Swedish Dental Journal Supplement 156, 2002

On Dental Erosion and Associated Factors

Ann-Katrin Johansson

Department of Cariology
Faculty of Odontology
Sahlgrenska Academy at Göteborg University

Göteborg 2002

ABSTRACT

On Dental Erosion and Associated Factors

Ann-Katrin Johansson, 2002
Department of Cariology, Faculty of Odontology, Sahlgrenska Academy at Göteborg University, Box 450, SE-405 30 Göteborg, Sweden

The aim of this thesis was to explore aspects of dental erosion by investigating its prevalence among young Saudi men and young children, develop a system for its assessment and to evaluate various tentative background factors that may be associated with its occurrence.

Saudi military inductees (n=95) were subjected to questionnaire and clinical examination, including recordings of severity of dental erosion and a number of other oral health parameters. The system applied for grading the severity of dental erosion showed an intraexaminer agreement of 78%. Around one-fourth of the maxillary anterior tooth surfaces exhibited pronounced dental erosion and the average soft drink consumption was 247 liters/year. High level of soft drink consumption and long retention time of the drink in the mouth before swallowing, intensified oral hygiene, mouth breathing and low gingival bleeding index were found to have significant correlations with the presence of dental erosion. Furthermore, less plaque on maxillary palatal tooth surfaces, increased numbers of buccal cervical defects, first permanent molar "cuppings", missing teeth, and lower salivary urea content had significant correlations with the severity of dental erosion.

High intake of acidic drinks and fruits, upper respiratory tract problems and frequent taking of medication were common findings in young Saudi children (n=16) with severe dental erosion. The clinical diagnosis of erosion in deciduous teeth was confirmed by SEM. Enamel from various healthy teeth were subjected to microhardness measurements before and after *in vitro* exposure to citric acid. Deciduous enamel was found to be softer and relatively more prone to erosion than permanent enamel but the potential for erosion was about the same regardless of the origin of the teeth.

Six methods of drinking a sugar-free cola-type drink were assessed in two groups of healthy volunteers. Intraoral pH was measured at specific locations and at predetermined time points using the microtouch method (n=12), and continuously by using telemetric measurement (n=6). Of the six methods tested, those in which the drink was in contact with the tooth surface for a prolonged period of time were found to strongly affect intraoral pH.

It may be concluded from this thesis that dental erosion is common among young Saudi men and that erosion is associated with many etiological, aggravating and modifying factors. Consumption of soft drinks, amount of palatal plaque on maxillary anterior teeth and salivary urea concentration are some factors related to erosion. The presence of dental erosion in children is likely to be associated with a number of general health and dietary factors but is also aggravated by the relatively more rapid progression of erosion in the deciduous teeth. Drinking method seems to be an important factor in the risk of developing dental erosion.

Key words: Dental erosion - dental plaque - drinking method - epidemiology - oral hygiene - saliva - soft drinks - tooth enamel - urea

ISBN 91-628-5432-1
ISSN 0348-6672

PREFACE

This thesis is based on the following original articles, which, in the subsequent presentation, will be referred to by their Roman numerals:

I. JOHANSSON A-K, JOHANSSON A, BIRKHED D, OMAR R, BAGHDADI S, CARLSSON GE. Dental erosion, soft-drink intake, and oral health in young Saudi men, and the development of a system for assessing erosive anterior tooth wear. *Acta Odontol Scand* 1996;54:369-378.

II. JOHANSSON A-K, JOHANSSON A, BIRKHED D, OMAR R, BAGHDADI S, KHAN N, CARLSSON GE. Dental erosion associated with soft-drink consumption in young Saudi men. *Acta Odontol Scand* 1997;55:390-397.

III. JOHANSSON A-K, SORVARI R, BIRKHED D, MEURMAN JH. Dental erosion in deciduous teeth - an in vivo and in vitro study. *J Dent* 2001;29:333-340.

IV. 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.

V. JOHANSSON A-K, LINGSTRÖM P, IMFELD T, BIRKHED D. Influence of drinking method on tooth surface pH in relation to dental erosion. *In manuscript.*

On Dental Erosion and Associated Factors

Ann-Katrin Johansson

Department of Cariology
Faculty of Odontology
Sahlgrenska Academy at Göteborg University

Department of Pediatric Dentistry
Postgraduate Dental Education Center
Örebro County Council

Göteborg 2002

INTRODUCTION

One of the most commonly used definitions of dental erosion is "loss of dental hard tissue by a chemical process that does not involve bacteria"[1]. The process involves an undersaturation of both hydroxyl- and fluorapatite under conditions of low pH, with the surface of the tooth removed layer by layer[2]. In its early stage, the clinical appearance of erosion is such that it is easy to overlook, bearing in mind that there will be no discoloration of the tooth, nor any stickiness during probing of the lesion, and perhaps only limited or no symptoms. In the late stage of dental erosion, the clinical signs are more obvious. Whenever the morphology of the tooth surface has changed, without having been influenced by a mechanical force or dental caries, the diagnosis of dental erosion should be considered (Fig 1. and Fig. 2). In addition, in cases of severe tooth wear, dental erosion should always be considered as a likely sustaining factor. Indeed, there is a strong belief among many researchers that erosion may be the main contributory factor in severe tooth wear and that attrition and abrasion are of lesser importance[3-6].

The surface appearance of erosion can be shiny or matte, perhaps irregular, but is often rounded or flat, as if "melted". Small concavities can sometimes be seen on the surface of the tooth. In advanced cases, shoulders could be present cervically (Fig. 3). Approximal surfaces are infrequently involved, except in very

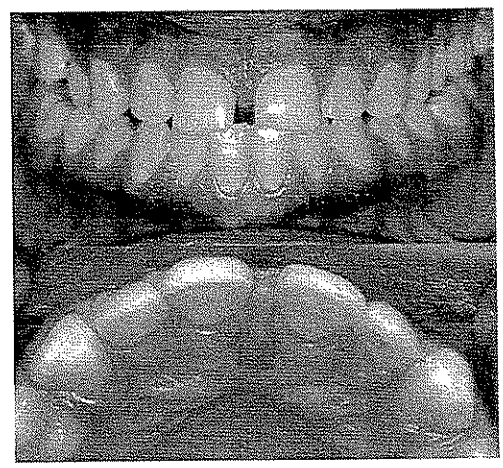


Fig. 1. A 20-year-old man with dental erosion.

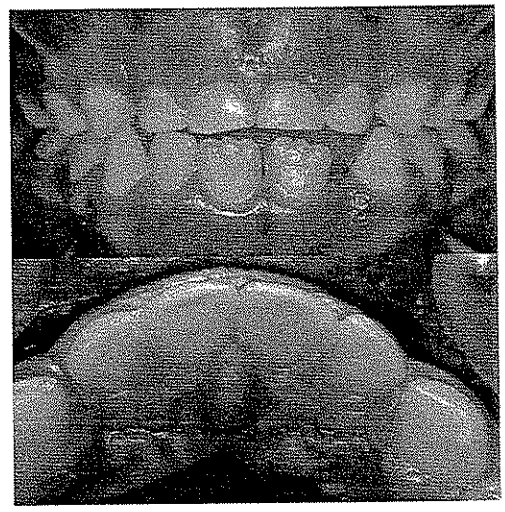


Fig. 2. Dental erosion in a 6-year-old boy.

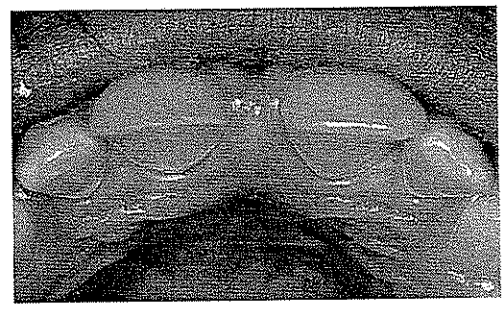


Fig.3. Palatal shoulders on maxillary anterior teeth in a 20-year-old man.

severe cases. Cuppings, a "peephole" in the enamel, often at a molar cusp tip, are a common clinical sign of an erosive lesion (Fig. 4). In addition, the pulp might be visible through the remaining tooth substance (Fig. 5) and there might be formation of clinically detectable protective tertiary dentin, and even direct pulpal involvement may occur. The erosive process might cause sensitivity and various degrees of other endodontic symptoms, ranging from slight sensitivity to severe pain, besides the more obvious loss of tooth substance resulting in esthetic and/or functional problems as well as orthodontic changes.

Tooth wear, or tooth surface loss, has a multifactorial etiology and is also frequently the result of more than a single wear-producing mechanism[7]. Besides erosion, other types of wear can occur. These are commonly accepted as attrition, which, by definition, implies wear from "tooth-to-tooth contacts" (e.g. bruxism), and abrasion, which is defined as wear from "foreign body influence" (e.g. tooth brushing). The term "abfraction" has been suggested for loss of tooth substance as a result of a combination of stress and acid challenges in the cervical region of the tooth[8]. An explanation for such defects invokes the influence of tensile forces and/or tooth flexure[9,10] and the terms "stress induced cervical lesions"[9] has been used to describe this type of lesion. These explanations are at variance with Xhonga, who in 1973 attributed their occurrence to toothbrush abrasion, stating "that

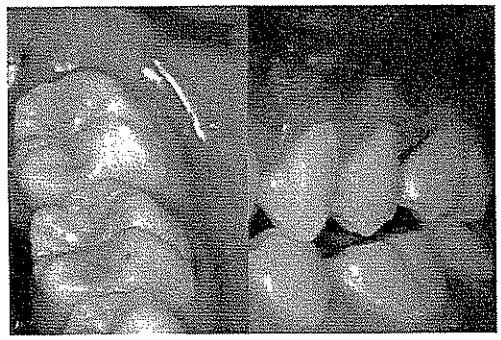


Fig. 4. Cuppings affecting the mesiobuccal cusp tip of tooth no. 36. Note the absence of occlusal contact in the area of the cupping.

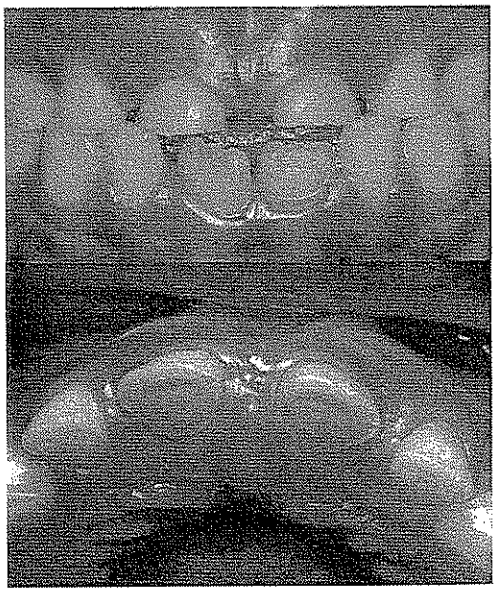


Fig. 5. Pulp visible through the remaining tooth substance in a 6-year-old girl.

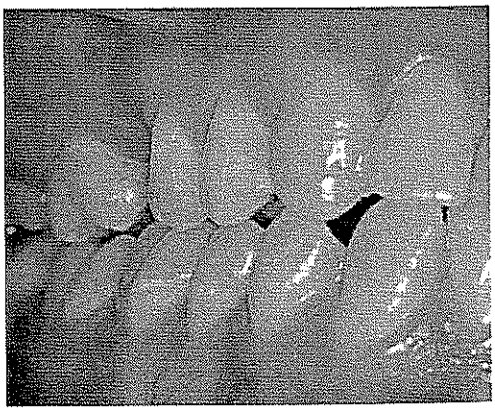


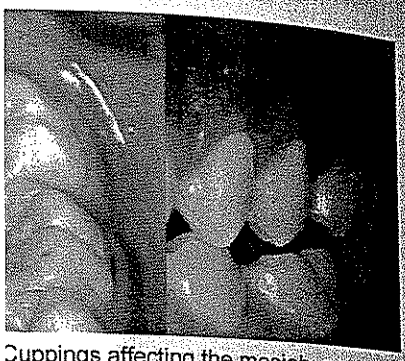
Fig. 6. Cervical defects in a 20-year-old man.

physical frictional forces significance in the origin o hand, following scanning el dentin, suggested that they instead to an erosive or gingival erosion and abrasi detectable lesions, lesions analyses[13], although clinic cervical lesions to be strong wedge-shaped cervical lesi wear and occlusal attritio cervical defects was found seems likely that the devel combination of etiologica erosion is one factor, in m types of tooth wear[10,13,15] (found in animals it follows cervical defects[16].

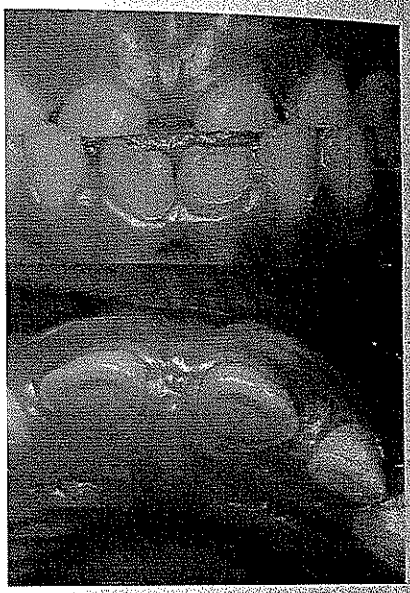
In regard to the multifac as 1907 shown that enam susceptible to wearing by n findings were supported indentations made in enam away much faster than in early studies clearly show t seems reasonable that it (factors are present. Thus, t bruxism is a significant fa this into account. The contr wear may only be of the c and wear was found in yo that, despite the reported p tooth wear was most likely

Epidemiology of Dental

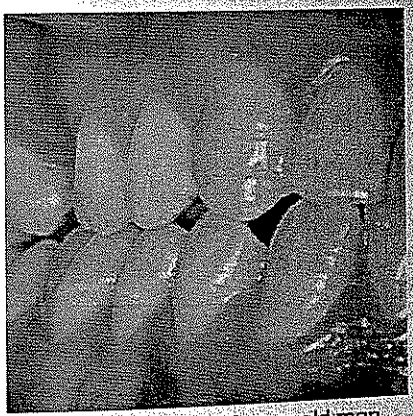
Until fairly recently, there l erosion in the literature, w material or case reports (erosion and the recording cervical, bucco-palatal, or have been variously applie



Cuppings affecting the mesiobuccal cusp oth no. 36. Note the absence of occlusal in the area of the cupping.



Pulp visible through the remaining tooth ıce in a 6-year-old girl.



Cervical defects in a 20-year-old man.

physical frictional forces rather than purely chemical ones, are of special significance in the origin of buccal cervical defects"[11]. Tronstad[12], on the other hand, following scanning electron microscopy (SEM) examination of "attritted" dentin, suggested that they were unlikely to have been related to attrition, but instead to an erosive or caries-like process. Another study suggested that gingival erosion and abrasion may worsen already existing but hardly clinically detectable lesions, lesions which are confirmed to be present under SEM analyses[13], although clinically yet undetectable. SEM has also shown shallow cervical lesions to be strongly associated with occlusal erosive pathology, while wedge-shaped cervical lesions had an association with both occlusal erosive wear and occlusal attrition; the association between occlusal pathology and cervical defects was found to be as high as 96%[14]. Collating the evidence, it seems likely that the development of buccal cervical defects are caused by a combination of etiological factors within a multifactorial model in which erosion is one factor, in much the same way as has been suggested for other types of tooth wear[10,13,15] (Fig. 6). Further, given the fact that such defects are found in animals it follows that tooth brushing cannot be the principal cause of cervical defects[16].

