (Minute Maid)	2.64
Coke Classic	2.53
Reference: Battery Acid	1.0

Adapted from Jain et al., General Dentistry.[37]

to the diet. A study by Credit Suisse compared the gross domestic product of various nations versus their annual consumption of sugar-sweetened beverages.[32] As shown in Figure 8, the US is well above other countries in this assessment, which indicates a very high risk for dental erosion in this country, due to the low pH and high acid levels in sugar sweetened beverages. In the US, the average person consumes over 40 gallons (151 L) of sugar sweetened beverages per year.[32,33] It is no surprise that the US has obesity problems, caries problems, and other related side effects.

The severity of erosive acid attacks depends on multiple factors, such as the pH (Table 2), the titratable acidity and the buffering capacity of both the beverage, or food, and the saliva of the individual ingesting the beverage. Another primary factor is the contact time of the acid on the teeth. The longer the teeth are subject to an erosive acid challenge, the more likely they will be to undergo erosive changes.

In addition, all acids are not alike with regard to their erosive potential. Studies have shown that citric and lactic acids have a higher erosive potential than acetic, maleic, phosphoric and tartaric acids, although all of these dietary acids have some degree of erosive potential. When included in products containing other ingredients, such as calcium, phosphate and/or fluoride, the erosive potential of an acid can be significantly decreased. For example, acidic beverages, when supplemented with calcium, phosphate and fluoride, have been shown to have a reduced erosive potential compared to controls.[34] In addition, yogurt, which has a relatively low pH, has little erosive potential due to its high calcium and phosphate content.[35]

Consumption of a single acidic beverage and drinking it normally has little impact on dental erosion. Although the pH of saliva does drop while drinking it, the saliva will generally provide sufficient buffering to quickly re-establish a neutral pH. If people swish their drinks, or if they sip these beverages over long periods of time, there is a much higher likelihood of having problems. One way to help minimize the potential for prolonged contact of acidic beverages with the teeth is to drink through a straw, as this may help to minimize contact with the teeth.[36]

While there is growing awareness of dietary issues related to the high consumption of soft drinks, particularly among school aged children, the issue of dental erosion is not limited to consumption of only these beverages. Equally challenging to the enamel surface is excess exposure to fruits, acid containing vegetables, fruit juices, wine, and other dietary foods and beverages that are otherwise considered healthy alternatives to soft drinks.[35,36,38-40] The 2023, 7 year study across 7 countries showed acidic fruit was commonly consumed, 53.2% reporting >1 daily acidic fruit consumption between mealtimes. Snacking fruit between meals associates more strongly with ETW than consuming it at mealtimes or consuming acidic beverages between meals.[19]

It can be difficult to protect against an increasing erosive challenge no matter the diet, however special diets, especially those rich in fruits and other acidic foods which can increase the risk of dental erosion. Approximately 1–9% of the western population is vegetarian and 0.1% lives on a vegan diet. The highest proportion of vegetarians are found in India, where 30% of the population is vegetarian. Veganism is less common with the prevalence reported to be about 2% in the United States and less 0.1% worldwide.[2,41] A systematic review found that there is possible two-fold greater risk of dental erosion in vegetarians.[42] Special diets need to be assessed during diet analysis and incorporated into risk assessments.

One of the driving factors for dental erosion is the duration of contact between dietary acids and the teeth. As a result, there is some perception that high viscosity drinks may be more erosive than those with lower viscosity, due to their tendency to be retained in the mouth for longer periods of time. Recent *in vitro* studies, however, have suggested that the opposite might be true,[43,44] possibly a result of the ingredients that enhance viscosity actually being able to slow the release of acids from the beverage, thus causing less damage. This area of research will be interesting to watch, as it will take more robust models and clinical trials to confirm whether increased viscosity enhances erosion or helps to prevent it.

Saliva

One of the most important factors influencing the progression of dental erosion is saliva, especially in our age of polypharma. Even before an acid attack takes place, saliva flow is often increased as a response to stimuli such as smell or chewing. A high saliva flow rate helps increase buffering, dilution and clearance of acids from the mouth, which is extremely important during an erosive acid challenge. A low salivary flow rate can have a number of negative effects. Saliva flow can be inhibited as a side effect to numerous medications, both prescription and over-the-counter. Medical conditions, such as xerostomia, dehydration, and salivary gland dysfunction can all put teeth at risk for erosion.[45]

The average adult in the US, over the age of 65, takes six or more prescription medications. Many of these medications have the potential to adversely impact saliva, or salivary flow rates, which can increase the risk of dental erosion. Low levels of saliva can impact the rate of pellicle maturation, and could also result in elevated risk of erosion due to excessive tooth brushing, chewing hard foods and bruxism. At the very least, changes in the saliva can make the process of dental erosion and toothwear much more complex.[46]

In older populations, where there is a combination of hyposalivation and polypharma, this can be a significant problem. These individuals can be exposed to very low pH acids in their mouth. When people are asleep at night, they only have about one-tenth of the saliva they have during the day. If someone is over 65, they likely have only half of the saliva they had when they were 20. Without sufficient saliva, it is difficult to provide sufficient buffering and clearance of acids, particularly if the patient suffers from acid reflux.

The chemical composition and buffering capacity of saliva are also important factors. If saliva has a high concentration of bicarbonate, it has an increased capability of neutralizing and buffering erosive acids, and if supersaturated with respect to calcium and phosphate, it is better equipped to reverse low levels of initial softening that might occur. Saliva that is undersaturated with respect to calcium and phosphate has little ability to help protect tooth surfaces against erosive acid challenges.[47]

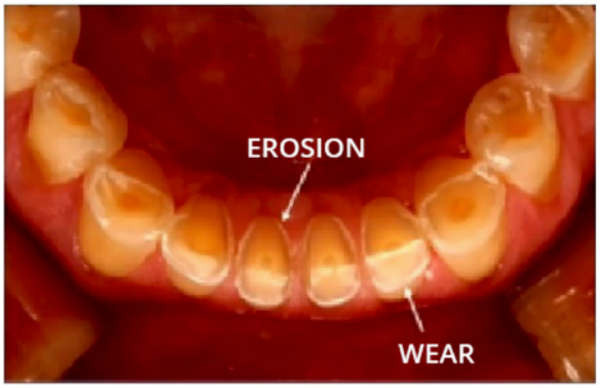


Figure 9. Multifactorial ETW with erosion and attrition.

Figure 10. The presence of NCCL lesions suggests the likelihood of improper brushing habits.

The Salivary Pellicle

Besides saliva, another key biological factor that can influence the progression of dental erosion is the pellicle. The salivary, or acquired, pellicle is a protein-based layer that covers all orally exposed surfaces of the teeth. Although this pellicle film can be modified somewhat through brushing, the pellicle film is essentially never removed from the teeth, with the exception of during a dental prophylaxis (prophy). During a prophy, the abrasiveness of prophy pastes is sufficiently high to enable the complete removal of this film from the tooth surface, exposing the natural enamel surface. The reason for removing the pellicle during the prophy is to allow for the complete removal of extrinsic stains from the tooth surface. While chemical cleaning agents like peroxide are able to bleach stains from an intact pellicle, prophy pastes actually remove the pellicle. In order to restore its natural level of protection, the saliva generates a new, fresh pellicle within just a few short hours. Though thin in absolute terms, the pellicle provides protection to the tooth surface against extrinsic acid damage.[10,45,48]

When acidic foods and beverages are taken in excess, the pellicle layer can be overwhelmed by either the sheer volume of dietary or gastric acids, the high titratable acidity of a particular beverage, or a complex combination of factors such as the mineral content of saliva.[47] When this occurs, the surface enamel softens quickly, and even the fluoride rich outer enamel, which provides a measurable level of 'second defense' against cariogenic acids, cannot defend itself against a strong erosive acid challenge. The outer enamel becomes softened and susceptible to damage; due primarily to a multitude of potential "tooth wear" factors present in the mouth.[18]

