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On Dental Caries and Dental Erosion in Swedish Young Adults

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“It is good to have an end to journey toward;
but it is the journey that matters, in the end”

Ernest Hemingway

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ABSTRACT

Background: All children in Sweden are entitled to regular, free dental care up to 20 years of age. While dental caries generally continues to decline, still there is a pronounced skewness in caries prevalence. Furthermore, the reported increase in dental erosion in young adults is cause for concern. **Aim**: The aim was to study the prevalence of dental caries and dental erosion in a cohort of Swedish 20 year-olds, with special reference to the influence of previous caries experience and lifestyle as well as parental, socioeconomic and psychosocial factors**. Material and Methods:** The study was prospective, longitudinal and cross-sectional in design and based on registration of caries lesions, dental erosion, body adiposity status, saliva sampling, interviews, and questionnaires at 20 years of age. Data were available for the same cohort at 1, 3, 6 and 15 years of age. 499 subjects (74 percent of the original cohort) were included. Five individuals were subsequently excluded, leaving a final sample of 494. **Results**: 74 percent of the subjects had initial and/or manifest caries lesions and/or restorations. The mean number of $D_{im}FS$ was 5.8 and the mean number of D_mFS on occlusal surfaces of molars was 1.1. There was a strong relationship between caries activity at 3 and 6 years of age and approximal caries prevalence in premolars and molars at 20 years of age. Overweight/obese individuals had significantly higher caries prevalence than normal weight individuals. Parental, socioeconomic and psychosocial factors during infancy were related to approximal caries at age 20. Dental erosion was found in 75 percent of the individuals: 18 percent of these had extensive erosion. There was a significant association between caries and dental erosion. A relationship was found between dental erosion and lifestyle factors and overweight/obesity. **Conclusions**: There is a strong relationship between caries prevalence at age 20 and caries experience in early childhood. Young adults show a high prevalence of dental erosion, but the severity is generally low. Overweight and obese individuals have more caries than normal weight individuals. Parental influence during the formative years has an impact on caries prevalence in young adulthood. In this cohort, dental caries and dental erosion at age 20 are related to overweight/obesity and lifestyle factors.

Key words:BMI, caries prevalence, childhood caries, dental erosion, lifestyle, obesity, overweight, parental factors, psychosocial factors, socioeconomic factors, young adults.

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SAMMANFATTNING PÅ SVENSKA

Bakgrund: Alla barn i Sverige har rätt till fri tandvård upp till 20 års ålder. Samtidigt som en generell minskning av kariesutvecklingen kan ses hos barn och ungdom kvarstår en uttalad snedfördelning av kariesförekomsten. Dessutom rapporteras en ökad förekomst av erosionsskador hos unga vuxna.

Mål: Att studera förekomsten av karies och erosion hos en grupp svenska 20-åringar samt dessa tillstånds påverkan av tidigare karieserfarenhet och livsstil samt föräldra-, socioekonomiska- och psykosociala faktorer.

Material och Metod: Undersökningen är en longitudinell- och tvärsnittsstudie baserad på registrering av karies, erosion, BMI, salivprover, intervjuer och frågeformulär vid 20 års ålder. Samma grupp av barn har tidigare följts upp vid 1, 3, 6 och 15 års ålder. Vid 20-års ålder undersöktes 499 av de ursprungliga 671 individerna, vilket är 74 % av ursprungsgruppen (5 individer blev exkluderade).

Resultat: 74 % av de 494 individer som undersöktes hade initiala och/eller manifesta kariesskador och/eller fyllningar. Medelvärdet av $D_{im}FS$ var 5,8 och motsvarande medelvärde på molarens occlusalyta var D_mFo 1,1. Det fanns ett starkt samband mellan karies vid 3 och 6 års ålder och förekomst av approximalkaries i premolarer och molarer vid 20 års ålder. Individer med övervikt/fetma hade signifikat högre kariesförekomst än normalviktiga. Det fanns också ett samband mellan föräldra-, socioekonomiska- och psykosociala faktorer i tidig barndom och approximalkaries vid 20 års ålder. Tanderosion förekom hos 75 % av 20-åringarna, varav 18 % hade omfattande erosionsskador. Ett statistiskt signifikant samband mellan karies och erosion kunde påvisas liksom en association mellan erosion och livsstilsfaktorer och övervikt/fetma.

Konklusion: Det finns ett starkt samband mellan kariesförekomst vid 20 års ålder och karieserfarenhet vid tidig ålder. Hos unga vuxna ses en hög förekomst av erosion men oftast i mild form. Ungdomar med övervikt eller fetma har högre kariesförekomst än normalviktiga i samma ålder. Föräldrarnas inverkan under uppväxten påverkar kariesförekomsten hos 20-åringen. Både karies och erosion i denna ålder är relaterade till övervikt/fetma liksom till livsstilen hos denna grupp.

LIST OF PAPERS

This thesis is based on the following papers, referred to in the text by their Roman numerals:

I. Isaksson H, Alm A, Koch G, Birkhed D, Wendt LK. Caries prevalence in Swedish 20-year-olds in relation to their previous caries experience. Caries Res 2013;47:234-42.

II. Isaksson H, Birkhed D, Wendt LK, Alm A, Nilsson M, Koch G. Prevalence of dental erosion and association with life style factors in Swedish 20-year olds. Accepted for publication in Acta Odontol Scand 2013.

III. Alm A, Isaksson H, Fåhraeus C, Koch G, Andersson-Gäre B, Nilsson M, Birkhed D, Wendt LK. BMI status in Swedish children and young adults in relation to caries prevalence. Swed Dent J 2011;35:1-8.

IV. Isaksson H, Alm A, Koch G, Birkhed D, Wendt LK. Caries prevalence at 20 years of age: influence of parental factors during infancy. In Manuscript

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ABBREVIATIONS

BMI	Body mass index (kg/m²)
CI	Confidence interval
defs	Decayed, extracted and filled tooth surfaces in primary teeth
D_i	An initial decayed tooth surface, including both caries diagnosed clinically and radiographically in permanent teeth.
D_m	A manifest decayed tooth surface, including both caries diagnosed clinically and radiographically in permanent teeth
$D_{im}FS$	Decayed (initial and/or manifest caries lesions) and filled surfaces of permanent teeth.
$D_{im}FSa$	Decayed (initial and/or manifest caries lesions) and filled surfaces of permanent teeth.
GORD	Gastro oesophageal reflux disease
LB	Lactobacilli
MS	Mutans streptococci
NANHES	National Health and Nutrition Examination Survey in USA
SD	Standard deviation
SE	Standard error

1 INTRODUCTION

1.1 Why?

During the past few decades, there has been a marked decline in dental caries in the developed countries, particularly among children and adolescents (Marthaler 2004, Petersen et al. 2005). In Sweden, caries prevalence in children, adolescents and young adults has decreased dramatically (Hugoson et al. 2008, Socialstyrelsen 2008). However, the disease has not been entirely eradicated in Swedish children and young adults. The pattern of the disease has changed and while many children are no longer affected, there persists a small group of individuals who remain highly susceptible to dental caries. This is difficult to explain in the context of Sweden's comprehensive children's dental health scheme, under which all children and adolescents are entitled to free dental care up to the age of 20 years.

Another recent change in oral health in the developed world is a significant increase in the prevalence of dental erosion in young individuals. Lifestyle changes are strongly implicated (Lussi 2006).

If untreated, both dental caries and dental erosion are conditions which lead to extensive, irreversible destruction of the dental hard tissues and may thus cause lifelong problems for the individual. Moreover, treatment of the advanced stages of these conditions is expensive and time-consuming and demands considerable dental resources.

In order to develop more effective preventive and management strategies, there is a need for further investigation into factors which might predispose to, or be associated with the development and progression of caries and dental erosion in young adults.

1.2 Public Dental Service in Sweden

Under the Public Dental Service Act of 1973 (Socialdepartementet 1973:457, uppdaterad SFS 2011:1168) the Swedish County Councils became responsible for providing free dental care, including specialist care, for all children up to 20 years of age. From the year they turn 3, children visit a dental clinic on a regular annual basis. Almost all children are enrolled in this system. Through a cooperative arrangement between the Public Dental Service and the Child Welfare Centres, parents are given information about

oral hygiene and dietary counselling, starting when the child is 6 months of age. Generally, there is major emphasis on preventive measures throughout the formative years. Today, there are no uniform national guidelines for preventive measures; each County Council has its own guidelines. For example, in the County of Jönköping, it is recommended that the occlusal surfaces of the permanent molars should be fissure-sealed as soon as possible after eruption.

In the year they turn 20, young adults are no longer eligible for free dental care through the Public Dental Service. The oral health of 20 year-olds thus reflects the outcome of 19 years of dental care provided by the county Public Dental Health Service.

