Pucker Up: The Effects of Sour Candy on Your Patients’ Oral Health  
A review of the dental erosion literature and pH values for popular candies

Although the harmful effects of acidic beverages on teeth have been well established and communicated through a variety of clinical articles and public education pieces, the Minnesota Dental Association’s Public Relations Committee has determined that the new and emerging concern of the erosive effects of sour candy on the dentition should be brought to the attention of dental professionals and the public alike. Furthermore, since the serious irreversible damage caused by erosion is difficult and costly to treat, early detection and the initiation of preventive strategies are paramount to minimizing long-term consequences. The following article should serve as a review of the general topic of erosion, and should provide additional information about the increasing prevalence of erosion and the specific risks of sour candy consumption.

Etiology of Tooth Wear  
Tooth wear is caused by a complex interrelationship between erosion (dissolution of hard tissue by acidic substances), attrition (loss of tooth substance from tooth-to-tooth contact), and abrasion (wear by contact between tooth and another material). It is difficult to assess the relative influence of each of these contributing factors to tooth wear.12,3 However, the location of the defects on teeth can assist in making a differential diagnosis.4

- Abrasion, such as that caused by overly aggressive tooth brushing, results in buccal indentations near the cervical margin or root surface of teeth, usually without any evidence of decay or decalcification.
- Attrition defects are identifiable by matching facets on occluding teeth, fractured cusps and restorations, and relatively similar wear rates of enamel and dentin.
- Erosion from industrial acid exposure typically manifests on the labial surfaces of maxillary incisors.
- Gastroesophageal reflux disease and frequent vomiting cause the loss of lingual enamel on the maxillary incisors and the lingual surfaces of the maxillary premolars and molars.
- Acidic liquids cause preferential erosion of the anterior maxillary and mandibular teeth, and are often accompanied by cervical decalcification and interproximal decay.

- Erosion from acidic solids such as candy manifests mainly on posterior teeth with smooth, glazed enamel which appears to be highly polished, “cupping” of cusp tips on posterior teeth, and the impression of “raised” restorations from a loss of the surrounding enamel (Photos 1–6 on opposite page).

Erosion  
Dental erosion was described as early as 1803 by John Hunter in his text The Natural History of the Human Teeth as “decay of the teeth by denudation”. Hunter specifically differentiated the characteristics of erosion from that of dental decay of bacterial origin.5 Since that time erosion has been defined as the irreversible loss of dental hard tissue due to a chemical process, without any involvement by microorganisms.6 The causative agents are usually acidic substances, whether intrinsic (gastric acid from reflux or repeated vomiting) or extrinsic (consumption...
of acidic foods or beverages, repeated exposure to chlorinated water, and industrial chemical exposure). Although identification of patients with intrinsic sources of acid erosion such as gastroesophageal reflux and those with environmental exposure are critical, this article will focus on the effects of dietary acids on the dentition, and will introduce new information on specific risks with frequent consumption of acidic candy.

The mechanism of tooth erosion has been widely described. When salivary pH levels drop to a critical level, enamel loses calcium by the formation of calcium citrate complexes, causing an etching of the enamel surface. After this superficial decalcification of enamel by acid, the remaining three to five micron layer of demineralized enamel or dentin is more susceptible to the effects of abrasion or attrition.7 The critical pH for enamel dissolution is 5.5. However, due to the modifying effects of the oral cavity, exposure to acidic foods and beverages with pH values below 4 can result in dental erosion.8

There has been increasing concern over the high prevalence of tooth erosion in children, with research activity taking place in Europe, Scandinavia, Australia, and North and South America within the last decade.9,10,11,12,13 England’s 1993 National Survey of Child Dental Health included the evaluation of tooth erosion for the first time.14 Studies of dental erosion show that the prevalence rates in children seem to be increasing.15 In epidemiologic studies prior to 2001, the prevalence of erosion in children had been estimated between 2 and 57%.16,6 In a more recent Australian study (2007), erosion rates in primary teeth were found to be as high as 68%.17

Significant erosion can cause dentin sensitivity and difficulty eating, pulpal inflammation and/or pulpal exposure, progressive enamel microfracture resulting in a loss of occlusal vertical dimension, and cosmetic changes due to the exposure of dentin, making the teeth appear yellow.