Gastroesophageal Reflex Disorder (GERD)

Another issue that has a significant impact on dental erosion is gastroesophageal reflex disorder (GERD). GERD constitutes a risk factor for ETW and there is a positive association between the two conditions.[49] Significant increases in severe erosion are seen in the older population, and between 10 to 28% experience gastric acid symptoms.[50] In 2015, over 113 million prescriptions for antacid medications were written, representing over $13 billion in sales.[51] Even more worrisome is silent GERD. A recent study found over one-third of patients may have silent GERD, where the reflux actually gets up into their mouth but the patients are asymptomatic.[52] This can have a significant impact on dental erosion. Controlling GERD has been shown to have a positive impact on dental erosion. In one study, patients who had dental erosions that were recorded as active lesions were prescribed proton pump inhibitors (PPIs) to help manage their gastric reflux issues. In 86% of cases, progression of the erosive lesions was stopped.[53] These results demonstrated that by suppressing the gastric acids, the incidence of erosion was reduced; and the progression of dental erosion was effectively managed. It is important that the appropriate preventive dental care should be considered for individuals with GERD and a multidisciplinary medical and dental approach for the management of individuals with ETW.[49]

Patient Age and Risk Factors

ETW is episodic throughout life and can start in infancy. It is generally accepted that deciduous ETW may be indicative of future erosion problems in the permanent dentition. Although studies in the literature have suggested the prevalence of dental erosion to be somewhere between 7-74%, an overall ETW prevalence of 30% has been found in a meta-analysis of studies in teenagers and young adults with at least one erosive lesion, and the condition becomes even more prevalent with age.[54] Different etiologies typically play more of a role at different ages. Figure 9 shows a case involving erosion and attrition.

Risk factors for ETW include: 1) dietary habits (amounts, frequency, manner of consuming acidic foods and beverages); 2) gastric reflux (GERD, bulimia, pregnancy vomiting); 3) xerostomia - reduced salivary flow decreases acid dilution and clearance; and, 4) exposure to mechanical insults such as hard foods, improper toothbrushing and bruxism. The severity of acid attacks varies with the pH of acid and its buffering capacity, whether a drink is swished/sipped/gulped or taken with a straw, and its contact time, the thickness of the acquired pellicle and salivation. Reduced salivary flow represents the greatest risk factor and must be evaluated. ETW is irreversible and, if observed in children or adolescents, it can be expected to progress unless intervention occurs.

In looking at minor erosion, the patient's age, habits, and whether wear is physiological or pathological should be considered. Early diagnosis is especially important as patients typically do not seek care until they experience pain or an esthetic problem.

Conducting an evaluation for dental erosion provides dental practitioners with a window into some of the other habits of a patient. For example, recession above the NCCL lesions in Figure 10 suggests that this patient has likely been brushing with a stiff toothbrush and abrading the tissue away; this has resulted in minimally attached gingiva, recession and a very deep erosive lesion. Care must be taken to appropriately manage this type of condition, in addition to the other issues that patient is experiencing.

Caries versus Erosion

We know that caries can occur on any tooth surface. However, it is generally accepted that caries occurs under plaque and is the direct result of bacterial acids. The primary acid that causes caries is lactic acid, a byproduct of the breakdown of fermentable carbohydrates (primarily sugar) by plaque bacteria. While the most dominant bacteria responsible for caries are *S. mutans*, other bacteria, such as *lactobacillus*, have also been suggested as contributors to various aspects of the caries process.[55,56]

Erosion, on the other hand, is a result of the direct action of extrinsic, dietary acids; such as those found in carbonated drinks and fruit juices or intrinsic acids, such as from GERD. Dietary acids include phosphoric, citric, and other acids commonly used to impart the tart, tangy flavors we associate with acidic foods and beverages. Although "diet" drinks are generally "sugar free", and thus more acceptable from a caries standpoint, the acid content of the diet beverages is no different from their sugar containing counterparts. From the standpoint of acid content, "sugar free" drinks offer no advantage when it comes to their potential to cause dental erosion.

Key Differences Between Caries and Dental Erosion

Generalities can be confusing. Caries is often described as the loss of minerals by the direct action of acids on the teeth, and dental erosion is also defined in a similar way. While both statements are true, of primary importance is the type of acid, where the acid comes from and specific sites on the tooth surface to which these acids are directed. It is important to differentiate enamel damage due to caries vs. damage that results from dental erosion. Both the etiology and symptoms of these two processes differ significantly, as do the appropriate management strategies for each (Table 3).

Table 3. Key Differences Between Caries and Dental Erosion.

		
Key Comparisons	**Cavities**	**Erosion**
Type of process	Mineral Change	Mineral Loss
Tooth site(s) affected	Enamel & dentin	Enamel & dentin
Primary cause	Bacterial acids	Dietary acids
Primary site(s) of damage	Subsurface, under plaque	Exposed, plaque free surface
Conditions	Exposure to weak acids for prolonged periods of time, usually at a pH above 4.0	Repeated exposure to dietary or gastric acids, generally below pH 4.0, for short time periods
Result	Sub-surface phenomenon with intact outer layer of enamel	Surface softening leading to loss of surface mineral
Reversible?	Reversible in early stages	Irreversible surface loss
Contributing factors	Buffering by saliva helps neutralize bacterial acids	Saliva and pellicle overwhelmed by dietary and gastric acids
Preferred therapeutic approach	Prevention as well as reversal of early damage	Prevention is critical for managing
Fluoride effectiveness	------------	------------
Sodium fluoride	Yes	Yes
Sodium monofluorophosphate	Yes	Minimal
Stannous fluoride	Yes	Yes

One major difference between caries and dental erosion needs to be clearly understood. Caries is a process that begins with demineralization and, at early stages, can be reversed, either through the natural process of remineralization or through enhanced remineralization due to fluoride therapy. Dental erosion, on the other hand, is essentially a non-reversible process that results in permanent damage to the tooth structure.

The Role of Fluoride in Caries Reversal

Dental caries is an infectious disease caused by the complex interaction of cariogenic (caries-causing) bacteria with carbohydrates (i.e., sugars) on the tooth surface over time. Cariogenic bacteria metabolize carbohydrates for energy and produce organic acids as byproducts. The acids lower the pH in the plaque biofilm.[57]

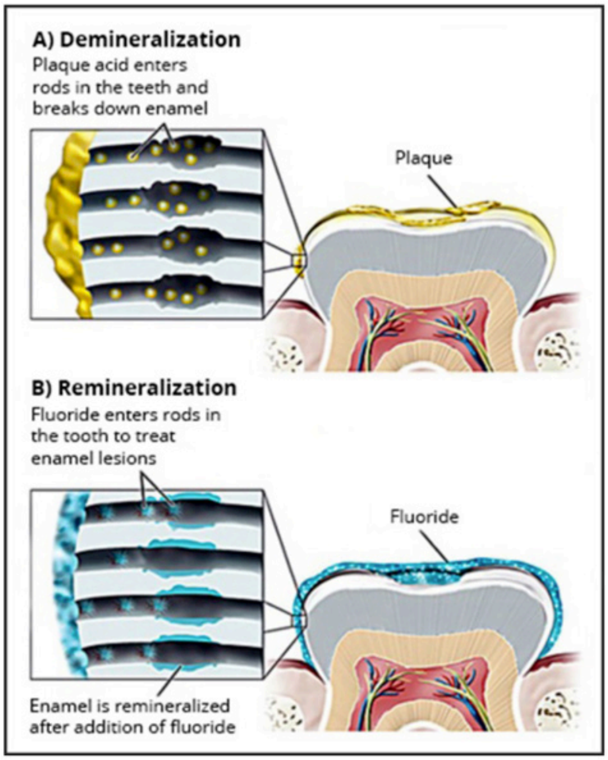


Figure 11. A) Demineralization – the caries formation process. Damage occurs in subsurface regions of the enamel, leaving an intact outer layer on the enamel surface. B) Remineralization – the caries reversal process. Caries is reversed through the process of remineralization, in which calcium, phosphate and fluoride are incorporated in the areas damaged due to demineralization processes, resulting in a stronger, fluoridated mineral.