1.3 Caries in young adults

Data on caries prevalence in young adults in Sweden are presented mainly in reports from the National Board of Health and Welfare, the County Councils and epidemiological research. Since 1985, the National Board of Health and Welfare has regularly reported national caries data for 3, 6, 12 and 19 year-olds (Socialstyrelsen 2003). In 2011, 32 percent of Swedish 19 year-olds were free of caries and the mean DFT was 2.5. The mean value for DFT in 1985 was 8.5.

In 2012, caries data for 19 year-olds presented by The County Council of Jönköping reported 43 percent to be caries free, and a mean DFT of 1.7. It is important to note that these data are for manifest caries lesions only: initial lesions are not included. Thus the caries prevalence is under-reported.

Since 1973, epidemiological, cross-sectional studies on oral health have been conducted in the Municipality of Jönköping every tenth year (Hugoson et al. 2005). Twenty year-olds comprise one of the age groups included in these studies. Initial lesions are included in the caries data. In 2003, 12 percent of the 20 year-olds were initial and manifest caries free and the mean DFT was 4.3.

Although figures vary in different reports, the overall decline in caries prevalence has continued over the years. To have a clearer picture of the total caries experience in individuals leaving the Public Dental Service, there is an urgent need for data on the prevalence of initial and manifest caries lesions in young adults.

1.3.1 Caries prevalence in young adults in relation to their earlier caries experience

A systematic review by the Swedish Council on Technology Assessment in Health Care (SBU: 2007) and systematic reviews by Powell and Tagliaferro (Powell 1998, Tagliaferro et al. 2008) concluded that early caries prevalence is the single best predictor of future caries development among pre-school children, school children and adolescents: numerous studies confirm that infants or toddlers who develop caries in the primary dentition tend to develop more lesions during their pre-school years than their caries free cohorts (Grindefjord et al. 1995, Pienihakkinen et al. 2004, Demers et al. 1992, Ismail et al. 2009, Leroy et al. 2012). It has also been shown that pre-school children with caries in the primary dentition are more likely than their caries free cohorts to develop lesions in the permanent dentition (Mejare et al. 2001, Helfenstein et al. 1991, Skeie et al. 2006, Li and Wang 2002, Leroy et al. 2009, Alm et al. 2012, Peretz et al. 2003).

In a study of the same cohort of individuals as in the present thesis, Wendt et al. found an association between caries prevalence at 3 and 6 years of age (Wendt et al. 1999). Monitoring of caries experience in the same cohort, from early childhood to adolescence, disclosed a strong relationship between caries prevalence in the primary and permanent dentitions (Alm et al. 2007).

To date, there are few longitudinal studies of caries prevalence in young adults in relation to caries in their primary dentition (Ekbäck et al. 2012).

1.3.2 Caries in relation to psychosocial and socioeconomic factors

Several studies have shown a relationship between socioeconomic status and oral health (Kallestal and Wall 2002, Marthaler 2004). Caries in early childhood (Kim Seow 2012) and in adolescence (Nicolau et al. 2003, Christensen et al. 2010) is associated with such factors as low income, a poorly educated mother, ethnicity or immigrant status and female sex. Parental dental avoidance and broken dental appointments also seem to impact on the child's caries prevalence (Goettems et al. 2011, Goettems et al. 2012, Alm et al. 2012).

In a report from the Swedish National Board of Health and Welfare, failure to keep dental appointments has been associated with parental factors such as living in a single parent household, young parents, low educational level, immigrant status and welfare-dependent families (Socialstyrelsen 2013). A relationship has also been shown between high levels of parental dental

anxiety and frequently broken dental appointments for children (Klingberg and Berggren 1992).

A study by Jamieson et al. reported an association between dental anxiety and decayed teeth (Jamieson et al. 2010). Other studies have disclosed that female adults with dental anxiety exhibit less use of preventive measures, impaired oral health and higher caries experience than those without dental anxiety (Mehrstedt et al. 2004, Armfield et al. 2009, Jamieson et al. 2010). The severity of maternal dental anxiety seems to have an impact on the child's caries prevalence (Wigen et al. 2009) and children with anxious mothers are more likely to present with untreated lesions (Goettems et al. 2012, Goettems et al. 2011).

The reported prevalence of dental anxiety among children and adolescents in Scandinavia varies widely, between 4 to 20 per cent. The variation is attributable to lack of conformity in study designs, populations and cultures (Klingberg et al. 1994, Alvesalo et al. 1993, ten Berge et al. 2002). A study of 18-year-old Norwegians, about to leave the Public Dental Service children's dental care system, disclosed dental fear and anxiety in 19 percent (Skaret et al. 1998). Dental fear and anxiety and dental behaviour management problems in children and adolescents are estimated to be 9 percent and more common in girls (Klingberg and Broberg 2007). Several studies show that the prevalence of dental anxiety peaks in young adulthood and then decreases in the middle and old age (Neverlien 1990, Hakeberg et al. 1992, Hagglin et al. 1999).

Thus there is a body of evidence that dental anxiety, psychosocial and socioeconomic factors have an impact on caries prevalence in children and adolescence. There is a need to investigate the implications of these findings with respect to caries prevalence in young adults.

1.3.3 Caries in relation to overweight and obesity

Overweight and obesity is one of the West´s most rapidly growing diseases. Obesity is classified as a chronic disease by The World Health Organization (WHO) (World Health Organization 2000, Lobstein and Frelut 2003). The increase in average body weight in recent decades is considered to be a"global epidemic". In Sweden this is manifest as a dramatic increase in the prevalence of overweight and obesity among children, adolescents and adults. A recent study of a Swedish cohort disclosed excessive weight gain between the ages of 15 and 20 years (Fåhraeus et al. 2012).

Dental caries and obesity are both multifactorial diseases with a complex aetiology and dietary habits are implicated in both.

The main factors contributing to overweight and obesity are genetics (Yang et al. 2007), improper diet and lack of physical activity. A Swedish national study of school children 7 to 9 years of age reported a higher incidence of overweight among children from low income and rural areas (Sjoberg et al. 2011). This is consistent with findings in 18 year-old Swedish male military service conscripts between the years 1971 to 2005: overweight and obese men were more often from families of lower socioeconomic status (Kark and Rasmussen 2005) and from rural areas (Neovius and Rasmussen 2008).

Several studies show an association between high sugar consumption in the form of soft drinks and the prevalence of obesity in children (Henriksen and Kolset 2007, Nissinen et al. 2009, Ludwig et al. 2001, Malik et al. 2006, Te Morenga et al. 2013). Other studies have shown that in females, high consumption of soft drinks during childhood and adulthood is associated with overweight and that there is a relationship between parental BMI and childhood obesity (Whitaker et al. 1997, Burke et al. 2001, Marild et al. 2004).

There have been pronounced behavioural changes in the population over recent decades, including a less active lifestyle, increased consumption of soft drinks (Jordbruksverket 2012, Cavadini et al. 2000) and greater consumption of convenience ("fast") foods. Several studies indicate that compared with the previous generation, young people of today are less active and exhibit more sedentary behaviour, spending more time watching TV or using the computer (Marshall et al. 2004, Fogelholm et al. 1999, Pate et al. 2011).

To date there is a lack of consensus about an association between caries and obesity. While conflicting results emerged from a review by Kantovitz et al. (Kantovitz et al. 2006), a study in adolescents in southern India reported a significant association between BMI and DMFT (Thippeswamy et al. 2011) and in a Swedish study. Alm et al. found a relationship between caries prevalence and overweight/obesity in adolescents (Alm et al. 2008a). Studies of German children and adolescents also reported a relationship between high weight and high caries frequency (Willerhausen et al. 2007, Willershausen et al. 2007, Willershausen et al. 2004).

In contrast, data from National Health and Nutrition Examination Surveys (NAHNES III, and NAHNES 1999-2002) in USA do not support an

association between caries and obesity (Kopycka-Kedzierawski et al. 2008, Macek and Mitola 2006); nor does a recent study of 5 year-old children in Southern Sweden (Norberg et al. 2012).

Thus the question of an association between dental caries and overweight/obesity in children and adolescents is unresolved. Because of the increasing prevalence of obesity in society, it is important to determine whether there is an association between obesity and dental caries in young adults.

1.3.4 Caries in relation to parental factors and lifestyle

Lifestyle is described by Andersson (Andersson 2006) as personal habits, affected by the current situation in life, in the context of socio-economic conditions, ethnicity, gender and age. Lifestyle is of relevance to oral health behaviour (Mattila et al. 2005a, Mattila et al. 2005b, Klingberg and Broberg 2007, Wigen et al. 2011). In the case of children, their dental health habits and caries development are influenced by their parents (Goettems et al. 2012, Petersen 2005).