In regard to the multifactorial etiology of tooth wear, Miller had as far back as 1907 shown that enamel "disintegrated by an acid thereby becomes more susceptible to wearing by mechanical agents"[17]. Almost 70 years later, Miller's findings were supported by Schweizer-Hirt et al.[18], who showed that indentations made in enamel, which had been softened in orange juice, wore away much faster than indentations made in unexposed enamel. Both these early studies clearly show the relationship between abrasion and erosion, and it seems reasonable that it ought similarly to apply to wear where attritional factors are present. Thus, the common view among the dental profession that bruxism is a significant factor in the development of tooth wear, should take this into account. The contribution of bruxism to the overall experience of tooth wear may only be of the order of 10%[19] and no association between bruxism and wear was found in young adults[20]. Indeed, a recent SEM study suggested that, despite the reported presence of bruxism, the major etiology of observed tooth wear was most likely of an erosive origin[21].

Epidemiology of Dental Erosion

Until fairly recently, there has been a paucity of epidemiological data on dental erosion in the literature, while the reports that do exist often include selected material or case reports only. Several indices have been used for grading erosion and the recording criteria have differed. Recordings of erosion on cervical, bucco-palatal, or inciso-occlusal surfaces, or combinations thereof, have been variously applied. In addition, selection criteria, sampling technique

and age composition have varied. The prevalences obtained from different studies are therefore difficult to compare, which leaves the epidemiological basis for its occurrence limited[22], and perhaps open to a degree of speculation.

"Early" Studies in Diverse Populations

In an early clinical study from 1949, between 21% and 27% of a group of adult controls were found to have some degree of erosion of the gingival third of the buccal tooth surfaces. The erosion was most common in premolars and more common in the maxillary than the mandibular teeth[23]. In 1972, a material comprising 10,000 extracted teeth from southern California was analyzed and it was found that 18% of the teeth, most commonly premolars, were affected with erosive lesions[24]. Xhonga performed an epidemiological study on over 500 patients aged 14-88 years, seeking routine dental care at the universities of Boston and Los Angeles. Erosion lesions, in the form of cervical defects were most common in premolars in both arches. The prevalence observed was about 25% of all individuals examined[25].

Robb[26] reported on a material comprising 151 British pre-Conquest skulls using the Tooth Wear Index (TWI)[27] analyzing four surfaces at each tooth in the dentition. Certain criteria had to be followed in order to record erosive tooth wear. For example, contact between the opposing teeth had not to be very likely, and/or wear in one jaw should be more severe than in the other jaw. It was concluded that about 20% of the skulls showed wear of possible erosive origin.

In Finland, Järvinen and co-authors[28] reported on a material of 106 patients referred for dental erosion. Using an index described by Eccles[29], for grading erosion, they found a prevalence of 5% among a matched control group of 100 individuals in the age range 17-83 years. Lussi[30] published the results of an epidemiological study of erosion in Switzerland using a modified version of a scale described by Linkosalo and Markkanen[31]. The material comprised 197 patients aged 26-30 years and 194 patients aged 46-50 years; the prevalences of buccal dental erosion in the two groups were 8% and 13% and of occlusal erosion 30% and 43%, respectively, and "slight" erosion lingually was found in 4% and 6% of the subjects, respectively[30].

Dental Erosion in Young Children and Adolescents – Mid 1990s

By the mid 1990s, several epidemiological studies on dental erosion in children and adolescents appeared for the first time[32-36], and a trend towards an increasing prevalence and severity of tooth wear and erosion was discussed. A national survey of the dental health of children in the United Kingdom was conducted in 1993 by seventy-six specially trained dentists. A version of the TWI[27], modified for erosion purposes, assessing only buccal and surfaces of maxillary incisors, was used[32]. More than 17,000 children ag years were examined clinically. Twenty-four percent of the 5-year-olds palatal erosion extending into the dentin or pulp. The recording of showed large variation, and the conclusion was drawn that, while these might not be completely accurate, they gave a good indication of the pr of erosion in children[32]. In 1994, another report of the prevalence of 178 4-year-old children in Liverpool, United Kingdom, appeared another modification of TWI[27] and it was found that 30% of palatal su maxillary anterior deciduous teeth showed severe erosion.

Again, using a modified TWI[32], 30% of a group of 135 3-year-old from East Cumbria, United Kingdom, were found to have erosion on th surface of at least one maxillary anterior tooth, with the majority of having dentin involvement[35]. Moynihan[36] reported on erosion as part national diet and nutrition survey of 1.5 to 4.5 year-old children" in th Kingdom using the modified TWI[32]. Erosion, extending into dentin or the palatal surfaces of at least one maxillary front tooth, was found in 1658 children clinically examined, while a similar degree of erosic buccal surfaces was found in 2% of the children. In reporting the find authors pointed out that erosion in young children was difficult to diag represented a weakness in evaluating the results.

During this period, also permanent teeth in groups of adolesc examined for the first time. In the aforementioned British survey, 3(13-15 year-old children showed erosion in at least one maxillary ante in enamel and 2% of them did so in to into dentin[32]. In a study invol 14-year old children in Liverpool, 30% had exposed dentin, mostly i Using the original TWI[27], 1014-14 year-olds were examined for erc eighty percent of maxillary incisors showing evidence of tooth wear a primary molar teeth having dentin exposed[37]. In a group of 525 14 from London, UK, using the modified TWI[32] on the maxillary inci had dental erosion, but this time with a greater propensity for labial th surfaces. Extension of erosion into dentin was found only in about group, and only on palatal surfaces[38].

The New Millennium and Reports from Many Countries

Since the start of the new millennium, several epidemiological studie erosion from different parts of the world have been reported. Amongs year old Cubans, 40% of those children, living in certain areas w related to the production of citrus fruits, showed erosion in maxill teeth while only 17% of individuals in the total sample did so[39] national study conducted in the United Kingdom and the United Stat

similar degrees of dental erosion in both countries. Using the modified TWI[32], of the 125 and 127 12-13 years old children comprising the two samples, respectively, 37% and 41% had erosion, and most frequently in enamel[40].

The first epidemiological data from Germany were published in 2001[41]. Erosion was recorded longitudinally from maxillary orthodontic study casts made from age 11 to 16 years, in a total of 1000 children[41] using a modified version of the index described by Linkosalo and Markanen[31]. For deciduous teeth (793 subjects), no grading of maxillary anterior teeth, except the canines was made; 26% of the subjects had severe erosive lesions on at least one tooth. Regarding permanent teeth (998 subjects; grading of all teeth), 0.2% showed severe erosive lesions on at least one tooth[41]. The prevalence of erosion was further compared during the periods 1977-1989 and 1990-1999, and was found to have nearly doubled. For deciduous teeth, the prevalence of severe erosion rose from 7% of molars and 1% of canines, to 13% and 11%, respectively from one period to the next, while 18% of children having at least one tooth with severe erosion rose to 32%[41]. Similarly, for permanent teeth, the number of children with at least one permanent first mandibular molar affected by erosion increased from 4% to 9% over the period[41]. In the same study, it was found that, among the children aged 11 years with dental erosion, 87% showed occlusal erosive lesions in at least one first mandibular molar, which by the age of 16 years, had risen to 94%[41].

In a study of 418 14-year-old British school children in Birmingham[42], using the modified TWI[33], 51% had moderate erosion and 1% severe, and most often located on palatal surfaces. In 2002, a study of 5-6 year old (n=354) and 12-14 year old (n=862) boys in Saudi Arabia, using a similar index to the 1993 British survey[32] found the prevalence of erosion in maxillary anterior teeth into dentin to be 34% and 26%, respectively[43]. In another study in Saudi Arabia, about 25% of 2-5 years old showed erosion into dentin or pulp in at least one tooth[44].

In summary of the growing body of epidemiological findings, it would appear that dental erosion affects both children and adults, and its prevalence must be considered high.

Etiology of Dental Erosion

Traditionally, the etiological factors attributable to dental erosion have been divided into those of extrinsic and intrinsic origins. The term idiopathic erosion has been used in cases of unknown etiology, but its clinical application is limited. In recent years, the list of possible erosive sources has grown and the complexity and the combinations of mechanisms involved in the erosion process have been acknowledged. Hence, while the fact that the tooth surface is exposed to an erosive agent does not necessarily mean that an erosive lesion will develop, the absence of such a challenge would certainly preclude the occurrence of a lesion. Ten Cate and Imfeld stated that the "poter factors for dental erosion are changed lifestyle and eating patter increased consumption of acidic foods and beverages" and also that gastrointestinal and eating disorders expose the dentition to frequent with very acidic gastric content, which may lead to erosion"[45].

Apart from the known dietary etiology[31,36,37,43,46,47], salivary fac occupational environment[53-55], including wine-making or tasting[56-57], diseases[58,59], including eating disorders[60-64], gastrointestinal disturb alcoholism[69-70], medication[6,71-74], including drug abuse[75,76] and ora habits[18,77-80] may also be associated with the development of erosion.

The cause of erosive defects may be an important factor in diagr ferent areas of the dentition may be affected depending on whether th is of intrinsic or extrinsic origin[81,82]. For example, it has been thou gastric cause may affect mainly the palatal surfaces of upper ante while an acidic diet may affect the teeth more randomly. However, the suggests that the cause of the erosion may not be exclusively and d identified by virtue of its location[83].

Host Defense Mechanisms

Salivary Factors

Meurman and Frank stated that "It is anticipated that saliva is a defense factor with regard to dental erosion"[49]. An increased eros during the intake of acidic drinks, may be expected if salivary buff and rate of salivary secretion are reduced[84]. The role of saliva in den is not fully understood, probably as a result of the complexity of intra-individual salivary conditions, and also due to different ava saliva in diverse areas of the dentition[85]. For example, in cases breathing or unfavorable position of the teeth, the effect of s modifying factor will be reduced even under normal salivary conditi dilutes the acid in the oral cavity and oral clearance will therefore de salivary secretion rate and the individual pattern of swallowing. suggested that oral clearance is not uniform in all parts of the oral neither is the ionic composition of saliva[86], all of which are impo outcome of an erosive challenge.

The concentrations of both calcium and phosphate are supersaturated in saliva with respect to apatite[87]. An acidic challeng in undersaturation of calcium and phosphate in saliva,[88] but, beside acids such as citric and phosphoric acid, also have the potential to free calcium ions in saliva and on the enamel surfaces until a reached. This seesaw of ions may result in re- or de-mineralization.

It has been suggested that a high sugar concentration in the presence of a low pH may increase the osmotic potential of a drink, and thus increase the erosive effect on tooth structure[132,142]. Diet-type beverages do not contain refined sugar but their pH is nevertheless low and the potential to induce dental erosion therefore remains[132]. In this regard, when comparing the diet and regular versions of Coke and 7-Up, similar buffering capacities for the light and regular versions of both brands of drinks have been found[143] which was confirmed by our own analyses (Table 1).Caffeine, found in most cola-type drinks but also other types of drinks, for example many sport drinks, is a central stimulant, mood-altering and physical dependence-producing drug which is added, according to manufactures, to enhance the flavor of the drink. However, it was found that only 8% of a group of regular cola consumers could detect by taste if the drink included caffeine or not in commonly used concentration[144]. Withdrawal from caffeine-containing soft drinks results in both physiologic and psychological effects in a dependant person[145].

The role of beverages as a single factor responsible for dental erosion has been discussed. In North America, there has been doubt expressed about a relationship between soft drinks and dental erosion in subjects "without high and unusual drinking habits"[105]. In Europe the position is quite different, and the apparent disparity between the two could be explained by differences in the definitions of terms used to describe tooth wear[146]. In a cross-sectional study, 12-13 year old children in the USA and the UK showed a similarly high prevalences of erosive tooth wear[40]. In October 2001, the American Dental Association, in a letter to the US Congress[147] regarding the possible risk posed by the consumption of soft drinks not only for dental health, but also for other general health risks, stated that: "Though there is limited epidemiological evidence assessing the association between oral health and soft drink consumption, it consistently indicates that soft drinks adversely affect dental caries and enamel erosion. Moreover, numerous *in vitro* and animal studies have consistently shown enamel erosion with the use of soft drinks. Given the evidence, it would seem appropriate to encourage children and adolescents to limit their intake of soda".

A number of general health concerns related to soft drink consumption have lately been reported. In the United States it has been found that a majority of children aged 5-17 years do not meeting the recommendation regarding calcium intake, which is attributed to a change in beverage consumption resulting in less milk and more soft drink consumption[148]. Consumption of regular carbonated soft drinks has been connected with increase in Body Mass Index[149] and the development of non-insulin dependent diabetes mellitus[150], additionally, caffeine may decrease insulin sensitivity[151]. Consumption of drinks including phosphoric acid has been associated with development of osteoporosis[152,153], hypocalcaemia[154,155] and urinary calcium-oxalate-stone formation[156,157].

Besides the general health risks that soft drinks may pose, it seems clear that, in the oral health context, the constituents of the drink are i determining its erosive potential. The widespread use and popul drinks in general is attributed to incessant advertising from the m companies, and associating the product with being part of "toda together with its widespread availability in places designed to sti popularity especially among young people.

Paper V

The study consisted of two series. The first series comprised twelve adults ($\bar{x}$=30 years; range=18-53), and was performed at the Faculty of Odontology in Göteborg. The second series involved six adults ($\bar{x}$=72 year, range=59-83) and was performed at the Dental Institute in Zürich, Switzerland. All subjects were healthy and had a normal salivary secretion rate and buffer capacity.

Questionnaire, Clinical Examination and Scoring of Dental Erosion

Papers I and II

Using a bilingual questionnaire (Arabic and English), a specially-trained translator obtained a history from each participant, in order to assess the role of various possible factors related to oral health in general, and to dental erosion in particular (Fig. 7). The questionnaire included questions on types of food and beverages consumed, number of daily meals and between-meal sweets and drinks. In addition, medication intake, general health conditions, symptoms of temporomandibular disorders, parafunctional and oral hygiene habits, subjective complaints and the individual's perceived need for treatment, were recorded. All clinical investigations were performed by one investigator (A-KJ) and included recordings of: severity of dental erosion, number of buccal cervical defects, visible plaque index[158], gingival bleeding index [158], DMFT and DMFS and severity of fluorosis[159]. In addition, a radiographic examination comprising four bitewing radiographs was performed. Third molars were excluded from all examinations. Maxillary and mandibular alginate impressions in perforated stock trays were made (Deguprint®, Degussa AG, Japan), and poured in a high-strength dental stone (Kerr®, Velmix Stone, Sybron Kerr, Kerr Europe). Intraoral color transparencies (maxillary and mandibular occlusal, left and right lateral, frontal, palatal-anterior and lingual-anterior views) were taken of all individuals. After gingival bleeding index and visible plaque index were recorded, meticulous cleaning of the teeth was performed, which included professional supragingival scaling and polishing with prophypaste. The teeth were carefully dried with an air syringe prior to the assessments of fluorosis and erosion, as well as before the photography.

An ordinal scale was used to assess the severity of dental erosion (Table 2, Fig. 8) The scale was designed as a modification of a similar grading system previously used[160-162]. Recordings were made by one examiner (A-KJ) after a period of examiner training and calibration with two other investigators (AJ and GEC). It became obvious that the reliability of distinguishing the different grades of dental erosion was complicated, and thus questionable, in the case of maxillary and mandibular premolars and molars, as well as on mandibular incisors. The incisal surfaces were also excluded from the examinat of the difficulties in distinguishing between attritional and erosive ir these surfaces. Thus, in the final analysis, only maxillary incisors were graded, and, furthermore, only their buccal and lingual surfac erosion score was obtained from the pooled assessments of clini study cast examination and evaluation of intraoral transparencies. characterize the severity of erosion, a mean value index of all grac was calculated for each individual.

