A longitudinal study of dental erosion and associated lifestyle factors in a group of Swedish

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Scientific environment

The work of this thesis was carried out between April 2012 and August 2017 at the Department of Clinical Dentistry – Cariology, Faculty of Medicine, University of Bergen, Bergen, Norway. Clinical data were collected at the Public Dental Service in Nora and Storå, County Council of Örebro / Region Örebro County, Sweden. The main supervisor was Professor Ann-Katrin Johansson, and co-supervisor was Professor Anders Johansson, both from the University of Bergen, Bergen, Norway.

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Abstract

Background: Erosive wear has been observed among Swedish adolescents, but with unknown prevalence. High prevalence of dental erosion is reported from different parts of the world, and often linked to an increasing consumption of soft drinks.

Objective: The aim was to study the prevalence and progression of dental erosion among Swedish children and adolescents related to some health and lifestyle parameters, and to develop a simplified system for scoring dental erosion.

Methods: 609 out of 801 individuals aged 5-6-, 13-14- and 18-19-years participated in the cross-sectional, prospective, longitudinal study, based on a clinical examination and questionnaires. 4-year progression was studied in the 13-14-year cohort. A Simplified Erosion Partial Recording System (SEPRS) was developed. The consumption of soft drinks was studied in relation to health and lifestyle.

Results: Severe erosion was found in 13.3%, 11.9% and 22.3% of the respective groups. Correlation was found between soft drink consumption, male gender and severity of dental erosion. High soft drink consumers showed worse oral health and dietary and other unhealthy behaviors. After 4 years 32.3% of tooth surfaces had deteriorated by one grade and 2.6% by two grades. SEPRS showed 100% sensitivity and 98% specificity for detecting severe erosion in permanent teeth, and 100% each for primary teeth.

Conclusion: Dental erosion was common among Swedish adolescents, especially among males. The high prevalence and progression was associated with worse oral health and some less healthy lifestyle factors. The simplified recording system, SEPRS, is a useful tool for screening for dental erosion in these age groups.

Consequences: In view of the high prevalence of dental erosion and soft drink consumption among Swedish adolescents, there is a need to introduce community-based preventive programs from early ages as well as epidemiological recording of dental erosion.

List of articles

Paper I. Hasselkvist A, Johansson A, Johansson AK. Dental erosion and soft drink consumption in Swedish children and adolescents and the development of a simplified erosion partial recording system. Swed Dent J 2010;34:187-95.

Paper II. Hasselkvist A, Johansson A, Johansson AK. Association between soft drink consumption, oral health and some lifestyle factors in Swedish adolescents. Acta Odontol Scand 2014;72:1039-46.

Paper III. Hasselkvist A, Johansson A, Johansson AK. A 4 year prospective longitudinal study of progression of dental erosion associated to lifestyle in 13-14 year-old Swedish adolescents. J Dent 2016;47:55-62.

CONTENTS

List of abbreviations

BEWE	Basic Erosive Wear Index
BMI	Body Mass Index
CI	Confidence Interval
DAFNE	Data Food Networking
DMFS	Decayed Missed Filled Surfaces
DMFT	Decayed Missed Filled Teeth
EMG	Electromyography
GBI	Gingival Bleeding Index
GER(D)	Gastro Esophageal Reflux (Disease)
HBSC	Collaborative Health Behaviour in School-aged Children
L	Litre
OR	Odds Ratio
SD	Standard Deviation
SEPRS	Simplified Erosion Partial Recording System
SPSS	Statistical Package for the Social Sciences
TWI	Tooth Wear Index
USA	United States of America
VPI	Visible Plaque Index

Introduction

Dental erosion

Tooth wear is caused by several overlapping mechanisms, which are frequently described as dental erosion, abrasion and attrition although it may also include demastication and abfraction [1]. Tooth wear is not a new phenomenon as extensive wear frequently occurred in ancient societies, where a coarse diet and using the teeth as tools caused abrasive/attritional wear, while dietary and/or disease conditions attributed to erosive wear [2-4]. Lifestyle has changed greatly since ancient times and dental erosion is nowadays regarded to be the main cause of tooth wear [5].

Within the oral environment, the tooth surface is covered and protected by the pellicle, a thin layer of salivary mucoproteins and lipids [6-9]. When the tooth surface is exposed to an acid, the acid diffuses through the pellicle and studies indicate that the pellicle also gradually dissolves in the presence of acids [7,9-11]. During the erosive process calcium and phosphate is dissolved in the outer layer of the enamel, reducing the micro-hardness and the resistance against mechanical forces, which, in turn, enhances the effects of abrasion and attrition [12]. In dentine, the demineralization takes place firstly in peritubular and thereafter in intertubular dentine, while the softer organic structure remains [13-15].

Clinical signs and symptoms of dental erosion

The early clinical signs of dental erosion are loss of the topographical features on the enamel surfaces including a slight flattening. As the erosive process continues there will also be changes in the macro-morphology of the teeth. Occlusal erosive wear in molars and premolars manifests as cuppings, which are lesions on the cusp tips, although cuppings may also be present on incisal surfaces**.** Some studies have shown an association between dental erosion and cuppings [16,17]. It has even been suggested that cuppings are an indicative sign of onset of erosion in young individuals [18-20].

Further progression of the erosive process gradually exposes the dentine, leaving the dentine tubules open, which increases the risk for hypersensitivity [21-23]. It is therefore quite common that individuals suffering from erosion experience problems when eating or drinking [24]. Extensive progression of the erosive wear may also involve the dental pulp, causing pulpitis or necrosis and, at a more advanced stage, even tooth loss. Studies have found direct, or close to, pulpal involvement in 1-13 % of patients with extensive tooth wear [22,25,26]. Kaifu et al. stated in 2003 that "*our synthesis of the available evidence suggests that the human dentition is designed on the premise that extensive wear will occur*" [27], and in 2014 Ganss explained that "*even extensive wear can be regarded as a condition rather than a pathology, provided that the amount of loss is related to the expected life span*" [28]. In the clinical situation it is mainly up to the clinician to judge whether the level of tooth wear is pathological or not, since there is no clear description of the accepted level of tooth substance loss related to function, age or expected life span in patients with tooth wear [29,30].

Grading of dental erosion and scoring systems

Today, there is no single internationally-accepted standardized tool for grading of dental erosion, and instead a broad range of scoring systems have been proposed and used. As far back as 1979 Eccles presented a system for grading dental erosion [31]. The scale was constructed for clinical use and many of the successive scales for grading of dental erosion were influenced by Eccles, such as: Linkosalo & Markkanen [32], Lussi et al. [33], O´Brien [34], Aine et al. [16], Johansson et al. [35], O`Sullivan [36], Bartlett et al. [37], Mulic et al. [38] and Margaritis et al. [39]. Another early system for grading tooth wear in general was the Tooth Wear Index (TWI), presented by Smith & Knight in 1984 which was primarily intended for use in research and epidemiological studies [40]. TWI also included some specific criteria for grading of dental erosion and the index has been modified and used by other researchers in several studies [41-45]. Efforts have also been made to link systems for grading wear to a treatment guide according to specified dietary and behavioral criteria [37,39,46], as well as treatment need [47].

The numbers of grades contained in various scales varies, with the range usually being between 0-5. In scales for grading erosive wear, score 1 mostly describes mild enamel surface loss. For more severe erosion, the levels between moderate and severe scores show major variation across the different scales. In several scales the amount of visible dentine is assessed, even though it has been suggested that it often is more or less impossible to make a reliable clinical assessment whether the dentine is exposed or not [19,21,48].

The number of teeth that are graded differ among the different scoring systems. Some include a full mouth recording while others include partial recording. Johansson et al. used a partial recording system and showed that specific surfaces exhibited pronounced erosive wear, i.e. on palatal surfaces in maxillary incisors and on occlusal surfaces in first lower molars [35]. This finding has been confirmed in later studies performing full mouth recording in epidemiological research [49-52]. The specific teeth used for partial recording have been termed “marker teeth” for erosive wear and such teeth have thereafter frequently been used in many studies, sometimes complemented with grading of mandibular anterior teeth and maxillary first molars [53-65].

The fact that a universally adopted scoring system for dental erosion has not yet emerged is probably at least partially due to the fact that the validation of such a system would be complicated. There are however a few reports on comparisons of the reliability among different scoring systems. Basic Erosive Wear Examination (BEWE) [37] was introduced in 2008 with an aim to provide an internationally accepted system for grading dental erosion. This system has been compared to a number of other indices [38-40,66,67]. In spite of the numerous comparisons between BEWE and other grading system, BEWE was not validated prior to the aforesaid comparative studies and, in addition it has received considerable criticism by other authors [46,68].

Epidemiology of dental erosion

Cross-sectional studies

Studies from all over the world report that dental erosion is common among children and adolescents. The studies have been performed in different age groups originating from different cultural and socioeconomic environments, and within groups of large age spans or selected groups. In addition, grading of teeth is performed by a single or by multiple investigators. Bearing in mind the different scales and methodologies applied, the reported prevalence rates vary considerably between studies. Furthermore, most studies report prevalence of "erosion into dentine", while some studies report prevalence as "signs of erosion", which are not always defined, making the different results even more difficult to compare.

In primary teeth the reported prevalence of erosive tooth wear varies largely. For example in Chinese children aged 3-5-years only 1% showed dental erosion into dentin, while an Australian study with an older age cohort of 5-14-years, found that 78% showed severe erosion in primary molars [69,57]. Studies on permanent teeth in children and adolescents show erosive wear within a narrower range. In the Netherlands none of 11-year-olds showed erosion into dentine [70], but in Saudi Arabia up to 26% of 12-14-year-olds did so [53]. In Iceland one study found that none of the 6-year-olds showed erosive wear in permanent teeth, while 1% of 12-year-olds and 6% of 15-year-olds had erosion into dentine [52]. In Denmark 2% of 15-17-year-olds showed erosion into dentine [71] and in Norway the corresponding figures for 16-18-year-olds was 15% [65]. A recent Swedish study among 20-year-olds found that 18% had erosion in to dentine [72].

Many studies report gender differences in the prevalence of dental erosion among children and adolescents. Most often it is reported that dental erosion is more common/severe among boys [50,54-56,65,70,71,73-75], though some studies did not find any difference among genders [39,58,62,64,76-78] and a few studies found more erosion among girls [60,79].

Longitudinal studies

Longitudinal studies of dental erosion are scarce. One German study performed on study casts during the period from 1977 to 1999 found that the number of individuals with erosion in permanent teeth increased four-fold during a five-year follow-up (mean age 10.2 years at baseline and 15.8 years at follow-up), rising from 6% to 25%. It was further reported that individuals with erosion in the primary teeth were at higher risk for erosion also in the permanent dentition. In the same study, the prevalence of dental erosion in primary teeth was almost twice as high during 1990-1999 than during 1977-1989, from 53% up to 87% [49]. In another clinical longitudinal study published in 2003 it was found that 27% of 12-year-old English children had developed new or more advanced lesions after two years [54]. Another 3-year longitudinal clinical study in the Netherlands found that dental erosion progressed from 30% among 11-12-year-olds up to 44% among 14-15-year-olds [70].