The hydroxyapatite of tooth enamel is primarily composed of phosphate ions ($PO4^{3-}$) and calcium ions (Ca^{2+}). Under normal conditions, there is a stable equilibrium between the calcium and phosphate ions in saliva and the crystalline hydroxyapatite that comprises 96% of tooth enamel. When the pH drops below a critical level (5.5 for enamel, and 6.2 for dentin), it causes the dissolution of tooth mineral (hydroxyapatite) in a process called demineralization. When the natural buffer capacity of saliva elevates pH, minerals are reincorporated into the tooth through the process of remineralization.[57]

The initial stage of the caries process results in white spot formation, a result of acid penetration and solubilization of some (but not all) of the subsurface mineral (Figure 11A). Left untreated, this subsurface damage can progress to a point where the crystal can no longer provide sufficient support to the enamel surface structure, and the surface collapses (cavitates).

The caries process can be affected in several ways. One of the most effective methods to prevent caries is by promoting remineralization and slowing down demineralization. This can be accomplished with fluoride therapy. It is widely accepted that the regular use of fluoride, such as in dentifrice and drinking water, is extremely effective at preventing dental caries. In 1999, the US Center for Disease Control (CDC) issued a statement that water fluoridation is one of the 10 most important public health measures of the 20th century.[58] Fluoride's presence in low concentration and high frequency is more effective at preventing caries than high levels of fluoride used in low frequency. Because water fluoridation is not available in many countries, dentifrice is considered to be one of the most important sources of fluoride globally.

When fluoride is present in oral fluids (i.e., saliva), fluorapatite, rather than hydroxyapatite, forms during the remineralization process. Fluoride ions (F^-) replace hydroxyl groups (OH^-) in the formation of the apatite crystal lattice (Figure 11B), resulting in a stronger, fluoridated tooth mineral (fluorapatite). Fluorapatite is less soluble than hydroxyapatite, even under acidic conditions. Because fluorapatite is less soluble than hydroxyapatite, it is also more resistant to subsequent demineralization when acid challenged.

Caries is generally considered to be a sub-surface phenomenon. With fluoride treatment, a non-cavitated lesion can be remineralized with fluorapatite and have greater resistance to subsequent demineralization than hydroxyapatite. Even at very low concentrations, fluoride is effective as an anticaries agent.[59]

In the US, there are three commonly used sources of fluoride in oral care products; sodium fluoride (NaF), sodium monofluorophosphate (SMFP) and stannous fluoride (SnF_2). All three of these fluoride sources provide the important F^- ion, which both inhibits demineralization and promotes remineralization of damaged tooth mineral. In addition, SnF_2 is considered to have unique properties, as it provides efficacy against bacterial acids in addition to its fluoridating benefits.

Fluoride and Erosive Tooth Wear

While dental erosion, like caries, is a mineral process, the erosion process follows a somewhat different pathway.[47,60] There is little possibility of reversal, as erosive acids are able to overwhelm the protective pellicle layer and soften outer surfaces of the tooth; these softened surfaces can then be lost to abrasive forces, resulting in permanent and irreversible loss of tooth structure (Figure 12).

It is well accepted that fluoride helps keep teeth strong. However, recent studies have demonstrated that all fluorides are not alike with their ability to help prevent dental erosion. While there would likely be a greater incidence of dental erosion in the absence of fluoride, the data suggest that most fluorides do not provide a high level of benefit against the increasing levels of challenge teeth are facing in today's environment. In spite of the fact that almost 100% of the world's toothpastes contain fluoride, the incidence and prevalence of dental erosion both appear to be on the rise. These data suggest many fluoride products may not be sufficiently effective to protect teeth against erosive acid challenges.

One of the currently used sources of fluoride, stannous fluoride (SnF_2) (Figure 13), has been demonstrated in a broad range of studies to be unique in its ability to help prevent the initiation and progression of dental erosion. These include both laboratory[61-64] and human *in situ* erosion clinical studies.[65-70] Stannous-containing dentifrice demonstrated significantly better protection than sodium fluoride under erosive and erosive/tooth wear conditions[71] and the use of these bioavailable SnF_2 toothpastes, as part of a daily oral hygiene regimen, will provide patients with enamel erosion protection, combined with alleviation of dentin hypersensitivity pain when present, improving quality of life.[72] Different from other sources of fluoride used, stannous fluoride deposits a retentive, acid resistant barrier layer onto exposed tooth surfaces that is protective against both the initiation and progression of dental erosion (Figure 14).[73]

A recent meta-analysis showed that Sn-compounded fluoride, prevented enamel wear by erosion and erosion/abrasion compared to the non-fluoride group and monovalent fluoride group. There is no concentration of monovalent fluoride that could prevent erosion wear associated or not with abrasion.[74] Along with a separate systematic review and meta-analysis both concluded that stannous fluoride showed a greater anti-erosive potential than non-stannous fluoride dentifrices and that as a treatment the use of stabilized stannous fluoride dentifrices to relieve dentin hypersensitivity and to prevent the initiation of dental erosion is favorable.[75]

Current Methodologies to Assess Dental Erosion

Methodologies used to assess dental erosion efficacy fall into 2 groups - those measuring total mineral loss from enamel (and dentin) due to lesion progression, and those measuring the surface properties of erosive lesions.

Lesion Progression Methods

Lesion progression can be assessed using sound enamel slabs subjected to cycles of acid challenges and salivary remineralization *in vitro*, or by *in situ* testing with patients drinking beverages that deliver acid challenges to enamel slabs worn in an appliance (Figure 15). Using the same methods, the efficacy of preventive measures to inhibit lesion progression can be assessed. Lesion progression in enamel and dentin can be measured using microradiography, contact profilometry, and non-contact (optical) profilometry; the latter two additionally measure surface roughness. A fourth option, confocal laser scanning microscopy (CLSM), measures total lesion progression and the softened zone of mineral caused by an erosive acid. A recent study compared CLSM, contact profilometry and non-contact profilometry and found all three methods gave similar results in measuring the loss of enamel.[77]

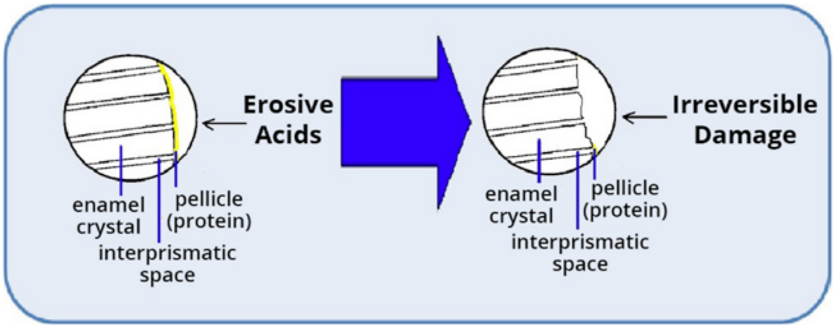


Figure 12. Dental Erosion processes result in permanent loss of surface mineral structure.

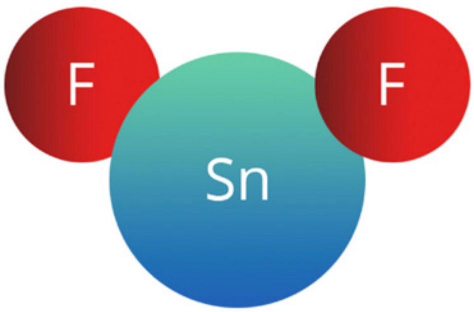


Figure 13. Stannous fluoride (SnF2) is unique among the sources of fluoride routinely used for toothpaste formulations.

