Managing Dental Erosion: Current Understandings and Future Directions

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Dear Colleagues,

On behalf of Procter & Gamble Oral Health, it is my pleasure to share with you highlights from the American Association for Dental Research symposium, titled ‘Managing Dental Erosion: Current Understandings and Future Directions,’ held March 17, 2016.

While the dental research community has made great strides in preventive dentistry over the past 60 years with breakthroughs such as the introduction of fluoride dentifrices and varnishes, dental erosion has arisen as a major new challenge for clinicians in recent years. First identified approximately 25 years ago, since then the prevalence of dental erosion has increased dramatically in children, adolescents and adults. This is especially of concern since the enamel and dentin loss associated with this multifactorial condition is irreversible.

Fortunately, we’ve recently learned a great deal about dental erosion, its progression and strategies to prevent it. Therefore, we are pleased to share with you the most current learnings on dental erosion which our distinguished panel presented during the symposium.

Please find enclosed synopses of talks by Dr. Noble, Dr. White and Prof. West providing an overview of the current state of diagnosing and managing dental erosion, research methodologies, and clinical perspectives that can help you with treatment planning. I hope you will find this publication informative and of practical benefit for you and your patients.

Sincerely,

J. Leslie Winston, DDS, PhD

J. Leslie Winston, DDS, PhD
Director, Global Oral Care Professional & Scientific Relations and Clinical Operations
Procter & Gamble Oral Health
Dental erosion involves the chemical dissolution of dental hard tissues without bacterial involvement. Research on erosion has expanded in recent years to the broader condition of erosive tooth wear (ETW) which also factors in the effects of attrition and abrasion.

**Erosive Tooth Wear**

ETW begins when exposure to dietary or intrinsic acid causes a drop in salivary pH. The saliva then comes into contact with the acquired pellicle and then the tooth surface, where acidic changes initiate tooth surface loss (TSL). Calcified material is removed producing a softened, demineralized surface layer. This exposes fragile organic material (collagen) that is easily removed, leaving the tooth vulnerable to further TSL through abrasion and attrition, e.g., by brushing or bruxing.

**The Response of Enamel and Dentin to Acid Challenges**

Enamel and dentin are distinctly different with respect to their organic and inorganic composition and therefore react differently to acid challenges (Table 1). In enamel, demineralization of the prisms leaves friable microscopic areas of tooth structure that are gradually broken off in cycles resulting in TSL (Fig. 1). In dentin, there is less calcified material and therefore less bulk loss during demineralization, however greater areas of exposed organic material remain. These collagen fibrils are subject to frictional forces and degradation by proteolytic enzymes including matrix metalloproteinases (MMPs). The result is progressive TSL (Fig. 2). While the effects of an acid challenge on enamel and dentin are different, both are at risk for TSL. Clinically, this makes it highly desirable and beneficial that early intervention occur as soon as erosion is observed.

**Table 1. Content of enamel and dentin**

<table>
<thead>
<tr>
<th></th>
<th>Enamel</th>
<th>Dentin</th>
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<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>

Figures 1 and 2. Erosion of enamel (1) and dentin (2). (Lussi et al, 2011). Images courtesy of Karger.
Patient Age and Risk Factors

While it is accepted that deciduous ETW may foretell future problems in the permanent dentition, studies on the prevalence of ETW in young children are inconclusive. An overall prevalence of 30% has been found in a meta-analysis of studies in teenagers and young adults with at least 1 erosive lesion, and the condition becomes even more prevalent with age. ETW is episodic throughout life and can start in infancy. Different etiologies typically play more of a role at different ages. Figure 3 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 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.

The Basic Erosive Wear Examination (BEWE)

The BEWE, introduced by Bartlett, Ganss and Lussi in 2008, is used to assess the level of erosion. Table 2 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 3).

Table 2. BEWE Scores and Criteria

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>No ETW</td>
</tr>
<tr>
<td>1</td>
<td>Initial loss of surface texture</td>
</tr>
<tr>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Distinct defect; hard tissue loss involving &lt;50% of the surface area</td>
</tr>
<tr>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Hard tissue loss involving ≥50% of the surface area</td>
</tr>
</tbody>
</table>

<sup>a</sup>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.

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 before eating
- Not brushing for at least 1-2 hours after an acid challenge

Conclusions

In conclusion, 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.

Dr. Noble is a Professor at the Arthur A. Dugoni School of Dentistry, University of the Pacific, San Francisco, CA, USA.
Current Methodologies to Assess Dental Erosion

Methodologies used to assess dental erosion fall into 2 groups – those measuring total mineral loss from enamel (and dentin) due to lesion progression, and those measuring the surface properties of 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 swishing/drinking beverages that deliver acid challenges to enamel slabs worn in an appliance. 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. 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.

Surface Layer Measurements

Surface layers can be assessed using in vitro or in situ models. Methods of analysis can include scanning electron microscopy (SEM) (Fig. 1), 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 (Fig. 2). Replica SEMs can be used with in situ research to measure the surfaces of eroded lesions or softened zones of enamel lesions. 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.

“By focusing on lesion progression models, the total microns lost and the ability of a given therapy to protect against erosive progression can be determined.”

Figure 1. SEM showing loss of enamel (a) and, at greater magnification, the softened layer at the advancing front of the lesion (b). (Lussi et al, 2011).
Images courtesy of Karger.
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 rehardening after re-immersion in saliva. Different responses to acid challenges have been observed in surface roughness assessments in studies of different fluorides and the concentration of fluorides.