Several studies have shown an association between frequent consumption of caries risk products during infancy and subsequent caries prevalence (Mattila et al. 2001, Alm et al. 2008a, Ruottinen et al. 2004). Alm et al. followed children from infancy to 15 years of age and disclosed an association between approximal caries prevalence at 15 years of age and frequent consumption of cariogenic products at an early age (Alm et al. 2008a). Similarly, a study by Mattila et al. showed an association between frequent consumption of caries-risk products during infancy and an increase in caries prevalence between 7 and 10 years of age (Mattila et al. 2001). In a study which followed children's sucrose intake from infancy to 10 years of age, Ruottinen et al. demonstrated that high sugar intake in early childhood seems to persist later in life (Ruottinen et al. 2004).

These studies highlight the important influence of lifestyle factors on caries development and provide evidence of a relationship between parental factors, such as oral hygiene and dietary habits during early childhood and caries development in later childhood. It is important to investigate whether the same factors are also determinants of caries development in young adults.

1.4 Dental erosion in young adults

Dental erosion is an irreversible, distinct form of destruction of dental hard tissue caused by a chemical process (Pindborg 1970). Various factors, dietary, gastric or environmental, may be implicated. Tooth wear is the result of more than a single mechanism: other components are attrition: i.e. wear induced by tooth-to-tooth contact, and abrasion, which is defined as wear by frictional components (Meurman and ten Cate 1996). Today there is general consensus that erosion is the major component of severe tooth wear and that attrition and abrasion are of secondary importance (Johansson 1992, Addy and Shellis 2006).

Dental erosion is induced by exposure to acids, which may be extrinsic or intrinsic in origin. Extrinsic factors include dietary acidic products. Intrinsic factors include gastric acid. Ganss describes the aetiology of dental erosion as follows: "chronic exposure of the teeth to extrinsic or intrinsic acids under the condition that the oral fluids are unsaturated with respect to tooth mineral" (Ganss 2008, Larsen 1990, Featherstone and Lussi 2006).

Erosion occurs more frequently in certain teeth than others. These so-called marker teeth include the permanent maxillary incisors and first molars (Khan et al. 2001). Erosion is more common on palatal than buccal surfaces of maxillary incisors and should be looked for, as well as cupping, on the occlusal surface of molars. On clinical examination, the early stages of erosion are easily overlooked: there are no pronounced changes in colour, or changes in texture which might be detected by probing the tooth surface. Clinically, there are various signs of erosion from changes in lustre of the enamel surface, changes in macromorphology, exposure of the dentine, cupping and cervical defects. Cupping presents as a shallow, rounded erosion of enamel, with exposed dentine and occurs on the occlusal surfaces of the molars, often on a cusp tip, (Figure 1).

Figure 1. Cupping on mesio-buccal cusp of permanent molar.

Loss of tooth substance may result in aesthetic and functional problems, but exposure of dentine in an erosive lesion may also cause sensitivity and endodontic symptoms.

A number of systems for grading dental wear and dental erosion have been presented (Eccles 1979, Smith and Knight 1984, Linkosalo and Markkanen 1985, Lussi et al. 1991, Johansson et al. 1996). The variations in prevalence reported in different studies (Kreulen et al. 2010, Jaeggi and Lussi 2006) may be due to the use of different scales and scoring systems (Eccles 1979, Smith and Knight 1984, Lussi 1996, Johansson et al. 1996, Mulic et al. 2010). The cohort groups studied may differ with respect to socio-economic background, age and clinical examination procedures, which in turn may have implications for the results.

A new scoring system, Basic Erosive Wear Examination index, BEWE (Bartlett et al. 2008), has recently been presented. The use of this index should improve conformity in clinical research on dental erosion.

In Scandinavia, there are few studies of erosion in young adults. One such study, in Icelandic young adults (19–22 years old), found dental erosion with dentine involvement in 39 percent of subjects (Jensdottir et al. 2004). A similar study in Norway, on 18 year-olds, reported 32 percent (Mulic et al. 2013) and in a study of 18-19 year-old Swedish subjects, Hasselkvist et al. reported erosion in 22 percent (Hasselkvist et al. 2010).

1.4.1 Dental erosion in relation to caries

Studies on children and adolescents of the relationship between dental erosion and dental caries have shown contradictory results. There are few studies in young adults. An association between erosion and caries in 20 year-old Norwegians was recently reported by Mulic et al. (Mulic et al. 2013). A statistically significant relationship between caries experience and dental erosion was found among British children and adolescents (Dugmore and Rock 2004, Bardolia et al. 2010). However, other studies found no such associations (Auad et al. 2009, Truin et al. 2005). A study by O'Sullivan and Curzon found that the salivary properties of subjects with erosion closely match those of caries active individuals (O'Sullivan and Curzon 2000).

1.4.2 Dental erosion in relation to behavioural factors and general health

The aetiology of dental erosion is multifactorial and includes dietary factors (Bartlett et al. 2011, Hasselkvist et al. 2010, Mulic et al. 2012, Jensdottir et

al. 2004, Lussi 2006, Okunseri et al. 2011), eating disorders (Bartlett 2006, Johansson et al. 2012, Ohrn et al. 1999), gastro-oesophageal reflux diseases (Chandra et al. 2004, Pace et al. 2008, Holbrook et al. 2009, Wang et al. 2010, Ranjitkar et al. 2012), salivary factors (O'Sullivan and Curzon 2000) and occupational exposure (Mulic et al. 2011, Wiegand and Attin 2007, Wiktorsson et al. 1997).

In recent decades, there have been dramatic changes in lifestyle. This is exemplified by the increased consumption of acidogenic products: in Sweden consumption of soft drinks has tripled over the last 50 years (Jordbruksverket 2012, Birkhed et al. 1989, Cavadini et al. 2000); a clear association has been reported between dental erosion and consumption pattern (Lussi 2006b). This is supported by the findings of Zero and Lussi that behavioural factors play a role in modifying the extent of dental erosion (Zero and Lussi 2006).

In order to develop more effective management strategies, there is a need for further study of dental erosion. Lifestyle factors are implicated in the increasing prevalence. Further investigation is warranted into the association between caries, lifestyle factors and the prevalence and severity of dental erosion in young adults.

2 AIMS

The oral health of Swedish children and adolescents is well-documented. With respect to dental caries, only a small group of children is now seriously affected by the disease and there is considerable evidence that the prevalence is influenced by such factors as lifestyle and parental socioeconomic status, from infancy through the formative years. There is however, much less extensive research on young adults, even though the oral health of Swedish 20 year-olds represents the outcome of 19 years of publicly-funded, comprehensive dental care. While the marked decline in dental caries in this age group is very gratifying, the significant increase in dental erosion is a cause for concern.

The overall aim of this thesis, which is part of a longitudinal study (Wendt 1995, Alm 2008), is to study the prevalence of dental caries and dental erosion in a sample of Swedish 20 year-olds, and to analyse the possible influence of lifestyle and other factors.

The specific aims of this thesis are:

1. To document caries prevalence in a sample of Swedish 20 year-olds, with special reference to prevalence recorded in the same cohort at 3, 6 and 15 years of age.
2. To document the prevalence and severity of dental erosion in a sample of Swedish 20 year-olds and assess the influence of lifestyle as a predisposing factor.
3. To investigate the association between body weight (BMI) and caries prevalence in young adults.
4. To investigate the influence of psychosocial, socioeconomic and parental factors during infancy, on caries prevalence in young adults.

3 STUDY POPULATION AND METHODS

3.1 Study design

The present study is part of a series of oral health surveys of preschool children, teenagers and young adults conducted in the Municipality of Jönköping, Sweden. The study has a prospective longitudinal and cross-sectional design and is based on registration of caries lesions, tooth wear, body adiposity status, saliva sampling, interviews and questionnaires (Table 1). The children have been followed from 1 to 20 years of age. The study was planned in 2006 and the data were collected in 2007 and 2008.

Table 1. Study design

Age in years	Caries	Interview	Salvia sampling	Questionnaire	Height, weight	Tooth wear
1	x	x	x	x	x	
2	x	x	x		x	
3	x	x	x		x	
6	x		x		x	
15	x*				x	
20	x	x	x	x	x	x

*At 15 years of age caries on premolars and molars was registered on bitewing radiographs.

3.2 Study population

All 671 individuals, aged 1 year in 1988 and living in four of the 13 districts affiliated with welfare centres in the Municipality of Jönköping, were invited to participate in the study. The four districts included urban, suburban and rural areas and were selected as representative of the socio-economic levels of the population in this part of Sweden. Clinical examinations were conducted at 1, 3, 6 and 20 years of age.

At 1 year of age 632 children (94 percent), 319 boys and 313 girls, were examined. The response rate at 3 and 6 years of age was 94 and 86 per cent, respectively. For further information see Wendt et al. (Wendt et al. 1991, Wendt et al. 1992, Wendt et al. 1999).