Etiological/contributory factors and dental erosion

The etiological factors for dental erosion are basically divided into intrinsic and extrinsic factors. Intrinsic factors are connected to the acidity of stomach acid entering the oral cavity under different circumstances and the extrinsic factors are associated with acid from outside of the body like, for example, acidic drinks, fruits and other food items entering the oral cavity resulting in an acidic challenge on the teeth.

Stomach acid, an intrinsic etiological factor, may enter the oral cavity by gastroesophageal reflux (GER) and/or by vomiting. In case the episodes of GER cause troublesome symptoms and/or complications it is classified as a disease, gastroesophageal reflux disease (GERD) [80]. Gastric juice has a pH close to 1.0 [81] and the esophageal pH is therefore often low during episodes of reflux [82].

The prevalence of diagnosed GERD among children varies for different ages and between studies [83]. Several studies have reported an association between GER(D) and dental erosion/tooth wear among children and adolescents [16,62,84-86] and among adults [87,88]. Contradictory results have also been reported, where no

association between stomach reflux and dental erosion has been found in children and adults [72,89-91]. In spite of the divergent results it is accepted that GER(D) is a risk factor for developing dental erosion [92,93].

Eating disorders often start early and the lifetime prevalence is 2-4% in young women [94]. Among Swedish patients with eating disorders it was found that more than half of the subjects had erosive lesions into dentine, and that the erosive tooth wear was strongly correlated with the numbers of years of binge-eating [95]. These results were supported by another Swedish study showing higher severity of dental erosion in eating disorder patients compared to matched healthy controls [96].

Other conditions/disorders such as pregnancy and alcoholism may also produce reflux and vomiting and increase the risk for dental erosion, but these conditions are uncommon among children and adolescents.

The most common extrinsic etiological factor related to dental erosion in children and adolescents is consumption of acidic soft drinks [3]. A soft drink is defined as "*any of a class of nonalcoholic beverages, usually but not necessarily carbonated, normally containing a natural or artificial sweetening agent, edible acids, natural or artificial flavours, and sometimes juice. Natural flavours are derived from fruits, nuts, berries, roots, herbs, and other plant sources. Coffee, tea, milk, cocoa, and undiluted fruit and vegetable juices are not considered soft drinks*" [97]. An early clinical study to show a clear association between consumption of acidic drinks and dental erosion was performed on young Saudi men [17]. Today many other clinical studies from different parts of the world have confirmed that acidic soft drinks are associated with tooth wear among children and adolescents [53,58,60,72,74,78,84,86,91,98-107], and there is a general acceptance that soft drink consumption is of importance for the development of dental erosion among younger people, even if other reports also have found weak or no association at all [50,59,61,64,85,108]. This is elaborated on in greater detail later in this thesis.

Other extrinsic factors regarded as risk factors for the development of dental erosion are frequent consumption of acidic medication such as Vitamin C tablets, aspirin or

consumption of sour candy [58,107,109,110]. Other dietary risk factors that have been shown to increase the risk for erosive wear in adults are, for example, vegetarian and raw food diets [32,111]. In addition, occupational environment such as airborne acid in chemical industries or professional wine tasting are also extrinsic sources known to cause dental erosion [112-114].

One of the contributory factors which is associated with dental erosion is oral hygiene practices. In this regard, a positive association between lower gingival bleeding and higher dental erosion has been found [17,101] as well as between different cleaning aids and techniques and dental erosion [17,88]. Toothbrushing may enhance wear by a mechanical action on a tooth surface softened after a foregoing erosive etching [115,116]. To what extent toothbrushing and toothpaste may produce loss of dental hard tissue is under constant debate [117-119]. A common advice to avoid wear is to postpone toothbrushing for 30 minutes after intake of an acidic item to allow remineralization of the tooth surface [120]. During the past years there have been doubts raised about this recommendation based on other studies and it has been suggested that such an advice to patients might be reconsidered [88,121].

As regards drink consumption, individual differences in developing dental erosion may be explained by different methods of drinking and it is clear that certain methods of drinking may extend the contact time between the acid and the tooth surface. Thus, a retaining drinking technique, i.e. when the acidic drink is kept in the oral cavity for a prolonged time before swallowing, or a sipping method, i.e. intake of small amounts of drink over a long period, are shown to be associated with dental erosion [101,122,123].

The salivary pellicle protects against dental erosion [7,124,125] and the salivary capacity to buffer and neutralize the acid is also an important factor in the protection of the tooth [12,13,126-128]. In an oral environment supersaturated with calcium and phosphorus ions, the enamel is not as easily dissolved [13] and calcium-rich dietary items, especially dairy products (even soured milk products), may therefore play a protective role against acidic challenges [110,129-132]. Apart from habitual and

physiological factors, recent studies have indicated that genetic variations may also play a role in the development of dental erosion, while an *in vitro* study has shown that enamel loss was higher in males than in females [133,134].

Lifestyle and dental erosion

Lifestyle is a term originally coined in 1929 by Austrian psychologist Alfred Adler (1870-1937), and has been defined as "the habits, attitudes, tastes, moral standards, economic level, etc., that together constitute the mode of living of an individual or group" [135]. Lifestyle includes amongst others, dietary habits and is therefore of utmost importance for the development of dental erosion. Among children and adolescents, frequent intake of soft drinks is regarded as the most important lifestyle factor related to dental erosion [3,17,35,98]

Consumption of soft drinks

It is clear that the lifestyle among younger people today frequently includes consumption of soft drinks. A substantial increase in soft drink consumption has in recent decades been reported in the USA [136]. In a national survey it was shown that the daily intake of all types of soft drinks among 4-8-year-olds was 138 L/year and 295 L/year among 14-18-year-olds. There was also a shift from a higher consumption of fruit juices in the younger ages to a higher consumption of carbonated drinks among adolescents [137]. In another study a shift from milk to soft drinks was reported among Canadian boys, and an increase in the consumption of carbonated drinks from 25 L/year among 4-8-year-old boys to 137 L/year among 14-18-year-old boys. Among the girls, the corresponding figures were 17 L/year and 65 L/year [138].

A report from a Union of Soft Drink Producers, covering 26 European countries, showed that the yearly production of carbonated soft drinks in 2014 was of 93 L per capita and that the production of all types of soft drinks in combination was 128 L per capita [139]. It was also concluded that the amounts of soft drinks produced varied considerably among countries. Among the European countries the highest production

of carbonated soft drinks per capita, 143 L/year, was reported from Germany and the lowest from Greece, 48 L/year [139].

In 2003 the consumption of soft drinks among 15-year-old Icelandic boys was found to be as high as 292 L/year [140]. Among Swedish children in 2003, the consumption of all types of soft drinks was 68 L/year among 4-year-olds and 87 L/year among 8- and 11-year-olds. Ten percent of the 8- and 11-year-old children reported a consumption all types of soft drinks as high as 183 L/year [141]. During 2014 the average per capita consumption of carbonated soft drinks in Sweden was reported to be 92 L/year [142].

Many other studies confirm these reports of high soft drink consumption among children and adolescents [143-155]. But, during recent years, there are also some reports about decreasing soft drink consumption among children and adolescents [156-159].

Soft drink consumption and health

It is evident that both oral and general health may be affected by consumption of soft drinks. Acidic soft drinks sweetened with regular sugar have, beside the potential to increase the risk for dental erosion, also the potential to increase the risk for dental caries. Many studies, in both children and adults, have found a correlation between consumption of soft drinks and dental caries [63, 160-162] although contradictory results have also been reported [163]. An association between dental caries and dental erosion has been found in many studies [57,61,72,75,77,100], indicating a triangular association between dental caries, soft drink consumption and dental erosion, while other studies report no such association [55, 63,65,74,78,164].

Regular soft drinks (sweetened with regular sugar) will add to the intake of calories. Therefore, the increasing soft drink consumption especially among children and adolescents has caused serious health concerns. There are numerous studies about soft drinks and its potential association with the globally increasing issue of overweight and obesity at young ages. The inferences from these studies are somewhat divergent, with some studies showing no association between soft drink

consumption and overweight [165-169], but in a majority of studies some relation between either gaining weight and the amount of soft drink intake, or between a combination of soft drink consumption, overweight and sedentary living has been shown [170-178]. There are also reports on possible associations between soft drink consumption and the development of other general health issues such as diabetes, stroke and coronary artery calcification [179-181].

Soft drink consumption: gender, socioeconomic and sociodemographic factors

A majority of studies report a gender difference regarding soft drink consumption. Most often it has been found that teenage boys have a higher consumption of soft drinks than teenage girls [85,143,145,147,149,152,153,182-184], but there are also some reports where it has been found that girls drink more [60].

The amount of consumption of carbonated drinks is influenced by both socioeconomic and sociodemographic status and varies between countries. In the World Heath Organisation - Collaborative Health Behaviour in School-aged Children (HBSC) – Study (2005-2006 year survey), covering 41 western countries (viz. Europe, USA, Canada and Israel), Bulgarian youths reported the highest frequency of daily soft drink intake, followed by Israel, with 50% and 45%, respectively, having daily consumption of soft drinks (unspecified). The lowest consumption was reported from Sweden, Finland, Iceland and Estonia, where 10% or less reported daily soft drink consumption [184]. Another study published in 2005, also from the HBSC database (2001-2002-year survey) comprising 28 European countries, found that in most European countries children with parents with a higher occupational status reported a lower soft drink consumption than children with parents with lower occupational status. An exception was that in Central and Eastern European countries, soft drink intake instead increased with increasing family affluence [147]. An international register study on the Data Food Networking database (DAFNE) (published in 2010), comprising 24 European countries, found more frequent soft drink consumption in families with lower education and socioeconomic status than in families of higher education and socioeconomic status [151].

Soft drink consumption has also been found to be influenced by both sedentary living and physical activity. Higher consumption was reported among 8-13-year-olds who watched TV at least 3.5 hours per day [145], This finding is supported by several other studies on the association between soft drink consumption and screen-watching activities [150,153,176,185-190]. Physical exercise has also been found to be connected with an increased consumption of acidic drinks, especially energy drinks [191,192].

Specific motivation for the study

The initiation of this study followed the observation in the author's clinical workplace of several clinical cases of severe erosive wear among older adolescents during 2004. At the time, attention to dental erosion among children was not highlighted in clinic, and nothing was known about the prevalence of dental erosion among Swedish children and adolescents. There were studies from other parts of the world that reported varied prevalences. Furthermore, the progression of dental erosion over time was sparsely documented. During this period it was also common that adolescents developed a lifestyle that involved spending several hours in front of a computer along with frequent consumption of carbonated soft drinks. Studies had shown that consumption of acidic soft drinks was associated with dental erosion. It was important to study the prevalence and progression of dental erosion among Swedish children and adolescents as it related to soft drink consumption and other factors that may have an impact on development of dental erosion.

