IN BRIEF

- The causes of tooth wear may be intrinsic or extrinsic and are usually chemical (acidic) or mechanical (frictional) in nature.
- Several factors may combine to cause tooth wear in any individual patient.
- Tooth wear, especially tooth erosion is an increasingly recognised clinical problem.
- Modifying the composition of soft drinks is an important concept in prevention that should be further developed.
- Although a conservative approach to restorative treatment seems justified, longitudinal clinical evaluations are needed.

3

VERIFIABLE CPD PAPER

Prevention. Part 3: Prevention of tooth wear

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Non-carious destruction of teeth has been observed in archaeological material from various parts of the world and clearly pre-dates the first appearance of dental caries. Attrition, abrasion and erosion are also described in the classic text of Pindborg[1] on the pathology of the dental hard tissues. Whilst the dental profession, at least in affluent parts of the world, was engaged in diagnosing, treating and later preventing dental caries these other causes of tooth destruction were largely ignored.

PREVENTION

1. Smoking cessation advice
2. Dietary advice
3. **Prevention of tooth wear**
4. Toothbrushing advice
5. Patients requiring osseointegrated oral implant treatment
6. Older dentate patient
7. Professionally applied topical fluorides for caries prevention
8. Pit and fissure sealants in preventing caries in the permanent dentition of children

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Striking clinical examples of attrition were seen in patients with bruxism. Abrasion was attributed to tooth brushing or occasionally to habits such as chewing on a pipe stem. Erosion was seen in patients with symptoms of gastric reflux[2,3] and later was recognised in patients with anorexia[4] or bulimia[5] or in patients with unusual dietary habits.[6] In some cases erosion has been recognised as an occupational disease where workers have been exposed to acidic fumes, for example in factories making batteries.[7,8] It is also recognised among wine-tasters[9] (Type 4,5).

Over the past 10–15 years, however, there has been a steady increase in reports of erosion seen especially in young adults, adolescents[10] (Fig. 1) and young children as noted particularly in the UK National survey.[11] The cause of this erosion has been largely linked to the high consumption of soft drinks, both fruit juice and carbonated drinks, by these age groups. This link has been made largely in Europe and the problem has received little attention in the literature coming from the USA[12,13] (Type 4).

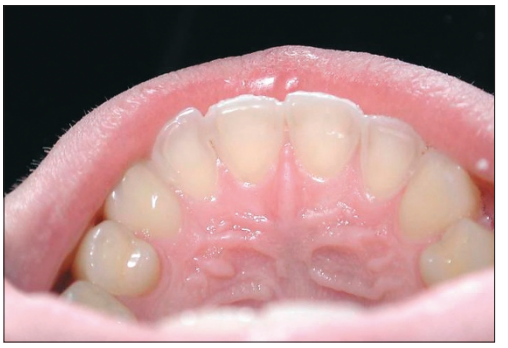

Fig. 1 Clinical appearance of erosion on the palatal surface of upper incisor teeth in a patient who consumed daily large quantities of carbonated drinks

DIAGNOSIS AND SEVERITY

In order to prevent or reduce the non-carious destruction of tooth substance it is important first of all to:

1. Recognise that the problem is present
2. Grade its severity
3. Diagnose the likely cause or causes and,
4. Monitor progress of the disease in order to assess the success, if any, of preventive measures.

Collectively the various manifestations of non-carious tooth destruction have been termed tooth wear which conveniently allows for discussion of the problem without the obligation to meet all the precise definitions of each manifestation of the condition. Indeed many patients present with tooth wear that is the result of several aetiological factors that do not fall conveniently into one or other of the categories, attrition, abrasion or erosion (Figs 2,3). Careful observation by the dentist or hygienist at a routine visit is still probably the most usual way for tooth wear to be seen. Tooth

Fig. 2 Erosion on the palatal surface of maxillary incisor teeth, note the 'step' in the dentine caused by abrasion in the dentine by the lower incisors

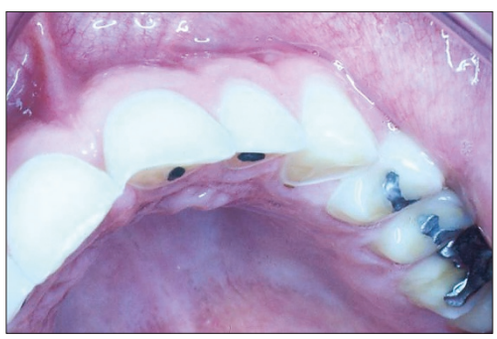

Fig. 3 Appearance of erosion in maxillary teeth of a teenage patient who consumed large quantities of carbonated drinks and also had a history of gastric reflux. Note the remains of incisal enamel at the gingival margin and erosion of the palatal cusps of the premolar and molar teeth

wear may be present in patients with gastro-oesophageal reflux disease (Figs 4-6), bulimia and anorexia. It is clearly important for doctors and nurses treating patients with these conditions to be aware of the possibility that the patient also has severe tooth wear.