Bitewing radiographs taken at 15 years of age were retrieved from the Public Dental Service Clinics at which the children were enrolled. In all, bitewings from 568 adolescents (85 percent), 282 boys and 286 girls, were analysed. For further information see Alm (Alm 2008).

In 2007, at 20 years of age, all the individuals from the original cohort were invited by letter to participate in a dental examination. They were informed that the examination was free of charge and that any radiographs that were taken would be forwarded to their general dental practitioner. Informed consent was obtained. Of the original cohort (671 individuals), 494 (74 per cent), 244 males and 250 females, participated. Reasons for failure to participate were relocated (59), address unknown (37), declined to participate (38), failed to present for examination (35) and death (3). Five individuals were excluded; one due to a serious illness, three due to on-going orthodontic treatment with fixed appliances in one or both jaws and one on technical grounds, (Table 2).

Table 2. Number of children and percentage of the original cohort in different analyses and papers.

Examination	Number of subjects		Paper
	n	%	
20 years	494	74%	
20 and 1 years	482	72%	IV
20 and 3 years	484	72%	I, III, IV
20 and 6 years	448	67%	I, III, IV
20 and 15 years	459	68%	I, III
20, 15, 6 and 3 years	420	62%	I, III
20 years and BMI values	491	73%	III
20 years and Dental erosion	494	74%	II

Due to transmigration in and out of the community or failure to attend during the period from 1 to 20 years of age, some individuals had not participated in all examinations (Figure 1).

Of the 39 children who did not present for examination at 1 year of age, 12 were examined at 20 years of age.

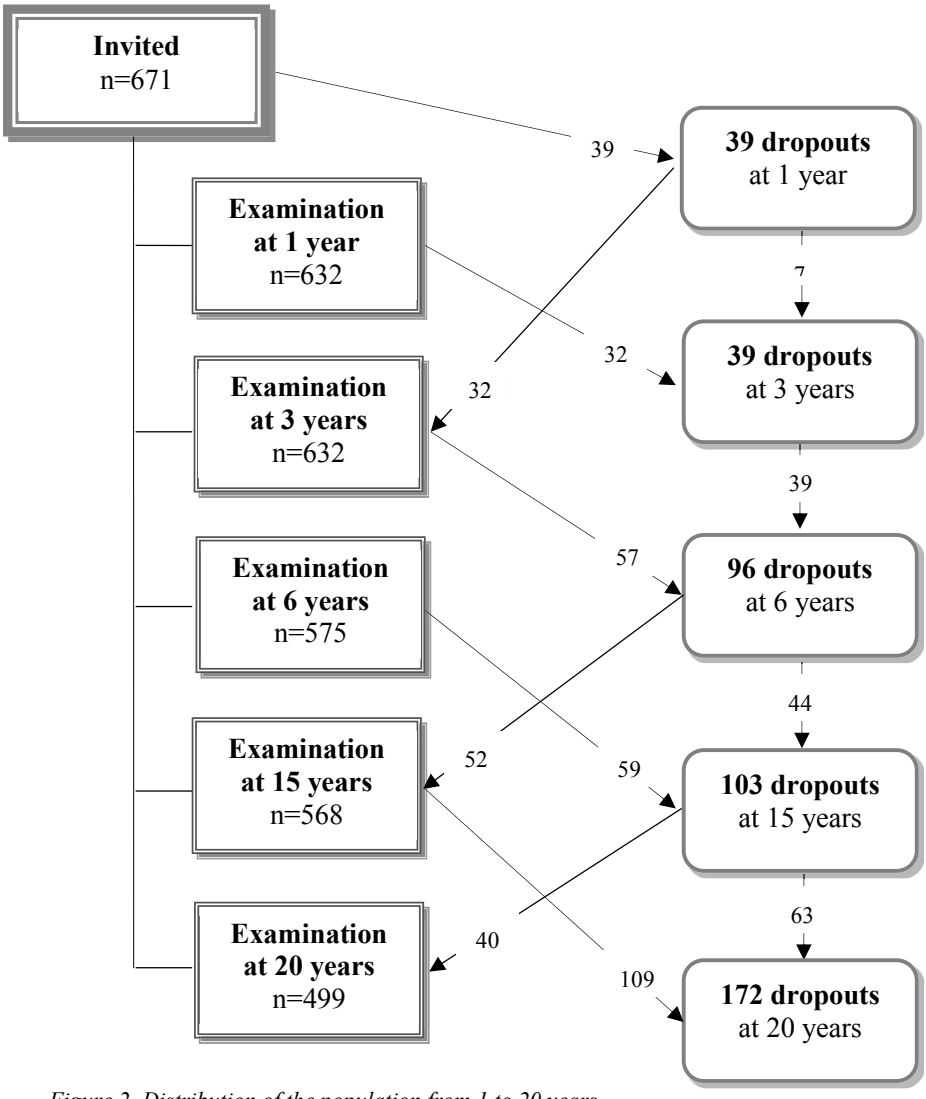

Figure 2. Distribution of the population from 1 to 20 years.

From the age of 1 year, the children had been enrolled in the regular dental care programme in the Municipality of Jönköping, including dental check-ups and special preventive care for children at risk of developing carious lesions. Thus at the regular clinical dental examination, the children receive fluoride varnish treatment and children at risk are usually recalled every three months for preventive measures including dietary counselling, oral hygiene instruction and repeated fluoride applications. The dental care programme

also includes fissure-sealing the occlusal surfaces of the permanent molars as soon as possible after eruption.

3.3 Methods

3.3.1 Dental caries

All examinations were carried out in a dental clinic with modern equipment and optimal lightning. The teeth were carefully dried before assessment. No professional tooth cleaning was undertaken before the clinical examination.

Clinical examination

At the 3-year examination, restorations, initial and manifest caries were registered on all tooth surfaces and at the 6-year examination on all tooth surfaces of molars and cuspids in the primary dentition. For further information see Wendt et al. (Wendt et al. 1992, Wendt et al. 1999).

At the 20-year examination, restorations, initial and manifest caries were registered on all tooth surfaces except for third molars. All clinical examinations were undertaken by one dentist, the principal investigator, (HI).

Caries criteria

The criteria described by Koch (Koch Odontol Revy 1967; 18 (suppl 12)) were applied for clinical registration of caries. Decayed, missing and filled teeth and tooth surfaces were recorded. Clinical caries was recorded on occlusal, buccal and lingual surfaces as follows: Initial caries (Di) – a carious lesion on the enamel surface, with whitish areas without cavitation. Manifest caries (Dm) – a "loss of tooth substance having reached the stage of cavitation that can be diagnosed with certainty, by clinical examination with mirror and explorer after drying with air, not having a character of erosion or hypoplasia and appearing on a tooth surface not earlier restored; pits and fissures, not earlier restored, where the probe with a little pressure, sticks without doubt and requires a definite pull for removal".

Reliability of the clinical examination at 20 years

Eighteen individuals were recalled after an interval of 1–2 weeks and re-examined with respect to caries (initial and manifest) and restorations. Simple and weighted intra-individual Cohen´s kappa values were calculated. The respective values were 0.85 and 0.86 for caries and 0.96 and 0.97 for restorations.

Radiographic examination

At 3 and 6 years of age, radiographs were taken if the primary molars were in approximal contact. Restorations, initial and manifest caries were recorded on all the surfaces of primary molars and cuspids. For further information see Wendt et al. (Wendt et al. 1992, Wendt et al. 1999).

At 15 years of age, radiographs were taken of the premolar and molar regions. Approximal surfaces from the distal surface of the first premolar to the mesial surface of the second molar were registered as sound, or having approximal restorations or initial or manifest caries, using the same definitions as at the radiographic examination at 20 years of age. For further information see Alm et al. (Alm et al. 2007).

At 20 years of age, radiographic examination comprised four posterior bitewing radiographs. The films were mounted in frames and subsequently examined using a magnifying viewer (Mattsson 1953) and an illuminated table. The approximal surfaces, from the distal surface of the canine to the distal surface of the second molar (a total of 36 surfaces), were evaluated. Of the approximal surfaces examined, 22 percent were recorded as unreadable due to overlapping. All analyses of bitewing radiographs taken at 20 years of age were made by the author (HI).

Caries criteria

At 20 years of age caries was recorded on approximal tooth surfaces as initial or manifest according to the National Board of Health and Welfare criteria (Socialstyrelsen 1988):

- Initial caries (Di) – a lesion in the enamel which has not reached the dentino-enamel junction or a lesion that reaches or penetrates the dentino-enamel junction but does not appear to extend into the dentine.
- Manifest caries (Dm) – a lesion which clearly extends into the dentine.