Cervical defects on the buccal surfaces were scored clinically for and recorded as the number of defects present in each individual. the requirement of clear demarcation, no distinction betwe morphologies of the defects was made. Cuppings on all first mola from color transparencies and study casts and recorded as total affected teeth per individual. Evaluation of occlusal and incisa performed on a tooth-by-tooth basis on the study casts by two exan and AJ) using a previously used, analyzed and described ordinal sc indices for the dentition, as well as for the anterior (canines and i posterior (premolars and molars) teeth were calculated. I disagreement, a final grade was mutually reached. Teeth which w or had extensive restorations were excluded from evaluations of and occlusal wear.

Visible plaque index and gingival bleeding index were recorc tooth on the buccal, mesio-buccal and lingual surfaces, accordin and Bay[158]. DMFT and DMFS were assessed in three ways: i) WHO recommendations[163]; ii) including approximal caries detectec radiographs and extending radiographically to, or beyond, the an junction; and iii) including approximal caries detected in bitewing and extending ≥2/3 of the enamel thickness. For the second assessment (ii), DMFT and DMFS were also divided into their that is, D (decayed), M (missing), F (filled), T (teeth) and S (surfac of fluorosis was graded on a tooth-by-tooth basis using a combined color transparency assessment, according to the Thylstrup-Fejersko

Paper III - *in vivo* study

A specially-trained bilingual interpreter completed a questionnair the history of each participant during a structured interview respective parents. Various possible factors related to dental e recorded, including dietary and oral hygiene habits. Since all attended the hospital since birth, a comprehensive medical histo current and past diseases and medications, could be obtained fror medical file. Gingival bleeding index and visible plaque index wer

and intraoral photographs taken. The parents were asked to hand in the eroded deciduous teeth to the clinic as soon as exfoliation occurred.

Fig. 7. Questionnaire used in Papers I, II and IV

1. Do you drink:*	Frequency (per day)	Quantity[1] (per day)		Frequency (per week)	Quantity[1] (per week)	Remarks
Sugar-cont.						
Pepsi-Cola						
Coca-Cola						
Mirinda						Type:
7-UP						
Teem						
Fanta						Type:
Others						Type:
Diet-type						
Diet Pepsi						
Diet Coke						
Others						Type:
Other						
Fruit juices						Type:
Sport drinks						Type:
Tea						sugar/sugarfree
Coffee						sugar/sugarfree
Others						Type:

2. Do you eat:*	Frequency (per day)	Quantity[1] (per day)		Frequency (per week)	Quantity[1] (per week)	Remarks
Citrus fruits[2]						
Apples						
Tomatoes						Uncooked/cooked
Grapes						
Dates						
Olives						
Pickles						

*N.B. "Frequency" and "quantity" refers to the average daily/weekly consumption during the past year.
1) in millilitres/ no of cans, etc. 2) e.g. orange, lemon, grape fruit, lime, etc.

3. Have you previously (prior to the past 12 months) frequently ("everyday") consumed some of the above?
   1 = No
   2 = Yes, Quantity/day.....

4. What type of water do you mainly drink?
   1 = Tap water.....Quantity/day
   2 = Bottled .....Quantity/day

5. How many main meals do you eat per day?
   .....

6. Which beverage(s) do you usually drink with 1) breakfast, 2) lunch and 3) dinner?
   1) .....Quantity/day
   2) .....Quantity/day
   3) .....Quantity/day

7. Which beverage(s) do you usually drink in-between main meals?
   .....Frequency/Quantity/day

8. How many times per day do you eat sweets?
   .....Quantity/day

9. How many times per day do you drink/eat laban or yogurt?
   .....Quantity/day

10. Do you eat hard cheese?
    1 = No
    2 = Yes, occasionally
    3 = Yes, once or more daily
    If "yes", which .....

11. Do you eat fresh **uncooked** vegetables?
    1 = No
    2 = Yes, occasionally
    3 = Yes, once or more daily

12. Do you eat **cooked** vegetables?
    1 = No
    2 = Yes, occasionally
    3 = Yes, once or more daily

13. Do you take medicine(s) regularly?
    1 = No
    2 = Yes, Quantity/day.....

14. Do you take vitamin C regularly?
    1 = No
    2 = Yes, occasionally
    3 = Yes, once or more daily
    If "yes", *tablets* or *effervescent*:
    Quantity/day.....

15. Do you take iron tonics regularly?
    1 = No
    2 = Yes, occasionally
    3 = Yes, once or more daily
    If "yes", which .....
    Quantity/day .....

16. Are you, or have you suffered from dryness of the mouth?
    1 = No
    2 = Yes, for less than 1 year
    3 = Yes, for 1 -5 years
    4 = Yes, for more than 5 years

17. Are you, or have you suffered from stomach problems?
    1 = No
    2 = Yes, for less than 1 year
    3 = Yes, for 1 -5 years
    4 = Yes, for more than 5 years

18. Do you, or have you suffered from frequent acid regurgitation or vomiting?
    1 = No
    2 = Yes, for less than 1 year
    3 = Yes, for 1 -5 years
    4 = Yes, for more than 5 years

19. Do you suffer from any chronic illness?
    1 = No
    2 = Yes, previously but not now
    3 = Yes, now
    If "yes", describe .....

20. Do you suffer from headache?
    1 = No
    2 = Yes, occasionally
    3 = Yes, frequently

21. Do you suffer from stiffness, tiredness or pain in the face or difficulty in wide mouth opening?
    1 = No
    2 = Yes, occasionally
    3 = Yes, frequently

22. How often do you clean your teeth?
    1 = Never
    2 = Occasionally
    3 = Once or more daily
    In 2 and 3, note frequency .....

23. How do you clean your teeth?
    1 = Toothbrush: If "yes", since when?
    2 = Miswak: If "yes", since when?
    3 = Finger: If "yes", since when?

24. Which cleaning technique do you use?
    1 = No special technique
    2 = Up-and-down
    3 = Back-and-forward
    4 = Combination of 2 & 3

25. When do you clean your teeth?
    .....

26. Do you use a dentifrice?
    1 = No
    2 = Yes, occasionally
    3 = Yes, once or more da
    If "yes", with fluoride?.....
    Paste or powder?.....

27. Do you frequently use the teeth ir ("Hab/fus-fus" shell splitting, nail
    1 = No
    2 = Yes, occasionally
    3 = Yes, once or more da
    If "yes", which habit .....

28. Do you, or have you frequently cl your teeth?
    1 = No
    2 = Yes, previously but r
    3 = Yes, now

29. Do you think your teeth are worn
    1 = No
    2 = Yes

30. Do you have problems associated
    1 = No
    2 = Difficulties in chewi
    3 = Sensitive teeth
    4 = Pain
    5 = Esthetic problems
    6 = Other, specify which

31. Do you need treatment for tooth
    1 = No
    2 = No, not now, but if it treatment
    3 = I need treatment now

32. Do you need treatment for sensiti
    1 = No
    2 = Yes

33. Do you consider ***regular*** soft drir your teeth?
    1 = No
    2 = Yes

34. Do you consider ***diet*** soft drinks c your teeth?
    1 = No
    2 = Yes

35. Do you consider ***fruit juices*** dang your teeth?
    1 = No
    2 = Yes

36. Do you consider ***fruit*** dangerous
    1 = No
    2 = Yes

37. Do you consider sweets dangerou
    1 = No
    2 = Yes

38. Do you use chewing gum?
    1 = No
    2 = Yes
    If "yes", which type .....
    and when? .....

39. How often do you visit the dentis
    1 = Never or seldom
    2 = Once in 5 year
    3 = Once a year or more

Table 2. Ordinal scale used for grading severity of dental erosion on buccal and lingual surfaces of maxillary anterior teeth.

Grade	Criteria
0	No visible changes, developmental structures remain, macro-morphology intact.
1	Smoothened enamel, developmental structures have totally or partially vanished. Enamel surface is shiny, matt, irregular, "melted", rounded or flat, macro-morphology generally intact.
2	Enamel surface as described in grade 1. Macro-morphology clearly changed, facetting or concavity formation within the enamel, no dentinal exposure.
3	Enamel surface as described in grades 1 and 2. Macro-morphology greatly changed (close to dentinal exposure of large surfaces) or dentin surface exposed by ≤1/3.
4	Enamel surface as described in grades 1, 2 and 3. Dentin surface exposed by >1/3 or pulp visible through the dentin.

Note: Approximal erosion and presence of "shoulder" should be recorded.

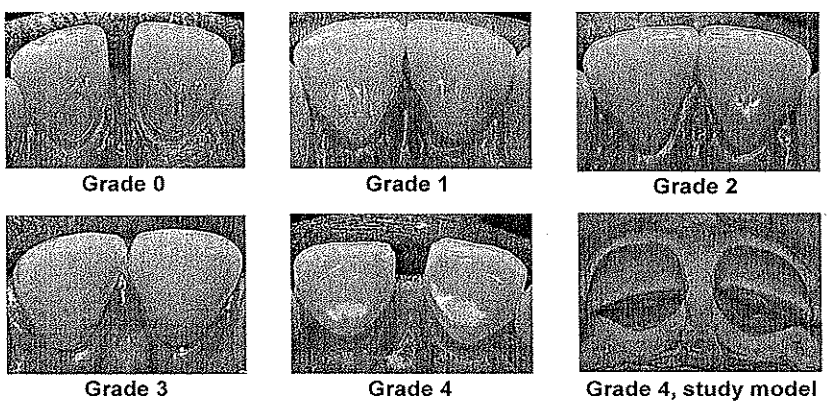


Fig. 8. Illustrations of the different severities of dental erosion.

Paper IV

The questionnaire used in Paper I was supplemented with additic questions. Data regarding dietary habits, number of cervical defe molar cuppings, visible plaque index and gingival bleeding index w from Paper I.

A standard disclosing solution was applied on the teeth directly measurements had been completed. Plaque registration was clinically following 3 days without any oral hygiene measures beir A specially designed topographic plaque index (TPI) was devel purpose. The index was calculated by dividing the buccal surf maxillary anterior tooth into five areas: 1) cervical, 2) mesio-proxir proximal, 4) mid-buccal and 5) inciso-buccal, and the palatal surfa areas: 1) cervico-proximal, 2) mid-palatal and 3) inciso-palatal.

Method of Drinking and Test Products

Paper IV

Subjects were asked to drink a can (330 ml) of regular Pepsi Cola® Beverage Plants, Saudi Arabia) (Table 1) in their customary without any time constraint. The drink was just opened and cc fridge. A choice between drinking from a glass or the can was numbers of intakes and swallows and the total time of consumptic the duration (s) for which the drink was kept in the mouth, were r regards the last parameter, the accumulated time for which the drink the mouth before swallowing was calculated.

Paper V

Six methods of drinking (herein referred to as Holding, Short-Sip Sipping, Gulping, Nipping and Sucking) were tested in a randomize subjects were requested to be silent during the entire test session oral movements as possible. The drink used was Coca-Cola Light® Company, Sweden), which was served fully carbonated and at perature. The volume consumed was carefully monitored for each pre-stipulated for the Holding and Gulping method (Table 3).

Table 3. Method of drinking, its definition, duration of consumption, volume consumed (±SD), and rate of consumption with the microtouch and telemetric method (Paper V).

Method of drinking	Definition	Duration (min)	Microtouch method		Telemetric method	
			Volume (ml)	Rate (ml/min)	Volume (ml)	Rate (ml/min)
Holding	Holding the drink in the mouth	2	10[1]		10[1]	
Short-Sipping	Sipping from a glass	2	80±42	40	135±41	68
Long-Sipping	Sipping from a glass	15	302±116	20	578±114	39
Gulping	Swallowing quickly, 3 times	5 min intervals	3x10[1]		3x10[1]	
Nipping	Nipping from a baby's feeding bottle	15	170±38	11	221±71	15
Sucking	Sucking from a straw	2	115±75	58	112±87	56

[1]Volume pre-stipulated

pH Measurements

Paper IV

pH was measured by the microtouch method[164] using a microelectrode (∅=0.1 mm; Beetrode®, MEPH-1, W.P. Instruments Inc., New Haven, CT, USA). The electrode was connected to an Orion SA 720 pH/ISE meter (Orion Research Inc., Boston, MA, USA), and equipped with a reference electrode (DRIREF-2, W.P. Instruments Inc). A salt bridge was established in a 3 M KCl solution between the reference electrode and the subject's finger. The electrode was calibrated before readings were made, according to Scheie et al.[164]. Measurements were performed before, and at various time points during and after consumption of the drink.

Prior to the pH measurements, subjects had refrained from oral hygiene for the previous 3 days, and from eating or drinking (except for water) for the preceding 2 h. Measurements were performed just before (baseline=0 min) and at 1, 2, 3, 5, 7, 10, 15, 20, 30, 40 and 50 min after the subject had consumed the whole drink. The subjects were requested to be silent during the whole 50-min period. Measurements were performed at six intraoral sites: 1) proximally between the left maxillary premolars, 2) proximally between the right maxillary premolars, 3) proximally between the maxillary central incisors, 4) buccally on the central part of the cervical third of the maxillary right central incisor, 5) palatally on the central part of the maxillary right central incisor, and 6) on the anterior third of the dorsal central surface of the tongue. All high erosion subjects showed evidence of dental erosion at sites 4 and 5.

Paper V

pH was measured by two different methods. The subjects in both ser
their teeth without any toothpaste on the day of the experiment an
from eating and drinking, except for water, for 2 h prior to the test.

In the first series the microtouch method was used. Instrument an
procedures were identical to those in Paper IV. Measurements were
at three dental sites: i) 11 palatally, on the central part of the tc
buccally, on the central part of the cervical third of the tooth, a
mesiobuccal cusp tip of 16. pH was recorded before (baseline=0 mi
2, 3, 5, 7, 10, 15, 20 and 30 min after the start of the experiment. Fo
ing method, measurements were also performed at 6 and 11 min. Tv
methods were investigated on a given day. After the first test, the
carefully rinsed for 1 min with 10 ml water before the start of the s
pH was confirmed as having returned to baseline level before starti
test.

In the second series, pH was measured continuously with the
method using a clean glass pH electrode with a diameter of 2 n
Glasbläserei AG, Zürich, Switzerland). The electrode was mounted
of human enamel, which was incorporated into the approximal sur
premolar region of a lower removable partial denture[130]. A skir
electrode was attached to the volunteer's arm. After an initial restin
20 min, a baseline value was recorded. Readings were continuously
h, during which two methods of drinking were tested. The ele
calibrated against standard pH buffers before and after each te:
Between the two drinking sessions, the subjects rinsed with water
after which paraffin wax was chewed for 2 min in order to re-e:
baseline value.

Salivary and Microbial Analyses

Paper IV

Subjects refrained from eating, drinking and smoking for a period
to the test. Unstimulated and paraffin-stimulated whole saliva were
the late afternoon, for periods of 15 and 5 min respectively, in tubes
been pre-cooled on ice. After determination of secretion rate (ml/m
aliquot of stimulated saliva was used to determine buffer capacity (I
Orion Diagnostica, Espoo, Finland) and numbers of lactobacilli
LB®; Orion Diagnostica Espoo, Finland). For mutans streptococci
SM® (Orion Diagnostica, Espoo, Finland) was used. The remair
collected saliva was stored at -80°C until needed for further analys

was used during transit of the samples from Saudi Arabia to Sweden. Different electrolytes (calcium, inorganic phosphate, potassium, sodium and urea) were analyzed in both types of saliva. Analyses of electrolytes were carried out at the same session in the Department of Clinical Chemistry and Transfusion Medicine at Sahlgrenska University Hospital, Göteborg, Sweden using a BM/Hitachi 917 instrument (Boehringer Mannheim, Indianapolis, IN, USA). Light photospectrometry was used for analyses of calcium and urea, while enzymatic photospectrometry was used for inorganic phosphate. An ion-selective electrode was used for determination of potassium and sodium. Fluoride content was measured at the Department of Cariology, Göteborg University using an ion-sensitive electrode (96-09, Orion Research) connected to an Orion SA 720 pH/ISE meter.

