Managing Dental Erosion: Current Understanding and Future Directions

Course Author(s): Donald J. White, PhD; Warden H. Noble, DDS, MS, MSEd; Nicola West, BDS, FDSRCS, PhD FDS (Rest Dent)

CE Credits: 2 hours

Intended Audience: Dentists, Dental Hygienists, Dental Assistants, Dental Students, Dental Hygiene Students, Dental Assistant Students

Date Course Online: 04/04/2017 Last Revision Date: N/A Course Expiration Date: 04/03/2020

Cost: Free Method: Self-instructional AGD Subject Code(s): 10, 430, 730

Online Course: www.dentalcare.ca/en-ca/professional-education/ce-courses/ce517

Disclaimer: Participants must always be aware of the hazards of using limited knowledge in integrating new techniques or procedures into their practice. Only sound evidence-based dentistry should be used in patient therapy.

Introduction

The purpose of this course is to provide information on the dental erosion process, highlight key similarities and differences between dental erosion and caries, provide effective strategies to help educate patients who are at risk for developing dental erosion, and manage patients who are already experiencing the condition to minimize its effects.

Acknowledgements

To Mr. Robert V. Faller for assistance developing the course.

ADA CERP

The Procter & Gamble Company is an ADA CERP Recognized Provider.

ADA CERP is a service of the American Dental Association to assist dental professionals in identifying quality providers of continuing dental education. ADA CERP does not approve or endorse individual courses or instructors, nor does it imply acceptance of credit hours by boards of dentistry.

Concerns or complaints about a CE provider may be directed to the provider or to ADA CERP at: http://www.ada.org/erp

Approved PACE Program Provider

The Procter & Gamble Company is designated as an Approved PACE Program Provider by the Academy of General Dentistry. The formal continuing education programs of this program provider are accepted by AGD for Fellowship, Mastership, and Membership Maintenance Credit. Approval does not imply acceptance by a state or provincial board of dentistry or AGD endorsement. The current term of approval extends from 8/1/2013 to 7/31/2017.

Provider ID# 211886
Conflict of Interest Disclosure Statement
• Dr. White is an employee of Procter & Gamble.
• Dr. Noble and Dr. West have done consulting work and given scientific lectures on behalf of P&G.

Course Contents
• Overview
• Learning Objectives
• Background
• Etiological Factors
  • Differences Between Dentin and Enamel Erosion
  • Dental Erosion and Diet
  • Saliva
  • The Salivary Pellicle
  • Gastroesophageal Reflex Disorder (GERD)
  • Patient Age and Risk Factors
• Caries versus Erosion
  • Key Differences Between Caries and Dental Erosion
  • The Role of Fluoride in Caries Reversal
  • Fluoride and Dental Erosion
• Current Methodologies to Assess Dental Erosion
  • Lesion Progression Methods
  • Surface Layer Measurements
  • Progression of the Erosive Lesion
• Clinical Strategies to Prevent and Manage Dental Erosion
  • Risk Assessment for ETW
  • Clinical Examination
  • The Basic Erosive Wear Examination (BEWE)
  • Challenges in the Management of ETW
  • Preventing and Managing Dental Erosion
  • Oral Hygiene Practices and Home Care
  • Professional Care
• Conclusions
• Course Test
• References / Additional Resources
• About the Authors

Overview
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 sensitivity reduction approaches and fluoride varnishes. In spite of these advances, dental erosion has become a major new challenge for dental professionals.

First identified approximately 25 years ago, the prevalence of dental erosion has increased dramatically in children, adolescents and adults ever since. This is of particular concern since the enamel and dentin loss associated with this multifactorial condition is irreversible.

Confusion exists, however, regarding the differences between dental erosion and dental caries. Although there are some similarities between these two unique processes, there are critical differences related to the etiological factors, the long-term effects, and the best ways to help manage these issues for each patient.

Over the past several years, we have learned a great deal about dental erosion. Fortunately, we have also learned about important strategies to help prevent it. This course provides you with the most current learnings on dental erosion, including research on the efficacy of fluoride sources to help prevent its initiation and progression.

Learning Objectives
Upon completion of this course, the dental professional should be able to:
• Discuss trends related to the prevalence of dental erosion.
• Understand similarities and differences between dental erosion and caries.
• Explain the etiology of dental erosion to patients.
• Discuss the long-term effects of dental erosion.
• Explain strategies for diagnosing and managing patients at risk for dental erosion.

Background
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, and also throughout Europe, this problem later gained significant interest on a more global scale. This condition is highly relevant to oral health professionals, and it presents these professionals with challenges regarding its treatment. From a patient's point of view, dental erosion 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 the condition; it sometimes requires changes in patient habits, which can present a significant hurdle.