Reliability of the radiographic examination at 20 years

Before undertaking the radiographic examination at 20 years the author was calibrated with the examiner who conducted the examination at 15 years of age. Analyses were based on radiographs from 20 individuals. The kappa value is presented as simple kappa, as there is no difference between the simple and weighted value. The inter-rater Cohen's kappa value was 0.86. For intra-individual calibration, 10 per cent of the radiographs were re-examined after an interval of 2 months. The kappa value is presented as

simple kappa, as there is no difference between the values. The Cohen's kappa value was 0.90.

3.3.2 Groups according to caries prevalence

All age groups were stratified according to caries experience: "caries-free group" (children with neither initial nor manifest caries); "initial caries group" (children with initial caries but without manifest caries); and "manifest caries group" (children with manifest carious lesions or restorations).

At 20 years of age, the subjects were stratified into the following three subgroups, according to total caries prevalence and fillings (DimFS): DimFS =0, DimFS =1-3 and DimFS ≥4. On the basis of approximal caries experience on premolars and molars (registered on bitewing radiographs) (DimFSa), the individuals were stratified into four subgroups: DimFSa=0, DimFSa=1-3, DimFSa=3-7 and DimFSa ≥8.

3.3.3 Dental erosion at 20 years

Clinical examination and grading

The occlusal surfaces of the molars and the buccal and palatal surfaces of the maxillary incisors were examined for dental erosion. Two scales were used for grading: one for erosion on molars, slightly modified after Hasselkvist et al. (Hasselkvist et al. 2010) and the other for maxillary incisors, slightly modified after Eccles (Eccles 1979) and Johansson (Johansson et al. 1996).

The severity of dental erosion was recorded on a five-point scale: no erosion, mild, moderate, severe or very severe erosion. The scales and clarification of grading of dental erosion are presented in Figure 3–5.

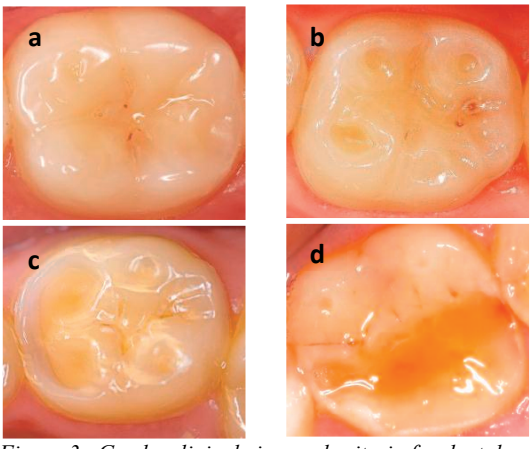

Figure 3. Grade, clinical view and criteria for dental erosion on occlusal surfaces of molars.

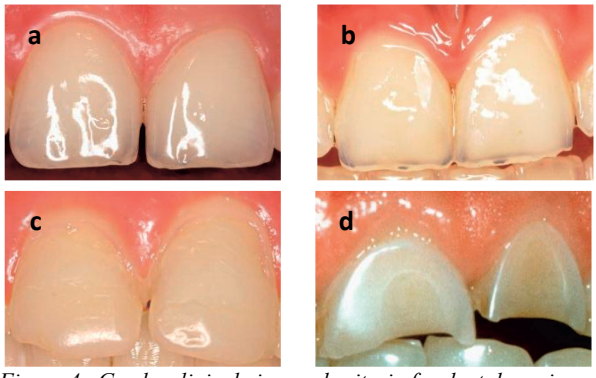

Figure 4. Grade, clinical view and criteria for dental erosion on maxillary incisors on buccal surfaces.

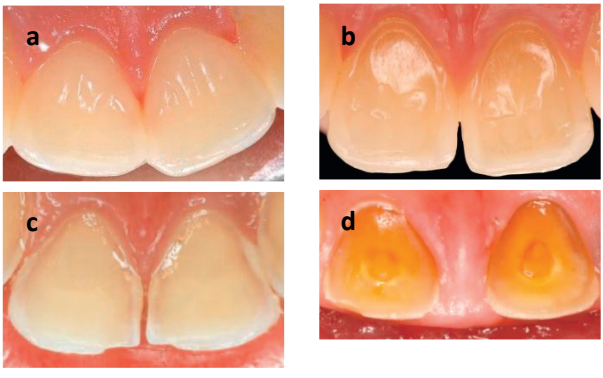

Figure 5. Grade, clinical view and criteria for dental erosion on maxillary incisors on palatal surfaces.

Figure 3. Grade, clinical view and criteria for dental erosion on occlusal surfaces of molars.
No erosion - No cuppings/intact cusp tip.
a) Mild erosion - Rounded cusp tip.
b) Moderate erosion - Reduction of crown height, small dentin exposure (cupping).
c) Severe erosion - Extensive change of tooth morphology. Major dentinal exposure (fused cuppings).
d) Very severe erosion - Erosion in secondary dentin. Pulp visible through the dentin.

Figure 4. Grade, clinical view and criteria for dental erosion on maxillary incisors on buccal surfaces.
No erosion – No visible changes, developmental structures remain, macro-morphology intact.
a) Mild erosion - Smoothened enamel, developmental structures have totally or partially varnished. Enamel surface is shiny or matt, irregular, "melted", macro-morphology generally intact.
b) Moderate erosion - Enamel surface as described in mild erosion. Macro-morphology clearly changed, faceting or concavity formation within the enamel, no dentinal exposure.
c) Severe erosion - Enamel surfaces as described in mild erosion. Macro-morphology greatly changed (close to dentinal exposure of large areas) or dentin surface exposed by ≤1/3.
d) Very severe erosion - Enamel surface as described in grades mild, moderate and severe erosion with dentin surface exposed by ≥1/3 or pulp visible through dentin.

Figure 5. Grade, clinical view and criteria for dental erosion on maxillary incisors on palatal surfaces.
No erosion – No visible changes, developmental structures remain, macro-morphology intact.
a) Mild erosion - Smoothened enamel, developmental structures have totally or partially varnished. Enamel surface is shiny or matt, irregular, "melted", macro-morphology generally intact.
b) Moderate erosion - Enamel surface as described in mild erosion. Macro-morphology clearly changed, faceting or concavity formation within the enamel, no dentinal exposure.
c) Severe erosion - Enamel surfaces as described in mild erosion. Macro-morphology greatly changed (close to dentinal exposure of large areas) or dentin surface exposed by ≤1/3.
d) Very severe erosion - Enamel surface as described in grades mild, moderate and severe erosion with dentin surface exposed by ≥1/3 or pulp visible through dentin (courtesy of Catharina Göthberg).

Groups according to prevalence of erosion

In order to describe and analyse the prevalence of erosion and related factors, the total cohort was subdivided in three groups. No Erosion = Individuals without clinical signs of dental erosion. Erosion = Individuals with clinically verified dental erosion. Extensive Erosion = Individuals presenting with one or more of the following clinical findings a) three or more molars with cupping (moderate to very severe erosion), and/or b) erosion on maxillary incisors (mild to very severe erosion). Please observe that the individuals with Extensive Erosion are also included in the Erosion group.

Reliability of clinical examinations of dental erosion

Eighteen individuals were recalled within 1–2 weeks of their clinical examination for re-examination of erosion on molars and maxillary incisors. Both simple and weighted intra-individual Cohen's kappa values were calculated. The values were 0.83 and 0.87, respectively.

3.3.4 Saliva sampling

Paraffin-stimulated whole saliva was sampled and sent to The Department of Cariology, University of Gothenburg, Sweden for analysis. The sample was shaken on a mechanical mixer for 30s and serially diluted in 0.05 M phosphate buffer (pH 7.3). Then, 25 µl portions were plated in duplicate onto mitis salivarius with bacitracin (MSB) agar for culture of mutans streptococci (MS), and onto Rogosa selective lactobacilli (SL) agar for lactobacilli (LB). The MSB agar plates were incubated in candle jars at 37 ºC for 2 days and the Rogosa SL agar plates were incubated aerobically at 37 ºC, for 3 days. The number of colony-forming units (CFUs) of MS was counted on the MSB agar and identified by their characteristic colony morphology. All CFUs in Rogosa SL agar were considered to be LB. The number of CFU was transformed to logarithms before statistical analysis. The buffer capacity of saliva was estimated using the chairside Dentobuff Strip test (Orion Diagnostica, Espoo, Finland) according to the manufacturer´s instructions.

3.3.5 Plaque and gingivitis

At 1 year of age plaque was registered if visible on the buccal surfaces of maxillary incisors when lit by a flashlight. For further information see Wendt (Wendt 1995).

At 20 years of age the presence of visible plaque was recorded on four tooth surfaces of all teeth after drying with air, using the criteria for Plaque Index (PI) 2 and 3 according to Silness & Löe (Silness and Löe 1964). The presence of gingival inflammation corresponding to Gingival Index (GI) 2

and 3 according to Löe & Silness (Löe and Silness 1963) was recorded for four tooth surfaces of all teeth.

