

Diagnosis and Management of Dental Erosion

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Abstract

Early recognition of dental erosion is important to prevent serious irreversible damage to the dentition. This requires awareness of the clinical appearance of erosion compared to other forms of tooth wear. An understanding of the etiologies and risk factors for erosion is also important. These form the basis of a diagnostic protocol and management strategy that addresses the multifactorial nature of tooth wear. The primary dental care team has the expertise and the responsibility to provide this care for their patients with erosion.

Key words: Tooth erosion, tooth wear, review, diagnosis, prevention, GERD, diet, eating disorders.

Introduction

Dental erosion is defined as irreversible loss of dental hard tissue by a chemical process that does not involve bacteria.^{1,2} Dissolution of mineralized tooth structure occurs upon contact with acids that are introduced into the oral cavity from intrinsic (e.g., gastroesophageal reflux, vomiting)

or extrinsic sources (e.g., acidic beverages, citrus fruits). This form of tooth surface loss is part of a larger picture of tooth wear, which also consists of attrition, abrasion, and possibly, abfraction. Table 1 lists the definitions of each of these forms of tooth surface loss or tooth wear.

Table 1. Definitions of Tooth Surface Loss*

| Term | Definition | Clinical Appearance |
|----------------------------------|--|---|
| Erosion (Figures 1-4) | Progressive loss of hard dental tissue by chemical processes not involving bacterial action | <ul style="list-style-type: none"> * Broad concavities within smooth surface enamel * Cupping of occlusal surfaces, (incisal grooving) with dentin exposure * Increased incisal translucency * Wear on non-occluding surfaces * "Raised" amalgam restorations * Clean, non-tarnished appearance of amalgams * Loss of surface characteristics of enamel in young children * Preservation of enamel "cuff" in gingival crevice is common * Hypersensitivity * Pulp exposure in deciduous teeth |
| Attrition (Figure 5) | Loss by wear of surface of tooth or restoration caused by tooth to tooth contact during mastication or parafunction | <ul style="list-style-type: none"> * Matching wear on occluding surfaces * Shiny facets on amalgam contacts * Enamel and dentin wear at the same rate * Possible fracture of cusps or restorations |
| Abrasion (Figure 6) | Loss by wear of dental tissue caused by abrasion by foreign substance (e.g., toothbrush, dentifrice) | <ul style="list-style-type: none"> * Usually located at cervical areas of teeth * Lesions are more wide than deep * Premolars and cuspids are commonly affected |
| Abfraction (Figure 5) | Loss of tooth surface at the cervical areas of teeth caused by tensile and compressive forces during tooth flexure (Studies needed to prove this hypothetical phenomenon) | <ul style="list-style-type: none"> * Affects buccal/labial cervical areas of teeth * Deep, narrow V-shaped notch * Commonly affects single teeth with excursive interferences or eccentric occlusal loads |

* Adapted from: Milosevic, 1983

Figures 1-6 illustrate examples of each type. However, inasmuch as these definitions relate to different causes, it is important to recognize that each of these types of tooth wear rarely occur alone in a given individual. A patient with generalized tooth wear may be diagnosed as being a bruxer or a heavy-handed toothbrusher, without recognition of an erosive component to the problem (Figure 7). This has made epidemiological and clinical research in the area of tooth wear difficult. Likewise, the diagnosis and management of patients with tooth erosion remains a challenging task.



Figure 1. This 14-year-old female exhibits total loss of surface characteristics and polished appearance of enamel on her maxillary incisors. The enamel layer was also very thin.



Figure 2. The fissure sealant in this 14-year-old boy stands "raised" from surrounding eroded occlusal enamel.

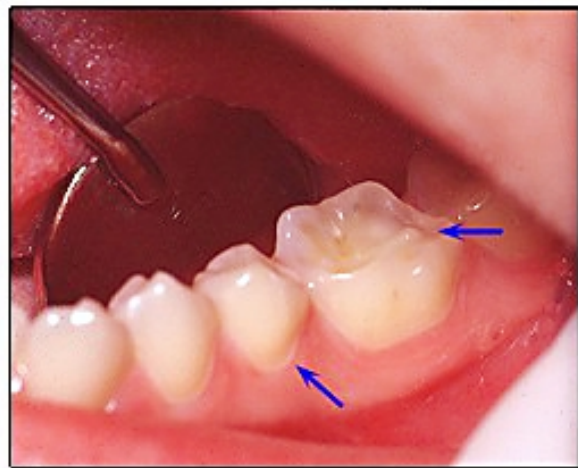


Figure 3. Gastroesophageal reflux disease (GERD) was discovered in this 19 year old boy who exhibited early, generalized erosion (arrow A). Note the preservation of the enamel at the gingival crevice (arrow B).



Figure 4. This 33-year-old male with GERD had severe asymptomatic erosion. Note the amalgams "rising" above the adjacent eroded occlusal surfaces.

Figure 5. This patient's canines and bicuspids have characteristics that can be attributed to both abrasion and abfraction. He had a bruxism habit and a tendency to brush his teeth vigorously. Slight recession of the gingiva and cemento-enamel wear is present in a well-delineated lesion of abrasion on a prominent root (arrow). Note the loss of the top layer of gold foil in tooth #5, suggesting possible cervical flexure forces during bruxing. Occlusal surface loss is characteristic of attrition.



Figure 6. This 42-year old female has a bruxism habit and no other known risk factors for erosion, demonstrating moderate to severe attrition.



Figure 7. Two years of continual consumption of canned citrus drinks in a hot country during Peace Corps service led to this erosion of the cervical areas of the posterior teeth. This 33-year old patient also had a bruxism habit which has contributed to occlusal attrition.



Figure 8. Restoration of eroded teeth in this patient will require crown lengthening procedures and full coverage restorations.



Erosion is often not recognized in its early stages nor are risk factors identified and addressed. Lack of awareness of the multifactorial nature of tooth wear may lead to only partial treatment of the problem (e.g., an occlusal splint). Partial treatment may eventually result in the necessity of complex and expensive restorative care (Figure 8). Since early recognition and initiation of preventive measures can prevent significant damage to the dentition, dental erosion warrants the careful attention of the primary dental care team.