Objectives

The overall aim of this thesis was to record prevalence and progression of dental erosion in children and adolescents and to evaluate related factors.
Specific aims were to:

- Study the prevalence among Swedish children and adolescents *(Paper I)*
- Develop a simplified system for scoring dental erosion useful for epidemiological research and clinical practice *(Paper I)*
- Study the relation between soft drink consumption, lifestyle factors and oral health parameters, including dental erosion *(Paper II)*
- Study progression and incidence of dental erosion over a period of four years in the 13-14-year-group *(Paper III)*
- Study the relationship between progression of dental erosion, oral health and lifestyle factors *(Paper III)*.

Hypotheses

- Boys would have higher prevalence of dental erosion than girls and the prevalence is correlated with soft drink consumption. The severity of dental erosion in an individual could be evaluated by scoring a reduced number of tooth surfaces *(Paper I)*
- Soft drink consumption among Swedish adolescents is related to oral health and lifestyle *(Paper II)*
- There would be a progression of dental erosion during the teenage period. The progression of erosion is higher in boys and related to a specific lifestyle and oral health factors *(Paper III)*.

Material and methods

Study design

This was a prospective longitudinal study that included a cross-sectional baseline study and a four-year follow-up cohort study. The same methodology was used at baseline and at follow-up. The study included variables collected from a clinical examination and from self-reported and interview-guided questionnaires. Data collected at baseline were also used to study lifestyle factors.

Patient selection

The baseline study was planned in 2004 and took place during 2005-2007 in Nora and Storå, County Council of Örebro / Region Örebro County, Sweden.

Three age cohorts were chosen for this study: 5-6-, 13-14-, and 18-19-years, and the clinic recall system served as a tool for planning the stages of the investigation. Patients were offered appointments for a regular oral health examination during which time all data collection took place.

Paper I: According to the sample size calculation, with an estimated prevalence of 40% erosion into enamel/dentine and a confidence interval of 5%, the size of the total group (5-19-years-olds) was calculated as 369 individuals. During the study period (January 2005 to December 2007) a total of 1580 children and adolescents within the chosen age cohorts were scheduled for their oral health recall examination at the Public Dental Service in Nora and Storå. From this recall-list a total of 801 patients were given appointments in consecutive order. Out of these, 609 (76%) children and adolescents accepted to participate. This included 135 5-6-year-olds, 227 13-14-year-olds, and 247 18-19-year-olds, 51% of the total number of participants being males.

Paper II: The analysis was performed on the 13-14-year (n=195) and 18-19-year (n=197) groups from the original 474 that made up these age groups. In this analysis, 47% were males. Eighty-two individuals from these two groups did not answer the self-reported questionnaire and were therefore excluded from this study.

Paper III: The baseline 13-14-year-old group (n=227) was followed-up after four years (between May 2009 and January 2012) using the same methodology as in the baseline study. A sample size estimation (with a power of 80%, significance level of 5% and discordant proportion of 10%) resulted in a minimum of 127 participants being required (McNemar's test). Since the group aged 13-14-years comprised 227 individuals at baseline, it was deemed to be large enough even with some drop-outs during the study period.

The investigation was planned to take place during the oral health examination that was closest to an interval of four years, again using the recall lists for calculating and scheduling the appointments. All participants who remained as recall patients between May 2009 and January 2012 were invited to take part in the study, and 175 individuals (77%) accepted to participate of which 54% were males.

Clinical investigation

The study comprised two parts: a clinical oral health examination including scoring of dental erosion and a questionnaire investigation regarding drinking and dietary habits and some lifestyle factors that may be of some importance in the development of erosive wear.

Clinical examination and scoring of dental erosion at baseline and follow-up

The clinical examination followed a routine protocol. Besides medical history, it included caries, gingival and plaque status, and when indicated, further examination was performed. Radiographs were taken based on individual indication, and bitewings not more than two years old were considered acceptable for diagnosis. An exception was the 19-year-olds who were all examined with bitewings. Only caries into dentine was utilized for calculation of DMFT and DMFS.

Severity of dental erosion was recorded along with plaque accumulation and gingival bleeding on buccal and palatal surfaces of all six maxillary anterior teeth, and occlusal erosive wear (cuppings) was recorded on first permanent molars and all

primary molars. The recording of anterior maxillary erosion and cuppings took place in ordinary clinical lightning, which may differ slightly between different units.

A high quality mouth mirror of intraoral photographic type was used (Fig.1). If necessary, plaque was removed by polishing with prophylaxis paste before the assessment.

Figure 1. Mirror of intraoral photographic type that was used for visual grading of dental erosion and cuppings.

The teeth were dried by compressed air before grading. For grading of dental erosion on maxillary anterior teeth a scale by Johansson et al. 1996 was used [35] (Table 1), illustrated in Fig. 2. Another scale for recording premolar and molar occlusal erosive lesions (cuppings) on both primary and permanent teeth was constructed for the study. (Table 2, Fig. 3). Surfaces that were impossible to assess, such as due to missing teeth, presence of orthodontic appliances, extensive fillings, or glossy flat facets covering most of the tooth surface that made it difficult to differentiate between erosion and other types of dental wear, were excluded from the study. When the erosive wear was deemed to be between two scale steps, the lower grade was chosen.

All marker teeth were registered for buccal cervical defects as ‘yes’ or ‘no’ according to Johansson et al. [35]. Visible Plaque Index (VPI) and Gingival Bleeding Index (GBI) on maxillary anterior teeth were recorded dichotomously as ‘yes’ or ‘no’, according to Ainamo and Bay [193].

Table 1 – Ordinal scale used for grading severity of dental erosion on buccal and palatal surfaces of maxillary anterior teeth. [35]

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 dentine surface exposed by ≤1/3.
4	Enamel surface as described in grades 1, 2 and 3. Dentine surface exposed by >1/3 or pulp visible through the dentine.

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

Table 2 – Ordinal scale used for grading cuppings on occlusal surfaces of first permanent molars and primary molars. (Paper I)

Grade	Criteria
0	No cupping/intact cusp tip
1	Rounded cusp tip
2	Cupping ≤ 1 mm
3	Cupping > 1 mm
4	Fused cuppings: at least two cuppings are fused together on the same tooth

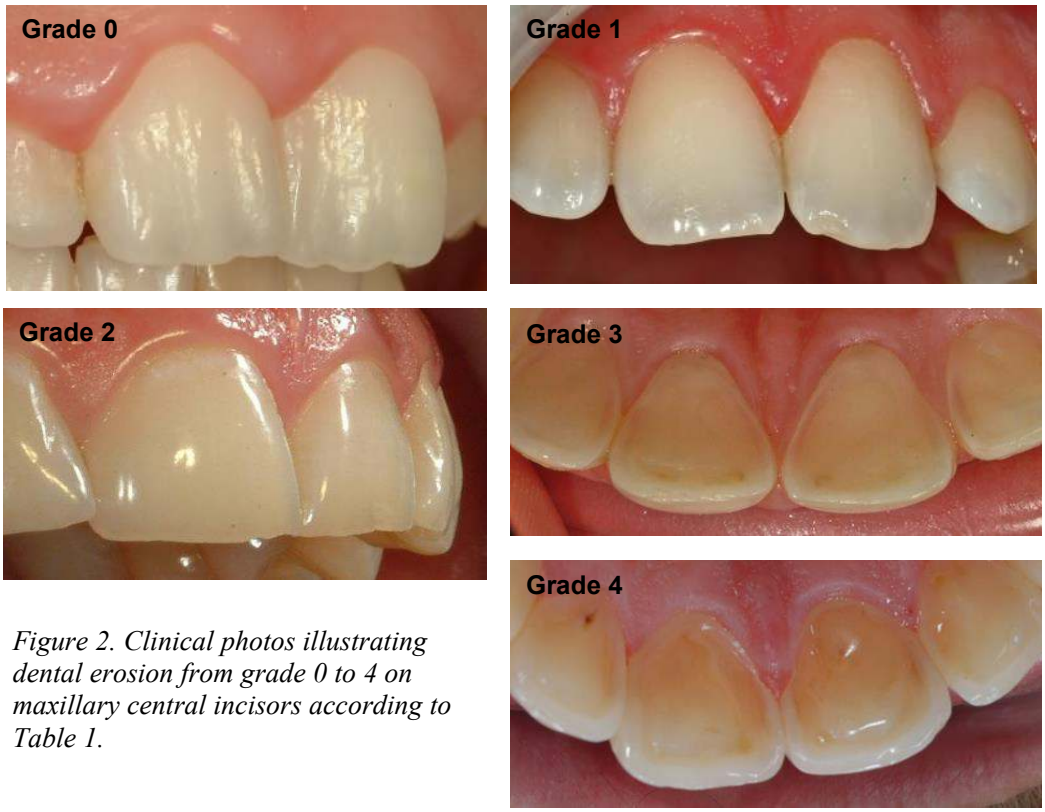

Figure 2. Clinical photos illustrating dental erosion from grade 0 to 4 on maxillary central incisors according to Table 1.

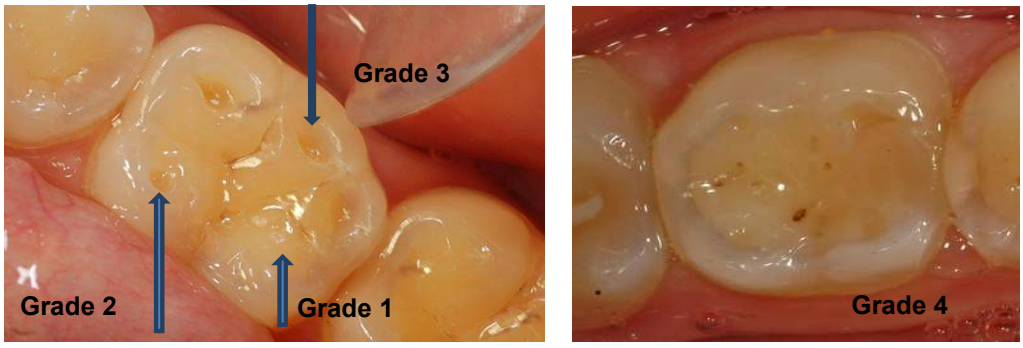

Figure 3. Clinical photos illustrating cuppings from grade 1 to 4 on first lower molars according to Table 2

Calibration for Paper I and Paper III

Paper I: An inter-examiner calibration on the grading of dental erosion, cupping and buccal cervical defects was performed between the principal investigator (AH) and an experienced researcher (AKJ) prior to Paper I as well as a test of intra-examiner concordance of the examiner (AH) in the use of the erosion scales (Tables 1 and 2). Two successive blind assessments were performed after an interval of two to six weeks in ten patients aged 5-6-years (140 primary teeth / 200 surfaces) and in 24 patients aged 13-14-/18-19-years (220 permanent teeth / 384 surfaces).