Once diagnosed, it is important that the location of the tooth wear and its severity be recorded. Several indices are available for this, ranging from the relatively simple index of Eccles and Jenkins[14] (Type 4), that was designed for recording the severity of erosion, through the more detailed modification of the same index proposed by Lussi[15] and the detailed Tooth Wear Index of Smith and Knight[16] (Type 4) that is somewhat cumbersome to use at first but gives a good record of wear on each tooth surface enabling monitoring of the progression of tooth wear. It is also not limited to tooth erosion as are most of the other indices. In epidemiological studies the degree of inter- and intra- examiner variability in detecting and scoring tooth wear may be as great a problem as determining the aetiology. Careful calibration of examiners is helpful. For an individual practitioner, clinical experience may not be sufficient for his or her purposes and even a brief examination and second opinion by a colleague may help confirm the diagnosis, its severity and possible aetiology. Study casts are clearly a useful record of the status at any particular time and can be used to monitor progression of tooth wear. Computer-aided analysis of direct imaging of the affected teeth, impressions or study models are being developed but have not yet reached the stage of being a useful clinical tool for general practice [17,18] (Type 4). For routine clinical purposes, tooth wear should be recorded separately for the anterior and posterior teeth. The clinician should note the tooth wear as being: in enamel only; into dentine; or severely affecting the tooth or series of teeth for example as seen frequently in erosion of the palatal surfaces of four maxillary incisor teeth.

Frictional forces and acids cause tooth wear, singly or in combination. Although the presence of tooth wear may be obvious to the clinician, determining its cause can be difficult

AETIOLOGY AND HISTORY TAKING

Following diagnosis of the presence of tooth wear, the clinician should attempt to determine the main aetiological factors. This will partly be based on clinical experience: examination of wear-facets; restorations that stand proud of the surrounding enamel; loss of vertical dimension; and the pattern of tooth wear. For example, a pattern of tooth wear involving the palatal surface of maxillary molar teeth, buccal surfaces of mandibular molars and palatal wear of maxillary anterior teeth is strongly suggestive of erosion caused by gastric acid. Nevertheless, other factors may play a part in the overall clinical picture. If there is a loss of occlusal enamel in the molar teeth the consequent loss of vertical dimension may produce 'step-like' wear facets palatally on the maxillary anterior teeth (Fig. 2), especially if the enamel has also been lost on these surfaces (Figs 5-6). The patient may also show other signs of more severe bruxism. A particular diagnostic problem is the condition sometimes termed abfraction where cervical erosions occur in several teeth thought by some authors[19,20] (Type 4) to be caused by lateral occlusal forces acting in an acidic environment. These conditions may be found in a patient with bruxism who also has gastric reflux or who consumes acidic foods or beverages frequently.

Fig. 4 Clinical appearance of maxillary anterior teeth in a patient with gastric reflux disease — note the enamel at the palatal gingival margin and the approximal surfaces

Good history taking is essential to determine the consumption of carbonated drinks, fruit juices and other dietary factors that may contribute to the observed tooth wear.[15] Medication, particularly frequent use of asthma inhalers containing steroid[21,22] (Type4) or effervescent medications,[23] should be checked as they may contribute to tooth erosion. Habits, including tooth brushing, that could contribute to tooth

Fig. 5 Clinical appearance of maxillary posterior teeth in a patient with erosion and gastro-oesophageal reflux disease. The erosion is largely confined to the palatal aspects of these teeth