A review of the literature on dental erosion indicates a relatively recent, growing interest in the topic, particularly in Europe. For the first time, England included the evaluation of tooth erosion in its national dental health survey in 1993, indicating the importance of this dental problem.⁴ The aim of this article is to review the etiologies of dental erosion and provide recommendations for diagnosis and management of this problem.

Prevalence

Prevalence studies have used different indices of measurement and often address tooth wear in general and not erosion specifically. In addition, most have been conducted in Europe, therefore, extrapolation of results to the US population must be guarded. However, these studies do give an approximation of the problem in general populations. In a Swiss study, 391 adults underwent dental examinations in their own homes.⁵ In subjects aged between 26 and 30 years, 7.7% had facial erosive lesions into dentin and 29.9% had occlusal tooth wear into dentin. In the 46-50 year old group, 13.2% exhibited facial erosive lesions into dentin and 42.6% had occlusal erosion involving dentin. In a study of 1007 patients in England, an index known as the Tooth Wear Index (TWI) was utilized.^{6,7} This index records tooth wear by number and degree of involved tooth surfaces. It takes into account that a degree of wear is natural and normal in certain age groups. The results indicated that 5.7% of tooth surfaces were worn to an unacceptable degree in the 15-26 year old group. In the 56-65 year old group, 8.2% of the tooth surfaces were unacceptably worn.

Several prevalence studies have been conducted in children. Dental erosion was included in the examination for the first time in the 1993 National Survey of Child Dental Health conducted in the United Kingdom.⁴ In this study, 17,061 children were examined. Over half of the 5 and 6 year olds had erosion, 25% with dentinal involvement of the primary dentition. In the 11+ year age group, almost 25% had erosion, 2% with dentinal involvement in the mixed dentition. In a study of 1035 14-year-old children randomly selected from a Liverpool population, 30% had exposed incisal dentin.⁸ Another 8% had exposed dentin on occlusal or lingual surfaces. Data such as these have caused oral health care providers in the United Kingdom to consider dental erosion as a public health problem, citing high consumption of

acidic beverages as the major etiologic agent.⁹ Figure 9, (Courtesy, Dr. Donald Milton, University of Washington), illustrates erosion in a 5-year-old child caused by frequent consumption of an acidic fruit juice at bedtime.

In a case control study of subjects selected from general practices in Helsinki, five cases of erosion (according to strictly defined criteria) were detected among 100 controls in a random sample from the source population, suggesting a prevalence rate of 5% (95% confidence limits).^{10,11} In another case control study of 15-year-old children in Liverpool, 6 of 54 controls developed tooth wear into dentin during a 12-month period following initial identification as controls.¹²

Figure 9



These studies suggest that the incidence of dental erosion ranges from 5 to 50% in various populations and age groups.

Comparable studies have not been conducted in the United States. One study that surveyed incoming patients to dental schools in Los Angeles and Boston examined 527 patients in the age range of 14 to 80 years old.¹³ Lesions that may have been abrasion rather than erosion were included. Approximately 25% of all teeth surveyed exhibited tooth wear, with a slightly higher rate in the Los Angeles population.

It is clear from a review of existing epidemiological studies that more population-based studies are needed. These studies should clearly delineate erosion, attrition, and abrasion with identification of etiologic factors. Since most of the studies have been conducted in Europe, it is important to also conduct studies in the United States, to determine if there are regional differences related to diet or other etiologic factors of

erosion. The effects of mechanical forces (occlusal attrition, abfraction, cervical abrasion) have garnered much attention in the US. However, recent evidence indicates that erosion may play a significant role in susceptibility to these mechanical forces.¹⁴ Based on informal communications, it is apparent that once a practitioner recognizes erosion and is aware of its etiologies, increasingly more patients are identified who have the problem. Well-designed studies are necessary to determine the true magnitude of the problem.

Causes

Extrinsic Causes

Erosion-producing acids can be either extrinsic or intrinsic in origin. Examples of extrinsic acids, (source is outside of the body), are acidic beverages, foods, medications or environmental acids. The most common of these are dietary acids. Table 2 lists the acidities of common foods. It can be seen that most fruits and fruit juices have

a very low pH (high acidity). Carbonated drinks and sports drinks are also very acidic. Several studies have found that the frequency of consumption of acidic drinks was significantly higher in patients with erosion than without.^{16,17} This finding is of concern, particularly since children and adolescents are the primary consumers of these drinks.^{16,17} This finding is of concern, particularly since children and adolescents are the primary consumers of these drinks.⁹ Marketing is heavily directed toward adolescent age groups. A contemporary example is public school districts contracting with soft drink companies for millions of dollars in exchange for exclusive marketing rights in the schools. Sales quotas accompany these payments and pressure school administrators to encourage students to consume the soft drinks. A recent editorial in the Journal of the American Dental Association brings attention to the potential of this marketing technique to increase dental problems such as erosion and caries in the adolescent population.¹⁸

Table 2 . Acidity of Common Foods and Beverages

(Adapted from: Clark DC, et al. 1990 15)