3.3.6 Body adiposity status

In conjunction with the clinical examination at 20 years of age, weight and height measurements were taken. Three subjects declined to be weighed, thus 491 were included in the analysis. Body adiposity status was determined by calculating BMI (kg/m²).

Groups according to BMI

At 20 years of age the individuals were categorized as: underweight (BMI < 18.5), normal weight (BMI 18.5-24.9), overweight (BMI 25-29.9) and obese (BMI ≥ 30), according to WHO classification (WHO 1995).

3.3.7 Interviews

At 1 and 3 years the accompanying parent was interviewed by the clinician who conducted the clinical examination. Interpreter assistance was offered when necessary. Using a semi-structured form, the parents were asked questions about the child's everyday oral hygiene routines. Responses to questions about frequency of tooth-brushing were stratified into three groups; *sometimes/never, once a day or twice daily or more*. Responses to questions about frequency of consumption of 'caries risk products', juice, fruit puree, sweets (candy, confectionery), ice cream or biscuits, were stratified into two groups: *three times a day or less and more than three times a day*. 'Consumption of juice' was stratified into two groups: *once a week or less and more than once a day*. The variable 'consumption of sweets' was stratified into two groups: *sweets once a week or less and sweets more than once a week*. The cut-off point of once a week or less was chosen, as this is the most common recommendation to parents of pre-school children in Sweden (Wendt and Birkhed 1995).

In conjunction with the clinical examination at 20 years of age, all individuals were interviewed about behavioural, dietary and general health factors. The following questions were raised and the responses stratified as follows: Consumption of soft drinks: *0-once a week, 2-3 times per week or once or several times per day:* Consumption of fruit juice (sweetened): *0-once a week, 2-3 times per week or once or several times per day:* Consumption of fruit juice: *0-once a week, 2-3 times per week or once or several times per day:* Consumption of fruit: *0-once a week, 2-3 times per week or once or several times per day*: Daily number of main meals: *0-2 meals or 3- ≥4 meals:* Use of chewing gum: *1-2 pieces or 3-6 pieces:* Tobacco habits: *yes or*

no: Physical activity: *≥4 times per week, 2-3 times per week or ≤ once a week:* Thirst quencher when exercising; *water or sport-drinks/juice:* Frequency of tooth brushing: *≥2 times daily or ≤1 once daily*: Perceived healthy: *yes or no:* Medication: *yes or no:* Medical check-ups; *yes or no.* The original interview form is available on request.

3.3.8 Questionnaires

At 1 year of age the questionnaire which the parents answered contained a series of questions covering several topics such as socioeconomic status and behavioural and attitudinal factors. There were also questions about the parent's dental anxiety (Dental Anxiety Scale, Figure 5). Socio-economic status was described in terms of the parent's educational level and social status. Educational level was stratified according to years of schooling as: *<12 years and ≥12 years*. The response to questions such as "satisfaction with social status" was described on a scale from 0 to 7, where 0 was "very satisfied" and 7 was "not satisfied"; the answers were then dichotomised into two levels: "*satisfied" (0-2) or "less" to "not satisfied" (3-7).* Satisfaction with social status was subdivided into subgroups as: *work, leisure time, health, accommodation, social interactions and financial status.* The answers were dichotomized into *"satisfied" (very satisfied and quite satisfied) and "dissatisfied" (dissatisfied and very dissatisfied).* Attitudes to dental care were described in terms of "self-estimation of oral health care". The responses, expressed on a scale of 0-9, from "very good" to "poor" were dichotomised into three levels *"very good" (0-2) or "less good"(3) to "poor" (4-9).*

The questionnaire for the subjects at 20 years of age contained a series of questions and covered several topics such as socioeconomic status and behavioural and attitudinal factors. The response to questions such as "satisfaction with social status" was expressed on a scale from 1 to 6, where 1 was "very satisfied" and 6 was "not satisfied"; the answers were then dichotomised into two levels: *"satisfied" (1-3) or "less" to "not satisfied" (4-7).* Satisfaction with social status was subdivided into subgroups as: work, leisure time, health, accommodation, social interaction and financial status. The responses were dichotomized into *"satisfied" (very satisfied and quite satisfied) and "dissatisfied" (dissatisfied and very dissatisfied):* Satisfaction with their dental appearance: *"satisfied, very satisfied" or "dissatisfied, very dissatisfied":* Attitudes to dental care were described in terms of "self-estimation of oral health care": the responses were expressed on a scale of 0 to 10, from "very good" to "poor" and were dichotomised into three levels *"very good" (0-2) or "less good"(3) to "poor" (4-10).*

The questionnaire also covered the topic of dental anxiety, using the Dental Anxiety Scale (DAS) which includes four multiple choice items to describe the patients' subjective reactions to a visit to the dentist (Figure 6). Points were assigned for the subject's choices, with one point for an (a) choice to five points for an (e) choice. Since the items in the questionnaire are ordered categorical data and summing is not allowed, we constructed the global DAS score by calculating the median over the items. The original questionnaire is available on request.

Corah's Dental Anxiety Scale (DAS)

1. If you had to go to the dentist tomorrow, how would you feel about it?
a) I would look forward to it as a reasonably enjoyable experience.
b) I wouldn´t care one way or the other.
c) I would be a little uneasy about it
d) I would be afraid that it would be unpleasant and painful.
e) I would be very frightened of what the dentist might do.

2. When you are waiting in the dentist´s office for your turn in the chair, how do you feel?
a) Relaxed
b) A little uneasy
c) Tense
d) Anxious
e) So anxious that I sometimes break out in sweat or almost feel physically sick.

3. When you are in the dentist´s chair waiting while he gets his drill ready to begin working on your teeth, how do you feel?
(Same alternatives as no. 2)

4. You are in the dentist´s chair to have your teeth cleaned. While you are waiting and the dentist is getting out the instruments which he will use to scrape your teeth around the gums, how do you feel?
(Same alternatives as no. 2)

Figure 6. Corah's Dental Anxiety Scale

3.3.9 Statistical methods

The following statistical software packages have been used: SAS®, SPSS and Statistica. Different versions have been utilized over the years.

Paper I. Independent sample t-tests were used to test differences in means between two independent groups. Unbalanced ANOVA was used to test differences in means with more than two independent groups, with the Bonferroni as a post hoc test. Descriptive results were presented as means, standard deviations (SD) and 95 percent confidence intervals (CI); p-values ≤ 0.05 were considered statistically significant.

Paper II. Descriptive statistics such as numbers, percentages, means and standard deviations as well as bar charts were used. To test for differences between groups on ordered categorical data, Fisher's exact test was used. For testing differences between groups on continuous data, Student's t-test was used. P-values ≤ 0.05 were considered to be statistically significant.

Paper III. In the unbalanced analyses of variance (ANOVA), Sheffe's test was used to compensate for multiple comparisons. When two groups were compared in terms of continuous variables, an unpaired t-test was used. Fisher's exact test was used to analyse differences when the data were categorical. P-values ≤ 0.05 were considered statistically significant.

Paper IV. Descriptive statistics were used and the data are presented as numbers, proportions, medians, per centiles, means and standard errors and standard deviations as well as 95 percent confidence limits, when appropriate. Fishers exact test was used, as well as the Mantel-Haenszel test for trend. A p-value ≤ 0.05 was considered to be statistically significant in hypothesis testing.

3.3.10 Ethical considerations

This study was approved by the Regional Ethics Review Board at the University of Linköping (Dnr M176-07), Sweden and the Regional Radiation Protection Board at the Municipality of Jönköping, Sweden and was carried out in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines. As emphasized in the Declaration of Helsinki it is important that research on humans is reviewed by an independent authority such as the Ethics Review Board. This Declaration also emphasizes respect for the individual and that participation in research should be preceded by informed consent (Helgesson 2006, Milton 2002, Gustafsson 2005). In the present study, written information by the principal investigator and the

principal supervisor and oral information by the research dental nurse on the aim of the study were given to the research subject when the appointment was made for the examination. In case of questions or concerns about the study, the research dental nurse has also acted as a contact person for research subjects.

4 RESULTS

4.1 Attrition

Between the ages of 15 and 20 years, 107 (16 percent) individuals were lost to the study. Analysis of the data (caries-free individuals, initial and manifest carious lesions, restorations in premolars and molars) at 15 years of age reveals no statistically significant difference between these 107 individuals and the 459 individuals examined at both 15 and 20 years. For information relating to dropouts before 15 years of age, see Alm (Alm 2008) and Figure 1.