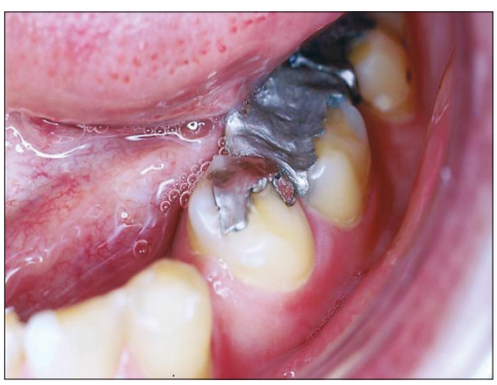

Fig. 6 Clinical appearance of mandibular posterior teeth in a patient with erosion and gastro-oesophageal reflux disease. The erosion is largely confined to the buccal aspects of these teeth

wear should be investigated with careful questions. It is important not to indicate that any blame for the clinical findings is being placed on the patient, otherwise a false history will be obtained. This is especially true when there are financial implications for the patient, for example the possibility of discretionary payments for necessary dental treatment, should the tooth wear be deemed not to be the 'fault' of the patient. The possibility of gastro-oesophageal reflux should be considered, not only bulimia and anorexia that patients are understandably reluctant to admit to, but also other possible causes of reflux including hiatus hernia.[24] It may be necessary for the dentist to refer the patient to a gastroenterologist for investigations including gastroscopy and 24-hour monitoring of oesophageal pH that is the 'gold standard' for diagnosis of gastro-oesophageal reflux disease.[25] Prompt diagnosis of reflux will in most cases lead to medication or possibly surgery to reduce reflux that will, in turn, remove the erosive challenge to the teeth (Type 4,5).

Tests of salivary function, particularly measuring salivary buffer capacity, may reveal contributing factors to tooth wear. There is no doubt that saliva plays an important role in the protection of enamel from erosion by acid, both by supplying the components of the acquired pellicle that coat the enamel surface and by promoting remineralisation of the enamel surface following acid attack. Clinical studies of the relationship between erosion and low salivary buffer capacity have, however, given conflicting results (Type 4).[25–27] Careful history taking and clinical examination bearing in mind a possible mixed aetiology of tooth wear and including questions on diet, reflux disease and functional habits should help the practitioner arrive at a correct diagnosis.

PREVENTION OF TOOTH WEAR

Preventing tooth wear is not the same as preventing caries. Dental caries is regarded as a disease that will affect most people in the world to some extent during their lifetime. This inevitability of caries developing, at least historically, was a strong stimulus to the development and promotion of preventive measures, especially those based on fluoride use and oral hygiene. Developed countries have experienced, by and large, higher prevalences of caries than less developed countries and their need for preventive measures has, therefore, been greater. Well-structured prevention programmes based on fluoride, organised dental examinations and regular recall and even financially subsidised treatments have become available that not only protect non-diseased teeth but also reduce the cariogenic challenge by removing the diseased tissue.

Tooth wear is a different and, in many ways, more difficult preventive problem. It has been regarded, until recently, as a problem for individual patients rather than being community based. With the high prevalences particularly of tooth erosion recorded in some surveys[11,28] (Type 4), it is arguable that this type of tooth wear at least has now achieved the status of a community-wide dental problem in several countries. Undoubtedly tooth wear that can be attributed to a coarse diet, to rituals such as filing down teeth and also to environmental factors can all be found in developing countries. Prevention of tooth wear in these circumstances calls for cultural and economic changes that lie outside the scope of this review.

Although tooth wear is increasingly recognised to be a problem, it is difficult to predict which individuals will be affected and true prevention is therefore difficult to achieve. Much that can now be done is aimed at limiting further tooth wear in individuals already found to be affected by this condition. Population-based strategies of prevention, such as by widespread modification of the composition of soft drinks and educational campaigns to increase awareness of the causes of tooth wear may be possible but it is not likely that they will meet with the widespread acceptance that preventive strategies for caries have achieved. This is in part due to the age group perceived to be most at risk of developing erosion, teenagers and young adults, being rather resistant to the messages of health educators, at least when the message relates to reducing the consumption of erosive drinks that

Although tooth wear is now a community-wide problem, population-based preventive strategies will probably be less effective than for dental caries

are so much a part of the lifestyle of this age group. More can possibly be done with an at-risk strategy aimed at specific individuals with early signs of tooth wear or with known risk factors for tooth wear present, such as those taking medicines known to be erosive and patients with bulimia. For such a strategy to work collaboration between the dentist and other healthcare professionals is important.

PREVENTIVE STRATEGIES

Strategies for preventing tooth wear are largely based on the individual. Abrasion and attrition are disorders that are individual-based. Erosion has certain features, including its prevalence and relationship to diet, that make the disease problem somewhat similar to that of caries. Few, if any, population-based strategies that have been so successful in caries prevention have, however, been shown to have an effect on erosion. The perceived increase in the prevalence of tooth erosion has produced an upsurge of research into possible ways of preventing erosion whereas other forms of tooth wear have received less attention.