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 erosion, abfraction, 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, abfraction, abrasion and attrition are the result of physical forces.

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. 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. 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.
- Abfraction is a form of physical wear along the gingival margin that is not caused by bacterial acid activity.
- Abrasion is a form of physical wear that is the result of mechanical interactions, such 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 (tooth grinding).

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, giving the pellicle sufficient time to regain a reasonable level of defense.

As we are all aware, people are living longer. If we were born today, our average life expectancy might be 100 years of age. Our medical colleagues recommend that we eat more fresh fruit and vegetables, which is sometimes a more erosive diet, in order to combat certain diseases, such as diabetes and cardiovascular disease. In addition, our consumption of acidic soft drinks is increasing dramatically year-on-year. Data comparing populations in both the

Figure 1. Erosive Tooth Wear (ETW) is an umbrella term that includes dental erosion, abfraction, attrition and abrasion, alone or in combination.
UK and US suggest we can anticipate finding a significant level of dental erosion in the general population, with even higher numbers anticipated for specific high risk groups. The evidence suggests the presence of erosion is growing steadily. A recent study in Europe showed that 30% of young adults, 18-35 year olds, had dental erosion, much of which may be attributed to excessive consumption of soft drinks.

‘Baby Boomers’ can represent a large patient population in many dental practices. These patients are much different than their similar age counterparts from 20-40 years ago. Patients now live longer, keep their teeth longer, and they’re more physically active. Many of them are aesthetically sensitive, with different kinds of demands; they’re not willing to settle for extractions and dentures. In fact, edentulism rates in the United States have decreased significantly in this age group, from about 45% in 1974 to around 17% now. This means that, for these patients in particular, we have far more teeth needing attention than we did several years ago. 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. As a start, 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 happening 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 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.

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.17

In terms of acid erosion per se, we first have 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 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 the issue even further is that the tissues involved in dental erosion, both enamel and dentin, 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 47% 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 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

---

Table 1. Composition of enamel and dentin.

<table>
<thead>
<tr>
<th>Component</th>
<th>Enamel</th>
<th>Dentin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inorganic Material</td>
<td>85%</td>
<td>47%</td>
</tr>
<tr>
<td>Organic Material</td>
<td>2%</td>
<td>33%</td>
</tr>
<tr>
<td>Water</td>
<td>11%</td>
<td>21%</td>
</tr>
</tbody>
</table>

---

*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.18
difference is that one challenge is controlled, and limited to a single exposure, while the other can occur over and over in the mouth, over a prolonged period of time. 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.

Another complicating factor is that dentin is subject to degradation by proteolytic enzymes, the MMPs, among other things. 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.

To briefly summarize, 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. 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**

Most researchers consider acid-containing soft drinks and beverages as primary culprits in the growing incidence of dental erosion. Over the past several decades, serving sizes in the US have increased dramatically. The average drink size, in the 1950s, was slightly less than seven (7) fluid (fl.) ounces (207 mL). By the 1960s, this average serving size had increased to twelve (12) fl. ounces (355 mL), and by the late 1990s 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. 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.

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 to the diet. A study by Credit Suisse compared the gross domestic product of various nations...
versus their annual consumption of sugar-sweetened beverages. 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. 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. In addition, yogurt, which has a relatively low pH, has little erosive potential due to its high calcium and phosphate content.

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.
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. It is difficult to protect against an increasing erosive challenge, no matter what kind of diet is consumed.\textsuperscript{28,29,31-33}

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,\textsuperscript{34,35} 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.\textsuperscript{36}

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.\textsuperscript{37}
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.

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. 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.

**Gastroesophageal Reflex Disorder (GERD)**

Another issue that has a significant impact on dental erosion is gastroesophageal reflex disorder (GERD). Significant increases in severe erosion are seen in the older population, and between 10 to 20% experience gastric acid symptoms. In 2015, over 113 million prescriptions for antacid medications were written, representing over $13 billion in sales. 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. 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. These results demonstrated that by suppressing the gastric acids, the incidence of erosion was reduced; and the progression of dental erosion was effectively managed.

**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. 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.

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).

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.47

The hydroxyapatite of tooth enamel is primarily
composed of phosphate ions (PO₄³⁻) and
calcium ions (Ca²⁺). 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.47

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.48 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 noncavitated lesion can be remineralized
with fluorapatite and have greater
Table 3. Key differences between caries and dental erosion.

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

While dental erosion, like caries, is a mineral process, the erosion process follows a somewhat different pathway.$^{38,50}$ There is little

---

**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.
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. However, one of the currently used sources of fluoride, stannous fluoride (SnF₂) (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 and human in situ erosion clinical studies. 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).