Although acid erosion creates significant enamel damage, caries is not frequently seen in eroded teeth until the late stages of the condition, when the exposed dentin is unable to withstand further bacterial acid challenges. Plaque does not typically build up on the highly polished surfaces. The lack of decay in the early stages of erosion can deceive patients into a false sense of “dental health,” which can make any motivation for changes to poor dietary habits difficult.

Interestingly, dental erosion is frequently seen in individuals exhibiting high levels of oral hygiene.18 Toothbrushing immediately following an acid attack can result in increased abrasion of the soft, demineralized surface.19 Similarly, toothbrushing immediately prior to the consumption of acidic foods...
Clinical Feature

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Dietary Acids

Numerous studies have shown the erosive potential of soft drinks, fruit juices, and sports drinks. The degree of enamel dissolution has been shown to be directly related to the acidity of the substance and varies by type of acid. Determinants of acidity include the total amount of acid available (titrable acidity), the amount of acid present in the solution (H+ ion concentration as measured by pH), and the strength of the acid (ease of dissociation as expressed by the acid dissociation constant, pKa). However, the erosive potential of a candy or beverage is a complex interaction of acidity, pH value, phosphate and fluoride levels, the type of acid, and its inherent calcium chelating properties. The in vitro erosive potential is further modified by salivary pH, salivary flow rates, salivary buffering capacity, calcium, phosphate and fluoride levels in saliva, duration of exposure, frequency of exposure, and time of day of exposure. For instance, exposure to acidic foods/beverages just before bedtime has been shown to be the most harmful.

The ability of food acids to chelate calcium is considered to be a major factor in dental erosion. Citric acid is the most erosive component in foods and beverages, because it chelates calcium even at higher pH levels, such as those found in buffered saliva. In fact, it is twice as destructive to dental enamel as hydrochloric or nitric acid. Significant dental erosion has also been shown to result from the use of vitamin C (ascorbic acid) supplements in tablet form. The pH of vitamin C tablets is 1.92, well below the levels considered safe for dental enamel.

Since the destructive effects of dietary acids have been well documented, one might ask why they are used in food products at all. Some of the functions of food acidulants include flavor enhancement and modification, food preservation, pectin modification, food leavening, and the complexation of cation impurities. A list of common dietary acids can be seen in Figure 1.

Sour Candy

Though the destructive potential of acidic beverages and foods has been studied extensively, there should be growing concern over the preponderance of low pH candies marketed toward children and their potential for a different pattern of occlusal enamel erosion, especially on posterior teeth. Dr. John Ruby, a pediatric dentist and associate professor at the University of Alabama at Birmingham School of Dentistry, is convinced that the combination of extremely low pH candies, immature tooth enamel, and a high frequency of ingestion is causing serious harm to children’s teeth.

Dr. Ruby recently tested the pH levels of many popular candies, with startling results. One gram of each candy was dissolved in 5 ml water, then tested with Fisher Scientific pH paper accurate to within 0.1 unit. Results of his testing can be found in Figure 2. Most of the sour and fruity candies had very low pH levels. Some of the more surprising findings from his testing included Warheads Sour Spray liquid — pH 1.6, and Altoids Citrus Sours hard candies — pH 1.9. (As a familiar frame of reference, battery acid has a pH of 1.0.) More importantly, most of the sour fruity candies had lower pH levels than any of the soft drinks previously studied. Citric acid is the common “sour” flavoring agent in these products, and as mentioned previously, is the most erosive dietary acid. The low pH of these candies can also cause localized soft tissue irritation from surface damage to the mucous membranes of the inner cheek and tongue. In fact, many of these candy package labels contain a written warning about potential soft tissue irritation with frequent ingestion.