Figure 15. Human enamel specimens mounted into appliances worn for human *in situ* erosion prevention studies.

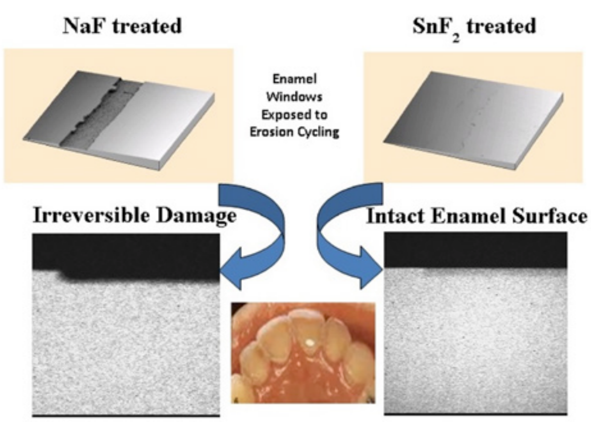


Figure 14. SnF_2 helps prevent erosion by depositing an acid resistant barrier layer on exposed tooth surfaces, thus preventing the initiation and progression of irreversible damage.
Adapted from Faller; Cosmetics & Toiletries, 2012.[76]

Surface Layer Measurements

Surface layers can be assessed using *in vitro* or in situ models. Methods of analysis can include scanning electron microscopy (SEM) (Figure 16), quantitative light fluorescence or optical coherence tomography which measure changes in the surface zone and are used to determine surface roughness. Additional methods include acid solubility testing and atomic force microscopy (Figure 17) Replica SEMs can be used with *in situ* research to measure changes in the surfaces of eroded lesions or softened zones of enamel lesions over time. An additional method of analyzing the surface layers, secondary ion mass spectroscopy (SIMS), can be used to measure the composition of the surface layer and to show material firmly deposited at the surface.

Hardness recovery, hardness loss inhibition, surface composition/fluoridation and solubility reduction measurements can all be used to assess the mechanisms and efficacy of a proposed preventive therapy against dental erosion. Protocols used include surface preparation using an acid challenge and measurement, treatment steps, surface measurements after secondary acid challenges (typically citric acid, or for *in situ* studies orange juice), and then measuring specimen hardness again after re-immersion in saliva.[61-65,68,69]

Progression of the Erosive Lesion

The 3 stages in progression of an erosive

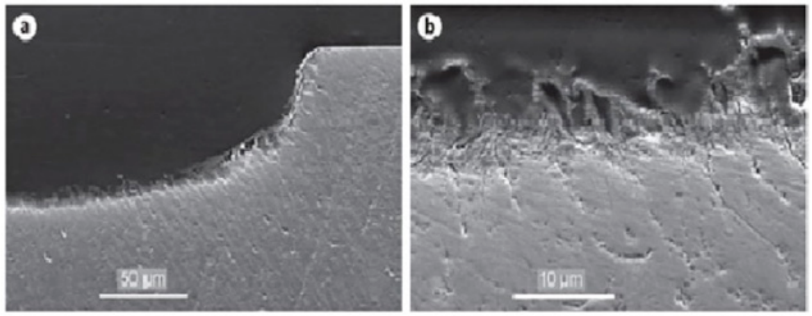


Figure 16. SEM showing loss of enamel (a) and, at greater magnification, the softened layer at the advancing front of the lesion (b).
Images courtesy of Karger.[24]

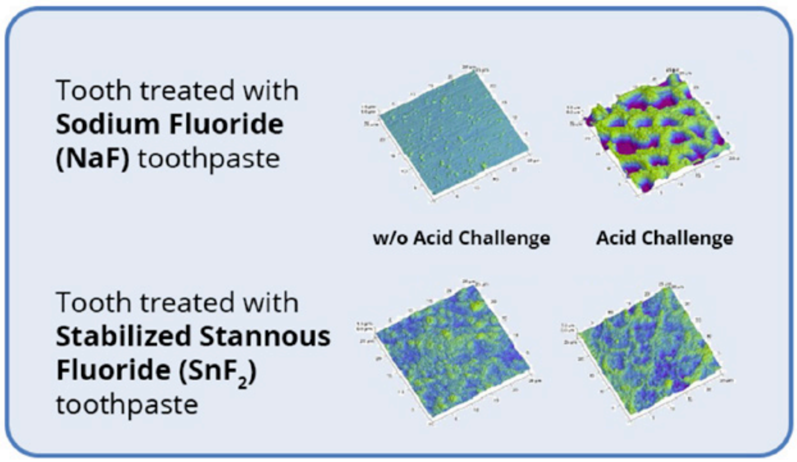


Figure 17. Atomic force micrographs show the decreased loss of structure on the enamel slab treated with stabilized stannous fluoride toothpaste. Stannous fluoride deposits are insoluble in concentrated acid and provide enhanced protection, especially at low pH.

lesion are initial surface softening, progressive loss of enamel and the creation of a lesion that involves dentin. By focusing on lesion progression models, the ability of a given therapy to protect against erosive progression can be determined. Two ways to help prevent dental erosion are to protect the tooth surfaces by, in effect, 'galvanizing' the surface with deposits that are acid-resistant, and/or to remineralize the surface between acid challenges. Superior efficacy for SnF_2 in reducing surface loss when measured *in vitro*, using microradiography (Figure 18) following several cycles of erosive challenges, immersion in saliva, and treatment with fluorides (Figure 19, Table 4) has been demonstrated in multiple studies. [61-64]

Reduced progression of erosive lesions has also been observed with stabilized SnF_2 toothpaste *in situ* compared with sodium fluoride toothpaste. In a study by Hooper and colleagues, the benefit of stannous fluoride increased over time (Figure 20).[65]

In a study by West et al (Figure 21), highly significant erosion protection benefits were found when comparing a stabilized SnF_2 dentifrice to a marketed dentifrice containing SMFP as the fluoride active and arginine bicarbonate.[69]

As noted earlier, many foods and beverages have a pH below 4.0 and are highly acidic (Table 2). Although pH values are not an absolute predictor of erosive potential, it is important to know the general pH values for different foods and beverages. It is also important to consider these values when performing erosion testing, as different pH values will result in different results. During an erosive acid challenge,

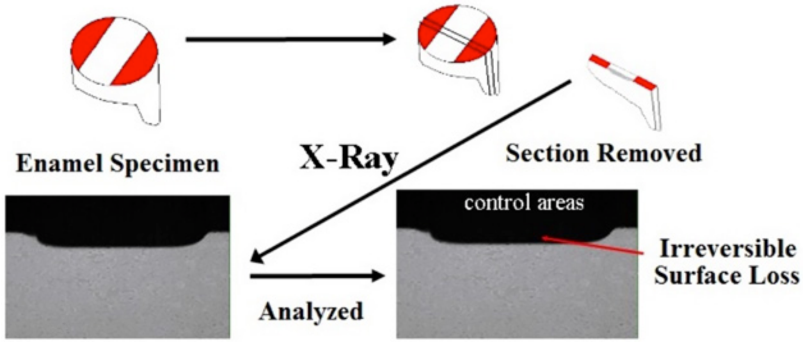


Figure 18. Microradiography is used to quantitatively measure tooth surface loss in vitro lesion progression models.
Adapted from: Eversole et al, 2014.[61]