Fluoride

Fluoride is the mainstay of caries prevention and it was, therefore, natural for fluoride to be considered as a possible vehicle for preventing tooth erosion. In fact the literature contains conflicting reports about the benefits of fluoride in this respect. A number of animal and *in vitro* studies suggest that adding fluoride to potentially erosive drinks will reduce the erosive potential of these drinks.[29–31] Addition of fluoride to sports drinks has also been shown to reduce the erosive potential of these, otherwise highly erosive, drinks.[32] Amaechi *et al.*,[33] have shown that xylitol and fluoride have an additive effect in reducing the erosive potential of orange juice in *in vitro* studies. Larsen,[34] however, showed that the protective effect against erosion of fluoride added to soft drinks was minimal. Clearly some more research is required in this area to resolve these differences, perhaps through the development of agreed test systems to evaluate erosive potential. It is known that tooth brushing shortly after drinking an erosive beverage causes an increase in tooth wear. Topical fluoride appears to protect against this subsequent tooth wear following acid challenge.[35–37] This is especially helpful in reducing dentine wear in previously eroded teeth.[38] Fluoride, therefore, appears to have only a limited protective effect against erosive challenge *in vivo* (Type 4).

Modifying drinks to make them less erosive is still the most promising and realistic preventive measure against tooth erosion

Drink modification

Drink modification has been developing in recent years with varying success.[30] Addition of calcium lactate to Coca Cola® has been shown to reduce the erosive potential of this most international of erosive beverages[39] but this research does not appear to have been taken up by the manufacturer. Rather the reverse trend is seen with the marketing of drinks with added citric acid to drinks such as Pepsi Cola® and to several diet preparations of carbonated drinks. This increases the erosive potential of these drinks, at least when measured *in vitro*.[40] A successful attempt to reduce the erosive potential of soft drinks by the addition of calcium citrate-malate was reviewed by Grenby[30] but a later *in vivo* investigation by Rugg-Gunn *et al.*[41] found no difference in the amount of erosion seen in enamel slabs treated with plain or modified orange drinks. One of the potentially most important steps in soft drink modification has been the development and subsequent marketing of Ribena Tooth Kind.[42–44] This low pH blackcurrant drink has been modified with the addition of calcium and has been shown in *in situ* and *in vitro* studies to be less erosive than blackcurrant drinks without added calcium and also less erosive than orange juice. Considering the increasing prevalence of tooth erosion, especially in young children and teenagers and the strong association between consumption of acidic drinks and tooth erosion, it still seems logical to continue the development of drinks with low erosive potential. Drink modification has considerable potential in combating erosion but clinical trials are needed.

Diet modification is a difficult area in which to achieve successful disease prevention as experience from dental caries has shown. Nevertheless the strong links between dietary factors and tooth wear make it sensible for the dental team to at least try to get patients with tooth wear to modify their diet. Patients with tooth wear thought to be linked to dietary acids should be closely questioned about their dietary habits and modifications, suggested including reducing the frequency of consumption of these foods limiting consumption of fruit and fruit juices to mealtimes. Consuming hard cheese or milk products after drinking an erosive beverage may promote re-hardening of the enamel[45,46] (Type 4). This is probably also a useful method of neutralising acid in the mouth after a bout of reflux or vomiting but patient compliance is perhaps questionable. Chewing-gum containing carbamide (urea) has been shown to raise salivary pH rapidly[47] (Type 4). This may, therefore, reduce the erosive effect of acid in the mouth.

The pattern of drinking erosive beverages is thought to contribute to tooth erosion[48] (Type 4) especially when cola-type drinks are swished around the mouth before swallowing. Drinking through a straw has been shown to reduce the potential for tooth erosion from acidic drinks[49] (Type 4), especially on the palatal surfaces of the maxillary incisors that are most commonly affected in patients with erosion.