4.2 Caries prevalence at 20 years of age (Paper I)

Of the 494 young adults examined at 20 years of age, 74 per cent had initial and/or manifest caries lesions and/or restorations. The mean number of DimFS was 5.8. Approximal initial and/or manifest lesions and/or fillings in premolars and molars were recorded in 51 per cent; the mean number of DimFSa was 2.0 (Table 3). Manifest caries or restorations were recorded in 14 per cent of the occlusal surfaces of first molars and in 11 per cent of second molars. Fissure sealants were recorded in 64 per cent of first molars and 76 per cent of second molars.

Table 3. Number and percentage of individuals with caries and mean number of decayed or filled tooth surfaces at 20 years of age, Paper I.

Variables	Individuals with caries		Caries surfaces		
	n	%	mean	SD	95% CI
All teeth					
$D_{i+m}FS$	366	74	5.8	7.8	5.0 - 6.6
D_mFS	331	67	3.4	4.6	2.9 – 3.9
D_mS	116	24	0.5	1.2	0.3 – 0.7
D_iS	242	49	2.3	4.6	1.7 – 2.9
Premolars and molars					
$D_{i+m}FSa$	250	51	2.0	3.1	1.8 – 2.3
D_mFSa	194	39	1.1	2.0	0.9 – 1.3
D_mSa	80	16	0.2	0.7	0.16 – 0.24
D_iSa	181	37	1.0	1.6	0.9 – 1.2

4.2.1 Caries at 20 years of age in relation to previous caries experience (Paper I)

Four hundred and twenty individuals participated in examinations at 3, 6, 15 and 20 years of age. At 20 years of age, the mean number of approximal initial or manifest caries lesions or restorations (DimFSa) was 1.8 (SD 2.9).

Of children with manifest caries at 3 years of age, 53 per cent had manifest caries or restorations on the approximal surfaces of premolars and molars at 20 years of age. For children who had been caries free at 3 years of age, the corresponding figure was 33 per cent ($p < 0.01$).

Of children with manifest caries or restorations at 6 years of age, 48 per cent had manifest caries or restorations on approximal surfaces of premolars and molars at 20 years of age. In children who had been caries free at 6 years of age the corresponding figure was 27 per cent ($p < 0.001$).

Of children with manifest caries or restorations at 6 years of age, 38 per cent had no approximal caries on premolars or molars at 20 years of age. In children who had been caries free at 6 years of age, the corresponding figure was 62 per cent ($p < 0.001$),

Of adolescents with initial approximal caries on premolars or molars at 15 years of age, 36 per cent had approximal manifest caries at 20 years of age. In adolescents who had no approximal caries of premolars or molars at 15 years of age, the corresponding figure was 7 per cent ($p < 0.001$).

Of adolescents with initial, but no manifest approximal caries on premolars or molars at 15 years of age, 21 per cent had initial approximal caries on these surfaces at 20 years of age. For those who had no approximal caries or restorations in premolars or molars at 15 years of age, the corresponding figure was 5 per cent ($p < 0.001$), (Paper I, Figure 4).

At 20 years of age the mean number of DimFSa was 3.6 for individuals who had developed manifest caries by 3 years of age, compared with 0.9 in those who had been caries free at 3, 6 and 15 years ($p <0.001$). Children who developed manifest lesions between 3 and 6 years of age had a mean DimFSa of 2.3 at 20 years of age. This was statistically higher than for those who had been caries free at 3, 6 and 15 years ($p<0.001$). There was a significant difference concerning caries prevalence at 20 years between individuals who had been caries free at 3, 6 and 15 years and those who had been caries free at 3 and 6 but had manifest caries at 15 years of age ($p< 0.001$), (Table 4).

Table 4. Mean number and 95% confidence interval of initial and manifest approximal caries lesions and fillings at 20 years of age, distributed according to caries experience at 3, 6 and 15 years of age, Paper I.

Age and caries examination	Caries experience presented as mean and 95% confidence interval			
	Manifest caries at 3 years (n=49)	Caries-free at 3 and manifest caries at 6 years (n=120)	Caries-free at 3 and 6 years and manifest caries at 15 years (n=29)	Caries-free at 3, 6 and 15 years (n=222)
	A	**B**	**C**	**D**
20 years D_{i+m} FSa (p+m) **I**	3.6 (2.4–4.9)	2.3 (1.8–2.8)	3.5 (2.4–4.6)	0.9 (0.7–1.2)
20 years D_m FSa (p+m) **II**	2.1 (1.3–2.9)	1.3 (0.9–1.6)	2.2 (1.5–2.9)	0.4 (0.3–0.6)

Statistically significant differences at 20 years of age: **A** vs. **B** $p < 0.05$ for (I +II); **A** vs. **D** $p < 0.001$ for (I+II); **B** vs. **D** $p < 0.001$ for (I+II); **C** vs. **D** $p < 0.001$ for (I+II).

p = premolars, m = molars

4.2.2 Caries prevalence at 20 years of age in relation to parental, psychosocial and socioeconomic factors (Paper IV)

The 20 year-old offspring of mothers who estimated their own oral health care as good showed significantly lower caries prevalence than those whose mothers estimated their oral health care as less to poor ($p < 0.01$).

In subjects whose fathers' educational level was < 12 years of schooling, the mean value for approximal caries in premolars and molars at 20 years of age (DimFSa) was 2.1, compared with 1.7 in those whose fathers' educational level was ≥ 12 years (N.S). The corresponding values in relation to maternal educational level were 1.9 and 1.9, respectively (N.S).

There was no statistically significant difference in approximal caries in premolars and molars at 20 years of age in relation to parental satisfaction with social status, including work, leisure time, health, accommodation, social life and financial status (reported at the time of the indivduals examination at one year of age).

At the individuals one year examination, some mothers had reported anxiety associated with dental visits: "so anxious that I sometimes break out in a sweat or almost feel physically sick" or "would be very frightened of what the dentist might do". At age 20, the mean number of caries lesions

(DimFSa) in subjects whose mothers had reported dental anxiety was 5.0, compared to 1.4 in those whose mothers had reported feeling “relaxed” about dental visits ($p < 0.01$), (Paper IV, Table 3).

The 12 subjects who had failed to attend the dental examination at 1 year of age had higher approximal caries prevalence at 20 years of age than those (n=482) who had attended the 1 year examination:, DimFSa 4.5 vs. 1.9 respectively ($p <0.05$). The 20 year-olds who had failed to attend at 1 year of age were more dissatisfied with their occupation ($p < 0.01$) and financial status ($p < 0.05$) than those examined at both 1 and 20 years of age.

At 20 years of age, those who at 3 years of age had good oral hygiene and good dietary habits had significantly lower caries prevalence than those recorded as having poor oral hygiene ($p <0.01$) and unfavourable dietary habits ($p <0.05$) at 3 years of age.

4.2.3 Caries in relation to overweight and obesity (Paper III)

At 20 years of age, 3 individuals refused to be weighed and measured. Thus, information about weight and height was available for 491 individuals. Overweight was found in 19 percent and obesity in 7 percent. Overweight/obese individuals (n=124) had statistically significantly higher mean caries prevalence than normal weight individuals (n=340): DFS 7.1 vs. 5.2 ($p < 0.05$), (Table 5). In the obese group (n=33), only 15 percent had no manifest caries lesions and restorations compared to 36 percent in the normal-weight group ($p = 0.01$).

Table 5. Mean number of decayed and filled tooth surfaces ($D_{im}FS$) in all participants and in different BMI groups at 20 years of age, Paper III.

	Caries prevalence at 20 years of age	
	$D_{im}FS$	
Groups	Mean	SD
All (n=491)	5.7	7.8
BMI < 18.5 (n=27)	6.3	7.5
BMI 18-24.9 (n=340)	5.2	7.5
BMI ≥ 25 (n=124)	7.1	8.6
BMI 25-29.9 (n=91)	6.8	8.0
BMI ≥ 30 (n=33)	7.8	10.2

4.3 Dental erosion at 20 years of age (Paper II)

Dental erosion was found in 75 per cent (n=369) of individuals, 183 females and 186 males. Of these, 18 per cent (n=90) had extensive erosion, 41 females and 49 males. Erosion on the occlusal surfaces of one or several molars was recorded in 74 per cent (n=367), cupping in 65 per cent (n=320) and severe erosion (fused cupping) in 1.6 per cent (n=8). Maxillary incisor erosion was observed in 3.8 per cent (n=19) on buccal surfaces and in 7.3 per cent (n=36) on palatal surfaces (Figure 6). Severe erosion in molars and on the buccal surfaces of maxillary incisors was registered in one individual. There were no gender differences with respect to severity of erosion.