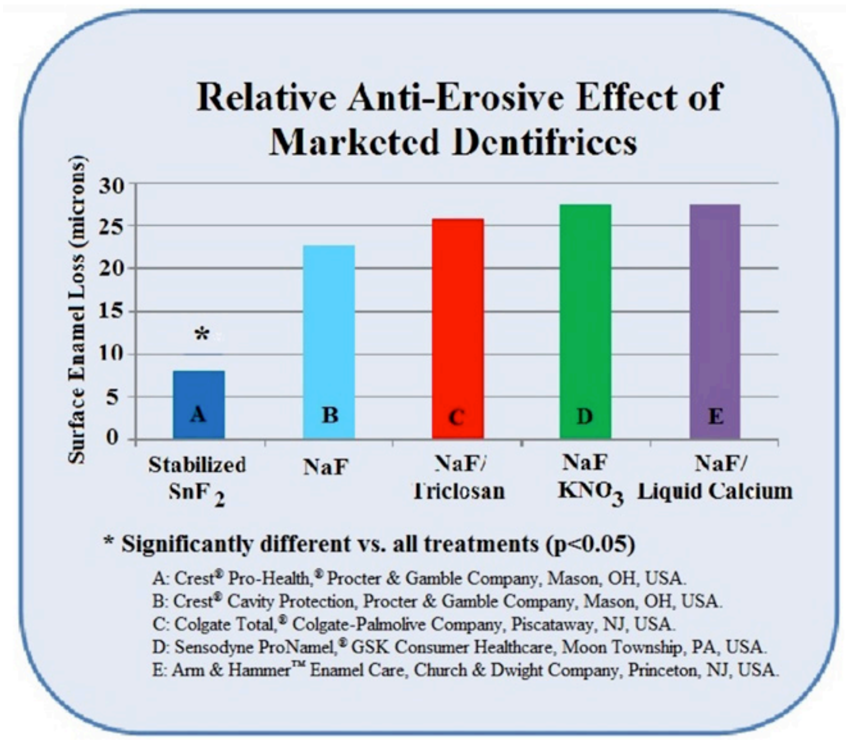


Figure 19. Surface enamel loss with marketed dentifrices using a lesion progression model with microradiography.
Adapted from: Faller et al, 2011.[63]

the tooth starts to dissolve, in an effort to restore an equilibrium, by releasing calcium, phosphate and fluoride salts. At pH4, more than 90% of the fluoride salt released is present as fluoride ions, which protects the surface against demineralization. At a pH of 2, it is overwhelmingly hydrofluoric acid that is present, rather than fluoride ions; as a result, insufficient fluoride ions are present to protect the tooth surface, which leads to dissolution of the surface layer of the tooth. Stannous fluoride has been shown to provide unique protection against acids, particularly at a low pH (e.g., orange juice, ~2.6).[65,68,69]

There are a variety of analytical methods, models and protocols that can be used to study erosion. Some measure lost mineral

Table 4. Results and Statistical Analysis: Percent Reduction in Enamel Surface Loss Comparing Marketed Dentifrices Using a Lesion Progression Model with Microradiography.

Type of Formula Tested	Mean Surface Loss ± SEM (µm)*	% Reduction vs. Control[b]
Stabilized SnF_2[a]	5.5 (1.2)	70.5
Mixed-active cavity protection[c]	16.0 (2.0)	14.0
SMFP/arginine bicarbonate[d]	17.1 (1.1)	8.2
Single active cavity protection[b]	18.7 (0.9)	-----

[a]Crest® Pro-Health, The Procter & Gamble Company, Cincinnati, OH, USA
[b]Crest® Cavity Protection, The Procter & Gamble Company, Cincinnati, OH, USA
[c]Colgate® Cavity Protection, Colgate-Palmolive (UK) Limited
[d]Colgate® Sensitive Pro-Relief™, Colgate-Palmolive (UK) Limited

*Mean ± Mean ± SEM from Least Significant Difference Analysis Means within the same bracket were not statistically significantly different at the 0.05 level of significance.

Adapted from Eversole et al, 2014.[61]

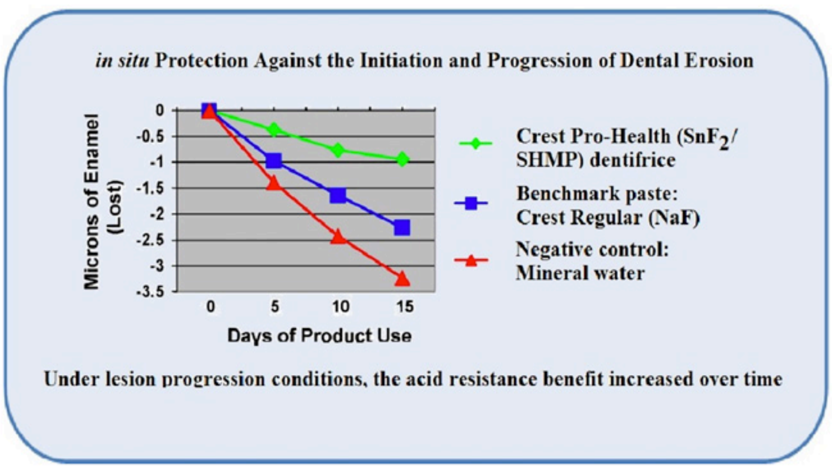


Figure 20. Superior erosion protection was demonstrated for SnF2 in an in situ human clinical study.
Adapted from Hooper et al, 2007.[65]

while others measure changes in the surface zone. Protocols differ depending on whether studies will be used to analyze the surface zone or to produce erosive lesions and measure effects on the progression of erosion. Depending on the method used, dramatic differences can be seen in the observed efficacy of various topical agents. Importantly, SnF_2 dentifrices, in particular stabilized SnF_2 dentifrices, have been demonstrated, using a wide range of both *in vitro* and *in situ* human clinical studies, to provide significantly greater erosion protection than other fluoride sources.[61-70]

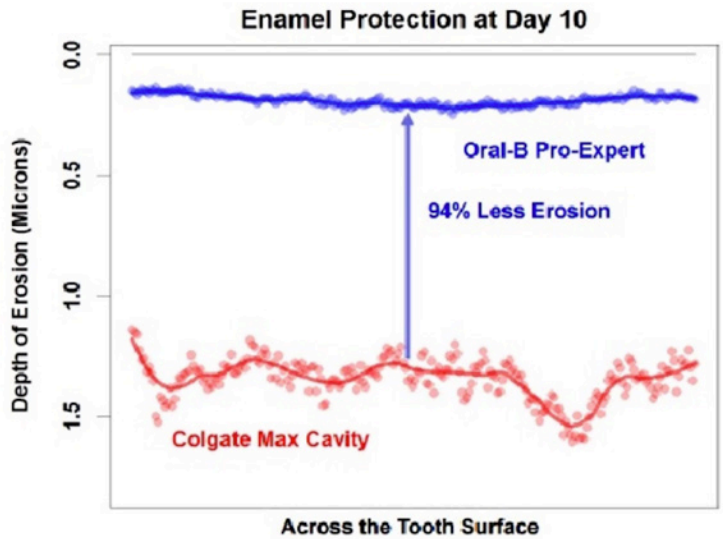


Figure 21. Results from a human *in situ* clinical lesion progression study comparing a stabilized SnF_2 dentifrice versus a marketed dentifrice formulated with SMFP and arginine bicarbonate.[69]

Clinical Strategies to Prevent and Manage Dental Erosion

Pathological tooth wear was rarely seen in ancient civilizations, and most of it was abrasion or attrition. While its prevalence and severity have increased in children and adults, ETW is a totally preventable condition for most individuals. Progressive ETW can lead to poor aesthetics, sensitivity, loss of function, and sometimes loss of self-esteem. (Figure 22).

Early identification and prevention is key. By the time lesions are clearly visible to the patient, restorative intervention and life-long dental treatment may be required. Regularly screening all patients for ETW makes it possible to diagnose erosive lesions at the earliest possible stage and allows implementation of preventive and treatment measures to preserve tooth structure and help stop further damage.