Abrasion caused by diet or tothbrushing is greater if the teeth have been recently exposed to dietary or gastric acid. It has been shown by Attin *et al.*[50] that resistance to this abrasion develops in the mouth but that at least 60 min should elapse after an acid challenge to the teeth before brushing. This is probably of particular significance for patients who have frequent

episodes of vomiting but it is also sensible for dentists to advise their patients not to brush shortly after consuming carbonated drinks. Similarly, mouthrinses with a low pH should not be recommended for prolonged use nor as pre-brushing rinses.[51] Remineralizing toothpaste (Enamelon™) has been shown to increase the hardness of acid-treated teeth significantly more than conventional fluoride toothpastes in *in vitro* studies.[52]

Saliva and pellicle are important factors in protection of tooth substance against acid attack. Amaechi *et al.*[33] and Johansson *et al.*[47] have shown that erosion is usually found in areas of the dental arches that are lacking in pellicle. Increasing salivary flow and hence accumulation of pellicle will, therefore, probably offer protection against erosion. Data from clinical trials are lacking, however, although Hall *et al.*[53] (Type 4) have demonstrated this protective effect of salivary pellicle in an *in-situ* model system. Increasing salivary flow and, consequently, buffer capacity should increase protection against erosion and promote remineralization. Sugar-free chewing gum and even fluoride-containing or carbamide-containing gum should be advised, particularly for adolescents who may be least willing to limit their consumption of acidic beverages. A number of preparations intended to promote salivation are available for patients including those with dry mouth symptoms who may not be willing to chew gum. Profylin™ (Prophylactor AB, Sweden) and Xerodent™ (Dumex-Alpharma, Denmark) lozenges are examples of such topical preparations and Xerodent™ has the added advantage of containing fluoride.

Gastric reflux

Reflux disease and vomiting are important causes of tooth erosion. Recognition of the erosion and presumptive diagnosis by the dentist should lead to appropriate referral for further investigation. Most often this will be to a gastroenterologist for gastroscopy and for 24-hour measurements of oesophageal pH. Medication to reduce gastric reflux and acid production includes drugs such as over-the-counter antacids or prescription drugs such as omeprazolum (Losec®) and ranitidinum (Asyran®). Should hiatus hernia be diagnosed then surgical intervention may be necessary. Diagnosis and treatment of the underlying condition is obviously a pre-requisite to stopping the progression of the tooth wear. In many cases of tooth wear associated with gastric disturbance, both attrition and erosion are seen. Because many individuals with erosion are young males, in our clinical experience at least, they are in the age group that is known to consume a lot of acidic drink but this is also the age group that is active in sport and training and may, for example experience gastric reflux as a consequence (Holbrook *et al.* unpublished findings, Type 4). Diagnosis of the tooth wear may be clear but determining the aetiological factors involved may, however, be difficult.[54] Should the dentist believe that the patient may have bulimia then referral to a psychiatrist may be indicated. This is often difficult and depends to a great extent on the rapport and trust that the dentist has built up with the patient. At the very least the dentist should convey his suspicion to the patient's general medical practitioner. Careful monitoring of the progress of the tooth wear over time, for example with study casts, is helpful both for the dentist and as an aid to increase patient cooperation. The use of fluoride and antacid medications as well as the protective effect of cheese should be emphasised and careful instruction on tooth brushing technique to minimise abrasion should be given (Type 5).[55]

Lifestyle changes

Lifestyle changes are particularly difficult to achieve, especially in the age groups that are frequently found to have tooth wear. Drinking carbonated beverages with a straw; eating a piece of cheese shortly afterwards; and taking antacids,[56] xylitol gum or xylitol-fluoride-containing lozenges[57] after exercise are not activities that fit in particularly well with the lifestyle of young people. Nevertheless the dental profession has the responsibility to inform patients of the problem and its consequences. The success of fluoride in preventing dental caries in populations that continue to consume sugar at high levels is not likely to be repeated with tooth erosion. Indeed the rise in awareness of tooth erosion, in Europe at least, has occurred as caries levels have rapidly declined. Whether or not modification of acidic drinks to make them less erosive will prove possible or even acceptable to manufacturers and public alike remains to be seen. Considerable financial sums are at stake for the industry and it seems unlikely that these will be risked without public demand or legislation.