Paper III: Prior to the follow-up study a new test of intra-examiner reliability of grading was performed in 13 non-participants aged 13-19-years (208 surfaces in 130 permanent teeth, comprising 78 maxillary anterior teeth and canines and 52 first permanent molars).

The principal investigator performed all clinical examinations at baseline and follow-up, and the recordings of plaque, gingival bleeding, erosion/cupping and cervical defects were always performed prior to the routine examination. The examiner was blinded to the results from the questionnaire during the assessment.

Questionnaire at baseline (Paper I and II) and follow-up (Paper III)

Paper I and II: The questionnaire was divided into two parts, a self-administered part that was filled in by the patient/parent at home and sent back by mail or handed over at the clinic visit, and an oral part that was completed at the clinic visit by interview. The interviews were performed by a specially trained dental assistant (BR-H). Paper I was based on the oral interview and paper II was based on both the oral interview and the self-administered questionnaire. The questionnaires were slightly modified from a form that has been used and successively modified in other studies [17,35]. The questions were related to different lifestyle and general health factors.

- Frequency of intake (per day/week/month) of dietary items: sweet/sour sweets, ice lolly/ice cream, snacks/biscuits, cheese, fresh/dried fruit, water, soft drinks, tea, coffee, milk/yoghurt/sour milk.

- General health: medication, stomach problems, vomiting, body height and weight, and if they had tried to change their weight.
- Oral health: symptoms from the mouth/teeth, dry mouth, frequency of tooth brushing (times per day/week).
- If the patient or either parent was born outside Sweden.
- Habits: drinking method (keeping the drink in the mouth before swallowing); screen-viewing (hours per day during weekdays and during weekends); and physical activity (frequency of exercising and competition/games per week).
- Vegetarian diet: yes/no

In the oral interview the daily amounts and frequency of consumption of all types of hot and cold beverages (except alcoholic) were recorded for breakfast, lunch, dinner, between meals, during physical exercise and during the night. To facilitate the estimation of the amount of drinks, glasses and cups of different sizes were showed as examples on specific volumes.

Paper III: Questions that concerned only the 5-6-year-old group were excluded in the self-administered questionnaire for the 13-14-year-olds at the follow-up, and there were minor changes in the oral interview that was complemented with questions about indigestion (symptoms of gastric reflux, yes/no) and recording of alcoholic beverages (beer, cider, wine, alcopops). The additional time needed for the extended examination and interview was approximately 15 minutes in both the baseline and follow-up examination.

Analyses of Data and Statistical Methods

In all three studies the prevalence of erosion was at the tooth surface level and the individual level by merging scores from Tables 1 and 2 into a combined scale (Table 3).

In all three papers, descriptive analysis was applied. Inferential statistics was used for comparing groups (Mann-Whitney U-Test) and for assessing the association between

groups (Pearson correlation analysis). Multivariate logistic regression was applied on high/low soft drink consumption (separately within the two age groups, *Paper II*) using high and low consumption as dependent variable, and on high/low progression groups as dependent variable (*Paper III*).

Paper I: Descriptive statistics were applied. The individuals were further divided into two groups based on the highest score recorded on any tooth, in which the high erosion group showed at least one tooth with severe or very severe erosion and the low erosion group showed no higher than mild erosion on any tooth (Table 3). The high and low erosion groups were compared with respect to gender and to the yearly consumption of carbonated soft drinks.

A simplified erosion partial recording system (SEPRS), using only four marker surfaces in permanent teeth (highest score on palatal surfaces of tooth numbers 11/21 and cuppings of tooth numbers 36/46) or six surfaces in primary teeth (palatal surfaces on 51/61 and all primary first molars) was evaluated against the total scoring of all marker teeth (16 and 20 surfaces respectively in permanent and primary teeth).

Table 3 – Combined erosion scale from grading of maxillary anterior teeth (Table 1) and molar cuppings (Table 2).

Grade	Localization	Criteria
0 = No erosion	Anterior teeth	No visible changes, developmental structures remain, macro-morphology intact
	Molars	No cupping/intact cusp tip
1 = Mild erosion	Anterior teeth	Smoothened enamel, developmental structures have totally or partially vanished. Enamel surface is shiny, matt, irregular," melted", rounded or flat, macro-morphology generally intact
	Molars	Rounded cusp tip
2 = Moderate erosion	Anterior teeth	Enamel surface as described in grade 1. Macro-morphology clearly changed, facetting or concavity formation within the enamel, no dentinal exposure
	Molars	Cupping ≤ 1 mm
3 = Severe erosion	Anterior teeth	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
	Molars	Cupping > 1 mm
4 = Very severe erosion	Anterior teeth	Enamel surface as described in grades 1, 2 and 3. Dentin surface exposed by >1/3 or pulp visible through the dentin
	Molars	Fused cuppings: at least two cuppings are fused together on the same tooth

Paper II: The 13-14-year-old and 18-19-year-old groups were divided into high and low soft drink consumption subgroups, derived respectively from approximately the highest and lowest one-thirds of carbonated soft drink consumption (n=58 High / n=60 Low in 13-14-year group and n=57 High / n=57 Low in 18-19-year group).

The middle soft drink consumption group was excluded from the analysis and the high and low consumption groups were compared with respect to gender, dietary habits including all kinds of drinks, oral and general health factors, oral hygiene habits, Body Mass Index (BMI) and physical activity.

Paper III: The progression of dental erosion/cupping between baseline and follow-up was compared at the tooth surface level. Since no greater progression than two grades was found, the progression was registered as: 0 (unchanged), +1 (one grade of progression and +2 (two grades of progression).

The mean progression per tooth surface and per individual was calculated and the material was divided into three groups based on the mean change: low progression group (0-0.2 scale steps), middle progression group (>0.2-<0.5) and high progression group (>0.5 steps). The middle progression group was excluded in the analysis, and the high and low progression groups were compared regarding differences with respect to gender, dietary habits including all kinds of drinks, oral and general health factors, oral hygiene habits, BMI and physical activity.

Ethical approvals and considerations

Approvals from the Regional Ethical Review Board in Uppsala, Sweden, was obtained for each study prior to the start (no. 2004/M-434, *Paper I* and *II* and 2009/031, *Paper III*). The patient and/or parent were provided with written and oral information about the study, and an informed consent was signed by the participant or by a parent in cases of under-aged children. If there was a diagnosis of erosion or any other oral condition, the patient was informed and preventive and/or restorative measures were carried out, following standard routines and free of charge.

Results

This section provides a summary of the most interesting findings from the included studies. The results are described in more details with figures and tables in the respective *Papers I, II* and *III*.

Dropouts and missing data analysis

Drop outs: Paper I; Out of 801 children, 609 (75%) accepted to participate in the study. Among the dropout of 192 individuals, 48 were excluded because they failed to return the signed consent. One hundred and three individuals did not want to participate or failed to cooperate due to functional disorders and/or communication problems, and 41 never showed up for their appointments.

Drop outs: Paper III; From the baseline group of 227 13-14-year-olds, 175 individuals accepted to participate (77%). Fifty-two individuals were lost, of which 10 were excluded because of failure to return the signed consent and 42 refused to participate or were no longer patients at the clinic.

Missing data analysis: In *Paper II*, the 82 individuals who were excluded from the analysis due to incomplete responses of the self-administered (written) questionnaire did not differ significantly to the responders as regards age group, gender, DMFT/S, severity of dental erosion and GBI. However, the non-responders reported significantly higher consumption of carbonated soft drinks, with the 18–19-years-old non-responders having significantly higher VPI. In *Paper III*, no significant differences for responders compared to non-responders with respect to gender or age (13- or 14-years) were found. However, non-participants reported a significantly lower frequency of intake of: carbonated soft drinks other than cola-type drinks, ice-cream and cheese, and a significantly higher frequency of intake of fruit drinks and juice. They also reported higher frequency of intake of carbonated soft drinks between meals. In the clinical variables, non-participants had greater severity of erosion according to SEPRS, and lower GBI.

Intra-examiner concordance

At the baseline examination, for *Paper I*, intra-examiner concordance between two successive recordings of erosive wear in permanent teeth (25 patients) was 70.7% in anterior teeth erosion and 80.0% in occlusal cuppings. For primary teeth (10 patients) the corresponding figures were 64.1% and 75.9%, respectively.

Intra-examiner concordance prior to the follow-up examination, in *Paper III*, was 77.4% in 13 patients (75% in maxillary anterior teeth and 84.6% in occlusal cuppings of first molars).

Prevalence, progression and incidence of dental erosion

Paper I: Males in age group 18-19-years exhibited a significantly higher mean erosion score than females (P=0.002), and 15% of males exhibited at least one anterior tooth with grade 3 or 4 erosion (*Paper I*, Fig. 1). No gender differences were found in 5-6- and 13-14-year-old groups. In age groups 13-14- and 18-19-years, males had significantly higher cupping scores than females (P=0.02 and P=0.01, respectively), but not in the age group 5-6 years (*Paper I*, Fig. 3).

In all age groups, severe erosion was found only on palatal surfaces, and cuppings were more often found on first maxillary molars in primary teeth and on first lower molars in permanent teeth, although severe anterior tooth erosion and cuppings were not always found in the same individuals. Cervical defects (total number/individual) showed higher prevalence among males in 5-6- and 18-19-year-old groups (*Paper I*, Fig. 2).

The use of Simplified Erosion Partial Recording System (SEPRS) for permanent teeth (four surfaces) for predicting severe/very severe dental erosion had a sensitivity and specificity of 100% and 98%, respectively, compared to scoring 16 surfaces. In primary teeth it was 100% for both sensitivity and specificity (six surfaces compared to 20 surfaces).

The prevalence of the combined anterior tooth erosion and cuppings (Table 3), according to SEPRS, was 11.9% among 13-14-year-olds, 22.3% among 18-19-year-

olds and 13.3% in primary teeth among the 5-6-year-olds (*Paper I*, fig 4). The prevalence was highest in boys aged 18-19-years, namely 34.4%. Gender differences were only significant in the 18-19-year-old group.

Paper III: The prevalence of severe/very severe erosion for boys, according to SEPRS, was 9.5% at baseline and 14.9% at follow-up, and for girls 2.5% and 6.3%, respectively (*Paper III*, Fig 5). While at baseline there was no significant difference between boys and girls, such a difference was observed at follow-up.

Ninety-three out of 2566 surfaces (3.6%) were graded as improved. These surfaces were counted as unchanged in the statistics. A deterioration by one grade was registered on 830 tooth surfaces (32.3%) and two grades on 67 surfaces (2.6%) (Table 4).

Thirty-six tooth surfaces (1.4%) had progressed to severe erosion. At baseline, 12 individuals showed severe erosion on at least one tooth, and at follow-up further nine individuals had progressed from mild/moderate to severe erosion.