Scanning Electron Microscopy and Microhardness Measurements

Paper III - *in vivo* study

Using a JEOL JSM-35 scanning electron microscope with a 15 kV accelerating voltage, SEM analyses were performed on the exfoliated Saudi deciduous teeth in order to confirm or reject the clinical diagnosis of erosion (n=8).

Paper III - *in vitro* study

Enamel specimens, 3x5 mm in size, were prepared according to Sorvari et al.[165]. The outermost surface of each specimen was polished flat using finest grade sand paper and water in order to facilitate microhardness measurements. The specimens were then rinsed in distilled water and stored in 100% humidity until used. Control blocks from each group were left in distilled water until used in SEM studies. Before the experiment, surface microhardness was measured for each specimen by using a Leitz Durimet hardness tester with a Vickers diamond and 200 g load (Ernst Leitz GmBH, Wetzlar, Germany). Six well-formed indentations were measured to calculate the mean Vickers value. The specimens were immersed in 1 ml of 2% citric acid solution (pH 2.1) at 37°C for 5 min under gentle agitation, and thereafter rinsed with distilled water. The microhardness measurements were then repeated after re-immersion of the same specimens in the acid solution for a further 10 min, and then a further 15 min. Thus, surface microhardness analyses were performed at baseline and following 5, 15, and 30 min of immersion. After the final erosion experiment, the specimens were mounted, dried, and covered with a layer of gold before SEM examination in a JEOL JSM-35 scanning electron microscope using a 15 kV accelerating voltage.

Analyses of Data and Statistical Methods

Papers I & II

Differences between variables in Paper I were tested using the Stuc for independent samples. In Paper II, a Spearman correlation analys erosion (1=low erosion subgroup; 2=high erosion subgroup) and 11 variables, and a Mann-Whitney U-test between the subgroups, were as the exploratory tests of correlations between factors investigated a of erosion. In addition, a logistic regression model was obtained b subgroups as the dependent variable. Independent variables were tl could provisionally be judged to have a causative association occurrence of erosion on the basis of having been found to be s correlated in the initial correlation analysis. In addition, those varia did not show significant correlation in the initial analysis, but were important, in a possible covariational relationship with the severity were included in the model as further independent variables[166]. I independent variables were used in the model. These were relat consumption of cola (including cola consumption prior to enlistme tea, juice, water and yogurt (ml/week); consumption of apples, c dates, grapes, tomatoes, vegetables, hard cheese and candy (weekly of intakes or items of fruits, or candy); oral hygiene habits (type of c duration of cleaning, cleaning technique, frequency, use of systemic diseases (including gastric diseases, dry mouth, acid regur vomiting); medication and parafunctional habits. Clinical paramete gingival bleeding index and visible plaque index and severity fluorosis.

Paper III

Results from the microhardness measurements were analyzed stat computing differences between the tooth specimen series (two-taile test), and with respect to periods of immersion (ANOVA).

Paper IV

For the pH registrations at the six intraoral sites, the area unde (AUC)[167], was calculated below both pH 5.5 ($AUC_{5.5}$) and 6.2 (AU These were carried out separately for the time spans of 0-10 min an A Mann-Whitney U-test was performed to analyze differences betw and low erosion groups regarding findings from the questionna examination and salivary analyses, $AUC_{5.5}$ and $AUC_{6.2}$, as well as p

the measuring points. The mean pH of the two premolar sites was used, while all other sites were evaluated separately; the mean of all six sites was also calculated.

Intraindividual differences in AUC between sites were analyzed by the Wilcoxon Matched-Pairs Signed-Ranks Test. For TPI, each subdivided area was scored as 1 (plaque) or 0 (no plaque). Buccal and palatal TPI scores were calculated separately by adding all scores and dividing the sum by the number of teeth (i.e. 6). In this way, maximum TPI scores were 5 and 3 buccally and palatally, respectively.

Paper V

Consumption rate was calculated, if not pre-stipulated in the method. In the first series, AUCs were calculated under pH 5.5 ($AUC_{5.5}$) and pH 6.2 ($AUC_{6.2}$) for the two time periods of 0-2 min and 0-30 min[167]. One-way ANOVA was used to analyze differences in AUC, and pH variations among the different methods of drinking as well as among the three measuring sites. In order to assess the differences with respect to drinking method, ANOVA supplemented with Fisher's PLSD test was used. For the telemetric method, the µmols H^+ x min was calculated[130].

Statistical Software

All analyses in Papers I-V were performed on an IBM Personal Computer using the Statistical Package for Social Sciences (SPSS, Releases 6 to 11). $P<0.05$ was considered as statistically significant.

RESULTS

Paper I

The reliability of the scale used for grading erosion was tested by the (A-KJ) performing two successive blind assessments within an inter weeks. Each of the buccal and lingual surfaces of 120 teeth, corres 230 buccal and lingual surfaces (10 surfaces were ungradeab individuals on a randomly selected and ordered basis, were recorded. examiner concordance (percentage agreement) was found to be 78%. 551 maxillary anterior teeth were available for assessment o corresponding to 1083 surfaces (19 surfaces were ungradeable c presence of restorations, cast inaccuracies, etc.). Seventy-seven per maxillary incisor and canine surfaces showed some degree of erosio of these scoring grades 3 or 4. Combining grades 2 to 4, which r considerable degree of erosive wear, 28% of all the graded surfa sample were so affected. Lingual surfaces were significantly more af buccal surfaces ($P<0.001$), while central incisors ($\bar{x}=1.36$; bucc exhibited significantly more erosion than the laterals ($\bar{x}=1.21$; bucca $P<0.001$) and the canines ($\bar{x}=0.70$; buccal+lingual; $P<0.001$); at the the laterals had significantly more erosion than the canines ($P<0.001$ teeth exhibited cervical shoulders, but approximal erosion could be one individual only. Of the individuals, 80% had one or more teeth w erosion or higher, while the corresponding figure for grade 3-4 wa 5% for grade 4. One or more cervical defects/cuppings were found i 49%, respectively, of the subjects.

The mean number of teeth in the sample was 27, with a range Mean DMFT and mean DMFS without the aid of radiographs we 17.5, respectively. With the two versions of radiographic int included, DMFT became 10.0 (ii) and 10.5 (iii), respectively, and D (ii) and 19.4 (iii), respectively. For the first radiographic assessme values of the individual components of the DMFT were: D=7.7, M= and for DMFS: D=12.6, M=2.5, F=3.2. Three individuals were without the aid of radiographs, but only one individual wa radiographic assessment. According to the Thylstrup-Fejerskov in premolars were most frequently affected by fluorosis, followed by t teeth and then the molars. On the other hand, fluorosis of greate (scores 5-9) was found mainly in molars, followed by the prer anterior teeth.

All subjects ate 3 main meals per day, and due to the military re were living under, meals were also consistently uniform within t Twelve percent drank water during or just after meals, while the

drank sweetened tea (44%), soft drinks in combination with other beverages (23%) or sweetened tea in combination with water (21%). Eighteen percent reported drinking only water as a between-meal drink; the rest generally drank regular cola-type drinks (73%) and/or other regular carbonated soft drinks (9%). Forty-six percent had a weekly intake of one or more sweets. For the total sample, the mean number of sweet intakes was 3.2 per week (range 0-21). As regards fruit consumption, the most frequently consumed item was dates (12.2 intakes/week). The mean soft drink consumption in the sample was 4.75 liters per week corresponding to 247 liters annually, of which regular (sugar-containing) cola-type drinks alone constituted 222 liters. Prior to starting military service soft drink consumption was reported to have been considerably higher at 373 liters annually.

Twenty-five percent of the subjects reported not cleaning their teeth, 57% doing so occasionally (defined as ≥once/week but not daily for the past ≥1 year), and 18% once or more daily for the past ≥1 year. On average, the 75% who reported any cleaning had done so for the past 3.5 years, with 24% of them using miswak, 44% a toothbrush and 32% a combination of toothbrush and miswak. Twenty-four percent never used toothpaste, 59% used it occasionally (defined as ≥ once/week but not daily) and 17% once or more daily. The toothpaste used was always fluoride containing. As regards the technique used for cleaning the teeth, 43% reported "no special technique", 36% "up and down", 14% "back and forward", and 7% a combination of "up and down" and "back and forward". Presence of systemic disease was reported by only one individual (dermatitis), while four were on regular medication. Thirty-two percent reported dryness of the mouth, 21% bruxism, 61% occasional headache and 39% occasional biting habits (nail-, pen-, nut-biting, etc.). Dental problems were common within the sample and 73% reported one or more symptom(s). The single most common complaint was "pain" (42%), followed by "worn teeth' (39%), "esthetics" (26%), "tooth sensitivity" (22%) and "difficulty in chewing" (9%) (one or more symptom could have been present in each individual). Seventy-two percent of the subjects "never or seldom visited a dentist", 11% "visited a dentist at least every 5 years", and 17% "visited a dentist once or more every year". As regards their awareness of the danger to oral health of regular (sugar-containing) soft drinks, 35% were unaware thereof; as for their knowledge about diet soft drinks (sugar-free), 90% said they were not dangerous. Fruit juices were not considered to be harmful to oral health by 84%, and 2% stated that sweets were not harmful.

Paper II

Mean cola-type drink consumption in the low erosion subgroup (2.5 liters/week) was significantly lower than in the high erosion subgroup (4.8 liters/week) ($P<0.01$). Those variables which differed significantly be subgroups were: type of cleaning aid used ($P<0.05$) and cleaning ($P<0.05$), reported dental problems ($P<0.05$), number of permanent fi with "cuppings" ($P<0.05$), number of buccal cervical defects ($P<$ number of missing teeth ($P<0.05$). Gingival bleeding index was sig higher in the low than in the high erosion subgroup ($P<0.01$). In erosion group, one or more cervical defects/cuppings were found in 64%, respectively, of the subjects. The corresponding figures for erosion group was 11% and 41%.

Analysis by logistic regression identified three variables of signific cola-type drink consumption (ml/week), GBI and type of cleaning a 0=no cleaning; 1=miswak only; 2=toothbrush only; 3=combi toothbrush and miswak). The correlations with cola-type drink cor and with type of cleaning aid in the high erosion subgroup were both while the correlation with gingival bleeding index was negative. For regression model based on the three variables entered, the specificity and the sensitivity 89% (overall 87%).

Paper III

In vivo Study

Factors that may be associated with the development of dental eros participating children, are shown in Table 4. Beverage consumpti group was generally found to be high ($\bar{x}$=410 liters/year, range=62- frequent, and consisted mainly of soft drinks, including juices. Intak varied and some reported lemon sucking. Daily oral hygiene with t and fluoridated toothpaste was reported by 8 of the 16 children, and 3 of them. One reported daily tooth brushing, but without toothpast practiced no oral hygiene at all. Of those cleaning their teeth, none miswak. The time for starting oral hygiene varied between 3 and 6 ye Mean gingival bleeding index and visible plaque index were found (range=0-24) and 35% (range=0-89), respectively.

Respiratory tract infections, and tonsil problems were common, ac the medical file. The majority of the children had had frequent presc medications, such as antibiotics, analgesics and cough suppre antitussives (Table 4). For example, three children had been diagn respiratory tract infections on 87, 42 and 38 occasions, given antibio and 8 times, cough suppressants or antitussives 70, 32 and 38 analgesics 67, 34 and 28 times from birth to the time the files were s as part of this study. Four other children had been referred to the ear throat clinic from the primary care doctor due to enlarged tonsils and

and with recurrent upper respiratory tract infection. All of these children were also reported to snore or mouth breath or both. Three of the children referred to the specialist underwent adenotonsillectomy. The fourth case referred did not undergo surgery as the tonsils were found to be non-obstructive.

Two other children were diagnosed as asthmatics and had medication for this. None of the children reported stomach problems or any clear dental problem, which could be related to their dental erosion. According to the medical file, the children were also diagnosed with other infectious conditions (not mentioned in Table 4), e.g. eye infections and gastroenteritis and were also prescribed medication for these. SEM assessment had confirmed the diagnosis of dental erosion in all teeth subjected to analysis (n=8; from eight different children), with a characteristic loss of enamel surface structure leading to a honeycomb appearance, seen in the specimens.

Table 4. Findings from questionnaire (intake of drinks and fruits, oral hygiene habits) and medical records (snoring and/or mouth breathing, adenotonsillectomy and number of prescriptions). 0 = none; - = missing data; d = daily; w = weekly

Pat no.	Age (years)	Breakfast [1]	Lunch [1]	Dinner [1]	At school [1]	At night [1]	Between meals [1]	Lemon sucking	Citrus fruits and apples	Oral hygiene	Number of diagnoses from the medical file [2]	Snoring and/or mouth breathing [3]	ENT surgery [4]	Number of prescriptions [5]
1	7	T	S	S, T	S	S	S, M	0	1-2/d	2/d	13 URTI	-	0	4 AB, 13 AN, 9 C
2	6	M	S	S	S	S	S	0	0	2/d	14 URTI	-	0	9 AB, 7 AN, 6 C
3	6	S, M	W	M	-	S	S, M	0	0	2/d	2 URTI	+	0	2 AB, 2 AN, 2 C
4	7	T	S	W, T	S	W	S, W	0	0	2/d	84 URTI, 3 LRTI	-	0	25 AB, 67 AN, 70 C
5	8	S, M	S	S	S	0	S	0	0	2/d	10 URTI	+	+	6 AB, 11 AN, 6 C
6	6	S, W	S, M	S, W	-	-	W	0	2/d	1/w	24 URTI, 2 LRTI, A	-	0	6 AB, 16 AN, 25 C
7	8	S, M	S, M	-	S	-	S	0	0	0	56 URTI, 7 LRTI, A	-	0	29 AB, 38 AN, 46 C
8	6	M	M	T	S	M, W	S, T	1/w	3/w	3-4/w	39 URTI, 3 LRTI	-	0	17 AB, 34 AN, 32 C
9	7	M	S, M	W	-	-	S	0	0	1/w	5 URTI	-	0	2 AB, 5 AN, 1 C
10	7	M	W	S, T	S	-	S	0	1-2/w	2/d	30 URTI, 1 LRTI	+	0	9 AB, 17 AN, 18 C
11	5	M	W	0	S, M	-	S	1-2/d	2/w	1/d	10 URTI	-	+	7 AB, 9 AN, 4 C
12	6	S	S	S	S	S	S	0	2/d	0	36 URTI, 2 LRTI	-	0	8 AB, 28 AN, 38 C
13	5	S, M	S, M	W	S	S	S	0	2/w	2/d	47 URTI	+	+	22 AB, 33 AN, 25C
14	7	M	W	M, W	S	W	0	0	2/d	0	17 URTI, 1 LRTI	-	0	7 AB, 14 AN, 16 C
15	7	M	W	S, W	S	M	0	0	4/w	1/d	2 URTI	-	0	6 AN, 3 C
16	6	T, S, M	M	S	S	-	S	1/d	2-3/d	0	22 URTI	-	0	10 AB, 1 C

[1] S= soft drinks; M= milk product; T= tea; W= water
[2] URTI= Upper Respiratory Tract Infection; LRTI= Lower Respiratory Tract Infection; A= Asthma
[3] Recorded from medical record only
[4] Referral resulting in adenotonsillectomy
[5] AB= antibiotics; AN= analgesic; C= cough suppressant

In vitro Study

The microhardness measurements showed that enamel surface decreased proportionately with increased time of acid immersion ir specimen groups, irrespective of ethnic origin. However, whei permanent teeth were compared to Finnish and Saudi deciduous differences in microhardness were found to be statistically signifi deciduous teeth being softer than permanent ones, both at baseline immersion in acid ($P<0.01$ to $P<0.001$). In all cases, typical erosi were observed as expected. No particular morphological differences detected between the deciduous and permanent teeth, or between th and Saudi deciduous teeth. Irregular patterns of pit-like erosion areas in all specimens, varying from site to site.