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)
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.

Figure 14. SnF₂ 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, 2012.²⁵

Figure 15. Human enamel specimens mounted into appliances worn for human in situ erosion prevention studies.
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 (Figures 19, Table 4) has been demonstrated in multiple studies.\textsuperscript{51-54}

Reduced progression of erosive lesions has also been observed with stabilized SnF$_2$ toothpaste in situ compared with sodium fluoride toothpastes.\textsuperscript{51-55}

Progression of the Erosive Lesion

The 3 stages in progression of an erosive 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 (Figures 19, Table 4) has been demonstrated in multiple studies.\textsuperscript{51-54}

Reduced progression of erosive lesions has also been observed with stabilized SnF$_2$ toothpaste in situ compared with sodium fluoride toothpastes.\textsuperscript{51-55}

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 \textit{in situ} studies orange juice), and then measuring specimen hardness again after re-immersion in saliva.\textsuperscript{51-55,58,59}

\textbf{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.\textsuperscript{62}

\textbf{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.
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, the tooth starts to

fluoride toothpaste. In a study by Hooper and colleagues, the benefit of stannous fluoride increased over time (Figure 20). As noted earlier, many foods and beverages have a pH below 4.0 and are highly acidic

In a study by West et al (Figure 21), highly significant erosion protection benefits were found when comparing a stabilized SnF₂ dentifrice to a marketed dentifrice containing SMFP as the fluoride active and arginine bicarbonate.
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 surface, which leads to dissolution of the surface layer of the tooth.
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).

There are a variety of analytical methods, models and protocols that can be used to study erosion. Some measure lost mineral 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, SnF₂ dentifrices, in particular stabilized SnF₂ 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.⁵¹⁻⁶⁰

Clinical Strategies to Prevent and Manage Dental Erosion

Pathological tooth wear was rarely seen in ancient civilizations, and the majority of it was
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.\textsuperscript{64-67}

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).

Table 5. Key risk factors influence the rate of progression and the extent of erosive lesions.

<table>
<thead>
<tr>
<th>Key Risk Factors Influencing the Rate of Progression and Extent of Erosive Lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of consuming erosive acid containing beverages</td>
</tr>
<tr>
<td>Duration of erosive acid exposure</td>
</tr>
</tbody>
</table>
Table 5. Key risk factors influence the rate of progression and the extent of erosive lesions (Continued).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>High consumption of acidic fruits and vegetables</td>
<td><img src="image1.png" alt="Image of fruits" /></td>
</tr>
<tr>
<td>Drinking alcohol</td>
<td><img src="image2.png" alt="Image of beverages" /></td>
</tr>
<tr>
<td>The manner in which acidic agents are consumed</td>
<td><img src="image3.png" alt="Image of child drinking" /></td>
</tr>
<tr>
<td>Having acidic drinks at night when saliva flow is low</td>
<td><img src="image4.png" alt="Image of woman drinking" /></td>
</tr>
</tbody>
</table>

Figure 23. Image of young 30-year-old presenting with multiple types of wear.
The Basic Erosive Wear Examination (BEWE)
The BEWE, introduced by Bartlett, Ganss and Lussi in 2008,68 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.

Table 6. BEWE Scores and Criteria.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No ETW</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>1</td>
<td>Initial loss of surface texture</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>2a</td>
<td>Distinct defect: hard tissue loss involving &lt;50% of the surface area</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>3a</td>
<td>Hard tissue loss involving ≥50% of the surface area</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
</tbody>
</table>

* Dentin often involved.

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.
Preventing and Managing Dental Erosion

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.

Table 7. Cumulative BEWE Scores and Management Guidelines.

<table>
<thead>
<tr>
<th>Cumulative Score</th>
<th>General guidelines for management</th>
</tr>
</thead>
</table>
| 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 |

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.
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 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. 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; 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 SnF₂ 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 SnF₂ 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 tooth pastes or mouth rinses, have the potential to slow the progression of ETW. 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 noncaries 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. For those individuals, the recommendations are rather straightforward (Table 9). The first recommendation is to try to minimize the excessive intake of these beverages, 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 will
Table 8. Individually tailored advice for patients.

<table>
<thead>
<tr>
<th>Dietary Considerations for Sharing with Patients.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce intake and frequency of acidic foods and drinks.</td>
</tr>
<tr>
<td>Eat cheese/milk after acid challenges.</td>
</tr>
<tr>
<td>Additional calcium content in food and beverages.</td>
</tr>
<tr>
<td>Drink cold rather than warm beverages (if acidic).</td>
</tr>
<tr>
<td>Rinse with sodium bicarbonate to help increase the pH after dietary acid challenges.</td>
</tr>
<tr>
<td>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.</td>
</tr>
</tbody>
</table>

Table 9. Awareness for patients who ingest excessive amounts of erosive, acid containing beverages.