Progression was most commonly seen in maxillary canines (56.4%), and least commonly in maxillary first molars 16/26 (7.8%). Anterior teeth showed more erosive progression than did first molars, that is, 43.2% and 12.1%, respectively. Buccal surfaces showed higher progression than palatal surfaces, that is, 48% and 38.2%, respectively.

There was no difference in progression between the individuals that were followed up after a shorter than after a longer interval (the follow-ups having taken place between 46 and 61 months). There was no difference in progression by gender although females showed lower grades according to SEPRS at both ages.

The incidence was 76% based on the individuals who showed none/minimal signs of dental erosion and cupping at baseline (n=59) and had developed grade two or more in at least one tooth at the follow-up (n=45).

Table 4 - Progression of erosion and cupping scores in all six maxillary anterior teeth (1881 surfaces) and all first molars (685 surfaces) between baseline and follow-up. N=175 individuals. Missing teeth = 234. Grading of dental erosion according to Table 3.

	Grading at follow-up					
Grading - at baseline	0	1	2	3	4	Total at baseline
No Erosion (grade 0)	232	443	63			738
Mild erosion (grade 1)		964	357	3		1324
Moderate erosion (grade 2)			446	30	1	477
Severe erosion (grade 3)				23	0	23
Very severe erosion (grade 4)					4	4
Total at follow-up	232	1407	866	56	5	2566

Lifestyle, clinical variables and dental erosion

Paper I: Boys drank significantly greater amounts of carbonated and non-carbonated drinks in both of the older age groups, and there was a significant correlation between reported soft drink intake and severity of dental erosion in the 18-19- group and in the 13-14-year-old group, ($r=0.36$, $p=0.001$ and $r=0.14$, $p=0.04$ respectively) (*Paper I,* Table 3).

Paper II: In both age groups there were significantly more boys than girls in the high soft drink consumption group groups, ($p< 0.01$ and $p>0.001$ respectively) (Table 5).

Table 5 - Consumption of carbonated soft drinks (L/year) at baseline by gender, low and high soft drink consumption in age groups 13-14-years (n=195) and 18-19-years (n=197), and calculated as the mean of the present and past consumption levels.

Age	Group	Gender	Mean soft drink consumption (L/year)	Range	SD
13-14 year	Low	Female n=39	7	0-17	6.7
	n=60	Male n=21	11	0-17	6.0
	High	Female n=22	74	45-226	39.1
	n=58	Male n=36	71	43-159	25.8
18-19 year	Low	Female n=43	8	0-26	8.0
	n=57	Male n=14	12	0-25	8.5
	High	Female n=18	137	78-333	73.9
	n=57	Male n=39	181	78-1248	207.0

Dietary variables, oral hygiene habits, sports exercise, meal patterns, screen-viewing behaviors, BMI and parents born outside Sweden differed significantly between high and low consumers in one or both of the two age groups. Dental erosion in both age groups and DMFT/DMFS in the oldest group were significantly higher among high soft drink consumers (*Paper II*, Table 4). Predictive variables for high consumption of carbonated soft drinks and according to logistic regression was male gender, unhealthy dietary habits, lesser physical activity, higher BMI and longer time spent in front of TV/computer (*Paper II*, Tables 5 and 6).

Paper III: The yearly mean consumption of carbonated soft drinks increased from 38 L up to 48, and the consumption of all soft drinks from 119 up to 132 L. There was a significant correlation between reported soft drink consumption between meals and progression of dental erosion (Table 6).

Table 6 - Differences in variables related to dietary habits and other lifestyle factors and clinical findings in the high progression group at follow-up. P denotes the difference between the high and the low progression groups.

Variables	High progression group at follow-up *p*
Dietary habits	
Higher intake of:	
Sour candy (at follow-up)	0.029
Soft drinks between meals (at baseline)	0.048
Lower intake of:	
Soured milk (at baseline)	0.046
Tea for breakfast (at follow-up)	0.032
Milk for lunch (at home) (at follow-up)	0.044
Other life style factors (at baseline)	
More often retaining soft drinks in the mouth before swallowing	0.004
More often dry mouth during night	0.038
More often pain from the teeth	0.034
More often taking medicine	0.021
Clinical findings (at baseline)	
Lower VPI	0.018
Lower GBI	0.031
Lower mean of erosion 13-23	0.001

No significant differences between the two groups were seen between progression and caries development, BMI, or sedentary living. In the adjusted logistic regression analysis, it was found that a lower severity of erosive wear at baseline had the highest OR (13.3) for progression of tooth wear (*Paper III*, Table 5).

DISCUSSION

Methodological aspects

Aspects of patient selection and participation rate

During the early years of the 2000s, the author and colleagues observed dental erosion in a number of teenagers at the dental clinics in Nora and Storå, Örebro County Council. At that time dental erosion in children and adolescents had been reported in other parts of the word [50,53,54,73,99,140,194], but the prevalence in these groups in Sweden was unknown. The dental clinics in Nora and Storå were located in small, typically Swedish communities, each with public schools for children and adolescents aged 6-16-years. Also, 98% and 97% of all 3-19-year-olds in Nora and Storå were enrolled in the Public Dental Service for their dental care. This is confirmed by Department of Dentistry, Region Örebro County, Örebro, which implies that a study cohort among these children and adolescents represents a mix of socioeconomic status in these communities. The study was performed during the ordinary recall appointments to achieve a participation rate high enough to be representative for the general Swedish population in smaller communities.

Since dental erosion is age dependent [54,70,195], as are the dental development and lifestyles of growing children, three different age groups were selected for the study. The 5-6-year-olds have mainly primary teeth and are to a large extent dependent on parents' care. The 13-14-year-olds with newly erupted permanent teeth are gradually reaching independence from parental influence while connecting with new friends and new habits. The teeth in 18-19-year-olds would have erupted for some time, while the individuals are often more independent from their families, and starting to create their own ways of living. The three groups selected for investigation in this study were therefore deemed to be representative for the different and important phases of childhood and adolescents.

Non-participation in epidemiologic studies is an increasing problem and has worsened during recent years [196]. The ability to generalize from the results of a

questionnaire and clinical findings depends on a sufficient number of participants. A response rate of at least 60% is set as a minimum requirement for publication by some scientific journals [197]. Considering the foregoing, the participation rate in this study of 75% in the baseline study (*Paper I*) and 77% in the follow-up study (*Paper III*) can be considered as good. In addition, the sample size calculation determined that there should be a minimum of 369 participants recruited for the baseline study (*Paper 1*) and 127 participants in the follow-up study (*Paper III*), numbers that were exceeded in both of the studies. Therefore, and in combination with the fact that more than 97% of all children in these regions attended the public dental clinics, the results from this study may allow some general conclusions to be drawn about prevalence of dental erosion and the association with soft drink consumption and other lifestyle factors among children and adolescents in smaller communities in Sweden. Unfortunately, there is still no other similar published study on children or younger adolescents in Sweden with which to compare the present findings.

The follow-up investigation (*Paper III*) was planned to take place at the individual's ordinary dental appointment as close as possible to an interval of four years. It was considered important to conduct the data collection as an adjunct to their regular recall appointment in order to minimize the dropout rate from the study. The ideal would have been to equalize the time span between baseline and follow-up according to Dugmore at al. [54], but in spite of every effort, the time span became fairly wide (41-63 months). Nevertheless, no statistical difference in progression of dental erosion between shorter or longer follow-up intervals was noted. In addition, if an extra non-regular appointment had been given for this study, the risk for attendance bias may have been higher since it is likely that participants who are more concerned with their oral health could have been overrepresented.

The analysis of differences between the study group and dropouts in *Paper II and III* differed in some respects since the drop-outs reported a higher frequency of intake of fruit drinks, juice and carbonated soft drinks between meals, so that a bias cannot be excluded. It can be mentioned that a drop out analysis has not been seen in other longitudinal studies on dental erosion [49,54,70].

Clinical examination and scoring of dental erosion

The study was performed in an actual clinical setting, with good illumination and complemented with large mirrors of high quality (designed for intraoral photographing), earlier described by Johansson et al. [35]. In that way, it was possible to visualize small details on the tooth surface topography, facilitating detection of the characteristics of the early signs of dental erosion. Among other longitudinal studies on dental erosion, only one has been performed in a clinical setting, but it is not clearly described whether it took place in conjunction with the participant's regular dental examination [70]. Performing studies in schools during schooldays may minimize the drop-out [54], but the clinical conditions may be impaired. If study casts were available this could minimize the drop-out, but the quality of the casts and inherent difficulty of grading mild erosive wear from casts could complicate the matter [49]. Besides, it has been shown that registration of wear on study casts showed lower reliability than clinical registration [198].

According to most researchers, the most common sites for dental erosion are maxillary anterior teeth and mandibular molars [35,49-52]. Previous studies have also shown an association between erosion and cuppings on molars [17,18,35]. Therefore, two scales were used, one for maxillary anterior teeth (Table 1) and one for molar cuppings (Table 2).

The scale for maxillary teeth, and modifications thereof, was first described by Johansson in 1996 [35], and has subsequently been used in other studies [17,72,79,96,112,199,200]. The scale is based on changes in surface structure and tooth morphology, and is designed to assess erosive wear while attempting to exclude wear caused by attrition and abrasion. The incisal surfaces are therefore omitted from grading and only buccal and palatal surfaces on the maxillary anterior teeth are included. The lower grades of the scale define the first changes of surface structure making it possible to follow the development of erosive wear over time; this is an important advantage especially among younger individuals.

A complementary scale was constructed for grading only the cupped lesions of the molar cusp tips, based again on changes in tooth morphology and also on clinical experience (Table 2). In order to assess the total "erosive burden" in an individual the two scales were combined (Table 3).

In the 13-14- and 18-19-year-old groups, severe erosion was found only on palatal surfaces of maxillary incisors and on occlusal surfaces on first lower molars. The individuals that showed severe erosive wear on anterior teeth were not always the same as those who showed severe cupping, which suggests that prevalence found in studies that record only maxillary anterior teeth is not entirely comparable to those that record a combination of maxillary anterior teeth and molars.

To further simplify detection of severe erosive damage, a simplified erosion partial recording index (SEPRS) was developed which showed high sensitivity and specificity compared to grading all maxillary anterior teeth and molars. Consequently, SEPRS can be recommended for routine clinical screening to identify individuals having extensive erosive tooth wear (grade 3 and 4, that is, approximately into dentine). In a recent study on Yemeni children and adolescents using the combined erosion/cupping scale (Table 3), severe erosion was found also on buccal surfaces in maxillary anterior teeth (11,21) [79], and the author suggests that the localization of severe erosion is influenced by cultural differences in dietary habits which may motivate the inclusion of these surfaces in the simplified grading system.