When different candy flavorings are compared, the citric-acid-related fruit flavors of lemon, cherry, and
grape destroy much more enamel than the near neutral aromatic flavors of cinnamon and mint.46 Some examples of currently popular candies with the potential for erosive damage are the intensely flavored sour chewy candies, powdered candies, sour gels and sprays, and powder-coated gums. In addition to a low pH level, the consistency of a candy substance contributes to the erosive potential of a product as well. For instance, insoluble starchy “gummy” candies, thick sticky gels, and citric acid powders are particularly harmful due to their prolonged clearance times and abrasivity.46

Not only are extremely sour candies prevalent and readily available at grocery and convenience stores, as well as athletic and movie concession stands, the marketing strategy of confection companies directed at very young children should be particularly disturbing to dentists and parents. For example, “Toxic Waste” is a sour hard candy presented in a colorful plastic garbage can. The label offers a challenge to hold the candy in the mouth as long as possible, with a scoring chart measured by the number of seconds tolerated. In addition, the label also refers young consumers to a “cool” website offering games and other activities, as well as advertisements for other candies made by their company. There is also a warning label on the packaging about potential soft tissue irritation with continued use.

Other youth-targeted packaging includes pacifier-shaped suckers, baby bottles filled with citric acid powder, and sour gel squeezed from a tube with a “real baby nipple”. Interestingly, the label for the sour gel with the baby nipple claims the candy has “no refined sugar, less than half the calories of the original and even better tasting. Real fruit juice concentrates make contents equal to 100% juice. A portion of the proceeds is donated.” (Since the manufacturer donates a portion of its proceeds to the American Diabetes Association, the logo for the American Diabetes Association can also be found on the label.) The label also has a warning: “Choking hazard – small parts, not for children under 3 years of age. Avoid getting into eyes. If this occurs, flush eyes with water immediately for 15 minutes. If irritation persists, consult your doctor. Consuming large quantities within a brief time period may cause temporary irritation to sensitive tongues.” …and teeth!

Figure 2. pH values for Sour Candy.*

<table>
<thead>
<tr>
<th>pH at which teeth decalciy</th>
<th>pH</th>
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<tbody>
<tr>
<td>1g candy/5mL water</td>
<td></td>
</tr>
<tr>
<td>Spree®</td>
<td>3.0</td>
</tr>
<tr>
<td>Sweetarts®</td>
<td>3.0</td>
</tr>
<tr>
<td>Big Stuff Pacifer® sucker</td>
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</tr>
<tr>
<td>Sour Gummie Bears®</td>
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<tr>
<td>X-treme Airheads®</td>
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<td>Sour Punch Straws®</td>
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<tr>
<td>Shockers®</td>
<td>2.5</td>
</tr>
<tr>
<td>Skittles®</td>
<td>2.5</td>
</tr>
<tr>
<td>Baby Bottle Pop® powder</td>
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<tr>
<td>Brach’s Gummie Bears®</td>
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<tr>
<td>Sqwiggles Gummie Worms®</td>
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<tr>
<td>Wonka Laffy Taffy®</td>
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<tr>
<td>Starburst®</td>
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<tr>
<td>Sweet Tarts Shock®</td>
<td>2.4</td>
</tr>
<tr>
<td>Lemon Heads®</td>
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<tr>
<td>Mentos® fruit chew</td>
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<tr>
<td>WarHeads® Sour Rips Roll</td>
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<tr>
<td>Lollipop Paint Shop®</td>
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<td>Sour Skittles®</td>
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<td>Airheads® cherry chew</td>
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<td>Wonka Nerds® grape</td>
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<td>Now and Later® cherry chew</td>
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<tr>
<td>Too Tart Extra Sour Goo®</td>
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<tr>
<td>Wonka Pixy Stix® powder</td>
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<tr>
<td>Altoids Mango Sours®</td>
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</tr>
<tr>
<td>Wonka Fun Dip® powder</td>
<td>1.8</td>
</tr>
<tr>
<td>WarHeads Sour Spray®</td>
<td>1.6</td>
</tr>
<tr>
<td>Battery acid</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*pH data generated by John Ruby, Betsy Brown, Brandon Wesley, Stephanie Momeni, and Mike Vann, Department of Pediatric Dentistry, School of Dentistry, The University of Alabama at Birmingham, Birmingham, Alabama.
pH foods and beverages is significant, and the potential for erosive damage to children’s teeth with frequent ingestion of these candies cannot be ignored.