Figure 22. Facial view of dentition of a 23 year-old-male with ETW, a condition that can lead to poor aesthetics, sensitivity, loss of function, and sometimes loss of self-esteem.

Risk Assessment for ETW

The risk assessment should consider all risk factors and include asking patients if they are aware of any tooth wear, or have sensitive teeth. The risk assessment includes determining dietary habits; oral hygiene regimens, the presence of gastroesophageal reflux (GERD) symptoms, eating disorders, xerostomia, and whether the patient is a lactovegetarian, taking acidic medications, or occupationally at risk (e.g., wine tasters, professional swimmers). Several factors influence the rate of progression and extent of erosive lesions and must be considered during the risk assessment. These factors (Table 5) include the frequency, amount, and duration of exposure to erosive acid challenges, such as a high consumption of carbonated drinks, acidic fruits and vegetables, drinking alcohol, the manner in which acidic agents are consumer, e.g., holding or swishing acidic drinks in the mouth which prolongs contact; and, having acidic drinks at night when salivary flow is low.[78-81]

Table 5. Key Risk Factors Influence the Rate of Progression and the Extent of Erosive Lesions.

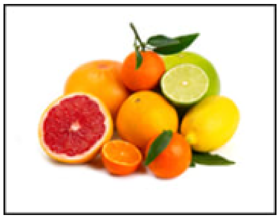
Key Risk Factors Influencing the Rate of Progression and Extent of Erosive Lesions	
Frequency of consuming erosive acid containing beverages	
Duration of erosive acid exposure	
High consumption of acidic fruits and vegetables	
Drinking alcohol	
The manner in which acidic agents are consumed	
Having acidic drinks at night when saliva flow is low	

Figure 23. Image of young 30-year-old presenting with multiple types of wear.

Clinical Examination

A full examination and tooth indexing for erosion, known as the Basic Erosive Wear Examination (BEWE), should be performed. The patient should be assessed for erosion, abrasion, attrition, abfraction, tooth wear etiology, recession, dentinal hypersensitivity, occlusion, salivary flow rate, and staining (which would suggest erosion is likely not occurring at that time) (Figure 23).

The Basic Erosive Wear Examination (BEWE)

The BEWE, introduced by Bartlett, Ganss and Lussi in 2008,[82] is used to assess the level of erosion. For this examination, the mouth is divided into six distinct areas for evaluation. Table 6 shows the criteria for sextant scores from 0 to 3, which are summed to obtain a cumulative score that is the basis for determining interventions (Table 7). The BEWE is a simple, quick index for screening a patient's erosion status.

Challenges in the Management of ETW

Management challenges for ETW include early diagnosis of erosive lesions, the initiation of preventive strategies and behavioral changes, and early intervention with minimally-invasive restorative procedures. Early diagnosis should include charting of erosive lesions, sensitive teeth, staining, and making note of areas of exposed dentin. In addition, a risk assessment should be performed.

Patients should be taught preventive habits that reduce the risk of ETW. These include:

- Staying hydrated.
- Rinsing with water before brushing.
- Brushing with a stannous fluoride toothpaste.
- Not brushing for at least 1-2 hours after an acid challenge.

The bottom line in the management of ETW is early diagnosis, initiation of preventive measures, and early intervention to avoid the need for extensive and invasive care.

Preventing and Managing Dental Erosive Tooth Wear

Once a diagnosis of dental erosion is made, an overall preventive management program is needed. ETW management focuses on oral hygiene practices, home care, professional care, and individually tailored advice, depending on the level of severity found, to prevent further erosion and to manage the condition effectively.

Routine maintenance and observation

Clinicians have used clinical notes, photographs, and study models to record the past and present tooth wear and use these to compare with previous records to determine if the wear is progressing faster than an expected physiological rate. Although there is no consensus in the scientific literature on a "gold standard" for the clinical evaluation of wear, the contribution of the indices to diagnosis is undeniable,[83] commonly used is the BEWE as described above or more detailed ones such as the Smith and Knight visual index.

Today, intraoral scanners are steadily becoming essential in dental practices.[84] An intraoral scanner is a non-invasive tool that can detect small scale changes. Ranges of 200 microns can be achieved, as opposed to classic indexes such as the Smith and Knight visual index, where the scale jump is 1 mm(16). If the rate of tooth wear that is higher than the average physiologic rate of approximately 0.02 to 0.04 mm per year is discovered, the dentist can promptly conduct a more thorough examination and update of the patient's history and oral habits. Once the cause can be defined, a comprehensive course of management can be offered to the patient. Patients appear to find intraoral scanning software to be an effective communication tool due to the simplicity with which the colors show the teeth and associated wear.[83,84]

Table 6. BEWE Scores and Criteria.

Score	Criteria	Image
0	No ETW	
1	Initial loss of surface texture	
2[a]	Distinct defect; hard tissue loss involving <50% of the surface area	
3[a]	Hard tissue loss involving ≥50% of the surface area	

[a]Dentin often involved.

Digital 3D scanning, superimposition and comparison, has been used to quantify changes in orthodontics, periodontics and tooth wear measurements, with varying degrees of accuracy. Clinicians need to bear in mind that the accuracy of superimposing and aligning two scans is complex and be prone to error due to the mathematical complexities of dataset alignment which are often hidden from the operator to make software easier to use.[85]

In summary, this new era of digital dentistry is quickly evolving. Currently detection and monitoring of early erosive tooth wear can be reliably aided by intraoral scanning supported by specific software. The measurement error and uncertainty involved in this method should be taken into consideration when interpreting the tooth substance loss measurements.[86] The intraoral scanner also provides an excellent route of communication[85] for patients to contextualise the diagnosis and understand management pathways.

Prevention

There are a number of suggestions that can be made to all patients, and particularly to those in some of the higher risk categories. These categories are best defined as those individuals with a high consumption of dietary acids, such as colas (diet or regular are no different), fruit juices, wine, acidic fruits such as oranges, grapefruit, berries, apples, acidic vegetables such as rhubarb, tomatoes, any vegetables processed in vinegar such as canned beets, pickles, sauerkraut, and a host of other dietary components.

From the standpoint of Management Strategies, there are two main approaches. One is directed to the patient, while the other is geared toward the Dental Professional.

Oral Hygiene Practices and Home Care

It is recommended that patients with ETW brush for no more than 2 minutes and a maximum of twice-daily. Normally, manual and powered brushing cause virtually no enamel loss and

Table 7. Cumulative BEWE Scores and Management Guidelines.

Cumulative Score	General guidelines for management
No ETW: 0 - 2	✓ Routine maintenance and observation ✓ Repeat at 3-year intervals
Low: 3 - 8	✓ Oral hygiene, dietary assessment ✓ Routine maintenance and observation ✓ Repeat at 2-year intervals
Medium: 9 -13	✓ Oral hygiene, dietary assessment ✓ Routine maintenance ✓ Fluoride measures ✓ Avoid restorations ✓ Repeat at 6-12 month intervals
High: ≥14	✓ Oral hygiene, dietary assessment ✓ Routine maintenance ✓ Fluoride measures ✓ Repeat at 6-12 month intervals ✓ Consider restorations

minimal dentin loss. Some studies have suggested that power brushes, due to their ability to control the force of brushing, may be preferred over manual brushes.[87,88] A common question is with respect to when is the best time to brush; before or after an erosive acid challenge. In a recent in situ study using enamel slabs, it took about 2 hours after an acid challenge before the enamel surfaces began to recover;[89] this suggests that it may be wise to wait for at least 2 hours after an erosive acid challenge before brushing. If brushing before an acid exposure, make sure to use a product that provides an acid resistant barrier layer, such as a SnF_2 toothpaste, to protect the teeth against erosive acid attack. Without that barrier layer, the teeth could be susceptible to erosive softening, due to the effect of the brushing on pellicle thickness. Not brushing at all, of course, leads to other issues.