Paper IV

Drinking Habits and Questionnaire

Consumption of other types of soft drinks apart from cola-type d negligible. The amount of cola-type drink consumption was almos high 253 liters/year and 140 liters/year in the high compared to the lc group ($P<0.05$). A similar level of difference was found for the subjects kept the drink in the mouth before swallowing, viz. 71 s fo and 40 s for the low erosion group ($P<0.05$). No differences w regarding the total consumption time and number of intakes and swa subjects preferred to drink directly from the can. Mouth breathing common in the high erosion group compared to the low erosion group

pH Measurements

There was a dropout of one individual in each group due to technic Only small differences between the two groups were found at baseli sites, apart from the proximal site of the maxillary central incisor erosion group showed the most pronounced pH fall during the firs Beyond 10 min, the general tendency was the opposite, i.e. a slower r the low erosion group. Differences in AUC_{0-10} and AUC_{0-50} between were not significant for any of the sites for both AUCs viz. below p 5.5.

On both buccal and palatal surfaces of tooth no. 11, a more pronc fall was found in the high erosion group, but no significant differe found between the groups when comparing the pH values at each tim the whole 50 min period. However, when comparing the anterior si

premolar sites, pH was significantly higher at anterior sites ($P<0.05$ or $P<0.01$) in both groups. Differences were also found when comparing the tongue and the dental sites, the tongue having higher pH ($P<0.05$ or $P<0.01$).

Salivary and Microbial Analyses

One salivary sample among the low erosion subjects failed due to technical reasons. The concentration of urea in unstimulated saliva was lower in the high erosion group ($P<0.05$). A numerically lower concentration of urea, although not statistically significant, was also found for the stimulated saliva in the high erosion group ($P=0.13$) (Fig. 9). There were no differences in concentrations of electrolytes between the groups. No significant differences between the groups were found with respect to variables related to unstimulated and stimulated secretion rates, buffer capacity and numbers of lactobacilli or mutans streptococci.

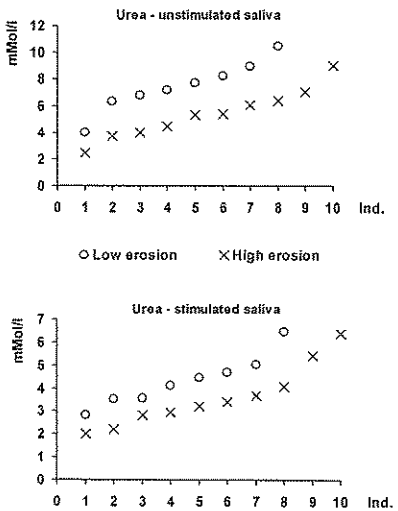


Fig. 9. Concentration of urea i High and low erosion subjects.

Clinical Parameters

The number of first molar cuppings and buccal cervical defects were more common in the high compared to the low erosion group ($P<0.05$ and $P<0.01$, respectively). In the high erosion group, one or more cervical defects/cuppings were found in 60% and 75%, respectively, of the subjects. In the the low erosion group none had cervical defects and 43% had cuppings. The palatal TPI was lower in the high compared to the low erosion group, while the buccal TPI was not. Visible plaque index did not differ significantly between the two groups, either for the whole dentition or the buccal and palatal surfaces of the maxillary anterior teeth only. Gingival bleeding index for the whole dentition was significantly lower in the high erosion group ($P<0.05$), but the index for the maxillary anterior teeth only was not.

Paper V

In general terms, a higher rate of consumption of the drink was foun two (telemetric method) than in series one (microtouch method), ex sucking from a straw (Table 3). The mean pH curves for the two methods showed similar results, although the telemetric method produ baseline values as well as more pronounced pH falls.

Microtouch Data

No statistical differences in pH and AUC between the three intraoral found. Holding resulted in the most pronounced pH fall during the minutes. pH then recovered close to the baseline value within 5 swallowing. Short-Sipping produced a pronounced drop in pl consumption, even if not as great as for holding, after which there w quick return to baseline. Long-Sipping resulted in a moderate pH fal microtouch method (in contrast to the telemetric method) during th min, after which pH stayed at a low level during the remaining exposu A slower recovery rate than for Short-Sipping was found and baselin not re-established until 10 min after the actual sipping had ceased. Th method showed only a minimal drop of pH immediately after each o intakes, followed by a quick recovery. Nipping resulted in a moder drop in pH, followed by a slow recovery to above baseline after t drinking. Sucking led to an initial drop during the first 2 min, follo quick rise back to above baseline within a few minutes. Long-Sippin highest mean $AUC_{6.2}$ value over 0-30 min. Holding resulted in th $AUC_{5.5}$ over 0-2 min, while at 30 min the cumulative $AUC_{5.5}$ was same as for Long-Sipping. In spite of the fact that Holding represent the shortest consumption times, it ranked second in terms of $AUC_{6.2}$ the 0-30 min period. Holding resulted in the highest number of s differences in AUC compared to the other methods. Fig. 10 shows erosion-conducive drinking methods based on pH-drop and acid x tim

Telemetric Data

The results obtained with the telemetric method were in many respec to those found with the microtouch method. However, the telemetri gave pH readings with more fluctuations, and especially so with m drinking of longer duration (Long-Sipping and Nipping). With Nippin difference in pH between the two measuring methods during the last observed. This was due to the extreme values obtained from only vidual. When the erosive effect of the different methods of drinking, by the telemetric method, was expressed as acid concentration x tin

found that Long-Sipping had the strongest erosive effect during the intake, followed by Holding and Nipping. The strongest erosive effect after the consumption was found with the Holding method.

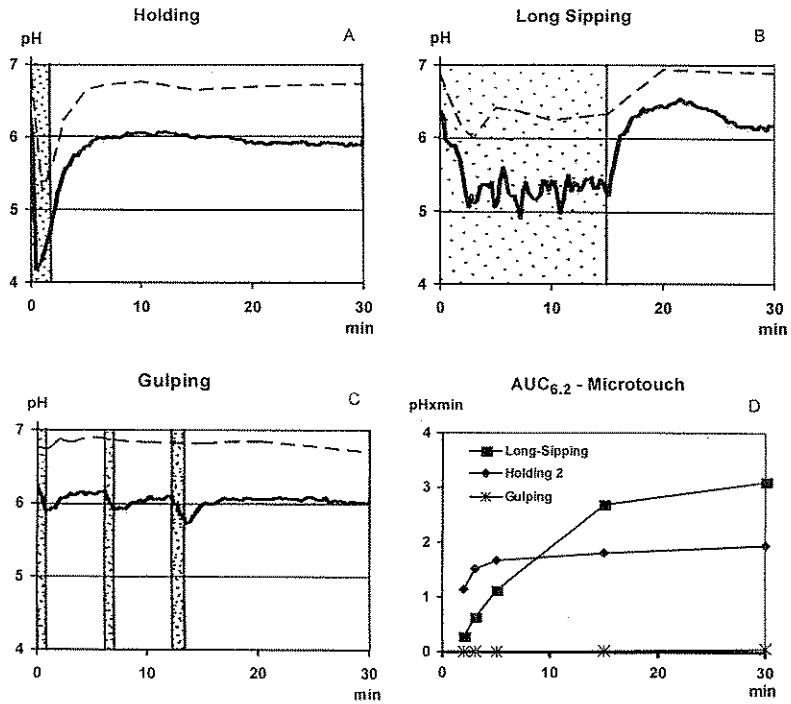


Fig. 10. pH fall (mean values) for three of the methods of drinking for both methods (A,B,C) and the corresponding $AUC_{6.2}$ with the microtouch method (D).
----- = Microtouch method, —— = Telemetric method; ⋯ = period of intake

DISCUSSION

Methodological Aspects

Reliability & Validity of the Questionnaire

Central to this investigation were the results and conclusions drawn responses to the questionnaire in Papers I-IV. From a general s questionnaires are useful in biomedical research and it is known, for that self-rated health is an accurate and independent predictor of fut and death, which may even exceed that of medical expert judgment[168] validity and reliability have similarly been found with the use of ques related to oral and orofacial conditions[170]. For the present purposes, t maximize validity and reliability was addressed by adopting certain p as discussed below. The questionnaire (Fig. 7) was constructed on th one previously used in similar types of research[5]. The questions were and additions were made on the basis of the results of an initial p which was performed prior to starting the work described in Paper I. study served the additional purpose of piloting the procedures inclu clinical examination. The original English questionnaire was trans Arabic by a co-author fully conversant with the customs and traditi country, and the translation validated by independent re-transl English. The completion of the questionnaire were performed by a trained bilingual translator who had served for many years in that c the dental department. All data obtained from the interview and ques were checked afterwards by the principal investigator (A-KJ). I reasonable to expect the foregoing measures to have increased the the responses since language problems, bias and/or misunderstandi interview would to a large extent have been eliminated. A specia arises when interviewing young children (Paper III), since, given their cannot reliably be expected to give accurate answers to relatively co questions. Besides this, parents may have difficulties answering correctly on behalf of their children. The children in this study (Pape all attended the hospital since birth, and there was therefore a comp medical file available. In order to increase the validity of the information given by the child and parent were cross-checked where and complemented where appropriate, with the information contain medical records, e.g. diseases and medications. As regards the reliabi questionnaire, one could argue that it is in fact a part of the validity. T though no separate analysis of the reliability of the questionnaire performed, the comprehensiveness and representativeness of the qu investigate wear had previously been found to be acceptable[5], whi

improvements in clarity and comprehensibility, in order to increase its reliability, were made to the present questionnaire. Statistical advice was sought in the construction of the questions and the numeric measures attached thereto, in order to facilitate inferential statistical analyses.

In summary, it may be fair to assume that the measures taken, in the context of the general limitations of questionnaires, conferred acceptable levels of validity and reliability to the instrument used. Such a contention may be further substantiated by the results, whereby the outcome of the analysis of the questionnaire in general terms confirmed theoretical expectations as regards the correlations that could exist between the responses obtained and the occurrence of dental erosion.

Assessment of Dental Erosion

Being able to accurately evaluate degrees of dental erosion was crucial to the integrity of the findings. Of particular relevance, in this regard, was the validity and the reliability of the scale used for grading dental erosion (Papers I, II, III and IV). Many different systems for grading dental wear and dental erosion have been described, each with its advantages and disadvantages. It is clear, when choosing a scoring system, that the type of investigation that is to be performed is important. In Paper I, a relatively large number of subjects was to be examined clinically for assessment of the occurrence of dental erosion. Therefore the use of a relatively simple ordinal scale was considered suitable. On the other hand, more sophisticated methods such as SEM and microhardness assessments (Paper III), iodine permeability[84] or ultrasonic measurements[171] could be applied in smaller, selected samples and for purposes that are more specific. The ordinal scale used in the present study has similarities with others[161,162] but is primarily a variant of Eccles, which was first described in 1979[160]. For the present purpose, so as to increase validity, the final diagnosis and scoring of dental erosion was reached from combined clinical, study cast and intraoral slide assessments.

The distribution of dental erosion is by no means uniform. Maxillary anterior teeth were found to be common sites of, and most severely affected by, erosive wear, making their accurate and reliable assessment for presence and degree of erosion possible. Other teeth in the dentition were not as reliably gradable, due to the fact that they were generally not so severely affected. In addition, morphological complexities and photographic and cast qualities are factors limiting the assessment of erosion in general, and particularly so for posterior teeth. It was also considered important to distinguish between erosion and other types of wear as much as possible. For these possible confounding reasons, the assessment of erosion was confined to the maxillary anterior teeth, with incisal surfaces excluded. In the clinical assessment of erosion, it was found that the standard mouth mirror was difficult to use. The mirror used for occl in intraoral photography, together with a good operating light, was fo preferable and was therefore utilized. The casts were valuable in v three-dimensional aspects of changes affecting morphological featur and palatal morphology, as well as any change in bucco-lingual could by this means be detected. Similarly, the effects of camera lighting on the photographic image, and the angle at which a cast is vi significantly affect the appearance and add a further dimension to t process of assessment (Paper I). In order to be able to diagnose the ear lesion, the scale also graded defects in enamel, which may reflect initi changes. Such lesions are commonly found in both children and ad and their detection is very important from an epidemiological and p point of view. When using a more coarse scale, and overlooking erosi in enamel, only more advanced erosive lesions will be recorded. Enar in thickness and dentinal exposure should not be uniformly judged; it considered in relation to the amount of enamel which needed first tc away. It could therefore be speculated that cuppings, which usually t on the cusp tip, where the enamel is relatively thick, should be juc manifestation of more severe erosive damage than, for example, dama buccal cervical one-third of the crown, where enamel is thinner. On th the practical lessons learnt in this series of assessments, it is cc proposed that the combined approach of grading erosive wear using cast and photographic examinations, offers significant advantages cor systems which rely on a single, or at most a dual approach[172].

A thorough program of examiner training and calibration, with r grading dental erosion, between the principal investigator (A-KJ) and investigators (AJ and GEC) was performed prior to the investigat permitted the use of a sole examiner (A-KJ) for grading purposes, wh be considered a strength of the study. In addition, the examiner had no information from the questionnaire during the final scoring of erosion, to the clinical erosion scores, the casts and the slides. The reliability of used for grading erosion was tested by repeat, blind assessments on a of teeth, producing an intra-examiner concordance of 78% which considered as acceptable (Paper I).

The Mean Index

An arithmetic mean erosion index for a subject was derived by summ his erosion scores and dividing the total by the number of teeth (Papers II & IV). Constructing a mean value index from an ordinal sc be considered controversial and some general objections could be raise subsequent discussion has been addressed previously[5]. The scale

between gradations in an ordinal scale are not identical and a mean value do not represent the severity of erosion in a subject in addition to that it does not exactly match with any of the grades in the scale which could render such a value useless from a descriptive point of view. From a general perspective, a mean value is likely to be biased because of possible extreme scores or a non-normal distribution of erosion scores within the sample, while a small sample size complicates inferential analysis.

The alternatives to using the arithmetic mean could be a median value, or a sum of scores, grouping of scores into clusters and weighting to compensate for the unequal distances between scales. All of these alternatives do, however, present their own specific problems and were therefore considered inappropriate for the present purposes. The use of a mean value was also deemed justified by virtue of the homogeneity of the sample with respect to the generally complete presence of maxillary anterior teeth. In addition, the sample size (n=95) was large enough to justify the use of means on the basis of the central limit theorem.

In summary, the use of mean of the ordinal scale in the statistical analyses was therefore considered appropriate.

Sample and Subgroup Selection

The representativeness of the sample in Paper I with respect to age needs discussion. Although the sample was not fully representative of this age group within the general population, it did represent a mix of socio-economic and educational scales. In addition, the sampling was randomized and the attendance was good (95%). It would also be reasonable to assume the generally fit and healthy status of young military inductees here, as would be the case elsewhere. Such an assumption is further supported by the general finding through the questionnaire of the relative absence of systemic diseases and use of medication in the sample. In light of the aforementioned factors together with clinical observations in the general population, the representativeness of the present sample of young adult Saudi men may be considered sufficient for some cautious general conclusions about men in their age group to be drawn.