| Fruits | pH Range | Fruits | pH Range |
|------------------------|----------|----------------------|----------|
| Apples | 2.9-3.5 | Lemons, Limes/Juice | 1.8-2.4 |
| Apricots | 3.5-4.0 | Oranges/Juice | 2.8-4.0 |
| Grapes | 3.3-4.5 | Pineapple/Juice | 3.3-4.1 |
| Peaches | 3.1-4.2 | Blueberries | 3.2-3.6 |
| Pears | 3.4-4.7 | Cherries | 3.2-4.7 |
| Plums | 2.8-4.6 | Strawberries | 3.0-4.2 |
| Grapefruit | 3.0-3.5 | Raspberries | 2.9-3.7 |
| Beverages | pH Range | Beverages | pH Range |
| Cider | 2.9-3.3 | Grapefruit/Juice | 2.9-3.4 |
| Coffee | 2.4-3.3 | 7 Up® | 3.5 |
| Tea (black) | 4.2 | Pepsi® | 2.7 |
| Beers | 4.0-5.0 | Coke® | 2.7 |
| Wines | 2.3-3.8 | Root beer | 3.0 |
| Ginger ale | 2.0-4.0 | Orange Crush® | 2.0-4.0 |
| Condiments | pH Range | Condiments | pH Range |
| Mayonnaise | 3.8-4.0 | Cranberry sauce | 2.3 |
| Vinegar | 2.4-3.4 | Sauerkraut | 3.1-3.7 |
| A-1® Sauce | 3.4 | Relish | 3.0 |
| Mustard | 3.6 | Ketchup | 3.7 |
| Italian salad dressing | 3.3 | Sour Cream | 4.4 |
| Other | pH Range | Other | pH Range |
| Yogurt | 3.8-4.2 | Tomatoes | 3.7-4.7 |
| Pickles | 2.5-3.0 | Vegetables/fermented | 3.9-5.1 |
| Rhubarb | 2.9-3.3 | Fruit jam/jellies | 3.0-4.0 |

Marketing by the soft drink companies is very successful. Retail sales in the US are rapidly increasing and totaled over \$54 billion in 1997, with a consumption rate of 54 gallons of soft drinks per person per year.¹⁹ This is more than twice the rate in the United Kingdom with approximately 20 gallons per person per year. With consumption of acidic drinks identified as a risk factor in erosion, this amount of soft drink consumption will likely lead to an increase in prevalence of erosion.²⁰

The erosive potential of beverages does not depend on pH alone.^{21,22} Other components of beverages, such as calcium, phosphates, and fluoride, may lessen erosive potential. Also, factors such as frequency and method of intake of acidic beverages as well as proximity of toothbrushing after intake may influence susceptibility to erosion. For example, drinking through a straw lessens the contact time of the beverage with the teeth compared to drinking from a cup.²³ Therefore, further investigation is required to clarify the relationship between acidic beverage intake and dental erosion.

Medications that are acidic in nature can also cause erosion via direct contact with the teeth when the medication is chewed or held in the mouth prior to swallowing. Numerous case reports exist describing extensive erosion secondary to chewing Vitamin C preparations or hydrochloric acid supplements.^{24,25,26}

Less common sources of extrinsic erosive acids are related to occupational and recreational expo-

sure. Chronic, hydrochloric, sulfuric and nitric acids have been identified as erosion-causing acid vapors. They are released into the work environment during industrial electrolytic processes.^{3, 27,28} However current work safety standards make this type of erosion very rare. Dental erosion has been reported in swimmers who work out regularly in pools with excessive acidity as well as individuals who are occupational wine-tasters.^{29,30}

Intrinsic Causes

Intrinsic causes, (acid source inside the body), for erosion are gastric acids regurgitated into the esophagus and mouth. Gastric acids, with pH levels that can be less than 1, reach the oral cavity and come in contact with the teeth in conditions such as gastroesophageal reflux and excessive vomiting related to eating disorders.

The association of gastroesophageal reflux disease (GERD) with dental erosion has been established in a number of studies in adults.^{10,31,32,33,34} GERD is a common condition, estimated to affect 7% of the adult population on a daily basis and 36% at least one time a month.³⁵ In this condition gastric contents pass involuntarily into the esophagus and can escape up into the mouth. This is caused by increased abdominal pressure, inappropriate relaxation of the lower esophageal sphincter or increased acid production by the stomach.³⁶ Symptoms of reflux are listed in Table 3. However, GERD can also be "silent" with the patient unaware of his or her condition until dental changes elicit assessment for the condition.³⁴

Table 3. Signs and Symptoms of Gastroesophageal Reflux Disease

| Common Symptoms in Adults | Common Symptoms in Children |
|--|--|
| <ul style="list-style-type: none"> • Acid taste in mouth • Persistent coughing • Vomiting • Sense of lump in the throat • Stomach ache • Sore throat • Hoarseness of voice • Choking spells • Voice change • Excess salivation • Gastric pain on awakening • Halitosis (bad breath) • Belching • Heartburn | <ul style="list-style-type: none"> • Difficulty sleeping • Failure to gain weight • Feeding problems • General irritability • Asthma • Recurrent pneumonia • Anemia • Bronchitis • Laryngitis |

A thorough health history may reveal elements of the treatment of GERD which may assist dental professionals in the correlation of erosion with this systemic condition.

Treatment of GERD usually begins with head elevation (extra pillows during sleep), dietary modification (avoiding spicy or fatty foods) and the use of antacids. If this doesn't manage the problem, several medications can be used. Histamine 2-receptor antagonists such as cimetidine, ranitidine, famotidine, and nizatidine are available over-the-counter as well as in prescription form. Others, such as cisapride, metoclopramide, and omeprazole, are available in prescription form only.

Dental erosion associated with GERD also occurs in children and may be an initial finding in this gastric condition.^{37,38} GERD in children can occur from infancy through the teenage years. Table 3 lists common symptoms of GERD in children, which differ from that of adults. Several studies have reported erosion of primary and permanent teeth in children with GERD, though not to the extent of that in adult patients with GERD.³⁹ This may be in part due to careful avoidance of acidic foods and beverages on the part of the parents. There is a high incidence of GERD in children with cerebral palsy, which coupled with the tendency for bruxism, places them at particular risk for tooth wear.⁴⁰

Chronic, excessive vomiting has long been recognized as causing erosion of the teeth. The patient with an eating disorder such as anorexia nervosa or bulimia is the classic example. The problem was first reported by Hellstrom and Hurst in 1977.^{41,42} Many reports and reviews have been published on the topic since that time.⁴³ Although erosion caused by vomiting typically affects the palatal surfaces of the maxillary teeth, it is also common for individuals with eating disorders to consume large amounts of acidic beverages and fresh fruits. This results in another source of acid exposure, primarily affecting the labial surfaces of the teeth. In addition, treatment for bulimia may include use of antidepressants or other psychoactive medications that may cause salivary hypofunction. Therefore, the cause of erosion cannot be reliably determined from its location.⁴⁴

Erosion associated with alcoholism is caused by frequent vomiting.^{44,45} Other causes of vomiting

that may cause erosion include gastrointestinal disorders such as peptic ulcers or gastritis, pregnancy, drug side effects, diabetes or nervous system disorders.