Questionnaire

The self-administered questionnaire is a slightly modified version of a form that has been used and modified over many years, and been applied successfully in previous studies [17,35]. Several participants failed to return it, and in order to minimize the dropout of questionnaires and signed consents, the patient/parent was asked to fill in the forms at the clinic visit when possible. The participants who did not return the forms were reminded twice by telephone or by mail with a new form attached, up to four months after the examination. Older participants filled in the questionnaire themselves, and the 5-6-year-old group and occasionally the 13-14-year-olds were

assisted by a parent. Since parents of teenagers are not always aware of the habits of their children, their assistance may increase the risk for biased answers. A better compliance with the self-administered questionnaire might have achieved if it had been performed orally at the clinic visit, but this was deemed to be too time consuming both for the patient and within our limits for the study. The question about height and weight may have been delicate since it was not always answered, and it may therefore have been better to ask, or ideally to measure, at the clinic visit. This would, however, have required movable equipment, which would have been complicated to move around, since the investigations were performed in different clinics and rooms.

The oral interviews both at baseline and follow-up required recall of detailed daily drinking and dietary intakes, both on weekdays and during weekends. These were all performed by the same dental assistant, which should have minimized the risk of bias, although in all dietary recalls there is always a risk of leaving out some intakes. The estimated drinking consumption one year earlier was also recalled, to avoid bias due to recently changed habits. Different sizes of glasses and cups were on hand during the interview to facilitate the estimation of the consumption of drinks. Although this is not frequently described in other studies, it has been used [35].

Analyses of data and statistical methods

In all three papers the sample was divided into subgroups: in *Paper I,* into high and low erosion groups; in *paper II,* into high and low soft drink consumption groups; and in *Paper III,* into high and low progression groups. The middle groups were excluded in the analysis and only high and low groups were compared to each other, a method that has been used in other studies [17,101]. Such a statistical approach of comparing the extremes (i.e. healthy vs. sick), makes it easier to detect associations but information is lost as regards individuals who fall in between.

In *Paper II,* separate analyses were performed for the 13-14- and 18-19-year-old groups, since some of the independent variables may be age-related or have direct association with soft drink consumption. This was suspected in particular for the

clinical findings and therefore there were only reported variables included in the regression analyses.

In *Paper III,* each tooth surface was compared between baseline and follow-up. While dividing the material into subgroups based on progression, the use of mean values from an ordinal scale may be questioned, but it was deemed to be the most relevant method.

Prevalence, progression and incidence of dental erosion

Prevalence

To compare the prevalence of severe maxillary anterior dental erosion and cupping in this study with other studies, an estimation was made that grade 3 (severe erosion) in the scales used in this study corresponds to dentine involvement in other scales. Further, the comparison was made with studies performed on similar age groups and where dental erosion specifically was graded. In primary teeth the prevalence of severe erosion was 13.3% which was lower than in other studies [53,99,194], but among younger and older adolescents it was at a higher level than in most other comparable studies. Of the 13-14-year-olds in this study, 8.8% showed erosion into dentine, which is similar to a British and a Libyan study [54,63], although most other studies in the age cohort 12-17-years found lower prevalence or no dentine involvement at all [50,52,56,58,60,61,71,73,140], and a few showed higher figures [39,53]. In the 18-19-year age group, 22.3% showed severe erosion which is higher than comparable studies, although this age group is not frequently studied: a Brazilian study among 15-19-year-olds found no severe erosion [64], a Norwegian study among 16-18-year-olds reported 15% [65], and a comparable Swedish study among 20-year-olds reported 18% [72].

It is interesting that the prevalence of severe erosive wear at follow-up was lower in the 17-19-year-olds (12%, *Paper III*) compared to the 18-19-year group at baseline (22.3%, *Paper I*). A possible effect of the baseline study may have been that the adolescents and parents probably were influenced by the extensive information about dental erosion that was given at the examination. Also, within the study cohort,

siblings of former participants sometimes showed up, so that the parents would already have had thorough information about dental erosion and preventive measures. Another effect may have been that the dental staff at the involved clinics paid more attention to dental erosion, soft drinks and potential risks, a sense that was transmitted to the patients. Other factors that may have had an impact was the highlighting of dental erosion in media that started during the middle of the baseline study (around 2006). There was a growing interest in marketing anti-erosion toothpastes with an explosion of commercials concerning dental erosion that brought a strong message about prevention of dental erosion. A decrease in soft drink consumption was reported in this group, since the yearly mean reported consumption of carbonated soft drinks at baseline was 63L among the 18-19-year-olds and at follow-up only 48L among the 17-19-year-olds. This decrease corresponds to a recent Swedish longitudinal study on oral health, reporting that between 2003 and 2013 there was a 40% reduction in individuals that consumed soft drinks regularly among 3-20-year-olds [201], a finding similarly found in a Norwegian study [156]. Altogether, the factors mentioned above could have contributed to the decrease of erosive prevalence among the older adolescents between baseline and follow-up. Besides the possible impact of variables related to dental health, it was also a growing awareness among child health workers about children´s and adolescents´ overweight, thus focusing on advising individuals about diet and physical activity.

In this study male adolescents had more dental erosion than females, which is the common finding in many other comparable studies [50,52,54-56,65,70,71,73-75]. When comparing these studies to others where no gender difference [58,64,77,78], or a higher prevalence among girls [60,79], are reported, there is a tendency that the studies where males have more wear report higher prevalence of wear into dentine than in those studies where there is no gender difference. Even if there is some uncertainty in comparing studies using different scales in different age cohorts, this indicates that it may be easier to detect gender differences in groups that show higher prevalence of more severe erosive wear.

Progression

The few available clinical longitudinal studies of progression of dental erosion are performed on younger age groups and the follow-up periods are shorter compared to this study (*Paper III*). In this material, 30% of the adolescents had deteriorated by one or two grades of severity on at least one tooth surface. This can be compared to a British follow-up where 27% of 12-year-olds showed progression after two years [54]. Higher progression was found in the Netherlands where 56% of 11-year-olds and 45% of 12-year-olds showed progression after 3 years [70].

The progression differed between different sites in the mouth, which has not been reported on in other longitudinal studies. Most affected were maxillary anterior teeth, especially the canines and buccal surfaces while molars were least affected by progression, which probably depends on the length of time for which the teeth had been present in the mouth. At baseline (age 13-14), the canines were recently erupted with the majority of surfaces graded 0 (no erosion) and about half of them deteriorated into grade 1 during the four-year follow up. This can be compared to the first molars where only 1.5% scored 0 at baseline, having been present in the mouth for several years, and consequently developed wear earlier in childhood. Since erosive wear is shown to be age dependent [54,70,195], the finding of higher progression of dental erosion on recently erupted teeth, suggests a possible explanation as to why participants with a lower mean score of erosion on anterior teeth at baseline showed higher progression. Besides, a deterioration from score 0 to score 1 may be regarded as normal erosive wear on newly erupted teeth.

The lower progression in individuals who showed higher means of erosion at baseline may be partly explained by the definition of the scale steps, where the lower steps (0-1) grade the finest visible changes of tooth structure while the higher steps (3-4) measure a broader loss of tooth tissue within each scale step. Therefore, a relatively greater amount of tooth tissue will have to be worn away between steps 2 to 3 and between 3 or 4. It is therefore more likely that it is easier to visualize progression of wear from 0 to 1 and/or from 1 to 2 than detecting surface structures worn away from 2 up to step 3 or 4. Nevertheless, the finding of high prevalence of severe erosion in

13-14-year-olds which further increased until the age of 17-19-years, shows that the onset of severe erosion may take place early in life, and motivates regular screening of dental erosion soon after eruption of the first permanent teeth as well as continuing monitoring during adolescence.

At follow-up (*Paper III*), boys had developed a significantly higher prevalence of severe/very severe erosion compared to girls, although neither the prevalence of severe erosion at baseline nor the numbers of surfaces that progressed during the study period differed significantly by gender. This indicates, however, that boys are at greater risk for developing severe erosion, and is supported by comparable studies where the prevalence of more severe erosion increased more in boys than in girls, although in these studies the prevalence was already higher in males at baseline [54, 70].

Incidence

The incidence of dental erosion of 76% in this study was higher than in other studies. In a 2-year follow-up British study, the incidence was 12% between 12- and 14-years of age [54], and in a study from the Netherlands the incidence was 27% between 11-14 years of age and 20% between 12-15-years [70]. The latter study also reports that at age 14 there were only a few erosion-free individuals, which is in concordance with this study, where nobody scored a maximum of 0 on all tooth surfaces at baseline. Therefore, the incidence was calculated on participants scoring maximum grade 1 (mild erosion) on any tooth at baseline (59/175 individuals), and consequently the incidence figure in this study actually reflects a deterioration from an already “unhealthy” tooth surface into a more “diseased” one.

Factors associated with progression of dental erosion

Diet

Among dietary factors, the consumption of soft drinks seems to have an influence on progression of dental erosion, since the high progression group showed higher consumption of drinks between meals (*Paper III*). This association between soft drink

consumption and progression of dental erosion has also previously been reported [100,202]. Besides soft drink consumption intake of sour candy showed to be more frequent in the high progression group, which is in accordance with a Norwegian study that found consumption of sour candy to be a risk factor for dental erosion is [107]. Another factor that is shown to influence the development of dental erosion is the mineral content (calcium and phosphate ions) in the saliva and the diet [13,110,129-132], and in this study the high progression group reported lower intake of milk (ordinary and sour), which is supported by the previously-mentioned report where lower progression was found in individuals who consumed more yoghurt products [202].

Lifestyle factors and clinical variables

Apart from dietary factors, some other factors were found to be associated to progression of dental erosion, among others, a retaining drinking technique, a finding supported by other studies [101,122,123]. There was also an association between higher progression and lower VPI and GBI. Low VPI and GBI could be an effect of intense oral hygiene practices or it could be a reduced ability to form a pellicle, which would reduce the effect of an acidic challenge. It is difficult to speculate on this association in the present study but intensified oral hygiene habits and lower urea concentration (a promotor for pellicle formation) have been found to be correlated with dental erosion [5,101,126]. However, in a recent Swedish study among 20-year-olds, no association was found between plaque or gingival index and dental erosion [72].

Soft drink consumption

Factors that might impact the level of consumption of soft drinks among younger people are parental attitudes and habits regarding the consumption of such drinks, along with accessibility to the drinks [145,149,151,203,204]. Parental attitudes were not investigated in this study, an aspect that would have been interesting to include. In any event, all adolescents in this study had easy access to soft drinks in shops close to the schools during school days.

The reported consumption of soft drinks in the baseline study *(Paper I)* was significantly correlated with increased severity of dental erosion among ages 13-14- and 18-19-years, a finding that is supported by several other studies [53,58,60,72,74,78,84,86,91,98-107]. It was therefore decided to further analyze the consumption of soft drinks in relation to gender, oral and general health and to some lifestyle factors (*Paper II*).