**Diagnosis and Intervention**

**Diagnosis**
Determination of erosion as the specific cause of tooth wear and the subsequent investigation into possible sources of intrinsic or extrinsic acid are the first steps to diagnosis. A simple questionnaire can elicit adequate information to begin to differentiate between the various causes of tooth wear, including erosion, attrition, abrasion, and possibly abfraction (Figure 3). If other causes of tooth wear have been ruled out and acid erosion is suspected, a source of acid must be identified.

Intrinsic acid sources such as gastroesophageal reflux or frequent regurgitation (eating disorders, stress vomiting) require referral to an appropriate medical professional for the patient’s overall health maintenance. Environmental exposure to an acid source requires thoughtful education as to the long term effects of the exposure, efforts to reduce exposure, and appropriate supportive care.

Discovery of a dietary source of acid will require careful questioning and dietary analysis. A five-day food diary has been suggested, and should include three weekdays and two weekend days. This diary should include all medicines and vitamin supplements, as well as the frequency and method of ingestion (i.e., chewables, effervescent liquid, swish and swallow, capsules to be swallowed). Review and interpretation of the diary can be performed by the dentist, with specific attention paid to the frequency and pattern of dietary acid consumption.

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**Figure 3. Erosion Assessment Tool.**

**Dietary History Interview**

Which of these snacks do you like? How often do you eat each type of snack?

*Oranges
Apples
Bananas
*Grapes
Nuts, like peanuts
Potato chips, like Lays
Tortilla chips (nacho cheese etc.), like Doritos
Popcorn
Chocolate candy, like Hershey’s, Reese’s
Caramel candy, like Milky Way
*Jelly beans, like Starburst
*Gummy candy, like Gummy Bears
*Sour gummy candy, like Sour Patch Kids
Chewing gum, like Double Bubble bubble gum
*Lemon flavored candies
Licorice – red or black, like Twizzlers
Sugarfree chewing gum, like Trident, Orbit
*Chewy sour candy, like Skittles
*Powdered sour candy, like Fun Dip
*Hard sour candy, like Ice Breakers, War Heads

*Asterisk designates erosive potential due to acid content.

**Dental Examination**

**Attrition**

Wear facets present?
History of bruxism?
Traumatic occlusion?

**Abrasion**

Buccal and/or cervical defects without decalcification?

**Erosion**

Cervical decalcification or decay? (erosive beverage consumption?)
Loss of surface texture?
Loss of occlusal anatomy?
Cupping of cusp tips – posterior teeth?
Thinning or grooving of incisal edges – anterior teeth?
Monitoring
Ongoing assessment of enamel loss is challenging in a clinical setting. Although comparative intraoral photographs and study models will assist in evaluating long term surface changes, actual quantitative measurements of enamel loss within short term intervals are more difficult to achieve. Detailed clinical notes of any visible changes in tooth anatomy, patient sensitivity, or functional problems are essential in an ongoing assessment of the rate and progression of enamel loss.

Standardization of monitoring techniques is needed. Several indices have been proposed for measuring tooth erosion. However, these indices are more useful for broad-based epidemiological studies of tooth wear, since they fail to localize and quantify actual enamel loss. Salivary tests also need to be developed that can easily be used in clinical practice to assess salivary buffering capacity, flow rate, and composition.

Diet and Hygiene Modifications
The behavior modifications listed in Figure 4 will aid dentists in coaching patients to minimize the risk of erosion. Every attempt should be made to reduce the frequency of consumption of acidic candies, and such foods should be restricted to main meals. For example, a change in the timing of eating sour candy between meals or at bedtime to a mealtime can reduce the severity of the acid attack due to more efficient clearance time and the buffering benefits of saliva. Encourage patients to finish a meal with something neutral or alkaline — cheese, milk, or sugar-free chewable antacid tablets. Chewing sugar-free gum will stimulate saliva flow, providing a natural buffering action. Rubbing bicarbonate-containing toothpaste on the teeth with a fingertip will reduce the acid challenge on the tooth surface. Also, rinsing with water rather than brushing teeth immediately following an acid challenge can reduce demineralization by clearing the acid from the oral cavity, and will prevent inordinate damage by toothbrush abrasion of the fragile enamel surface. Finally, patients should use less abrasive “sensitive” toothpastes or those with bicarbonate as an active ingredient, rather than highly abrasive whitening toothpastes.