Saliva as a Modifying factor

Buffering capacity of saliva refers to its ability to resist a change in pH when an acid is added to it. This property is largely due to the bicarbonate content of the saliva which is in turn dependent on salivary flow rate. Bicarbonate concentration also regulates salivary pH. Therefore, there is a relationship between salivary pH, buffering capacity and flow rate, with pH and buffer capacity increasing as flow rate increases.⁴⁸

Normally, when an acid enters the mouth, whether from an intrinsic or extrinsic source, salivary flow rate increases, along with pH and buffer capacity. Within minutes, the acid is neutralized and cleared from the oral cavity and the pH returns to normal. Patients with erosion were found to have lower salivary buffer capacity when compared with controls in several studies.^{31,32,45,49} In other studies, low whole salivary flow rates in patients with erosion were determined to be the major difference.^{20,49,50} Therefore, salivary function is an important factor in the etiology of erosion. Since many common medications and diseases can lower salivary flow rate, it is important to assess these salivary characteristics when evaluating a patient with erosion.

Risk Factors

Given the numerous possible etiologies of erosion, it is important clinically to assess which risk factors a patient may have. Table 4 lists risk factors that have been determined by various studies. In a study conducted in Finland in which 106 erosion cases (defined by strict criteria) were compared with 100 randomly selected controls, the results indicated that when citrus fruits were consumed more than twice a day, this was associated with an erosion risk 37 times greater than in those who consume citrus fruits less frequently.²⁰ Consumption of sports drinks weekly or soft drinks daily increased the erosion risk by 4 times, compared to those who did not consume these beverage types. Vomiting once a week or more, symptoms of gastroesophageal reflux and a low unstimulated whole salivary flow rate (<0.1 mL/min) were also significant risk factors. Presently, there are no longitudinal studies of

Table 4. Risk Factors for Dental Erosion

(Adapted from Jarvinen, 1991²⁰)

| Risk Factors | |
|---|--|
| Citrus fruits intake (more than twice daily) | Sports drinks intake (weekly or more often) |
| Soft drinks consumed (4-6 or more per week) | Apple vinegar intake (weekly or more often) |
| Eating disorder | Vomiting (weekly or more often) |
| Bruxism habit | Excessive attrition |
| Whole saliva unstimulated flow rate (≤ 0.1 mL/min) | Symptoms or history of gastroesophageal reflux disease |

patients with erosion. However, two recent studies raise the possibility of an inherent susceptibility to erosion. In a study of 14-year old children, horizontal wear of the maxillary anterior teeth predicted the continuing wear of these teeth at 18 years of age.⁵¹ In a similar longitudinal study of 223 orthodontically treated cases, orthodontic casts obtained during childhood years were compared with adult records.⁵² Statistical analysis indicated that tooth wear could be predicted in the adult stage from wear observed on the deciduous teeth. Although the authors considered bruxism as the possible common etiologic mechanism, the scoring system for tooth wear was very similar to that of erosion, raising the question that erosive factors could have been the etiologic mechanism for tooth wear. It is important to keep in mind when interpreting results of these studies that factors yet to be identified may modify the susceptibility a given individual has for erosion. These factors may include characteristics of saliva, tooth enamel constitution, and microenvironments within the oral cavity related to fluid/food bolus movement.

Patient Assessment

Given the current state of knowledge of causes of erosion and keeping in mind the frequent concurrence of attrition and abrasion, a protocol for assessment and management of patients who present with tooth surface loss is presented in Table 5.

Medical History

Initial evaluation begins with a thorough medical history review, including a listing of all prescription and non-prescription medications and supplements. Items that are relevant to the problem of erosion include medications that may cause salivary hypofunction and those used to treat GERD. The reader is referred to excellent articles that address this cause of decreased salivary flow rate.^{53,54} Acidic medications or supplements such as Vitamin C and the method of ingestion should be noted.

Table 5. Diagnostic Protocol for Dental Erosion

| I. Obtain historical data. Check for following items: | |
|---|--|
| Medical History <ul style="list-style-type: none"> • Excessive vomiting, rumination • Eating disorder • Gastroesophageal reflux disease • Symptoms of reflux (Table 3) • Frequent use of antacids • Alcoholism • Autoimmune disease (Sjogren's) • Radiation tx of head and neck • Oral dryness, eye dryness • Medications that cause salivary hypofunction • Medications that are acidic | Dental History <ul style="list-style-type: none"> • History of bruxism (grinding or clenching) <ul style="list-style-type: none"> -Grinding bruxism sounds during sleep noted by bed partner? -Morning masticatory muscle fatigue or pain? • Use of occlusal guard |
| Dietary History <ul style="list-style-type: none"> • Acidic food and beverage frequency • Method of ingestion (swish, swallow?) | Oral Hygiene Methods <ul style="list-style-type: none"> • Toothbrushing method and frequency • Type of dentifrice (abrasive?) • Use of mouthrinses • Use of topical fluorides |
| Occupational/Recreational History <ul style="list-style-type: none"> • Regular swimmer? • Wine-tasting? • Environmental work hazards? | |
| II. Perform physical assessment. Observe for following features: | |
| Head and Neck Examination <ul style="list-style-type: none"> • Tender muscles (bruxism?) • Masseteric muscle hypertrophy (bruxism?) • Enlarged parotid glands (autoimmune disease, anorexia, alcoholism) • Facial signs of alcoholism: <ul style="list-style-type: none"> -Flushing, puffiness on face -Spider angiomas on skin | Intra-oral Examination <ul style="list-style-type: none"> • Signs of salivary hypofunction: <ul style="list-style-type: none"> -Mucosal inflammation -Mucosal dryness -Unable to express saliva from gland ducts • Shiny facets or wear on restorations (bruxism?) • Location and degree of tooth wear (document with photos, models, radiographs) |
| General Survey <ul style="list-style-type: none"> • Underweight (anorexia) | Salivary function assessment <ul style="list-style-type: none"> • Flow rate • pH, buffer capacity (in research) |