Soft drink consumption related to gender

The reported mean yearly consumption per capita of carbonated soft drinks in Sweden has been around 80-90 L over the last ten years [142], which is close to the mean consumption of 81.5 L/year among 18-19-year-old males in the baseline study (*Paper I*). The consumption of all types of soft drinks increased with age, and was especially high among 18-19-year-old males who on average consumed twice as much as females, viz. ~200 L/year and ~100 L/year, respectively. Among 13-14-year-old males, consumption of carbonated drinks was significantly higher than females. This gender difference accords with numerous other studies [85,143,145,147,149, 152,153,182,183,205], although the opposite has also been presented [60]. One explanation for the higher soft drink consumption among male adolescents could be that boys usually consume more food than girls [206] and/or have a preference for sweet tasting foods than girls of the same age [207]. Besides different patterns of consumption, teenage girls are reported to spend more of their money on items such as clothing and personal care than boys do, probably leaving less available money for fast foods [208,209]. The factors mentioned above could at least partly explain the gender difference in drink consumption.

Soft drink consumption related to oral health

Impaired oral health was associated with a high intake of soft drinks, particularly among the 18-19-year-olds *(Paper II)*. Unsurprisingly, the high consumption group showed significantly higher severity of dental erosion. A higher number of filled surfaces among 18-19-year-old high soft drink consumers was also noted, indicating that a comorbidity between dental caries and erosion exists in this material. A similar

association between dental caries and dental erosion among children and adolescents is supported in some studies [57,61,72,75,77,100], while others do not find this association [50,55,62,63,65,78,164]. The finding of worse oral hygiene with lower frequency of toothbrushing in both high soft drink consumption groups and higher GBI found in the 18-19-year-old group is also supported by other studies [17,86]. Consequently, from the results of this study, it would seem that high soft drink consumption has a negative effect upon oral health other than dental erosion.

Soft drink consumption related to other dietary habits

Several studies report that soft drink consumption is related to other unhealthy dietary habits [143,144,150,151,169,175,183], which is in concordance with the results in *Paper II.* It was clear that teenagers with high soft drink consumption also showed other dietary behaviors such as having salty snacks, sweets and sweetened milk more frequently. They also reported less frequent intake of fruit and sour milk/yoghurt and more infrequently having breakfast and lunch at school (school lunch is always free in Sweden), which amounts to a less healthy dietary behavior, so that it seems clear that high intake of soft drinks is interrelated with a number of other unhealthy dietary behaviors.

Soft drink consumption related to sedentary living and overweight

Many studies show an association between high soft drink consumption and sedentary behavior [145,150,153,176,185-190], although there are exceptions [168]. In this study the high soft drink consumers reported lower physical activity and significantly more time spent on screen viewing activities than the low soft drink consumers (*Paper II*). Unfortunately, it was not possible to evaluate the sedentary variable in the follow-up study *(Paper III),* since there had been considerable changes in screen viewing activities between baseline and follow-up, with an increase in the use of smart phones and individual laptops at school, along with demands to perform computerized home-work documents.

The amount of time spent in front of the TV and computer is influenced by family rules [186], and it is shown that higher screen-watching in turn is a risk of higher

consumption of soft drinks [145,150,153,176,185,186,188,189]. In this regard, the issue of obesity in children and adolescents has been widely studied during recent years, but its association with soft drinks is still somewhat unclear. It may also be hard to confirm since both soft drink consumption and sedentary living may be associated with overweight, and with cross-wise associations between higher BMI, screen-viewing and higher soft drink consumption [170-177]. Anyway, in this study there was an association between soft drink consumption and BMI, where 18-19-year-olds with high BMI had 8.5 increased risk (OR) of being high soft drink consumers.

It would have been interesting to study the association between socioeconomic/ sociodemographic factors and erosive wear/soft drink consumption but such variables were not collected in this study except for immigrant status. In this study *(Paper II),* an immigrant background was predictive of high soft drink consumption among 13-14-year-olds, whereas a study among Norwegian 16-18-year-olds found no association between dental erosion and birth origin [65].

Gastric reflux, a common symptom of GERD, had a tendency for statistical significance for a positive correlation with high soft drink consumers in the 18-19-year-olds *(Paper II),* but no association was found as regards dental erosion. Only a few of the participants reported any gastric symptoms. The question of eating disorders was not dealt with. Although it is a relatively common condition, especially among young women [94], it may be difficult to obtain such information from patients/participants [96]. Due to the type of investigation that this study represented it would have been unrealistic to put too much effort into this matter and consequently both gastric problems and eating disorders may have been underdiagnosed.

Tooth grinding/sleep bruxism is another factor that may influence development of erosive wear because of its possible additional attritive influence, but this was not investigated in this study. In this regard, self-report (which would have been the option for assessing bruxism in this study) of sleep bruxism is considered unreliable

and confounded with bias [210]. More reliable methods for diagnosing bruxism such as polysomnography or recording of nocturnal electromyographic activity was not possible to perform in this study. In addition, there is a strong belief today that the contribution of sleep bruxism to contemporary tooth wear is small and that erosion is the main etiological factor [3]. In relation to the forgoing, in a recent study where sleep bruxism was diagnosed with portable EMG equipment, no correlation between attritional wear and bruxism was found [211].

Other oral health factors that may influence progression of erosion, like salivary flow and buffering capacity and saliva constituents, were also outside the limits of this investigation.

While it would have been interesting to include eating disorders, sleep bruxism and salivary factors in this study, it would have broadened the study so much that it would have been difficult to perform in a regular clinical setting. Therefore, the study was focused on clinical oral health factors and behavioral factors that were possible to register during a regular oral health examination.

Aspects of prevention and treatment of dental erosion

The primary prevention method for dental erosion among children and adolescents is of course to prevent acid from reaching the tooth surfaces [82]. Unfortunately, there has been no interventional study focused on prevention of dental erosion, although there are studies focused on prevention of overweight/obesity among children through reduction of intake of sugar-sweetened beverages [212-215]. This has been performed through randomized controlled interventions [212,214] and following information campaigns in schools [213]. The impact of these efforts has in some studies been found to reduce the intake of sugar-sweetened beverages [212,214], while increasing the consumption of water and/or fresh fruit [213,214].

Many efforts have also been made to find effective secondary prevention measures against dental erosion, in particular searching different formulas and distribution modes of fluoride (mostly in forms of dentifrices or mouth rinses) for protecting

and/or strengthening the tooth surface against the acidic challenge [216-218]. For example, there are indications that stannous fluoride and titanium tetrafluoride have a better effect than sodium fluoride and that higher concentration of fluoride in general is needed than is used in caries prophylaxis [217,219]. It is important to bear in mind that none of the methods for prevention of dental erosion so far have been a complete success and that research in this matter still is in its early stages [220].

If dental erosion is diagnosed clinically, it is important to inhibit, or at least reduce progression, of erosive wear and thus eliminate or reduce the need of future severe complications that may include restorative therapy [83]. In any case, a medical history should be taken to find out the main etiological and contributing factors in each individual. The history should comprise detailed records of dietary and drinking habits and methods, general health including medication, vomiting or symptoms of reflux and oral hygiene habits. When behavioral factors are predominant, in particular at early stages of erosive wear, the treatment can concentrate on counselling the individual on how to avoid the predominant etiological factors to prevent further development, including reduction of the intake of erosive beverages and other potentially erosive dietary items between meals. If indicated, the investigation may be supplemented with testing of salivary secretion and buffering capacity. Clinical implifications of the study

The high prevalence of severe dental erosion among Swedish adolescents in this study accords with, or is higher than in, other studies on the same ages [54, 63, 65, 75]. It stresses the importance of early detection of individuals at risk for developing severe erosive wear, to be able to take preventive measures before severe tissue loss is developed. Assessment of erosive wear ought to be implemented during routine dental health examination, followed by risk estimation and, if needed, taking the adequate measures, similarly to the established management of caries in the Swedish dental care system. This study provides a scale, the Simplified Erosive Partial Recording System, that is time-efficient and simple to use to identify individuals at risk during regular clinical examinations, and when severe erosion for the given age is detected, it is recommended that the examination be expanded to the whole

dentition. Should such examination suggest that the erosive wear is beyond an acceptable level for the given age, a comprehensive history should be taken. Finally, a decision about adequate preventive and/or restorative measures must be taken, and patient education is needed in order to build a platform for the treatment. The potentially rapid progression of dental erosion indicates that documentation by serial study casts and/or photographs is important for detection of progressive erosive wear. In addition, new routines for expanded clinical examination, documentation and treatment of dental erosion may have to implemented. In this regard, increased costs for such an approach may present an obstacle in the publically financed dental care (at the time of writing, including ages 0-21-years).

The association between soft drink consumption and dental health is also supported by other studies [72,79,91,100,107], as is the association with some less healthy lifestyle factors [151,184,188,190]. The Swedish Public Dental Care has resources to support children and adolescents on an individual level to perform adequate oral and dietary practices, and to some extent, also to conduct information campaigns in schools. However, it is not equipped to influence adolescent lifestyle in general, so that cooperation with other health actors may expand the contacts with parents and others around the children.

Conclusions

The prevalence of dental erosion among Swedish adolescents was high, especially among 18-19-year-olds, where 34% of the boys showed erosion into dentine. The findings in this thesis confirm the hypothesis that boys would have higher prevalence of dental erosion than girls and that the prevalence would be correlated with soft drink consumption.

It was also confirmed that soft drink consumption among adolescents was correlated with oral health and lifestyle. High soft drink consumers more often reported an unhealthier lifestyle and showed poorer oral health than the low consumers, indicating that high soft drink consumption may be a marker for other unhealthy habits.

Over a 4-year period, those between ages 13-14-years and 17-19-years showed high progression and incidence of dental erosion, and the hypothesis that it was associated with certain lifestyle factors was confirmed. The hypothesis that the progression of dental erosion would be higher in boys than in girls was not confirmed. Anyway, both at baseline and follow-up, girls showed lower grading according to the Simplified Erosion Partial Recording System (SEPRS).

The high prevalence and progression of dental erosion point to the need for erosion preventive programs from an early age, as well as to introduce epidemiological routines for recording dental erosion during oral health examinations. SEPRS showed a high sensitivity and specificity in this group, and may be useful in both oral health examinations and epidemiological screening of dental erosion among younger people.

Future perspectives

In the light of the present knowledge about dental erosion among children and adolescents, and from my point of view, I would like to focus on the following fields:

Because of the detrimental effects of high soft drink consumption on dental and general health it is urgent to perform studies on the effects of soft drink consumption in younger people including young adults. In this regard, it is also desirable to develop cooperation in research and health education between preventive health actors within the public dental care and the general child care to promote healthier lifestyles among children and adolescents from early ages.

The importance of an increased observation of erosive wear and implementing new routines for early screening and clinical registration on a national level need to be highlighted. This could be facilitated by creating a test model for clinical registration of dental erosion. It is also dependent on reaching a consensus on which grading system should be used. The combined scale used in this study is suitable for grading younger ages, and the simplified erosion partial recording system, SEPRS, is useful in general practice as a screening tool for detection of dental erosion, extended to full mouth grading, if necessary.