<table>
<thead>
<tr>
<th>Erosion Awareness for Patients with High Intake of Acidic Beverages.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid excessive use of acid beverages.</td>
</tr>
<tr>
<td>Use a straw.</td>
</tr>
</tbody>
</table>

Avoid excessive use of acid beverages.

Use a straw.
Table 9. Awareness for patients who ingest excessive amounts of erosive, acid containing beverages (Continued).

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Drink acidic beverages in a short period of time.</td>
<td>![ Stopwatch ]</td>
</tr>
<tr>
<td>Rinse with water after drinking to minimize exposure.</td>
<td>![ Woman drinking ]</td>
</tr>
<tr>
<td>Cold beverages are probably better than warm ones.</td>
<td>![ Cola with ice ]</td>
</tr>
<tr>
<td>Wait 1-2 hours after ingesting acidic products before brushing.</td>
<td>![ Hands pointing to 1 and 2 ]</td>
</tr>
</tbody>
</table>
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. 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 SnF₂ 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 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 are able to 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 SnF₂ 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.

Table 10. Key areas of erosion awareness for dental professionals.

<table>
<thead>
<tr>
<th>Erosion Awareness for Professionals.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer trends are creating new dental needs.</td>
</tr>
<tr>
<td>Dental erosion is an emerging trend.</td>
</tr>
<tr>
<td>Maintaining strong, healthy teeth for life begins at the earliest ages.</td>
</tr>
<tr>
<td>Dental erosion is irreversible.</td>
</tr>
</tbody>
</table>
Table 10. Key areas of erosion awareness for dental professionals.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoride provides some protection from erosion, but all fluorides are not equally effective.</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>SnF₂ is recognized as being highly effective in the prevention of dental erosion.</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
</tbody>
</table>
Course Test Preview
To receive Continuing Education credit for this course, you must complete the online test. Please go to: www.dentalcare.ca/en-ca/professional-education/ce-courses/ce517/start-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 erosion 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 acid attacks depends on which of the following factors?
   A. pH
   B. Titratable acidity
   C. Buffer capacity
   D. Contact time on the teeth
   E. All of the above.

6. Preventive habits that reduce the risk of ETW include ______________.
   A. staying hydrated
   B. rinsing with water before brushing
   C. brushing with a stannous fluoride toothpaste
   D. not brushing for at least 1-2 hours after an acid challenge
   E. All of the above.

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** _________.
   A. dental erosion
   B. abfracton
   C. attrition
   D. abrasion
   E. All of the above.

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 erosion 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. None of the above.

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. Citric acid
    B. Phosphoric acid
    C. Tartaric acid
    D. Acetic acid
    E. All of the above.

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
   E. Only 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 a primary causative factor for dental erosion?
   A. S. mutans
   B. Lactobacillus
   C. Sucrose
   D. S. sobrinus
   E. None of the above.
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 erosion 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.
References


About the Authors

**Donald J. White, PhD**

Dr. Donald White is 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, carrying out research on the mechanisms of formation and solubilization of kidney stones. Since 1982, Dr. White's dental research interests include 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 has published extensively, including over 100 peer-reviewed publications, approximately 200 meeting presentations and abstracts, and over 40 global patents.

Email: white.dj.1@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
Nicola West, BDS, FDSRCS, PhD FDS (Rest Dent)

Professor Nicola West is a graduate of the University of Wales College of Medicine (Cardiff). After attaining her fellowship from the Royal College of Surgeons of England, Nicola gained her PhD from the University of Wales (Cardiff) in 1995, on dentine hypersensitivity and tooth surface loss. Nicola gained her chair in Periodontology at Bristol Dental School, where she conducts research at an international level, leading the Clinical Trials Unit and attracting substantial industrial funding. Current research interests include: developing research methodologies, periodontal conditions, bone augmentation and peri-implant lesions, the scientific evaluation of oral health care products, tooth wear, dentine hypersensitivity and tooth whitening. Nicola leads Restorative Dentistry at the Bristol Dental School and is an Honorary Consultant.

Nicola lectures regularly in the national and international forum, is an active member and secretary of the British Society of Periodontology and currently is the regional postgraduate tutor for the British Society of Periodontology in the South West of England and European BSP representative. She is a Fellow of the Higher Education Academy, a UK member of the International Standards Committee and on the advisory board of the British Dental Health Foundation.

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