Figure 10

Diseases that cause salivary hypofunction are also important to note.⁵⁵ Sjogren's syndrome is an autoimmune condition in which chronic inflammation of the salivary and tear glands cause dry mouth and eyes. A history of radiation therapy of the head and neck also leads to non-reversible oral dryness. Lack of mechanical clearance and buffering of acids by saliva can increase the risk of erosion regardless of the source of the acid. In addition, a patient may use acidic beverages in efforts to stimulate residual salivary flow and keep the mouth moist. Together with diminished salivary flow, this compounds the risk of erosion. Figure 10 illustrates attempts of the dentist to repair erosion in a patient with Sjogren's syndrome. The patient sipped an acidic sugarless drink all day to maintain oral moisture until he was made aware of the cause of his erosion. Arrow



“A” points to a restored surface placed to protect the dentin. Arrow “B” points to exposed dentin.

Frequent use of over-the-counter medications such as antacids may indicate the presence of gastroesophageal reflux disease (GERD). The patient may not realize there is any relevance to

the teeth and fail to mention it. However, as described previously, there is a significant association between the presence of GERD and erosion. Therefore, it is important to ask about the presence of symptoms (Table 3) and note if the patient is taking medications for this condition.

Figure 11



Several important medical history items which require sensitivity to elicit are frequency of vomiting associated with eating disorders or alcoholism.⁵⁶ An uncommon habit that bears mentioning for sake of completeness is rumination. Rumination is the chewing of regurgitated gastric contents before re-swallowing. This habit has been described in highly motivated professionals as a response to stress as well as institutionalized individuals with learning difficulties.^{57,58}

Dietary Questionnaire

Many studies investigating risk factors for erosion have identified higher intake of acidic foods and beverages in individuals with erosion compared to those without. Therefore, a dietary questionnaire focused on acidic foods and beverages should be completed by the patient. In addition to frequency of intake, the manner of ingestion should be included. Acidic beverages which are sipped over a long period of time or held in the mouth for extended periods can cause considerable damage to the teeth.

Figure 12 illustrates erosion of the left side mandibular molars of a 20-year old female who habitually enjoyed holding a cola beverage in this area for several minutes before swallowing.

Figure 12



Other parts of the dentition were not affected. It has been suggested that using a straw to drink acidic beverages may minimize possible erosive effects by allowing the bulk of the fluid to bypass the teeth.²³

It is important to include intake of alcohol as many alcoholic beverages such as wine and beer are acidic. Beverages used in mixed drinks are also generally very acidic. High levels of consumption may also indicate alcoholism, which increases the risk of frequent vomiting and GERD.

Dental History

A history of jaw parafunction and bruxism may increase the possibility of attrition in addition to erosion. Figure 11 shows erosion (arrow) secondary to day-long sipping of a cola drink in a patient who presented initially with a complaint of muscle pain related to bruxism. Her acidic oral environment most likely contributed to the extensive occlusal attrition. To help determine if a bruxism habit exists, ask whether the patient makes grinding noises during sleep and whether he or she experiences morning jaw muscle tenderness or fatigue.⁵⁹

To determine the extent that toothbrushing habits may be contributing to tooth wear, information about frequency and method of brushing, as well as the type of dentifrice used, should be obtained. Brushing immediately after the consumption of acidic foods, or vomiting may also accelerate tooth structure loss because the enamel is softened by the presence of acid. As enamel thins from erosion, the teeth may appear more yellow as the underlying dentin shows through. A patient may attempt to whiten the teeth by more rigorous brushing with a toothpaste that is more abrasive (e.g., toothpaste advertised to smokers), compounding the erosion with abrasion. Fluoride use should be assessed.

Occupational/recreational history

Current industrial safety standards have lessened the occurrence of erosion associated with environmental hazards in the work area. However, individuals who swim frequently in chlorinated pools should obtain information about pool water acidity. The character of the patient's work environment, or hobbies such as wine-tasting should be included in the historical inquiry.

Head and Neck/Oral Examination

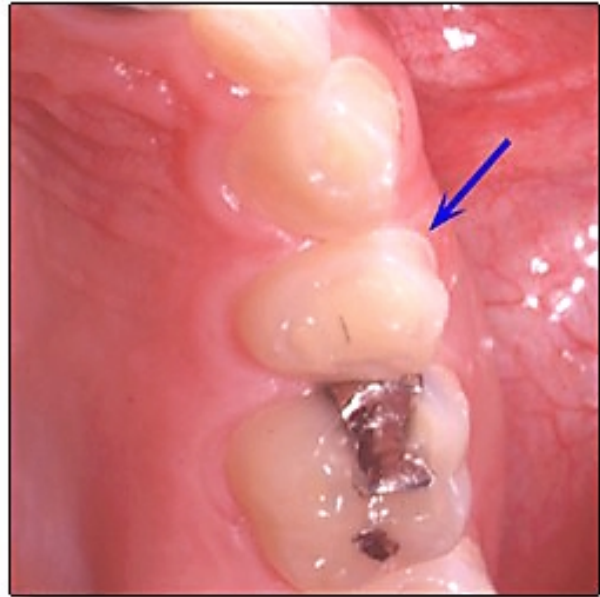
Upon conducting a head and neck exam, note any signs of tenderness or hypertrophy of the masticatory muscles which may indicate a bruxism habit.⁵⁹ Signs of chronic alcoholism such as enlarged superficial capillaries in the facial skin (spider angiomas) or frequent breath odor of alcohol should be noted. Enlargement of the parotid salivary glands may be a sign of Sjogren's syndrome, chronic alcoholism, or bulimia.