In order to evaluate different factors that potentially influence dental erosion, high and low erosion subgroups were selected (Papers II and IV) on the basis of the highest and lowest erosion mean individual indices in the sample (Paper I, Fig. 11 A). As an indication, a large proportion of surfaces was graded as either 3 or 4 in the high erosion groups while in the low erosion groups the majority of surfaces was graded as 0 (Paper II and IV, Fig. 11 B, C). This supports our contention that the subgroups represented individuals with clearly contrasting levels of dental erosion in Papers II and IV.

Other Methodological Aspect

When applying multivariat statistics, it is important t recognize that co-variatio between the different factors ca sometimes produce a "false relationship with the examine factor, in this case the mea value index of dental erosion. A the dependent variable wa dichotomous (low or high denta erosion) a logistic regressio model, which takes into accoun the problem of cross-correlation was applied to evaluate th association of different factor with dental erosion (Paper II).

The absence of a contro group in Paper III require clarification. Data collection wa performed in the first half of th 1990s, at which time reports o dental erosion affecting deciduous teeth were almost non-existent. The rationale wa consequently confirmational, t the extent that dental erosion firstly, could affect the primary dentition, and secondly to verify the observed erosive damage by SEM. In addition, it was intended to characterize differences between deciduous and permanent teeth on the basis of SEM and microhardness properties. Considering the largely exploratory aims of the study, a control group was therefore not deemed necessary.

The measurement of intraoral pH during drinking requires some comments (Paper

V). The microtouch technique, inasmuch as no new methodological assessment was made, requires elaboration. Firstly, the method is accepted and has a strict technical protocol to be followed in order to minimize recording errors[164] (Paper V). Secondly, in most instances, a mean of several registrations was used in both descriptive and inferential analyses which reduced the effects of interval measurements and its measurement errors. It is further suggested that the use of the telemetric method as an additional measuring technique complements the microtouch method, to strengthen the conclusions drawn regarding the effect of method of drinking on intraoral tooth surface pH.

Dental Erosion - Prevalence and Associated Factors

Assessment of Prevalence

An absolute comparison of the prevalence of dental erosion in the present investigation with results from other population samples is not possible primarily due to the different grading systems used and dissimilar age and sex composition. Restricting evaluations to only maxillary anterior teeth and then to only their buccal and palatal surfaces, has similarly been applied in other epidemiologic studies[32,35,36]. In addition, the recognition and recording of concavities on smooth surfaces as being a characteristic of grade 2 in the scale for grading erosion (Paper I), has recently been shown to be correlated with dental erosion[173]. Within these constraints, a few comparisons to other studies can be made as regards the prevalence of erosion. In 14-year-old British children it was found that 80% of the children showed evidence of enamel erosion using the TWI[37]. This corresponds roughly with the prevalence of erosion reported in Paper I where 80% of the subjects had at least one tooth affected with grade 2 erosion or higher. In another British survey, 2% of the 13-15 year-old children studied showed erosion into dentin[32]. Among 12-14 year-old Saudi boys, 26% were found to have exposure into dentine[43]. However, 16% of the subjects in Paper I had one or more teeth affected with severe erosion if one combines grades 3 and 4 erosion and 5% if only grade 4 is counted.

In general, the prevalence figures and pattern of dental erosion presented in this study seems to conform to data presented elsewhere in regard to findings of dental erosion in young adults. The background factors of dental erosion are to a large extent dependent on the prevailing period and/or culture in which the subjects are living. Lifestyle changes can occur quickly which make comparison of findings over even short time spans difficult[41].

Cuppings and Cervical Defects

A not unexpected finding was a significant correlation between cup first permanent molars and dental erosion, since cupping is on recognized clinical features of dental erosion[41,43]. In high erosion subje more common than in low erosion subjects (Papers II and IV). Cupping been found more common in high erosion subject among 11-year-old compared to non-erosion subject[41]. In a recent Australian study, it w that cuppings were most common in mandibular first molars foll maxillary first molars, and it was suggested that mandibular first p molar cuppings indicate the age of onset and severity of dental erosic also found that cuppings on first molars were more common and larg in younger than older individuals with dental erosion[174].

Buccal cervical defects were also significantly correlated with the s dental erosion (Paper II, IV). In a recent SEM study, shallow cervic were strongly associated with occlusal erosive pathology, while wedg cervical lesions had an association with both occlusal erosive wear and attrition[14]. The prevalence of cervical lesions in the present materia likely underestimated due to the decision to only record defects w demarcation, and omitting the small defects. However, the extent to wh vigorous oral hygiene activity *per se* in the high erosion subgroup acco the defects needs to be taken into consideration (Paper II, IV).

In conclusion, it seems certain that morphological changes showing of erosion on the buccal and palatal surfaces of maxillary anteri cuppings on first permanent molars and presence of cervical defects, clinical signs of, and represent the onset of dental erosion in young adu

Oral Hygiene

Oral hygiene measures among the military cadets in Paper I were minimal and none had started practicing oral hygiene before the a years. This can be compared to a recent study in which about 60% of 6 Saudi children reported cleaning their teeth on a daily basis, and of the used the miswak[175]. Comparing this, in turn, with the high erosion ch this investigation (Paper III), oral hygiene practices were even more The improving level of oral hygiene compared to the cadets could in g a result of the rapid development and accompanying changes in lif Saudi Arabia. In this regard, it has been found that oral hygiene subjects aged 10-60 years in Saudi Arabia is strongly associated with of education[176] but among 2-5 year-old Saudi Arabian children, no rel with dental erosion was found regarding either oral hygiene or social cl

In Paper II, a significant correlation between lower gingival bleedi and high erosion was found. This may partly be explained by the fact

prevent dental erosion, an individual's method of drinking should therefore be investigated. Information and recommendations to patients at risk should include advice to reduce consumption of acidic drinks and to avoid a method of drinking which could cause low pH values for a long period of time.

Quality of Dental Hard Tissue

Among the teeth collected from the children with severe dental erosion (Paper III), the clinical diagnoses of dental erosion were confirmed by SEM in all teeth analyzed. Deciduous enamel was softer than enamel of permanent teeth and, subsequently, more prone to erosion. This was not unexpected because deciduous teeth are less mineralized than permanent teeth and have a less mature enamel surface. The erosion in deciduous enamel was found to be relatively more rapid than that of permanent enamel. Some studies has suggested that the progression of dental erosion is faster in deciduous than permanent enamel[99,100] while in another study no difference was found[101]. The SEM results of the *in vitro* experiment (Paper III) mainly reaffirmed earlier observations from similar studies with permanent teeth, showing wide variations in eroded surface enamel[165]. It has earlier been pointed out that great complexity can be seen in the different patterns of loss of enamel structure in eroded deciduous teeth[197], similar to the findings in this study.

Nevertheless, based on SEM observations alone, no definitive conclusion can be drawn on the degree or severity of erosion. SEM analysis was instead used to visualize the associated pathology, while the assessment of surface microhardness was performed to obtain quantitative data. Such a combined approach for understanding dental erosion has been applied in other studies[84,165].

It can be speculated whether susceptibility to erosion might depend on differences in hard tissue quality, culture and/or ethnic origin, or perhaps even genetics and/or environmental conditions. As regards Paper III, no clear difference was observed between the degrees of erosion sustained by Finnish and Saudi deciduous teeth *in vitro*, which renders the aforementioned bases for possible differences, in the case of these two population groups, invalid.

Since the erosion in this experiment was induced under *in vitro* conditions, it is clear that the results are not completely transferable to the *in vivo* situation where the amount and quality of saliva[28] and the pellicle will protect the teeth from acidic challenges[49,50]. From a clinical standpoint, and in regard to young children, it has been shown that children aged 3-7 years have larger variations and slower salivary sugar clearances and also lower salivary flow rates than older children and adults[198]. From the standpoints of both hard tissue quality and salivary conditions, deciduous teeth seem, therefore, to be at greater risk than permanent teeth as regards erosive challenges.

In summary, deciduous enamel has about the same potential for *in vitro* regardless of the origin of the teeth, and that deciduous relatively more prone to *in vitro* erosion than permanent enamel.

The Clinical Implications of Dental Erosion

Changes in the patterns and distributions of the major diseases affec and oral health are well recognized[199-201], changes which may ap widespread presence of dental erosion. The evaluation of th significance of a diagnosis of dental erosion should be made on an rather than an absolute basis. A degree of erosion that may be acceptable, and not warranting treatment, in one set of circumsta amount to a severe, possibly functionally debilitating condition, situation. In this regard, the existence of grade 3 erosion acros generations of the same family, come to mind. When severe den affects a child, the main disability may include pain initially, but can grow in seriousness to affect eating, appearance and the quality of individual. Prevention may at times involve making lifestyle changes, for the affected individual, but for the whole family. For example, i shown that the children's dietary patterns commonly reflect thei choices of food and drinks[202].

Frequently, the etiological, modifying and/or aggravating factors erosion will persist throughout life. Therefore, a patient, once diagn dental erosion, should be monitored and, if needs be, observed and for a long time. Besides providing the patient with all necessary in about their condition and prophylactic advice, photographs and st casts, salivary analysis and, if needed, consultations with the patien physician are good tools to use in the battle with the dental eros patient suffering from progressive dental erosion, it is especially im hasten the investigation in order to retard or prevent further deteri morphological changes, sensitivity, perhaps irreversible pulpal invol even complex orthodontic alterations. The central tenet of managen effective implementation of preventive measures, followed b necessary, restorative or prosthodontic corrective solutions. This is true for adolescents since the longevity of the reconstructions is lir will result in complications which implies an on-going future treatm The child with eroded deciduous teeth presents both a challeng opportunity to prevent later involvement of the permanent dentitio advice and information about dental erosion at the right time may patients totally prevent further damage, while in others the situatic more difficult. However, even in very severe cases, like in eating di has been shown that information and prophylaxis is useful for the

further progression dental erosion[62].

Thus, it is important for the dental team today to recognize the early stages of the condition, to understand its pathogenesis and to be able to distinguish its diagnostic features. Equally important are the need and the means to effectively communicate any positive findings as regards dental erosion to the patient, or the respective parents, since any chance of success with preventive measures strongly will depend on the patient's or his/her parents' proper understanding of the condition.

GENERAL SUMMARY AND CONCLUSIONS

1. The system applied for identification and assessment of dent showed an acceptable precision and reliability.

2. Dental erosion is a common finding in young Saudi men and drink consumption is high.

3. Cola-type beverage consumption and oral hygiene practices app important factors in the development of dental erosio morphological changes on maxillary anterior teeth, first molar and cervical defects are early clinical signs of dental erosion, serve as markers for its onset in adolescents.

4. High intake of acidic drinks and fruits, upper respiratory tract pro frequent taking of medications were common findings in smal with severe dental erosion. The clinical diagnosis of erosion deciduous teeth was confirmed by SEM.

5. Deciduous tooth enamel has about the same potential for *in vit* regardless of the origin of the teeth, but is relatively more prone erosion than permanent enamel.

6. Method of drinking, less plaque on maxillary anterior pal surfaces, lower urea content in unstimulated saliva, and bette status are associated with severe dental erosion.

7. The period of low pH after an acidic challenge seems largely re the time of consumption. The method of drinking greatly influenc on the surface of the teeth and consequently the risk of erosion.

It may be concluded from this study that dental erosion has a mu etiological, aggravating and modifying factors. At a commun information campaigns related to life style factors and its implic dental erosion must be launched.

1. PINDBORG JJ. *Pathology of the dental hard tissues.* Copenhagen: Munksgaard, 1970, pp. 312-321.
2. LARSEN MJ, BRUUN C. Caries chemistry and fluoride-mechanisms of action. In: THYSLSTRUP A, FEJERSKOV O (EDS.). *Textbook of Clinical Cariology.* 2nd ed. Copenhagen: Munksgaard 1994, pp. 231-257.
3. SMITH BGN, ROBB ND. The prevalence of tooth wear in 1007 dental patients. *J Oral Rehabil* 1996;23:232-239.
4. SMITH BGN, BARTLETT DW, ROBB ND. The Prevalence, etiology and management of tooth wear in the United Kingdom. *J Prosthet Dent* 1997;78:367-372.
5. JOHANSSON A. A cross-cultural study of occlusal tooth wear. *Swed Dent J* 1992; Suppl. 86.
6. YOUNG WG. The oral medicine of tooth wear. *Aust Dent J* 2001;46:4:236-250.
7. CARLSSON GE, INGERVALL B. Occlusal variations and problems. In: MOHL N, ZARB G, CARLSSON GE, RUGH JD (EDS.): *A textbook of occlusion.* London: Quintessence, 1988, pp. 209-212.
8. GRIPPO JO, SIMRING M. Dental "erosion" revisited. *J Am Dent Assoc* 1995;126:619-620, 623-630.
9. BRAEM M, LAMBRECHTS P, VANHERLE G. Stress-induced cervical lesions. *J Prosthet Dent* 1992;67:718-722.
10. BADER JD, MCCLURE F, SCURRIA MS, SHUGARS DA, HEYMANN HO. Case-control study of non-carious cervical lesions. *Community Dent Oral Epidemiol* 1996;24:286-291.
11. XHONGA FA, SOGNNAES RF. Dental erosion: progress of erosion measured clinically after various fluoride applications. *J Am Dent Assoc* 1973;87:1223-1228.
12. TRONSTAD L. Scanning electron microscopy of attrited dentinal surfaces and subajacent dentin in human teeth. *Scand J Dent Res* 1973;81:112-122.
13. BEVENIUS J, LINDSKOG S, HULTENBY K. The micromorphology in vivo of the buccocervical region of premolar teeth in young adults. A replica study by scanning electron microscopy. *Acta Odontol Scand* 1994;52:323-334.
14. KHAN F, YOUNG WG, SHAHABI S, DALEY TJ. Dental cervical lesions associated with occlusal erosion and attrition. *Aust Dent J* 1999;44:176-186.
15. JOHANSSON A, OMAR R. Identification and management of tooth wear. *Int J Prosthodont* 1994;7:506-516.
16. GRAEHN G, MUHLER HH. Wedge-shape defects of animal teeth. *Dtsch Zahn Mund Kieferheilkd Zentralbl* 1991;79:441-449.
17. MILLER WD. Experiments and observations on the wasting of tooth tissue variously designed as erosion, abrasion, chemical abrasion, denudation etc. *Dent Cosmos* 1907;49:225-247.
18. SCHWEIZER-HIRT CM, SCHAIT A, SCHMID R, IMFELD T, LUTZ F, MUHLEMANN HR. Erosion und Abrasion des Schmelzes. Eine experimentelle Studie. *SSO Schweiz Monatsschr Zahnheilkd.* 1978;88:497-529.

19. EKFELDT A, HUGOSON A, BERGENDAL T, HELKIMO M. An individual tooth wear index and an analysis of factors correlated to incisal and occlusal wear in an adult Swedish population. *Acta Odontol Scand* 1990;48:343-349.

20. NYSTRÖM M, KÖNONEN M, ALALUUSUA S, EVALAHTI M, VARTIOVAARA J. Development of horizontal tooth wear in maxillary anterior teeth from five to 18 years of age. *J Dent Res* 1990;69:1765-1770.

21. KHAN F, YOUNG WG, DALEY TJ. Dental erosion and bruxism. A tooth wear analysis from South east Queensland. *Aust Dent J* 1998;43:117-127.