**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 total microns lost and the ability of a given therapy to protect against erosive progression can be determined. The two methods available to help prevent dental erosion are to protect it by, in effect, ‘galvanizing’ the surface with deposits that are acid-resistant, and to remineralize the surface between acid challenges. It has been possible to demonstrate superior efficacy for stannous fluoride in reducing surface loss when measured in vitro, using microradiography following several cycles of erosive challenges, immersion in saliva, and treatment with fluorides (Figure 3).

Reduced progression of erosive lesions has also been observed with stabilized stannous fluoride toothpaste in situ compared with sodium fluoride toothpaste. In a study by Hooper and colleagues the benefit of stannous fluoride increased over time (Figure 4).

* Significantly different vs all treatments (p<0.05)
In real life, many foods and drinks are below pH4 and are highly acidic (Table 1). This is important when considering the pHs of foods and drinks, and also important to consider when performing erosion testing as different pHs will result in different results. During an acid challenge, the tooth starts to dissolve in an effort to recreate 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 pH2, 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, leading 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).

Conclusions
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.

“Stannous fluoride has been shown to provide unique protection against acids, particularly at a low pH (e.g., orange juice, ~2.6).”

<table>
<thead>
<tr>
<th>Beverage</th>
<th>pH</th>
</tr>
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<tbody>
<tr>
<td>Pure Water</td>
<td>7.0</td>
</tr>
<tr>
<td>Milk</td>
<td>6.6</td>
</tr>
<tr>
<td>Tea</td>
<td>6.2</td>
</tr>
<tr>
<td>Coffee and milk</td>
<td>5.3</td>
</tr>
<tr>
<td>Black coffee</td>
<td>5.0</td>
</tr>
<tr>
<td>Tomato Juice</td>
<td>3.7</td>
</tr>
<tr>
<td>Sprite</td>
<td>3.29</td>
</tr>
<tr>
<td>Diet Pepsi</td>
<td>3.03</td>
</tr>
<tr>
<td>Gatorade</td>
<td>2.92</td>
</tr>
<tr>
<td>Dr. Pepper</td>
<td>2.90</td>
</tr>
<tr>
<td>Fruit Punch</td>
<td>2.82</td>
</tr>
<tr>
<td>Orange Juice (Minute Maid)</td>
<td>2.64</td>
</tr>
<tr>
<td>Coke Classic</td>
<td>2.53</td>
</tr>
<tr>
<td>Reference: Battery Acid</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Sources: University of Ottawa; General Dentistry, March/April 2007; preventdisease.com

**Dr. White is a Victor Mills Society Research Fellow at The Procter & Gamble Company, Mason, OH, USA.**
Clinical Strategies to Prevent and Manage Dental Erosion

Pathological tooth wear was rarely seen in ancient civilizations, and the majority of it was abrasion or attrition. While its prevalence and severity have increased in children and adults, erosive tooth wear (ETW) is a totally preventable condition for most individuals. Progressive ETW can lead to poor esthetics, sensitivity, loss of function, and sometimes loss of self-esteem. (Figure 1)

Early identification and prevention are key, and 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 to implement preventive and treatment measures to preserve tooth structure and to help stop further damage.

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 symptoms, eating disorders; xerostomia; and, whether the patient is a lactovegetarian, taking acidic medications, or occupationally at risk (e.g., wine tasters). A number of factors influence the rate of progression and extent of lesions, and must be considered during the risk assessment. These factors include the frequency, amount and duration of exposure to an erosive challenge; high consumption of carbonated drinks, acidic fruits and vegetables; drinking alcohol; the manner in which acidic agents are consumed, e.g., holding or swishing acidic drinks in the mouth which prolongs contact; and, having acidic drinks at night when salivary flow is low.
Clinical Examination

A full examination and tooth indexing for erosion (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 not occurring at that time). (Figure 2)

Biological Factors

Poor salivary flow impacts clearance of acid and buffering, and therefore delays a return to the resting pH. The saliva also supplies the pellicle, with the evidence showing that the pellicle can 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.

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, to prevent further erosion and manage lesions. If preferred, moderate/severe cases can be referred for treatment. All etiological factors should be assessed.
Oral Hygiene Practices and Home Care

It is recommended that patients with ETW brush for no more than 2 minutes and maximum twice-daily. Normally, manual and powered brushing cause virtually no enamel loss and minimal dentin loss. Based on a recent study using in situ enamel slabs, it took about 2 hours to see early repair following an acid challenge; this suggests that brushing should occur at least 2 hours after an acid challenge.

Patients with erosion can benefit from twice-daily use of stannous fluoride 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. 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. 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. If intrinsic acid erosion is present, the patient should be referred for medical assessment and care. Restorative and bonding materials are only used if absolutely necessary to reduce sensitivity, improve esthetic considerations or restore function. For noncarious cervical lesions, it may be preferable to avoid restorative care, particularly for early lesions. (Figure 3)

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 1 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.
Clinical Strategies to Prevent and Manage Dental Erosion

Conclusions

In conclusion, ETW is multifactorial and its prevalence is increasing, especially in young 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. Stannous fluoride or stannous chloride has been shown to slow the progression of erosive tooth wear. 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.

Table 1. Individually tailored advice

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

Prof. West is an Honorary Consultant in Periodontology, University of Bristol Dental School and Hospital, Bristol, UK.
References