Mucosal signs of decreased salivary flow include inflammation, dryness and inability to express saliva from gland orifices.⁶⁰ However, although decreased salivary flow has been associated with erosion in some studies, it is not uncommon to find normal flow rates in patients with erosion. Therefore, the oral mucosa is likely to appear normal. However, a prominent linea alba of the buccal mucosa, and lateral tongue indentations may indicate a bruxism habit.

Caries is generally an uncommon occurrence in patients with erosion. Additionally, teeth with erosion do not tend to retain plaque. A frequent finding is preservation of a cuff of enamel within the gingival crevice. Figure 13 illustrates this phenomenon, which may be due to protection of the enamel by the gingival crevicular fluid.

The location, degree and type of tooth surface loss should be documented by careful description.

Figure 13



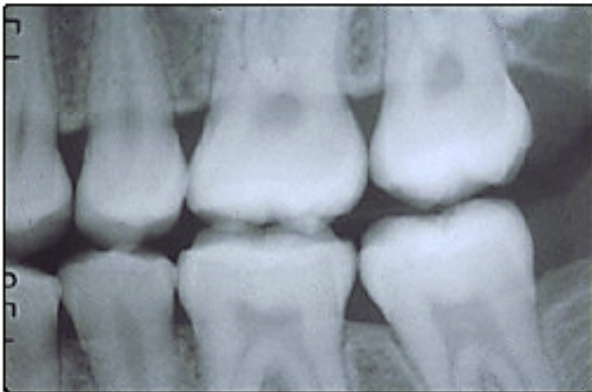
Several indices of measurement have been described in the scientific literature and are important for epidemiological studies.^{2,6} However, in managing a patient in a practice over a number of years, it may be easier and more accurate to document tooth wear by taking impressions and making models of the patient's teeth (Figure 14). The models can then be retrieved later for visual comparison with current models at various times of reevaluation. Intraoral photos are also useful for documentation of erosion and monitoring of success of preventive measures. Comparison of teeth in radiographs may also reveal loss of tooth surface. Figure 15 is a radiograph of the same patient depicted in Figure 1. Taken at age 14, the radiograph shows the thinned enamel of #19 and #20 compared to #18, which erupted more recently and had less exposure time to acids. The only possible risk factor for erosion was a very low salivary buffer capacity.

Figure 14
Study casts of eroded teeth



Courtesy, Dr. Douglas Ramsay, University of Washington)

Figure 15
Radiograph of eroded teeth



Salivary Function Assessment

The subjective sensation of oral dryness may not reflect actual salivary gland function.⁶¹ Therefore, it is important to assess salivary flow rate when evaluating patients with erosion. This measurement can be conducted in the typical dental office by quantifying the amount of saliva collected over several minutes, expressed in milliliters per minute, both under non-stimulated and stimulated conditions (e.g., gum-chewing).⁶⁰

Although low buffer capacity of saliva has been associated with erosion, the utility of measuring salivary pH and buffer capacity in these patients has not yet been validated but remains an important area for further investigation. A commonly used method for measuring buffer capacity in European studies (Dentobuff, Orion Diagnostica) is available for research purposes only in the US.

Management of Erosion

Treatment of the Etiology

Identification of the etiology is important as a first step in management of erosion. If excessive dietary intake of acidic foods or beverages is discovered, patient education and counseling are important. If the patient has symptoms of GERD, then he/she should be referred to a medical doctor for complete evaluation and institution of therapy if indicated. A patient with salivary hypofunction may benefit with the use of sugarless chewing gum or mints to increase residual salivary flow. The use of oral pilocarpine (Salagen) may be beneficial in patients with dry mouth caused by Sjogren's syndrome or post therapeutic head and neck radiation. A patient suspected of an eating disorder should be referred to a medical doctor for evaluation.

In some cases, an etiologic agent is not identifiable. In other cases, the etiologic agent may be difficult to control, such as the problem of alcoholism. However, regardless of the cause, it is important to follow preventive measures to prevent the progress of erosion.⁶² There are several preventive measures that can be taken to control tooth erosion. These are listed in Table 6. Patient education is of paramount importance. Much of erosion prevention depends on the compliance of the patient with dietary modification, use of topical fluorides, use of occlusal splint, etc.

Table 6. Protocol for the Prevention of Progression of Erosion

| Preventive Measures: |
|---|
| <p>1. Diminish the frequency and severity of the acid challenge.</p> <ul style="list-style-type: none"> * Decrease amount and frequency of acidic foods or drinks. * Acidic drinks should be drunk quickly rather than sipped. The use of a straw would reduce the erosive potential of soft drinks. * If undiagnosed or poorly controlled gastroesophageal reflux is suspected, refer to a physician. * In the case of bulimia, a physician or psychologist referral is appropriate. * A patient with alcoholism should be assisted in seeking treatment in rehabilitation programs. |
| <p>2. Enhance the defense mechanisms of the body (increase salivary flow and pellicle formation).</p> <ul style="list-style-type: none"> * Saliva provides buffering capacity that resists acid attacks. This buffering capacity increases with salivary flow rate. * Saliva is also supersaturated with calcium and phosphorus, which inhibits demineralization of tooth structure. * Stimulation of salivary flow by use of a sugarless lozenge, candy or gum is recommended |
| <p>3. Enhance acid resistance, remineralization and rehardening of the tooth surfaces.</p> <ul style="list-style-type: none"> * Have the patient use daily topical fluoride at home. * Apply fluoride in the office 2-4 times a year. A fluoride varnish is recommended. |
| <p>4. Improve chemical protection.</p> <ul style="list-style-type: none"> * Neutralize acids in the mouth by dissolving sugar-free antacid tablets 5 times a day, particularly after an intrinsic or extrinsic acid challenge. * Dietary components such as hard cheese (provides calcium and phosphate) can be held in the mouth after acidic challenge (e.g., hold cheese in mouth for a few minutes after eating a fruit salad).⁶³ |
| <p>5. Decrease abrasive forces.</p> <ul style="list-style-type: none"> * Use soft toothbrushes and dentifrices low in abrasiveness in a gentle manner. * Do not brush teeth immediately after an acidic challenge to the mouth, as the teeth will abrade easily. * Rinsing with water is better than brushing immediately after an acidic challenge. |
| <p>6. Provide mechanical protection.</p> <ul style="list-style-type: none"> * Consider application of composites and direct bonding where appropriate to protect exposed dentin. * Construction of an occlusal guard is recommended if a bruxism habit is present. |
| <p>7. Monitor stability</p> <ul style="list-style-type: none"> * Use casts or photos to document tooth wear status. * Regular recall examinations should be done to review diet, oral hygiene methods, compliance with medications, topical fluoride and splint usage. |