Patients with erosion can benefit from twice-daily use of SnF_2 toothpaste, because polyvalent metal ions interact with the tooth surface to form an acid-resistant insoluble layer. In fact, the recent consensus report by the European Federation of Conservative Dentistry notes that oral hygiene products containing stannous fluoride or stannous chloride, such as toothpastes or mouth rinses, have the potential to slow the progression of ETW.[80] There is robust evidence that stannous-compounded fluoridated and titanium tetrafluoride agents are effective in preventing erosion and erosion/abrasion compared to the non-fluoride group and other interventions.[74] Additional options include recommending a calcium phosphate-based or bioactive glass home use product to promote remineralization.

Professional Care

Oral health education and advice must be individualized. In addition to recommending the use of stannous fluoride dentifrices, preventive care can include fluoride varnishes. Tooth surface protective coatings may also be indicated and dentinal hypersensitivity requires treatment or use of a desensitizing toothpaste (e.g., stannous fluoride). If intrinsic acid erosion is present (e.g., from GERD or bulimia), the patient should be referred for appropriate medical assessment and care. Restorative and bonding materials are only used if absolutely necessary to reduce sensitivity, improve esthetic considerations or restore function. For non-carious cervical lesions (NCCLs), it may be preferable to avoid restorative care, particularly for early lesions. (Figure 10).Patients should be given advice on simple, practical ways to reduce the risk of erosive tooth wear such as dietary advice and modifying habits. Table 8 contains a list of areas to consider when tailoring patient advice. Regular reassessment and monitoring are needed to determine if ETW has been halted and to provide patients with advice and care.

From the patient standpoint, probably the biggest area of concern is for those individuals with a high intake of acidic beverages and snacking on acidic fruit . For those individuals, the recommendations are rather straightforward. (Table 9) The first recommendation is to try to minimize the excessive intake of these beverages and fruit, as the pellicle can certainly accommodate some level of intake without issue. When consuming these types of beverages, it is generally considered best to drink with a straw, as this helps direct the acids past the teeth and into the mouth directly. Recommend drinking acidic beverages in a short period of time in order to minimize the overall time of contact of the acids with the enamel surfaces. Rinsing with water after drinking an acidic beverage or fruit will help dilute acids and rinse them away from susceptible tooth surfaces. There is some belief that drinking chilled beverages may be more advantageous, from the standpoint of erosive potential, than drinking warm beverages; as the reduced temperature may favorably alter the kinetics associated with erosive acid attack and the resulting insult to the enamel surface.[47] It is probably best to advise patients to wait 1-2 hours after ingesting acidic products before brushing; and when they do brush, it is best to use a stabilized SnF_2 dentifrice that has been demonstrated effective in its ability to help protect against erosive acid damage.

From the professional standpoint, there are a few key points to consider (Table 10). Clearly, consumer trends are creating new dental needs. Dental health is a constantly evolving issue, and one that requires an eye toward the future in order to help stop problems

Table 8. Individually Tailored Advice for Patients.

Dietary Considerations for Sharing with Patients.
Reduce intake and frequency of acidic foods and drinks.
Eat cheese/milk after acid challenges.
Additional calcium content in food and beverages.
Drink cold rather than warm beverages (if acidic).
Rinse with sodium bicarbonate to help increase the pH after dietary acid challenges.
Chew nonacidic gum to stimulate saliva. Mint-flavored, sugar free gum should be suggested rather than citrus flavored gums, which are likely to be more acidic.

Table 9. Awareness for Patients who Ingest Excessive Amounts of Erosive, Acid Containing Beverages.

Erosion Awareness for Patients with High Intake of Acidic Beverages.	
Avoid excessive use of acid beverages.	
Use a straw.	
Drink acidic beverages in a short period of time.	
Rinse with water after drinking to minimize exposure.	
Cold beverages are probably better than warm ones.	
Wait 1-2 hours after ingesting acidic products before brushing.	
Brush with a stabilized stannous fluoride toothpaste.	

Table 10. Key Areas of Erosion Awareness for Dental Professionals.

Erosion Awareness for Professionals.	
Consumer trends are creating new dental needs.	
Dental erosion is an emerging trend.	
Maintaining strong, healthy teeth for life begins at the earliest ages.	
Dental erosion is irreversible.	
Fluoride provides some protection from erosion, but all fluorides are not equally effective.	
SnF_2 is recognized as being highly effective in the prevention of dental erosion.	

before they get to epidemic levels. Based on a host of information available from studies conducted in the UK and Europe, as well as initial studies done in the United States, dental erosion is clearly one of the next big trends that is emerging and will require dental intervention. Due to the irreversible nature of dental erosion, this may ultimately be a bigger issue than caries. Caries formation is a reversible process that does not involve, at least in the early stages, total destruction of the enamel crystal matrix. Of primary importance in controlling dental erosion is the recognition and appreciation for preventive measures to be put in place at the earliest ages, in order to preserve the natural enamel surface as long as possible. Particularly important is the transition stage from deciduous to permanent dentition, where patients need to be reminded of the long-term need to maintain strong, healthy teeth for life.

Conclusions

While caries and dental erosion involve the loss of mineral, there are differences between caries and erosive processes. Caries occurs under plaque and is the direct result of bacterial acids. The primary acid that causes caries is lactic acid, a byproduct of the breakdown of fermentable carbohydrates (primarily sugar) by plaque bacteria. Erosion, on the other hand, is a result of the direct action of extrinsic, dietary acids; such as those found in carbonated drinks and fruit juices or intrinsic acids, such as from GERD. With caries, the mineral structure remains intact. Thus, fluoride and other mineral can penetrate into the enamel crystal matrix and rebuild or remineralize the challenged enamel. However, dental erosion is different. Once erosive factors overwhelm the pellicle, the result is an initial, relatively fast softening of the enamel followed by abrasive insults that result in complete and permanent removal of the enamel crystal. Net, there is no crystal structure to rebuild.

Dental erosion, a major component under the umbrella term of ETW, is multifactorial and its prevalence is increasing, especially in adolescents and older adults. Advanced ETW causes patients to experience problems with esthetics, function, and pain, and creates treatment dilemmas for dental professionals. Effective management of ETW includes screening and evaluation of all etiological factors, preventive and restorative care, and using the least invasive therapy possible. Dentifrices containing stabilized SnF_2 have been shown to be very effective at inhibiting both the initiation and progression of dental erosion. ETW must be effectively managed, with a focus on preventive care at the earliest stages, and monitoring and evaluation of ETW management should be performed regularly during recall sessions. This will help reduce the need for extensive and expensive restorative care in the future.

Course Test Preview

To receive Continuing Education credit for this course, you must complete the online test. Please go to: www.dentalcare.com/en-us/ce-courses/ce517/test

1. Which of the following statements about the erosion versus caries processes is false?

A. Erosion occurs on the surface; caries development begins sub-surface.
B. Caries occurs on the surface, while erosion is a subsurface phenomenon.
C. Erosion is often the result of excessive ingestion of acidic beverages.
D. Unlike caries, which is a result of bacterial acids, erosion is a result of external acids.

2. Methods that have proven useful for measuring the progression of erosive lesions in the laboratory include ____________.

A. microradiography
B. contact profilometry
C. confocal laser scanning microscopy
D. Only A and B
E. A, B and C

3. Which ingredient has the most evidence behind it demonstrating benefits to prevent erosive acid damage?

A. Sodium fluoride.
B. Sodium monofluorophosphate.
C. Stannous fluoride.
D. All of the above.
E. A and B.

4. Over time, the difference in erosive tooth wear prevention effectiveness of SnF2 over NaF, as measured in human in situ erosion prevention studies, becomes ____________.