22. NUNN JH. Prevalence of dental erosion and the implications for oral health. *Eur J Oral Sci* 1996;104:156-161.

23. ZIPKIN I, MCCLURE FJ. Salivary citrate and dental erosion. *J Dent Res* 1949;28:613-626.

24. SOGNNAES RF, WOLCOTT RB, XHONGA FA. Dental erosion. I. Erosion-like patterns occurring in association with other dental conditions. *J Am Dent Assoc* 1972;84:571-576.

25. XHONGA FA, VALDMANIS S. Geographic comparisons of the incidence of dental erosion: a two-center study. *J Oral Rehabil* 1983;10:269-277.

26. ROBB ND, CRUWYS E, SMITH BG. Regurgitation erosion as a possible cause of tooth wear in ancient British populations. *Arch Oral Biol* 1991;36:595-602.

27. SMITH BG, KNIGHT JK. An index for measuring the wear of teeth. *Br Dent J* 1984;156:435-438.

28. JÄRVINEN VK, RYTÖMAA I, HEINONEN OP. Risk factors in dental erosion. *J Dent Res* 1991;70:942-947.

29. ECCLES JD, JENKINS WG. Dental erosion and diet. *J Dent* 1974;2:153-159 .

30. LUSSI A, SCHAFFNER M, SUTER P, HOTZ P. Dental erosion in a population of Swiss adults. *Community Dent Oral Epidemiol* 1991;19:286-290.

31. LINKOSALO E, MARKKANEN H. Dental erosion in relation to lactovegetarian diet. *Scand J Dent Res* 1985;93:436-441.

32. O'BRIEN M. Children's dental health in the United Kingdom 1993. London: Office of population Census and Surveys. London: HMSO, 1994.

33. MILLWARD A. SHAW L, SMITH A. Dental erosion in four-year-old children from differing socioeconomic backgrounds. *ASDC J Dent Child* 1994;61:263-266.

34. MILOSEVIC A, YOUNG PJ, LENNON MA. The prevalence of tooth wear in 14-year-old school children in Liverpool. *Community Dent Health* 1994;11:83-86.

35. JONES SG, NUNN JH (EDS). The dental health of 3-year-old children in east Cumbria 1993. *Community Dent Health* 1995;12:161-166.

36. MOYNIHAN PJ, HOLT RD. The national diet and nutrition survey of 1.5 to 4.5 year old children: summary of the findings of the dental survey. *Br Dent J* 1996;181:328-332.

37. MILLWARD A, SHAW L, SMITH AJ, RIPPIN JW, HARRINGTON E. 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.

38. WILLIAMS D, CROUCHER R, MARCENES W, O'FARREL M. The prevalence of dental erosion in the maxillary incisors of 14 year old schoolchildren living in Tower Hamlets and Hackney, London UK. *Int Dent J* 1999; 49:211-216.

39. KUNZEL W, CRUS MS, FISCHER T. Dental erosion in Cuban children ass excessive consumption of oranges. *Eur J Oral Sci* 2000;108:104-109.

40. DEERY C, WAGNER ML, LONGBOTTOM C, SIMON R, NUGENT ZJ. The p dental erosion in a United States and a United Kingdom sample of adolesc *Dent* 2000;22;6:505-510.

41. GANSS C, KLIMEK J, GIESE K. Dental erosion in children and a crosssectional and longitudinal investigation using study models. *Communi Epidemiol* 2001;29:264-271.

42. AL-DLAIGAN YH, SHAW L, SMITH A. Dental erosion in a group of British school children. Part I: Prevalence and influence of differing so backgrounds. *Br Dent J* 2001;190:145-149.

43. AL-MAJED I, MAGUIRE A, MURRAY JJ. Risk factors for dental erosion in and 12-14 year old boys in Saudi Arabia. *Community Dent Oral Epidemiol* 46.

44. AL-MALIK MI, HOLT RD, BEDI R. Erosion, caries and rampant caries children in Jeddah, Saudi Arabia. *Community Dent Oral Epidemiol* 2002;30

45. TEN CATE JM, IMFELD T. Dental erosion, summary. *Eur J Oral Sci* 1996;10

46. O'SULLIVAN EA, CURZON ME. A comparison of acidic dietary factors in and without dental erosion. *ASDC J Dent Child* 2000;67:186-192.

47. AL-MALIK MI, HOLT RD, BEDI R. The relationship between erosion, caries caries and dietary habits in preschool children in Saudi Arabia. *Int J P* 2001;11:430-439.

48. MANNERBERG F. Saliva factors in cases of erosion. *Odontol Rev* 1963;14:15

49. MEURMAN JH, FRANK RM. Scanning electron microscopic study of the effe pellicle on enamel erosion. *Caries Res* 1991;25:1-6.

50. AMAECHI BT, HIGHAM SM, EDGAR WM, MILOSEVIC A. Thickness of acq pellicle as a determinant of the sites of dental erosion. *J Dent Res* 1999;78:1

51. BEVENIUS J, L'ESTRANGE P. Chairside evaluation of salivary parameters in tooth surface loss: a pilot study. *Aust Dent J* 1990;35:219-221.

52. YOUNG W, KHAN F, BRANDT R, SAVAGE N, RAZEK AA, HUANG Q. Syr salivary dysfunction predispose to tooth wear: Case reports of congenital d major salivary glands, Prader-Willi, congenital rubella, and Sjögren's syn *Surg Oral Med Oral Pathol Oral Radiol Endod* 2001;92:38-48.

53. TEN BRUGGEN CATE HJ. Dental erosion in industry. *Br J Ind Med* 1968;25:

54. TUOMINEN ML, TUOMINEN RJ, FUBUSA F, MGALULA N. Tooth surface loss to organic and inorganic acid fumes in workplace air. *Community Dent O* 1991;19:217-220.

55. AMIN WM, AL-OMOUSH SA, HATTAB FN. Oral health status of workers ex fumes in phosphate and battery industries in Jordan. *Int Dent J* 2001;51:169

56. WIKTORSSON AM, ZIMMERMAN M, ANGMAR-MÅNSSON B. Erosive prevalence and severity in Swedish winetasters. *Eur J Oral Sci* 1997;105:5

57. CHAUDHRY SI, HARRIS JL, CHALLACOMBE SJ. Dental erosion in a wine occupational hazard? *Br Dent J* 1997;182:226-228.

58. FINCH LD. Erosion associated with diabetes insipidus. *Br Dent J* 1957;103:280-282.

59. SHAW L, AL-DLAIGAN YH. Childhood Asthma and dental erosion. *ASDC J Dent Child* 2000;67:102-106.

60. HELLSTRÖM I. Oral complications in anorexia nervosa. *Scand J Dent Res* 1977;85:71-86.

61. RYTÖMAA I, JÄRVINEN V, KANERVA R, HEINONEN OP. Bulimia and tooth erosion. *Acta Odontol Scand* 1998;56:36-40.

62. ÖHRN R, ENZELL K, ANGMAR-MÅNSSON B. Oral status of 81 subjects with eating disorders. *Eur J Oral Sci* 1999;107:157-163.

63. ÖHRN R, ANGMAR-MÅNSSON B. Oral status of 35 subjects with eating disorders-A 1-year study. *Eur J Oral Sci* 2000;108:275-280.

64. MILOSEVIC A, BRODIE DA, SLADE PD. Dental erosion, oral hygiene, and nutrition in eating disorders. *Int J Eat Disord* 1997;2:195-199.

65. JÄRVINEN V, MEURMAN JH, HYVÄRINEN H, RYTÖMAA I, MURTOMAA H. Dental erosion and upper gastrointestinal disorders. *Oral Surg Oral Med Oral Pathol* 1988;65:298-303.

66. MEURMAN JH, TOSKALA J, NUUTINEN P, KLEMETTI E. Oral and dental manifestations in gastroesophageal reflux disease. *Oral Surg Oral Med Oral Pathol* 1994;78:583-589.

67. BARTLETT DW, EVANS DF, ANGGIANSAH A, SMITH BGN. A study of the association between gastro-oeusophageal reflux and palatal dental erosion. *Br Dent J* 1996;181:125-132.

68. GUDMUNDSSON K, KRISTLEIFSSON G, THEODORS A, HOLBROOK WP. Tooth erosion, gastroesophageal reflux, and salivary buffer capacity. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1995;79:185-189.

69. MEURMAN JH, VESTERINEN M. Wine, alcohol, and oral health, with special emphasis on dental erosion. *Quintessence Int* 2000;31:729-733.

70. HEDE B. Determinants of oral health in a group of Danish alcoholics. *Eur J Oral Sci* 1996;104:403-408.

71. MEURMAN JH, MURTOMAA H. Effect of effervescent vitamin C preparations on bovine teeth and on some clinical and salivary parameters in man. *Scand J Dent Res* 1986;94:491-499.

72. LINKOSALO E, MARKKANEN S, ALAKUIJALA P, SEPPÄ L. Effects of some commercial health beverages, effervescent vitamin C preparations and berries on human dental enamel. *Proc Finn Dent Soc* 1988; 84:31-38.

73. MARON FS. Enamel erosion resulting from hydrochloric acid tablets. *J Am Dent Assoc* 1996;127:781-784.

74. MCCRACKEN M, O'NEAL SJ. Dental erosion and aspirin headache powders: a clinical report. *J Prosthodont* 2000;9:95-98.

75. KAPILA YL, KASHANI H. Cocaine-associated rapid gingival recession and dental erosion. A case report. *J Periodontol* 1997;68:485-488.

76. LÖKKEN P, BIRKELAND JM. Ecstasy-generelle og odontologiske implikasjoner, tannslit hos unge og ecstasy - en differensialdiagnostisk utfordring. *Nor Tannlaegeforen Tid* 2000;110:560-565.

77. GRAEHN G. Säureerosion der Zahnhartsubstanzen. *Dtsch Stomatol* 1991;41:494-499.

78. LUSSI A, HELLWIG E. Erosive potential of oral care products. *Caries Res* 1:52-56.

79. RYTÖMAA I, MEURMAN JH, FRANSSILA S, TORKKO H. Oral hygiene produ dental erosion. *Proc Finn Dent Soc* 1989;85:161-166.

80. PONTEFRACT H, HUGHES J, KEMP K, YATES R, NEWCOMBE RG, ADDY M effects of some mouthrinses on enamel. A study in situ. *J Clin Periodontol* 324.

81. IMFELD T. Dental erosion. Definition, classification and links. *Eur* 1996;104:151-155.

82. VALENA V, YOUNG WG. Dental erosion patterns from intrinsic acid reg vomiting. *Aust Dent J* 2002;47:106-115.

83. JÄRVINEN V, RYTÖMAA I, MEURMAN JH. Location of dental erosion population. *Caries Res* 1992;26:391-396.

84. LUSSI A, JÄGGI T, SCHÄRER S. The influence of different factors on in erosion. *Caries Res* 1993;27:387-393.

85. DAWES C, MACPHERSON LM. The distribution of saliva and sucrose arou during the use of chewing gum and the implications for the site-specificity calculus deposition. *J Dent Res* 1993;72:852-857.

86. DAWES C, WEATHERELL JA. Kinetics of fluoride in the oral fluids. *J Den* Spec No:638-644; discussion 682-683 .

87. LARSEN MJ. Degrees of saturation with respect to apatites in parotid saliva values. *Scand J Dent Res* 1975;83:7-12.

88. LARSEN MJ. On the chemical and physical nature of erosions and caries les enamel. *Caries Res* 1991;25:323-329.

89. SREEBNY LM. Recognition and treatment of salivary induced condition 1989;39:197-204.

90. O'SULLIVAN EA, CURZON ME. Salivary factors affecting dental erosio *Caries Res* 2000;34:82-87.

91. TENOVUO J. Salivary parameters of relevance for assessing caries activity and populations. *Community Dent Oral Epidemiol* 1997;25:82-86.

92. BARTLETT DW, COWARD PY, NIKKAH C, WILSON RF. The prevalence of t cluster sample of adolescent schoolchildren and its relationship w explanatory factors. *Br Dent J* 1998;184:125-129.

93. MOAZZEZ R, SMITH BG, BARTLETT DW. Oral pH and drinking habit durin a carbonated drink in a group of adolescents with dental erosion. *J Dent* 397.

94. MILOSEVIC A, DAWSON LJ. Salivary factors in vomiting bulimics with pathological tooth wear. *Caries Res* 1996;30:361-366.

95. MEURMAN JH, TEN CATE JM. Pathogenesis and modifying factors of denta *J Oral Sci* 1996;104: 199-206.

96. WEST NX, HUGHES JA, ADDY M. The effect of pH on the erosion of denti by dietary acids in vitro. *J Oral Rehabil* 2001;28:860-864.

97. GANSS C, KLIMEK J, SCHWARZ N. A comparative profilometric in vitro study of the susceptibility of polished and natural human enamel and dentine surfaces to erosive demineralization. *Arch Oral Biol* 2000;45:897-902.

98. WILSON PR, BEYNON AD. Mineralization differences between human deciduous and permanent enamel measured by quantitative microradiography. *Arch Oral Biol* 1989;34:85-88.

99. AMAECHI BT, HIGHAM SM, EDGAR WM. Factors influencing the development of dental erosion in vitro: enamel type, temperature and exposure time. *J Oral Rehabil.* 1999;26:624-630.

100. HUNTER ML, WEST NX, HUGHES JA, NEWCOMBE RG, ADDY M. Erosion of deciduous and permanent dental hard tissue in the oral environment. *J Dent* 2000;28:257-263.

101. LUSSI A, KOHLER N, ZERO D, SCHAFFNER M, MEGERT B. A comparison of the erosive potential of different beverages in primary and permanent teeth using an in vitro model. *Eur J Oral Sci* 2000;108:110-114.

102. AMAECHI BT. HIGHAM SM. Eroded enamel lesion remineralization by saliva as a possible factor in the site-specificity of human dental erosion. *Arch Oral Biol* 2001;46:697-703.

103. HARRISON JL, ROEDER LB. Dental erosion caused by cola beverages. *Gen Dent* 1991;39:23-24.

104. ZERO DT. Etiology of dental erosion - extrinsic factors. *Eur J Oral Sci* 1996;104:162-177.

105. Moss SJ. Dental erosion. *Int Dent J* 1998;48:529-539.

106. EDWARDS M, ASHWOOD RA, LITTLEWOOD SJ, BROCKLEBANK LM, FUNG DE. A videofluoroscopic comparison of straw and cup drinking: the potential influence on dental erosion. *Br Dent J.* 1998;185:244-249.

107. MEURMAN JH, RYTÖMAA I, KARI K, LAAKSO T, MURTOMAA H. Salivary pH and glucose after consuming various beverages, including sugar-containing drinks. *Caries Res* 1987;21:353-359.

108. JAEGGI T, LUSSI A. Toothbrush abrasion of erosively altered enamel after intraoral exposure to saliva: an in situ study. *Caries Res* 1999;33:455-461.

109. KUROIWA M, KODAKA T, KUROIWA M, ABE M. Brushing-induced effects with and without a non-fluoride abrasive dentifrice on remineralization of enamel surfaces etched with phosphoric acid. *Caries Res* 1994;28:309-314.

110. AL-DLAIGAN YH, SHAW L, SMITH AJ. Dental erosion in a group of British 14-year-old, school children. Part III: Influence of oral hygiene practises. *Br Dent J* 2002;192:526-530.

111. ALMAS K. The antimicrobial effects of extracts of Azadirachta indica (Neem) and Salvadora persica (Arak) chewing sticks. *Indian J Dent Res* 1999;10:23-26.

112. GAZI MI, DAVIES TJ, AL-BAGIEH N, COX SW. The immediate- and medium-term effects of Meswak on the composition of mixed saliva. *J Clin Periodontol* 1992;19:113-117.