Restorative Treatment

Depending on the degree of tooth wear, restorative treatment can range from placement of bonded composites in a few isolated areas of erosion, to full mouth reconstruction in the case of the devastated dentition. Description of the specific techniques of restoration is beyond the scope of

this article. Regardless of the type of restorative therapy provided, prevention of the progression of erosion should be the basis of management of the patient with erosion. This will increase the likelihood of successful, long-term outcomes of the restorative treatment.

Summary

Early recognition of erosion is important to successfully manage and prevent disease progression. A brief review of etiologic factors has been presented and recommendations made for evaluation and management of the patient with erosion. These include a complete problem and medical history aimed at identifying possible risk factors, including those for other forms of tooth wear. This is important to determine the etiology and help direct treatment. Specialized testing such

as GERD assessment may be appropriate and necessitate referral. Whether or not an etiology can be determined, a prevention protocol for prevention of progression of erosion should be initiated. The patient should be monitored at regular intervals by photographs or impressions of the dentition to determine compliance and success of treatment. The primary dental care team is in the ideal position to provide this care for their patients with dental erosion and other forms of tooth wear.

References

1. Pindborg JJ. In: Pathology of Dental Hard Tissues. Copenhagen: Munksgaard 1970:312-321.
2. Eccles JD. Dental Erosion and Diet. *J Dent* 1974;2:153-159.
3. Milosevic A. Toothwear: aetiology and presentation. *Dent Update* 1998;25:6-11.
4. O'Brien M. Children's Dental Health in the United Kingdom 1993. Office of Population Censuses and Surveys 1994. Her Majesty's Stationery Office, London.
5. Lussi A, Schaffner M, Hotz P, et al. Dental erosion in a population of Swiss adults. *Community Dent Oral Epidemiol* 1991;19:286-290.
6. Smith BG, Knight JK. An index for measuring the wear of teeth. *Br Dent J* 1984; 156:435-438.
7. Smith BG, Robb ND. The prevalence of tooth wear in 1007 dental patients. *J Oral Rehabil* 1996;23:232-239.
8. Milosevic A, Young PJ and Lennon MA. The prevalence of tooth wear in 14-year-old school children in Liverpool. *Community Dent Health* 1994;11:83-86.
9. Shaw L, Smith A. Erosion in Children: An increasing clinical problem? *Dental Update* 1994; 21:103-106.
10. Jarvinen V, Meurman JH, Hyvarinen H, et al. Dental erosion and upper gastrointestinal disorders. *Oral Surg Oral Med Oral Pathol* 1988; 65:298-303.
11. Nunn JH. Prevalence of dental erosion and the implications for oral health. *J Oral Sci* 1996;104:156-161.
12. Milosevic A, Lennon MA and Fear SC. Risk factors associated with tooth wear in teenagers: A Case Control Study. *Community Dent Health* 1997;14:143-147.
13. Xhonga FA, Valdmanis S. Geographical comparisons of the incidence of dental erosions: a two centre study. *J Oral Rehab* 1983;10(3):269-77.
14. Khan F, Young WG, Daley TJ. Dental erosion and bruxism. A tooth wear analysis from southeast Queensland. *Aust Dent J* 1998;43:117-127.
15. Clark DC, Woo G, Silver JG, et al. The influence of frequent ingestion of acids in the diet on treatment for dentin sensitivity. *J Can Dent Assoc* 1990;56:1101-1103.
16. Asher F, Read MJF. Early enamel erosion in children associated with excessive consumption of citric acid. *Br Dent J* 1987;162:384-387.
17. Millward A, Shaw L, Smith AJ, et al. The distribution and severity of tooth wear and the relationship between erosion and dietary constituents in a group of children. *Int J Paediatr Dent* 1994;4:151-157.
18. Meskin LH. Outrageous. *J Am Dent Assoc* 1999;130:308-312.
19. National Soft Drink Association Website
20. Jarvinen VK, Rytomaa II, and Heinonen OP. Risk factors in dental erosion. *J Dent Res* 1991;70:942-947.
21. Grenby TH, Phillips A, Desai T, et al. Laboratory studies of the dental properties of soft drinks. *Br J Nutr* 1989;62:451-464.
22. Grenby TH. Lessening dental erosion potential by product modification. *Eur J Oral Sci* 1996;104:221-228.
23. Edwards M, Ashwood RA, Littlewood SJ, et al. A videofluoroscopic comparison of straw and cup drinking: the potential influence on dental erosion. *Br Dent J* 1998; 185:244-249.
24. Giunta JL. Dental erosion resulting from chewable vitamin C tablets. *JADA* 1983;107:253-256.
25. Maron FS. Enamel erosion resulting from hydrochloric acid tablets. *JADA* 1996;127:781-784.
26. Hays GL, Bullock Q, Lazzari EP, et al. Salivary pH while dissolving vitamin C-containing tablets. *Am J Dent* 1992;5:269-271.
27. Skogedal O, Sillness J, Tangerud T, et al. Pilot study on dental erosion in a Norwegian electrolytic zinc factory. *Comm Dent Oral Epidemiol* 1977;5:248-251.
28. Tuominen M, Tuominen R, Ranta K, et al. Association between acid fumes in the work environment and dental erosion. *Scand J Work Environ Health* 1989;15:335-338.