A. more apparent
B. less apparent

5. The severity of erosive attacks depends on all of the following, EXCEPT __________.

A. pH
B. titratable acidity
C. buffer capacity
D. contact time on the teeth
E. number of carious teeth

6. Preventive habits that reduce the risk of ETW include ____________.

A. using effective whitening products
B. daily flossing
C. using chewing gum with Xylitol
D. eating whole meal bread
E. brushing with SnF2 toothpaste

7. Which of the following low pH foods or beverages is not considered to be highly erosive?

A. Acid-containing vegetables
B. Fruit juices
C. Yogurt
D. Fresh fruits

8. Erosive Tooth Wear (ETW) is an umbrella term that includes: dental erosion, attrition and ___________.

A. caries
B. gingivitis
C. periodontal disease
D. essential oils
E. abrasion

9. Gastric acids are never associated with erosive tooth wear (ETW).

A. False
B. True
C. It depends on which gastric acid is being considered.

10. The increasing prevalence of dental erosive tooth wear is often related to significant increases in the consumption of _____________.

A. acid containing beverages
B. healthier foods, such as fruits and some vegetables
C. bottled water
D. A and B
E. A, B and C

11. Erosive tooth wear (ETW) is a multifactorial process that may include acid excesses and _____________.

A. abrasion alone
B. attrition alone
C. the functional forces of abrasion and attrition
D. soft bristle tooth brushing

12. Which of the following statements best describe acid erosion?

A. Dissolution of tooth surfaces by bacterial acids.
B. Dissolution of tooth surfaces by acids that are not of biological origin.
C. Dissolution of tooth surfaces by either dietary or gastric acids.
D. B and C

13. BEWE is an acronym for _____________.

A. Begin Erosion Wear Experiment
B. Basic Erosive Wear Exam
C. Basic Enamel Wasting Estimate
D. Biological Enamel Wear Evaluation

14. Which of the following dietary acids have erosive potential?

A. Lactic
B. Citric
C. Tartaric
D. B and C
E. A and B

15. Dental erosion occurs when the pellicle, nature's natural protection against erosion, is _____________.

A. overwhelmed by excessive exposure to dietary or gastric acids
B. supersaturated with calcium and phosphate from saliva
C. heavily stained
D. B and C

16. The process of dental erosion can be described by which of the following?

A. Surface removal due to abrasion of the sound tooth surface, followed by remineralization.
B. Surface softening due to erosive acid attack, followed by abrasive factors that can remove this softened layer, followed by additional softening.
C. Surface softening due to bacterial acid attack, followed by abrasive factors that can remove this softened layer, followed by additional softening.
D. Sub-surface demineralization of tooth mineral, ultimately leading to cavitation.

17. Which of the following statements is/are true?

A. Erosive tooth surface loss is a growing problem that is seen day-to-day in general practice.
B. Both enamel and dentin are susceptible to erosive tooth surface loss.
C. BEWE is a simple, quick index for screening a patient's erosion status.
D. A, B and C
E. Only A and C

18. Which of the following statements is/are false?

A. Both enamel and dentin are susceptible to erosive tooth surface loss.
B. Recent studies indicate the average person in the United States consumes approximately 20 gallons of sugar sweetened beverages each year.
C. Dental erosion is increasing in children, adolescents and adults.
D. A and C

19. Stannous fluoride is more protective than other fluoride sources against dental erosion because _____________.

A. it deposits a protective, acid resistant layer on exposed tooth surfaces
B. it penetrates deeper into the tooth than other fluoride sources
C. it tastes better than other fluoride agents
D. it has been in use longer than other fluoride actives

20. Important aspects of managing patients with erosive tooth wear are _____________.

A. be familiar with and recognize tooth wear lesions at the earliest possible stage
B. implement preventive and treatment measures to preserve the tooth
C. reconstruction
D. A and B
E. A and C

21. The most important biological risk factor in Erosive Tooth Wear (ETW) is _____________.

A. the number of cavities the patient has
B. the type of bacteria present in the patient's mouth
C. saliva
D. the age of the patient

22. Which of the following is the most dominant bacteria responsible for dental caries?

A. P. gingivalis
B. Lactobacillus
C. S. cavitalis
D. S. sobrinus
E. S. mutans

23. Although the prevalence of dental erosion has been reported to be between 7 - 74%, what is the generally accepted value describing the prevalence of dental erosive tooth wear in teenagers and young adults?

A. 10%
B. 20%
C. 30%
D. 40%

24. The BEWE index divides the mouth into how many areas for evaluation?

A. 2
B. 4
C. 6
D. 8

25. Besides saliva, what is another key biological factor that can influence erosion?

A. Level of stain.
B. Hardness of the teeth.
C. The salivary pellicle.
D. The number of permanent teeth with cavities.

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Additional Resources

- No Additional Resources Available.

About the Authors

Nicola West , BDS PhD FDS RCS (Eng) FDS (Rest Dent) FDS RCS Ed FHEA
Nicola West is a Professor and Honorary Consultant in Restorative Dentistry at Bristol Dental School, and the Director of the Clinical Trials Unit conducting research in the international forum, attracting substantial funding from industry, charities and NIHR funding streams. Current research interests are investigating the associations between periodontal diseases and systemic diseases and conditions including Alzheimer's Disease & Parkinson's Disease, cardiovascular diseases and cystic fibrosis. Novel clinical periodontal research methodologies are developed alongside the scientific evaluation of oral health care products for gingivitis, tooth wear, dentine hypersensitivity, tooth staining and whitening. Research is also conducted into oral hard and soft tissue augmentation and peri-implant lesions and conditions.

Nicola is the Secretary General of the European Federation of Periodontology, Specialist Advisor for the General Dental Council UK and President elect for the British Society of Periodontology and Implant Dentistry. Nicola was Treasurer of the high successful international Europerio 10 meeting in Copenhagen 2022 and has instigated UK adoption of the European periodontal guidelines on management of periodontal diseases.

In parallel Nicola has maintained a thriving periodontal and dental implant specialist practice in the centre of Bristol, a particular sphere of interest includes the management of peri-implantitis lesions.

Email: richter.ns@pg.com

Warden H. Noble, DDS, MS, MSEd
Dr. Noble graduated from and was on the faculty at University of California, San Francisco. He is a board certified prosthodontist and was formerly a Clinical Professor and Co-director of Graduate Prosthodontics at UCSF. After 40 years in private practice, he is now a Professor in the Department of Integrated Reconstructive Dental Sciences at the Arthur A. Dugoni School of Dentistry, University of the Pacific, San Francisco, CA.

Email: wnoble@pacific.edu

Donald J. White, PhD
Dr. Donald White was a Research Fellow at the Procter & Gamble Company Health Care Research Center in Cincinnati, Ohio, USA. Dr. White received his BS in Chemistry and PhD in Physical Chemistry from the State University of New York at Buffalo. He carried out research on the mechanisms of formation and solubilization of kidney stones. Dr. White's dental research interests included the contribution of physical chemistry to Oral Biological processes including fundamental aspects of tartar formation, stain development, dental caries, and dental plaque formation. Dr. White published over 100 peer-reviewed publications, approximately 200 meeting presentations and abstracts, and over 40 global patents.

Email: N.X.West@bristol.ac.uk

Natasha West, BDS, MFDS RCSEd

Dr Natasha West is a graduate of the University of Cardiff and after attaining her fellowship from the Royal College of Surgeons of Edinburgh works part time as a clinical research fellow in the Clinical Trials Unit at Bristol Dental School and part time in general dental practice. Natasha's main areas of research are erosive tooth wear, digital dentistry and dentine hypersensitivity. Alongside working largely in aesthetic and restorative dentistry.

Email: natasha.west@bristol.ac.uk