Restorative procedures

Restorative treatment of teeth affected by tooth wear is very expensive and not always covered by health services, even in Europe. There is also still a need for long-term studies on tooth wear, particularly into how erosion and related tooth wear progresses in young people. This makes authoritative recommendations on restorative measures impossible until further research has been completed. Various non-or minimally-invasive procedures have been tried in order to prevent further tooth wear but clearly extensive crown and bridge work is sometimes required. Lambrechts *et al.*[58] have reviewed the various therapeutic approaches and point out that the durability of crown and bridgework is only 15–20 years which should be borne in mind in the light of the age group frequently presenting in the dental surgery with tooth wear. Conservative approaches that may also offer a degree of protection/prevention against further wear are therefore urgently sought as are restorative techniques that do not involve further destruction of remaining tooth substance. Dentine-

Tooth wear may be an indication of underlying reflux disease or bulimia. Collaboration between medical and dental practitioners is important in treating such cases

Restorative procedures that do not involve yet more destruction of tooth substance should be attempted. More research in this area is needed

bonding agents have been shown to be effective in reducing sensitivity and offering protection against further dissolution of erosive lesions[59,60] (Type 3). These should be applied and the patient monitored before any final decision is taken on restorative measures.[55]

Prevention of attrition and abrasion is not usually considered until the patient actually has signs of the problem. Diagnosis is usually more straightforward than with erosion except in cases where attrition or abrasion are superimposed on erosion when diagnosis can become problematical. Patients with bruxism may well need occlusal splints, at least to use at night, and restorative treatment is frequently necessary. Correction of tooth brushing technique and the use of less abrasive toothpaste should help reduce abrasion and habits that may lead to abrasion should be controlled. As with tooth erosion it is helpful to make study casts and to monitor progression of the tooth wear.

CONCLUSION

A considerable increase in tooth wear has been observed in recent years. This is predominantly erosion though often complicated by other forms of tooth wear. Careful diagnosis and monitoring of progress are important and the underlying aetiological factors should be corrected wherever possible. The aetiology of tooth wear is often complex but individualised prevention can usually only be initiated once the disease has started. This is largely aimed at limiting progression of tooth wear in the affected individual. Population-based strategies are largely inappropriate in preventing tooth wear although modification of erosive drinks, medicines and foods may prove to be an acceptable future strategy for manufacturer and customer alike. Careful monitoring of patients following diagnosis of tooth wear, removal of causative factors and relatively simple dental treatments may enable the patient to avoid extensive restorative procedures.