113. IMFELD T, TEN CATE JM. Preface. *Eur J Oral Sci* 1996;104:149.

114. AL-DLAIGAN YH, SHAW L, SMITH AJ. Vegetarian children and dental erosion. *Int J Paediatr Dent* 2001;11:184-192.

115. HARNACK L, STANG J, STORY M. Soft drink consumption among US adolescents: nutritional consequences. *J Am Diet Assoc* 1999;99:436-441.

116. RUGG-GUNN AJ, NUNN JH. Diet and dental erosion. In: Nutrition, diet and *Oxford University Press Oxford*, 1999.

117. ANGMAR-MÄNSSON B, OLIVEBY A. Örtte-en erosionsrisk? pH, buffer fluorinnehåll i örtte. *Tandläkartidningen* 1980;23:1315-1317.

118. BRUNTON PA, HUSSAIN A. The erosive effect of herbal tea on dental ena 2001;29:517-520.

119. SORVARI R, RYTÖMAA I. Drinks and dental health. *Proc Finn Dent Soc* 631.

120. MILOSEVIC A. Sports drinks hazard to teeth. *Br J Sports Med* 1997;31:28-3(

121. LENANDER-LUMIKARI M, LAURIKAINEN K, KUUSISTO P, VILJA P. Stimul flow rate and composition in asthmatic and non-asthmatic adults. *Arc* 1998;43:151-156.

122. MILLER CD. Enamel erosive properties of fruits and beverages. *J Am* 1951;28:319-324.

123. LINKOSALO E. Dietary habits and dental health in Finnish Seventh-Day Ad *Finn Dent Soc* 1988;4:109-115.

124. MEURMAN JH, HÄRKÖNEN M, NÄVERI H, KOSKINEN J, TORKKO H, RYTÖ INEN V, TURUNEN R. Experimental sport drinks with minimal dental e *Scand J Dent Res* 1990;98:120-128.

125. LUSSI A, JÄGGI T, JÄGGI-SCHÄRER S. Prediction of the erosive poten beverages. *Caries Res* 1995;29:349-354.

126. RUGG-GUNN AJ, MAGUIRE A, GORDON PH, MCCABE JF, STEPHENSON G. C erosion of dental enamel by four drinks using an intra-oral appliance 1998;32:337-343.

127. LARSEN MJ, NYVAD B. Enamel erosion by some soft drinks and orange jui their pH, buffering effect and contents of calcium phosphate. *Caries Res* 19

128. EDWARDS M, CREANOR SL, FOYE RH, GILMOUR WH. Buffering capa drinks: the potential influence on dental erosion. *J Oral Rehabil* 1999;26:92

129. GRENBY TH. Lessening dental erosive potential by product modification. *E* 1996;104:221-228.

130. IMFELD TN. Identification of low caries risk dietary components. *Mon* 1983;11:1-198.

131. PARRY J, SHAW L, ARNAUD MJ, SMITH AJ. Investigation of mineral w drinks in relation to dental erosion. *J Oral Rehabil* 2001;28:766-772.

132. RYTÖMAA I, MEURMAN JH, KOSKINEN J, LAAKSO T, GHARAZI L, TURUNI erosion of bovine enamel caused by acidic drinks and other foodstuffs. *Sca* 1988;96:324-333.

133. HOLLOWAY PJ, MELANBY M, STEWART RJ. Fruit drinks and tooth erosi 1985;104:305-309.

134. WEST NX, HUGHES JA, ADDY M. The effect of pH on the erosion of dentine and enamel by dietary acids in vitro. *J Oral Rehabil* 2001;28:860-864.

135. McCay CM, Will L. Erosion of molar teeth by acid beverages. *J Nutr* 1949;39:313-324.

136. REUSSNER GH, COCCODRILLI G JR, THIESSEN R JR. Effects of phosphates in acid-containing beverages on tooth erosion. *J Dent Res* 1975;54:365-370.

137. AMAECHI BT, HIGHAM SM, EDGAR WM. The influence of xylitol and fluoride on dental erosion in vitro. *Arch Oral Biol* 1998;43:157-161.

138. GRENBY TH, PHILLIPS A, DESAI T, MISTRY M. Laboratory studies of the dental properties of soft drinks. *Br J Nutr* 1989;62:451-464.

139. LARSEN MJ. RICHARDS A. Fluoride is unable to reduce dental erosion from soft drinks. *Caries Res* 2002;36:75-80.

140. 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.

141. LARSEN MJ. Prevention by means of fluoride of enamel erosion as caused by soft drinks and orange juice. *Caries Res* 2001;35:229-234.

142. GROBLER SR, SENEKAL PJ, LAUBSCHER JA. In vitro demineralization of enamel by orange juice, apple juice, Pepsi Cola and Diet Pepsi Cola. *Clin Prev Dent* 1990;12:5-9.

143. EDWARDS M, CREANOR SL, FOYE RH, GILMOUR WH. Buffering capacities of soft drinks: the potential influence on dental erosion. *J Oral Rehabil* 1999;26:923-927.

144. GRIFFITHS RR, VERNOTICA EM. Is caffeine a flavoring agent in cola soft drinks? *Arch Fam Med* 2000;9:727-734.

145. WATSON JM, LUNT MJ, MORRIS S, WEISS MJ, HUSSEY D, KERR D. Reversal of caffeine withdrawal by ingestion of a soft beverage. *Pharmacol Biochem Behav* 2000;66:15-18.

146. 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.

147. JOINT REPORT OF THE AMERICAN DENTAL ASSOCIATION. Council on Access, Prevention and Interprofessional Relations and Council on Scientific Affairs to the House of Delegates: *Response to Resolution 73H-2000*. October 2001.

148. JOHNSSON RK. Changing eating and physical activity patterns of US children. *Proc Nutr Soc* 2000;59:295-301.

149. LUDWIG DS, PETERSON KE, GORTMAKER SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analyses. *Lancet* 2001;357:505-508.

150. TEUFEL NI, RITENBAUGH CK. Development of a primary prevention program: insight gained in the Zuni Diabetes Prevention Program. *Clin Pediatr* (Phila) 1998;37:131-141.

151. KEIJZERS GB, DE GALAN BE, TACK CJ, SMITS P. Caffeine can decrease insulin sensitivity in humans. *Diabetes Care* 2002;25:364-369.

152. ROOT AW. Bone strength and the adolescent. *Adolesc Med* 2002;13:53-72.

153. FERNANDO GR, MARTHA RM, EVANGELINA R. Consumption of soft drinks with phosphoric acid as a risk factor for the development of hypocalcemia in postmenopausal women. *J Clin Epidemiol* 1999;52:1007-1010.

154. MAZARIEGOS-RAMOS E, GUERRERO-ROMERO F, RODRIGUEZ-MORAN M BURCIAGAG, PANIAGUA R, AMATO D. Consumption of soft drinks with ph as a risk factor for the development of hypocalcemia in children: a case-cc *Pediatr* 1995;126:940-942.

155. GUERRERO-ROMERO F, RODRIQUEZ-MORAN M, REYES E. Consumption with phosphoric acid as a risk factor for the development of hyp postmenopausal women. *J Clin Epidemiol* 1999;52:1007-1010.

156. RODGERS A. Effect of cola consumption on urinary biochemical and phy risk factors associated with calcium oxalate urolithiasis. *Urol Res* 1999;27:

157. SHUSTER J, JENKINS A, LOGAN C, BARNETT T, RIEHLE R, ZACKSON D, W R, DALEY M, MALIK I. Soft drink consumption and urinary stone randomized prevention trial. *J Clin Epidemiol* 1992;45:911-916.

158. AJNAMO J, BAY I. Problems and proposals for recording gingivitis and plaq 1975;25:229-235.

159. FEJERSKOV O, MANJI F, BAELUM V, MØLLER I. *Dental fluorosis - a handb workers*. 1st ed. Copenhagen: Munksgaard, 1988.

160. ECCLES JD. Dental erosion of nonindustrial origin. A clinical survey and cl *Prosthet Dent* 1979;42:649-653.

161. JOHANSSON A, HARALDSON T, OMAR R, KILIARIDIS S, CARLSSON GE. assessing the severity and progression of occlusal tooth wear. *J* 1993;20:125-131.

162. LARSEN IB, WESTERGAARD J, STOLTZE K, LARSEN AI, GYNTELBERG F, HO clinical index for evaluating and monitoring dental erosion. *Communi Epidemiol* 2000;28:211-217.

163. WORLD HEALTH ORGANIZATION. *Oral Health Surveys. Basic Methods*. G 1977.

164. SCHEIE AA, FEJERSKOV O, LINGSTRÖM P, BIRKHED D, MANJI F. Use of pa microelectrodes under field conditions for in vivo assessment of dental children. *Caries Res* 1992;26:44-51.

165. SORVARI R, MEURMAN JH, ALAKUIJALA P, FRANK RM. Effect of fluorid solution on enamel erosion in vitro. *Caries Res* 1994;28:227-232.

166. MUNRO BH, PAGE EB. *Statistical methods for health care research*. 2nd ed. J.B. Lippincott Company, 1993.

167. LARSEN MJ, PEARCE EL. A computer program for correlating dental plaqu plaque titration, critical pH, resting pH and the solubility of enamel apat *Biol* 1997;42:475-480.

168. BUE BJORNER J, SONDERGAARD KRISTENSEN T, ORTH-GOMÉR K, TIBBLIN M, WESTERHOLM P. *Self-rated health – a useful concept in research, p clinical medicine*. Swedish council for planning and coordination of rese Ord och Form AB, 1996.

169. NILSSON P, ORTH-GOMÉR K (EDS). *Self-rated health in a European perspe* council for planning and coordination of research. Uppsala: Ord och Form

170. JOKOVIC A, LOCKER D, STEPHENS M, KENNY D, TOMPSON B, GUYATT G. Validity and Reliability of a Questionnaire for Measuring Child Oral-health-related Quality of Life. *J Dent Res* 2002;81:459-463.

171. HUYSMANS MC, THIJSSEN JM. Ultrasonic measurement of enamel thickness: a tool for monitoring dental erosion? *J Dent* 2000;28:187-191.

172. AL-MALIK MI, HOLT RD, BEDI R. Clinical and photographic assessment of erosion in 2-5-year-old children in Saudi Arabia. *Community Dent Health.* 2001 ;18:232-235.

173. GANSS C, KLIMEK J, BORKOWSKI N. Characteristics of tooth wear in relation to different nutritional patterns including contemporary and medieval subjects. *Eur J Oral Sci* 2002; 110:54-60.

174. KHAN F, YOUNG WG, LAW V, PRIEST J, DALEY TJ. Cupped lesions of early onset dental erosion in young southeast Queensland adults. *Aust* Dent *J* 2001;46:100-107.

175. AL-TAMIMI S, PETERSEN PE. Oral health situation of schoolchildren, mothers and schoolteachers in Saudi Arabia. *Int Dent J* 1998;48:180-186.

176. AL-OTAIBI M, ZIMMERMAN, ANGMAR-MÅNSSON B. Toothbrush or Miswak? Prevailing Oral Hygiene Habits among Saudi Arabians. *Caries Res* 2002; 36:174-222.

177. KATZ PO. Gastroesophageal reflux disease-state of the art. *Rev Gastroenterol Disord* 2001;1:128-138.

178. CINQUETTI M, MICELLI S, VOLTOLINA C, ZOPPI G. The pattern of gastroesophageal reflux in asthmatic children. *J Asthma* 2002;39:135-142.

179. BARTLETT DW, EVANS DF AND SMITH BG. The relationship between gastro-oesophageal reflux disease and dental erosion. *J Oral Rehabil* 1996;23:289-297.

180. MORGAN KJ, STULTS VJ, STAMPLEY GL. Soft drink consumption patterns of the U.S. population. *J Am Diet Assoc* 1985;85:352-354.

181. SMICKLAS-WRIGHT H, MITCHELL DC, MICKLE SJ, COOK AJ, GOLDMAN JD. Foods commonly eaten in the United States. Quantities consumed per eating occasion and in a day, 1994-1996. *US Department of Agriculture, NFS report no. 96-5*, 2002.

182. HOLM AK, SANDAHL C. Kostanamnes och kostrådgivning. In: JOHANSSON I, BIRKHED D (EDS): *Kost och Oral Hälsa.* Växjö: Invest-Odont AB, 1988, pp.98-110.

183. NATIONAL ASSOCIATION OF SOFT DRINK MANUFACTURERS LTD. *Fact sheet no. 8.* Twickenham, Middx: NASDM Ltd., 1985.

184. DIEHL JM, ELMADFA I. Der konsum alkoholischer und alkoholfreier getränke im erwachsenalter. *Akt Ernähr* 1986;1:258-268.

185. AL-DLAIGAN YH, SHAW L, SMITH A. Dental erosion in a group of British 14-year old school children Part II Influence of dietary intake. *Br Dent J* 2001;190:258-261.

186. MORTON JF, GUTHRIE JF. Changes in Children's Total Fat Intakes and Their Food Group Sources of Fat, 1989-91 Versus 1994-95: Implications for Diet Quality. *Fam Econ Nutr Rev* 1998;11: 44-57.

187. SWEDISH BOARD OF AGRICULTURE, Division of Statistics, 2002.

188. PETTER LP, HOURIHANE JO, ROLLES CJ. Is water out of vogue? A survey of the drinking habits of 2-7 year olds. *Arch Dis Child* 1995;72:137-140.

189. MACPHERSON LM, DAWES C. Urea concentration in minor mucous glands the effect of salivary film velocity on urea metabolism by Streptococcus an artificial plaque. *J Periodont Res* 1991;26:395-401.

190. YOUNG WG, KHAN F. Sites of dental erosion are saliva-dependent. *J* 2002;29:35-43.

191. WONG L. Plaque mineralisation in vitro. *N Z Dent J* 1998;94:15-18.

192. GOLUB LM, BORDEN SM, KLEINBERG I. Urea content of gingival crevicul relation to periodontal disease in humans. *J Periodont Res* 1971;6:243-251

193. SINGER DL, KLEINBERG I. Quantitative assessment of urea, glucose changes in human dental plaque and saliva following rinsing with urea anc *Oral Biol* 1983;28:923-929.

194. DIBDIN GH, DAWES C. A mathematical model of the influence of salivary of fastened dental plaque and on the changes occurring during a cariog *Caries Res* 1998;32:70-74.

195. DAWES C. Effects of diet on salivary secretion and composition. 1970;49:1263-1273.

196. BIRKHED D. Sugar content, acidity and effect on plaque pH of fruit juice carbonated beverages and sport drinks. *Caries Res* 1984;18:120-127.

197. GRANDO LJ, TAMES DR, CARDOSO AC, GABILAN NH. In vitro study of caused by soft drinks and lemon juice in deciduous teeth analysed by ste and scanning electron microscopy. *Caries Res* 1996;30:373-378.

198. CROSSNER CG, HASE JC, BIRKHED D. Oral sugar clearance in children adults. *Caries Res* 1991;25:201-206.

199. NUTTALL NM, STEELE JG, PINE CM, WHITE D, PITTS NB. The impact of people in the UK in 1998. *Br Dent J* 2001;190:121-126.

200. ÖSTERBERG T, CARLSSON GE, SUNDH V. Trends and prognoses of dent Swedish population: analysis based on interviews in 1975 to 1997 by Sta *Acta Odontol Scand* 2000;58:177-182.

201. NUNN J, MORRIS J, PINE C, PITTS NB, BRADNOCK G, STEELE J. The condit the UK in 1998 and implications for the future. *Br Dent J* 2000;189:639-6

202. FISHER J, MITCHELL D, SMICIKLAS-WRIGHT H, BIRCH L. Maternal mil predicts the tradeoff between milk and soft drinks in young girls' 2001;131:246-250.