Remineralization
Treatment for erosive defects should begin with stabilization of the structural integrity of the tooth surface and the promotion of remineralization. Topical fluoride found in over-the-counter rinses and toothpastes, prescription-strength toothpastes, professionally applied fluoride treatments, and fluoride varnishes will provide reduced enamel solubility and control the symptoms of tooth sensitivity. Oral hygiene products containing amorphous calcium phosphate can enhance fluoride uptake for more efficient remineralization and an increased resistance to further demineralization.

Restoration
The goal of restorative treatment should be to maintain adequate function and esthetics of primary and permanent teeth. Erosion from the chewing or sucking of acidic candy primarily affects the occlusal surfaces of the posterior teeth. Eroded primary teeth should be restored to maintain vertical dimension and mesial-distal width, reduce symptomatic sensitivity, and provide pulpal protection for the maintenance of vitality until exfoliation. Frequently, full-coverage stainless steel crowns are the most appropriate restorative choice for severely eroded posterior primary teeth.

The restoration of eroded permanent teeth requires choosing the least invasive procedure while providing maximum protection from...

**Figure 4. Preventive Measures to Reduce Erosion Risk from Acidic Foods.* **

- Diminish frequency of consumption of acidic foods and beverages.
- Restrict acidic foods to main meals.
- Rinse with water after acid consumption.
- Chew sugar-free gum to stimulate salivary flow.
- Use only a soft toothbrush.
- Use low-abrasive fluoride and bicarbonate-containing toothpaste.
- Avoid toothbrushing immediately following an acid challenge.
- Rinse with a low-concentration, non-acidulated fluoride mouthwash two times daily.
- Apply pH neutral, highly concentrated fluoride gel or toothpaste two times weekly.
- Fluoride varnish to be professionally applied two to four times per year.
- Regular dental visits for ongoing assessment.

*Adapted from Imfeld 1996 and Gandara.
the further loss of tooth structure. Occlusal sealants and resin-bonded restorations in “cupped” cusp tip lesions will provide mechanical protection for the affected surfaces, reduce dentin hypersensitivity, and improve the appearance of severely eroded posterior teeth. Many of these teeth will eventually require full-coverage cast or ceramic restorations to preserve remaining tooth structure and provide adequate esthetics and function. Since full-coverage restorations are costly and involve significant additional loss of tooth structure, it is essential that appropriate early counseling and behavior modification should occur to prevent the need for such invasive treatment.

Summary
Children’s increasing preference for “extreme” sour candy and the industry’s response in the variety of sour candies marketed to children has created a new twist on the dental erosion front. Additional research is needed to test the actual erosive potential of sour candies in vivo and the modifying effects of factors such as salivary buffering capacity. Streamlined measurement tools and standardization of assessments are needed to enable population-based epidemiological studies of the effects of all types of tooth wear. New remineralizing products are reaching the market, but long term efficacy studies on their ability to actually provide protection from erosive demineralization are needed. Lastly, a practical clinical method to measure salivary flow rate, salivary pH, and buffering capacity needs to be developed, so that individual susceptibility factors can be assessed. However, a simple awareness of the potential for increased erosion from extrinsic food sources and an understanding of the mechanism of demineralization are essential to early detection, intervention, and the prevention of invasive restorative procedures.

Author’s Note
This author knows from personal experience as a parent how much these products appeal to children. Dentists and parents need to realize the possible harm to their children’s teeth with repeated exposure to these “treats”. As advocates for our patients and their families, Minnesota dentists need to spread the word about this emerging trend and its potentially devastating effects.

References