When erosive wear is detected the clinical registration should be accompanied by information and preventive measures. Knowledge about risk factors may improve preventive programs and reduce progression of dental erosion. Therefore further studies on the prevalence of dental erosion and associated factors among groups of different socioeconomic/sociodemographic circumstances is needed. Further on, the knowledge is scarce about the prevalence of dental erosion and related lifestyle factors among young adults, who have lived most of their lives with easy access to soft drinks and a growing tendency of sedentary living in front of a screen. It should be possible to find representative groups of young Swedish adults for epidemiological studies, especially since the oral care will be free until 23 years of age within the next years.

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Appendix 1. Written questionnaire

(First part of the questionnaire), *(Paper III)*

Var vänlig och svara på alla frågor!

Ringa in det alternativ som stämmer bäst *Även små mängder ska räknas*	**Sällan eller aldrig**	**En till flera gånger i månaden**	**En gång i veckan**	**Två till flera gånger i veckan**	**Varje dag**	**Flera gånger varje dag**
Hur ofta äter du:						
1. Godis	1	2	3	4	5	6
2. Sura godisar	1	2	3	4	5	6
3. Isglass	1	2	3	4	5	6
4. Glass	1	2	3	4	5	6
5. Chips/ostbågar	1	2	3	4	5	6
6. Kakor, bullar	1	2	3	4	5	6
7. Kex	1	2	3	4	5	6
8. Ost	1	2	3	4	5	6
9. Färsk frukt	1	2	3	4	5	6
10. Torkad frukt (russin m.m.)	1	2	3	4	5	6
11. Tuggar tuggummi	1	2	3	4	5	6

Ringa in det alternativ som stämmer bäst *Även små mängder ska räknas*	**Sällan eller aldrig**	**En till flera gånger i månaden**	**En gång i veckan**	**Två till flera gånger i veckan**	**Varje dag**	**Flera gånger varje dag**
Hur ofta dricker du:						
12. Vatten	1	2	3	4	5	6
13. Cola (alla sorter)	1	2	3	4	5	6
14. Cola light (alla sorter)	1	2	3	4	5	6

15. Annan läsk/dricka (utom Cola)	1	2	3	4	5	6
16. Annan läskdricka light (utom Cola)	1	2	3	4	5	6
17. Saft	1	2	3	4	5	6
18. Saft light	1	2	3	4	5	6
19. Andra fruktdrycker (måltidsdryck, nektar m.m.)	1	2	3	4	5	6
20. Juice	1	2	3	4	5	6
21. Te **med** socker	1	2	3	4	5	6
22. Te **utan** socker	1	2	3	4	5	6
23. Kaffe **med** socker	1	2	3	4	5	6
24. Kaffe **utan** socker	1	2	3	4	5	6
25. Mjölk	1	2	3	4	5	6
26. Oboy eller annan mjölkdryck	1	2	3	4	5	6
27. Fil	1	2	3	4	5	6
28. Yoghurt	1	2	3	4	5	6

Hur ofta: *Kryssa det alternativ som stämmer bäst*	**Sällan eller Aldrig**	**En till flera gånger i månaden**	**En till flera gånger per vecka**	**Varje dag**	**Varje dag, morgon och kväll**
29. borstar du dina tänder	1	2	3	4	5

Var dricker du läsk/dricka: *Kryssa det alternativ som stämmer bäst*	**Hemma**	**I skolan**	**Det varierar från gång till gång**	**På annan plats (inte hemma eller i skolan)**	**Dricker inte läsk**
30. Var dricker du läsk/dricka/Cola	1	2	3	4	5

Hur dricker du: *Kryssa det alternativ som stämmer bäst*	**Sväljer direkt**	**Håller drycken i munnen och sväljer efter ett tag**
31. Vatten		
32. Kolsyrad läsk/dricka/Cola		

Kryssa det alternativ som stämmer bäst	**Håller inte drycken i munnen**	**Vet inte**	**Känner på smaken**	**Har svårt att svälja**	**Annat**
33. Om du håller **vattnet** i munnen innan du sväljer, **varför** gör du det					
34. Om du håller **kolsyrad dryck** i munnen innan du sväljer, **varför** gör du det					

Brukar du ofta: *Ringa in det alternativ som stämmer bäst*	**Sällan eller Aldrig**	**En till flera gånger per månad**	**En till flera gånger per vecka**	**Varje dag**	**Varje dag, flera gånger**	**Alltid**
35. Vara torr i munnen på dagen	1	2	3	4	5	6
36. Vara torr i munnen på natten	1	2	3	4	5	6
37. Ha ilningar i dina tänder	1	2	3	4	5	6
38. Ha värk från dina tänder	1	2	3	4	5	6
39. Ha ont i magen	1	2	3	4	5	6
40. Ha sura uppstötningar	1	2	3	4	5	6
41. Kräkas	1	2	3	4	5	6

42. Är du ofta sjuk	**43. Har du ofta öroninflammation**	**44. Är du ofta förkyld**	**45. Äter du mediciner**
Ja □ Nej □	Ja □ Nej □	Ja □ Nej □	Ja □ Nej □

46. Vad tycker du om din kropp *Kryssa **ett** alternativ som stämmer bäst*	**Alltför tjock**	**Lite för tjock**	**Lagom**	**Lite för smal**	**Alltför smal**
47. Upplever du dig som					
48. Tror du andra upplever dig som					

Vilket land är	**Sverige**	**Norden**	**Europa (utom Norden)**	**Övriga**
49. Du född i	1	2	3	4
50. Din mamma född i	1	2	3	4
51. Din pappa född i	1	2	3	4

Hur mycket brukar du idrotta på din fritid (utom skolidrott) *Uppskatta ett medeltal för säsongsidrotter*	**Antal timmar per vecka**	**Antal gånger per vecka**
52. Träning		
53. Tävling/match		
54. Vilken idrott håller du på med mest……		
55. Hur många gånger/vecka deltar du i skolidrott? ……		

Hur många timmar per dag tittar du på TV / filmer /spelar TV-spel	**0-1 tim**	**2-3 tim**	**4-5 tim**	**Mer än 5 tim**
56. På vardagar				
57. På helger				

Hur många timmar sitter du framför datorn / spelar dataspel				
58. På vardagar				
59. På helger				

60. Har du någon gång försökt gå ned i vikt	**61. Har du någon gång försökt gå upp i vikt**	**62. Hur mycket väger du**	**63. Hur lång är du**
Ja □ Nej □	Ja □ Nej □	..…….kg	..…….centimeter

64. Vad gör du under dagarna (kan vara två alternativ)					
Hemma	Skola	Gymnasium	Jobbar	Arbetslös	**65. Annat**

66. Vilket tandkrämsmärke använder du oftast?
……

Använder du regelbundet någon fluorprodukt förutom tandkräm? Ja □ Nej □

67. Vilken typ i så fall? Fluortabletter □ Fluortuggummi □ Fluorsköljning □ Annat □

68. Om du haft problem med magen/sura uppstötningar/kräkningar:

a) Hur länge har det pågått?.....månader

b) Hur ofta har du besvär?.....gånger/månad

c) Är du vegetarian? Ja □ Nej □

Appendix 2. Oral interview

(Second part of the questionnaire), *(Paper I and II)*

Hur mycket av dricker du i veckan av (senaste året):	**Typ av dryck**	**Antal glas per dag**	**Antal burkar/flaskor per dag**	**Antal milliliter per vecka**
1. Colalläsk				
2. Annan läsk				
3. Juice				
4. Annan fruktdrink				
5. Sportdryck				
6. Mjölk				
7. Oboy/mjölkdryck				
Hur mycket har du tidigare (mer än ett år sedan) druckit/vecka av:	**Typ av dryck**	**Antal glas per dag**	**Antal burkar/ flaskor per dag**	**Antal milliliter per vecka**
8. Colalläsk				
9. Annan läsk				
10. Juice				

11. Annan fruktdrink				
12. Sportdryck				
13. Mjölk				
14. Oboy/mjölkdryck				

Hur många gånger i veckan äter du	**15.** Mjölk	**16.** Frukost	**17.** Skol-lunch	**18.** Middag	**19.** Mellan mål (även i skolan)
	…… gånger	……gånger	……gånger	……gånger	……gånger

Vad dricker du oftast:	**Typ av dryck**	**Antal glas per dag**	**Antal burkar per dag**	**Antal milliliter per vecka**
20. Till frukost				
21. I skolan				
22. Till lunch i skolan				
23. Till lunch hemma				
24. Till middag				
25. Mellan måltiderna				

26. Under träning/tävling				
27. Kvällen innan du somnar				
28. På natten				

29. Använde(r) du nappflaska	Ja □ Nej □	**30.** Hur många år har du använt nappflaska ……år

Vad dricker du ur nappflaskan	**31.** □ Välling	**32.** □ Mjölk	**33.** □ Läsk	**34.** □ Juice
	35. □ Saft	**36.** □ Annat		

37. Anamnes tagen Ja □ Nej □ **38. Munandare** Ja □ Nej □

	Dricker mest under helgen	Dricker mest under vanliga veckodagar	Dricker under både helg och vanliga veckodagar
39. När under veckan dricker du läsk och juice			

Appendix 3. Oral interview (Paper III)

(Second part of the questionnaire), *Paper III*

Vad dricker du oftast:	**Typ av dryck/mängd/dag**	**Antal milliliter per vecka**
1. Till frukost		
2. På raster och håltimmar		
3. Till lunch i skolan		
4. Till lunch hemma		
5. Till middag		
6. Mellan måltiderna		
7. Under träning/tävling		
8. Kvällen innan du somnar		
9. På natten		

Hur många gånger i veckan Äter/dricker du	**10.** Mjölk (ren)	**11.** Frukost	**12.** Skol-lunch	**13.** Middag	**14.** Förutom huvudmålen (även i skolan)
	…… gånger	…… gånger	…… gånger	…… gånger	…… gånger

Hur mycket av dricker du i veckan av (senaste året):	**Typ av dryck/mängd/dag**	**Antal milliliter per vecka**
15. Mjölk		
16. Oboy/mjölkdryck		
17. Juice		
18. Annan fruktdrink		
19. Sportdryck		
20. Colaläsk		
21. Annan läsk		
22. Alcopop		
23. Cider		
24. Öl		
25. Vin		
Hur mycket har du tidigare (mer än ett år sedan) druckit/vecka av:	**Typ av dryck /mängd/dag**	**Antal milliliter per vecka**
26. Mjölk		
27. Oboy/mjölkdryck		
28. Juice		
29. Annan fruktdrink		
30. Sportdryck		
31. Colaläsk		
32. Annan läsk		
33. Alcopop		
34. Cider		
35. Öl		
36. Vin		

	Dricker mest under helgen	Dricker mest på vardagar	Dricker under både helg och vardag	Aldrig
29. När under veckan dricker du läsk och juice				

30. Anamnes tagen Ja □ Nej □ **31.** Munandare Ja □ Nej □

32. Laktoskänslig Ja □ Nej □ **33**. Debut? (år). ……

34. Andra magbesvär? …….
35. Debut? (år)……..