29. Centerwall BS, Armstrong CW, Funkhouser LS, et al. Erosion of dental enamel among swimmers at a gas-chlorinated swimming pool. *Am J Epidemiol* 1986;123:641-647.
30. Ferguson MM, Dunbar RJ, Smith JA, et al. Enamel erosion related to winemaking. *Occup Med* 1996;46:159-62.
31. Meurman JF, Toskala J, Nuutinen P, et al. Oral and dental manifestations in gastroesophageal reflux disease. *Oral Surg Oral Med Oral Pathol* 1994; 78:583-589.
32. Gudmundsson K, Kristleifsson G, Theodors A, et al. Tooth erosion, gastroesophageal reflux, and salivary buffer capacity. *Oral Surg Oral Med Oral Pathol* 1995;79:185-189.
33. Schroeder PL, Filler SJ, Ramirez B, et al. Dental erosion and acid reflux disease. *Ann Intern Med* 1995;122:809-815.
34. Bartlett DW, Evans DF, Anggiansah A, et al. A study of the association between gastro-oesophageal reflux and palatal dental erosion. *Br Dent J* 1996; 181:125-131.
35. Nebel OT, Fornes, MF and Castell DO. Symptomatic gastroesophageal reflux: incidence and precipitating factors. *Am J Dig Dis* 1976; 21:953-956.
36. Gaynor MD. Otolaryngologic manifestations of gastroesophageal reflux. *Am J Gast* 1991;86:801-808.
37. Taylor G, Taylor S, Abrams R, et al. Dental erosion associated with asymptomatic gastroesophageal reflux. *ASDC J Dent Child* 1992;59:182-185.
38. Dodds AP, King D. Gastroesophageal reflux and dental erosion: case report. *Pediatr Dent* 1997;19:409-412.
39. Aine L, Baer M, Markku M. Dental erosions caused by gastroesophageal reflux disease in children. *J Dent Child* 1993;3:210-214.
40. Shaw L, Weatherill S, Smith A. Tooth wear in children; an investigation of etiologic factors in children with cerebral palsy and gastroesophageal reflux. *ASDC J Dent Child* 1998;65:484-439.
41. Hellstrom I. Oral complications in anorexia nervosa. *Scand J Dent Res* 1977;85:71-86.
42. Hurst PS, Lacey JH, Crisp AH. Teeth, vomiting and diet: a study of anorexia nervosa patients. *Postgrad Med J* 1977;53:298-305.
43. Milosevic A. Eating disorders and the dentist. *Brit Dent J* 1999;186:109-113.
44. Jarvinen V, Rytomaa I, Meurmann JH. Location of dental erosion in a referred population. *Caries Res* 1992;26:391-396.
45. Bevenius J, L'Estrange P. Chairside evaluation of salivary parameters in patients with tooth surface loss: a pilot study. *Aust Dent J* 1990;35:219-221.
46. Simmons MS, Thompson DC. Dental erosion secondary to ethanol-induced emesis. *Oral Surg Oral Med Oral Path* 1987;64:731-733.
47. Smith BGN, Robb ND. Dental erosion in patients with chronic alcoholism. *J Dent* 1987;17:219-221.
48. Birkhed D and Heintze U. Salivary Secretion Rate, Buffer Capacity, and pH. In: Tenovou JO, ed. *Human Saliva: Clinical Chemistry and Microbiology, Volume 1*. Boca Raton: CRC Press; 1989:25-73.
49. Johansson A, Kiliaridis S, Haraldson T, Omar R, Carlsson GE. Covariation of some factors associated with occlusal tooth wear in selected high-wear sample. *Scand J Dent Res* 1993;101:398-406.
50. Woltgens J, Vingerling P, de Blicck-Hogervorst JMA, et al. Enamel Erosion and Saliva. *Clin Prev Dent* 1985;7: 8-10.
51. Nystrom M, Kononen M, Alauusua S, et al. Development of horizontal tooth wear in maxillary anterior teeth from five to eighteen years of age. *J Dent Rs* 1990;69:1765-1770.
52. Knight DJ, Leroux BG, Zhu C, et al. A longitudinal study of tooth wear in orthodontically treated patients. *Am J Orthod Dentofac Orthop* 1997;112:194-202.
53. Smith RG, Burtner AP. Oral side-effects of the most frequently prescribed drugs. *Spec Care Dentist* 1994; 14:96-102.
54. Sreebny LM. A reference guide to drugs and dry mouth- 2nd edition. *Gerodontology* 1997;14:33-47.
55. Mandel ID. Sialochemistry in diseases and clinical situations affecting salivary glands. *Crit Rev Clin Lab Sci* 1980;12:321-366.
56. Kidd EA, Smith BG. Tooth histories: a sensitive issue. *Dent Update* 1993;20:174-178.
57. Gilmour AG, Beckett HA. The voluntary reflux phenomenon. *Br Dent J* 1993;175:368-372.
58. Bartlett DW, Smith BGN. The dental impact of eating disorders. *Dent Update* 1994;21:404-407.
59. Lavigne GJ, Rompre PH, Montplaisir JY. Sleep bruxism: validity of clinical research diagnostic criteria in a controlled polysomnographic study. *J Dent Res* 1996; 75:546-552.
60. Navazesh M, Christensen C, and Brightman V. Clinical criteria for the diagnosis of salivary gland hypofunction. *J Dent Res* 1992;71:1363-1369.
61. Fox PC, van der Ven PF, Sonies BC, et al. Xerostomia: evaluation of a symptom with increasing significance. *J Am Dent Assoc* 1985; 110:519-525.
62. Imfeld, T. Prevention of progression of dental erosion by professional and individual prophylactic measures. *Eur J Oral Sci* 1996; 104: 215-220.
63. Gedalia I, Braunstein E, Lewinstein I, et al. Fluoride and hard cheese exposure on etched enamel in neck-irradiated patients in situ. *J Dent* 1996; 24:365-368.

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