1. Pindborg J J. *Pathology of the dental hard tissues.* Copenhagen: Munksgaard 1970.
2. Järvinen V, Meurman J H, Hyvärnen H, Rytömaa I, Murtomaa H. Dental erosion and upper gastrointestinal disorders. *Oral Surg Oral Med Oral Pathol* 1988; **65;** 298-303.
3. Meurman J, Toskala J, Nuutinen P, Klemetti E. Oral and dental manifestations in gastroesophageal reflux disease. *Oral Surg Oral Med Oral Pathol* 1994; **78:** 583-589.
4. Hellström I. Anorexia nervosa-odontologiska problem. *Swed Dent J* 1974; **67:** 253-269.
5. Trygstad O. Bulimi-et liv uten kontroll. *Nord Med* 1986; **101:** 72-77.
6. Linkosalo E, Markanen S. Dental erosions in relation to lactovegetarian diet. *Scand J Dent Res* 1989; **93:** 436-441.
7. Petersen P E, Gormsen C. Oral conditions among German battery factory workers. *Community Dent Oral Epidemiol* 1991; **19:** 104-106.
8. Tuominen M, Tuominen R. Dental erosion and associated factors among factory workers exposed to inorganic acid fumes. *Proc Finn Dent Soc* 1991; **87:** 359-364.
9. Gray A, Ferguson M M, Wall J G. Wine tasting and dental erosion. Case report. *Aust Dent J* 1998; **43:** 32-34.
10. Lussi A, Schaffner M, Hotz P, Sutter P. Dental erosion in a population of Swiss adults. *Community Dent Oral Epidemiol* 1991; **19:** 286-290.
11. Downer M C. The 1993 national survey of children's dental health. *Br Dent J* 1995; **178:** 407-412.
12. Bartlett D, Phillips K, Smith B. A difference in perspective — the North American and European interpretations of tooth wear. *Int J Prosthodont* 1999; **12:** 401-408.
13. Deery C, Wagner M L, Longbottom C, Simon R, Nugent Z J. The prevalence of dental erosion in a United States and a United Kingdom sample of adolescents. *Pediatr Dent* 2000; **22:** 505-510.
14. Eccles J D, Jenkins W G. Dental erosion and diet. *J Dent* 1974; **2:** 153-159.
15. Lussi A. Dental erosion : clinical diagnosis and history taking. *Eur J Oral Sci* 1996; **104:** 191-198.
16. Smith B G, Knight J K. An index for measuring the wear of teeth. *Br Dent J* 1984; **156:** 435-438.
17. Hall A F, Sadler J P, Strang R, de Josselin de Jong E, Foye R H, Creanor S L. Application of transverse microradiography for measurement of mineral loss by acid erosion. *Adv Dent Res* 1997; **11:** 420-425.
18. Azzopardi A, Bartlett D W, Watson T F, Smith B G. A literature review of the techniques to measure tooth wear and erosion *Eur J Prosthodont Restor Dent* 2000; **8:** 93-97.
19. Grippo J O, Simring M. Dental 'erosion' revisited. *J Am Dent Assoc* 1995; **126:** 619-630.
20. Rees J S. A review of the biomechanics of abfraction. *Eur J Prosthodont Restor Dent* 2000; **8:** 139-144.
21. Al-Dlaigan Y H, Shaw L, Smith A J. Is there a relationship between asthma and dental erosion? A case control study. *Int J Paediatr Dent* 2002; **12:** 189-200.
22. O'Sullivan E A, Curzon M E. Drug treatments for asthma may cause erosive tooth damage. *Br Med J* 1998; **317:** 820.
23. Nunn J H, Ng S K, Sharkey I, Coulthard M. The dental implications of chronic use of acidic medicines in medically compromised children. *Pharm World Sci* 2001; **23:** 118-119.
24. Scheutzel P. Etiology of dental erosion-intrinsic factors. *Eur J Oral Sci* 1996; **104:** 178-190.
25. Gudmundsson K, Kristleifsson G, Theodors A, Holbrook P. Tooth erosion, gastroesophageal reflux and salivary buffer capacity. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1995; **79:** 185-189.
26. 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.
27. Wöltgens J, Vingerling P, de Blieck-Hogervorst, Bervoets D. Enamel erosion and saliva. *Clin Prev Dent* 1985; **7:** 8-10.
28. Milosevic A, Young PJ, Lennon M A. The prevalence of tooth wear in 14-year-old school children in Liverpool. *Community Dent Hlth* 1993; **11:** 83-86.
29. Holloway P J, Mellanby M, Stewart R J C. Fruit drinks and tooth erosion. *Br Dent J* 1958; **104:** 305-309.
30. Grenby T H. Lessening dental erosive potential by product modification. *Eur J Oral Sci* 1996; **104:** 221-228.
31. Ganss C, Klimek J, Schaffer U, Spall T. Effectiveness of two fluoridation measures on erosion progression in human enamel and dentine *in vitro*. *Caries Res* 2001; **35:** 325-330.
32. Sorvari R, Kiviranta I, Luoma H. Erosive effect of a sport drink mixture with and without addition of fluoride and magnesium on the molar teeth of rats. *Scand J Dent Res* 1988; **96:** 226-231.
33. Amaechi B T, Higham S M, Edgar W M, Milosevic A. Thickness of acquired salivary pellicle as a determinant of the sites of dental erosion. *J Dent Res* 1999; **78:** 1821-1828.
34. Larsen M J. Prevention by means of fluoride of enamel erosions as caused by soft drinks and orange juice. *Caries Res* 2001; **35:** 229-234.
35. Sorvari R, Meurman J H, Alakuijala P, Frank R M. Effect of fluoride varnish and solution on enamel erosion *in vitro*. *Caries Res* 1994; **28:** 227-232.
36. Bartlett D W, Smith B G, Wilson R F. Comparison of the effect of fluoride and non-fluoride toothpaste on tooth wear in vitro and the influence of enamel fluoride concentration and hardness of enamel. *Br Dent J* 1994; **176:** 346-348.
37. Attin T, Deifuss H, Hellwig E. Influence of acidified fluoride gel on abrasion resistance of eroded enamel. *Caries Res* 1999; **33:** 135-139.
38. Attin T, Zirkel C, Hellwig E. Brushing abrasion of eroded dentin after application of sodium fluoride solutions. *Caries Res* 1998; **32:** 344-350.
39. Beiraghi S, Atkins S, Rosen S, Wilson S, Odom J, Beck M. Effect of calcium lactate in erosion and *S.mutans* in rats when added to Coca-Cola. *Pediatr Dent* 1989; **11:** 312-315.
40. Jensdottir T. *Dental erosion and beverages-clinical and laboratory investigation.* Thesis. Reykjavik: University of Iceland 2002;pp33-44 (ISBN 9979-9525-0-4)
41. Rugg-Gunn A J, Maguire A, Gordon P H, McCabe J F, Stephenson G. Comparison of erosion of dental enamel by

four drinks using an intra-oral appliance. *Caries Res* 1998; **32:** 337-343.
42. Hughes J A, West N X, Parker D M, Newcombe R G, Addy M. Development and evaluation of a low erosive blackcurrant juice drink *in vitro* and *in situ*. 1. Comparison with orange juice. *J Dent* 1999a; **27:** 285-289.
43. Hughes J A, West N X, Parker D M, Newcombe R G, Addy M. Development and evaluation of a low erosive blackcurrant juice drink. 3. Final drink and concentrate, formulae comparisons in situ and overview of the concept. *J Dent* 1999b; **27:** 354-350.
44. West N X, Hughes J A, Parker D M, Newcombe R G, Addy M. Development and evaluation of a low erosive blackcurrant juice drink. 2. Comparison with a conventional blackcurrant juice drink and orange juice. *J Dent* 1999; **27:** 341-344.
45. Gedalia I, Dakuar A, Shapira L, Lewinstein I, Goultschin J, Rahmim E. Enamel softening with Coca-cola and rehardening with milk or saliva. *Am J Dent* 1991; **4:** 120-122.
46. Gedalia I, Davidov I, Lewinstein I Shapira L. Effect of hard cheese exposure with and without fluoride prerinse on the rehardening of softened human enamel. *Caries Res* 1992; **26:** 290-292.
47. Imfeld T, Birkhed D, Lingström P. Effect of urea in sugar-free chewing gums on pH recovery in human dental plaque evaluated with three different methods. *Caries Res* 1995; **29:** 172-180.
48. Johansson A-K, Lingström P, Birkhed D. Comparison of factors potentially related to the occurrence of dental erosion in high- and low- erosion groups. *Eur J Oral Sci* 2002; **110:** 204-211.
49. Edwards M, Ashwood R A, Littlewood S J, Brocklebank L M, Fung D E. A videofluoroscopic comparison of straw and cup drinking: the potential influence on dental erosion. *Br Dent J* 1998; **185:** 244-249.
50. Attin T, Knofel S, Buchalla W, Tutuncu R. *In situ* evaluation of different remineralization periods to decrease brushing abrasion of demineralised enamel. *Caries Res* 2001; **35:** 216-222.
51. Pontefract H, Hughes J, Kemp K, Yates R, Newcombe RG, Addy M The erosive effects of some mouthrinses on enamel. A study *in situ*. *J Clin Periodontol* 2001; **28:** 319-324.
52. Munoz C A, Feller R, Haglund A, Triol C W, Winston A E. Strengthening of tooth enamel by a remineralizing toothpaste after exposure to an acidic soft drink. *J Clin Dent* 1999;**10** (1 Spec no):17-21.
53. Hall A F, Buchanan C A, Millett D T, Creanor S L, Strang R, Foye RH. The effect of saliva on enamel and dentine erosion. *J Dent* 1999; **27:** 333-339.
54. Bartlett D W, Coward P Y, Nikkah C, Wilson R F. The prevalence of tooth wear in a cluster sample of adolescent schoolchildren and its relationship with potential explanatory factors. *Br Dent J* 1998; **184:** 125-129.
55. Sundram G, Bartlett D. Preventive measures for bulimic patients with dental erosion. *Eur J Prosthodont Restor Dent* 2001; **9:** 25-29.
56. Meurman J H, Kuittinen T, Kanga M, Tuisku T. Buffering effect of antacids in the mouth- a new treatment of dental erosion? *Scand J Dent Res* 1988; **96:** 412-417.
57. Tenovuo J, Hurme T, Ahola A, Svedberg C, Ostela I, Lenander-Lumikari M, Neva M. Release of cariostatic agents from a new buffering fluoride- and xylitol-containing lozenge to human whole saliva *in vivo*. *J Oral Rehabil* 1997; **24:** 325-331.
58. Lambrechts P, Van Meerbeek B, Perdigao J, Gladys S, Braem M, Vanherle G. Restorative therapy for erosive lesions. *Eur J Oral Sci* 1996; **104:** 229-240.
59. Brunton P A, Kalsi K S, Watts D C, Wilson N H. Resistance of two dentin-bonding agents and a dentin desensitizer to acid erosion *in vitro*. *Dent Mater* 2000; **16:** 351-355.
60. Azzopardi A, Bartlett D W, Watson T F, Sheriff M. The measurement and prevention of erosion and abrasion. *J Dent* 2001; **29:** 395-400.