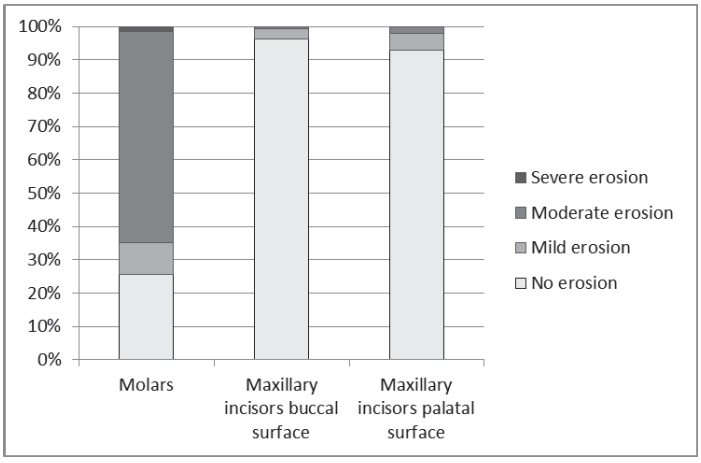

Figure 7. Per centage distribution of individuals according to grade of severity of erosion in molars and maxillary incisors, Paper II.

4.3.1 Dental erosion in relation to caries and salivary factors (Paper II)

A statistically significantly difference in caries prevalence was revealed between individuals with erosion and extensive erosion and those with no erosion ($p < 0.01$ respectively $p < 0.01$). In those with erosion and extensive erosion, 49 and 58 per cent, respectively had ≥4 DimFS, compared to 34 per cent of those with no erosion.

The number of mutans streptococci was statistically significantly higher in individuals with extensive erosion than in those with no erosion ($p < 0.01$). No differences were found for buffer capacity or lactobacilli counts.

4.3.2 Dental erosion in relation to behavioural factors and general health (Paper II)

Of the obese individuals, 9 per cent (n=31) had erosion, 8 per cent (n=7) had extensive erosion and 2 per cent (n=15) had no erosion, (Paper II, Table 3).

Young adults with extensive erosion had a higher frequency of obesity, consumption of soft drinks and consumption of chewing gum than those without erosion ($p \leq 0.05$). Less frequent tooth-brushing (less than twice a day) was more common in those with extensive erosion than in those with no erosion ($p < 0.05$).

There were no differences among young adults with or without erosion with respect to self-perceived health, medical treatment, regular medication, physical activity or consumption of thirst quenchers. Moreover, no association was found between self-assessed gastric reflux and dental erosion.

5 DISCUSSION

The most important findings were:

Caries prevalence at 20 years of age is strongly related to previous caries experience: those with early caries experience are at greater risk for caries in young adulthood.

Caries prevalence at 20 years of age is strongly related to overweight/obesity.

Parental factors during infancy are related to caries prevalence at 20 years of age.

At 20 years of age, the prevalence of dental erosion is high but the severity is generally low.

There is a relationship between dental erosion and caries prevalence at 20 years of age.

There is a relationship between dental erosion and overweight/obesity at 20 years of age.

5.1 Methodological considerations

5.1.1 Study group

In this longitudinal study a cohort has been followed from 1 to 20 years of age. All 671 individuals aged 1 year in 1988 living within the uptake area of four child welfare centres in the Municipality of Jönköping were invited to participate in the study. This comprised around half the number of 1 year-olds in the Municipality of Jönköping; hence the study cohort may be regarded as representative for this region of Sweden. At the age of 20, attrition of 26 percent may be considered acceptable after 19 years' follow up.

A potential problem in longitudinal studies such as this, is that over time changes may occur in society, in terms of dietary habits, sedentary lifestyles etc. These changes could in turn have an effect on the prevalence of caries, erosion and overweight.

5.1.2 Material and methods

Between 15 and 20 years of age, 107 individuals were lost to the study. Analysis of caries data at 15 years of age revealed no statistically significant

difference between those lost between 15 and 20 years of age and those examined at both 15 and 20 years of age. Thus the dropouts should not have any impact on the results.

All the study subjects have been covered by a publicly-funded, comprehensive dental care programme from 1 to 20 years of age. While this might have reduced the total caries prevalence, it should not affect caries experience at 20 years of age in relation to previous caries experience, or the comparisons between groups. Furthermore, the dental care programme in the Municipality of Jönköping includes recommendation of fissure-sealing of all newly erupted molars. This might account for the low number of decayed and restored occlusal surface in molars.

The cohort was examined by different examiners at different ages. In the radiographic examination the result of the kappa calculation gives the same results for simple kappa as for weighted kappa. The calibration with inter-rater kappa value for the two examiners (A.A, H.I) was good (Cohen's kappa value of 0.86). At 20 years of age, one observer (H.I) analysed all bitewing radiographs and conducted all the clinical examinations. The intra-rater kappa value for radiographic examination was good, presented as simple kappa (Cohen's kappa value 0.90). Simple and weighted Cohen's kappa values were calculated for the clinical examination. The values were 0.85 and 0.86 for caries and 0.96 and 0.97 for restorations, respectively.

One limitation of the study was that 22 percent of the bitewing radiographs taken at 20 years of age for examination of approximal surfaces on premolars and molars were recorded as unreadable due to overlapping. This attrition has to be judged as acceptable.

It was found that the distribution of caries lesions and restorations was skewed. In studies with skewed distribution, median values should be used in the analysis. In epidemiological studies, caries prevalence is expressed as means, because means provide more useful information about caries prevalence. For that reason, means were used in this study and t-test and ANOVA were therefore used in the analyses.

A limitation in the present cross-sectional study of dental erosion is that diagnosis of early signs and symptoms of wear, particularly those of an erosive nature, may be difficult to detect and classify. To overcome this problem, a simplified scoring system was developed for the present study. This scoring system is in many respects similar to those proposed by Hasselkvist et al. (Hasselkvist et al. 2010), and Johansson et al. (Johansson et

al. 1996). Furthermore, in most scoring systems for erosion, the grading on the occlusal surfaces of molars is based on dentine involvement. In the present study a modified scoring system was used, in order to facilitate comparisons and a new definition, namely “extensive erosion”, has been introduced. This is potentially a better definition than the use of high scores on individual tooth surfaces. In cross-sectional studies of young adults the observed tooth wear can have occurred at a younger age. This makes it difficult to associate the erosion with information about etiological factors taken from the actual questionnaire.

The Dental Anxiety Scale (Corah 1969), used in the present study, includes four multiple choice items with the patients’ subjective reactions to a visit to the dentist. This scale is adapted for teenagers and adults, with reference to their level of vocabulary and emotional development. Despite the interval of 20 years between the questionnaires answered by the parents when the subject was one year of age and those answered by the individuals themselves, at 20 years of age, data from DAS allow good comparison of dental anxiety because the same tool was used on both occasions.

5.2 Caries prevalence in young adults (Paper I)

The mean caries prevalence at 20 years of age was $D_{im}FS$=5.8 and $D_{im}FSa$=2.0. Twenty-six percent were caries free. This is less than the frequency of caries free individuals reported by the Swedish National Board of Health and Welfare (Socialstyrelsen 2008) (30 percent) and from the Municipality of Jönköping in 2008 (38 percent). In the present study, initial caries lesions were included, which might explain the difference.

Data from 2003 presented by Hugoson et al. (Hugoson et al. 2008), from the same area as the present study and used the same diagnostic criteria revealed that the percentage of caries free individuals at 20 years of age was 12 percent, and the mean $D_{im}FS$ was 9.7, compared to 26 percent and $D_{im}FS$=5.8 in the present study, conducted during 2007. In the present study manifest caries or restorations on occlusal surfaces were recorded in 14 percent of first molars and in 11 percent of second molars. At 20 years of age the number of manifest caries or restorations on occlusal surfaces of molars was 1.1, compared to 2.8 in the study by Hugoson et al. (Hugoson et al. 2008). This indicates that caries prevalence in young adults is continuing to decrease.

In the present study, fissure sealants were recorded on 70 percent of first and second molars. This is in agreement with the study by Hugoson et al. (Hugoson et al. 2008), in which 63 percent of the molars in 20 year-olds were

fissure sealed. The mean number of $D_{m=}$Fo1.1 must be considered low at the age of 20 and could be attributable to the policy, adopted by the Municipality of Jönköping, of fissure-sealing all caries free molars as soon as possible after eruption.

It was found that the distribution of initial or manifest approximal caries lesions and restorations in premolars and molars was skewed. Ten per cent of the 20 year-olds had 62 percent of all the initial lesions and 56 percent of all the manifest lesions and restorations. This highlights the importance of tailoring preventive strategies to target children at risk.

On approximal surfaces in premolars and molars, initial caries lesions were found to be 5 times more prevalent than manifest lesions. An epidemiological study from 2003 (Hugoson et al. 2008) reported similar results for 20 year-olds: initial caries lesions on approximal surfaces were reported in about 56 percent and 6 times more prevalent than manifest lesions. This clearly shows the importance of including initial caries lesions in diagnosis of caries prevalence and also the importance of intervention at an early stage, to arrest the progression of initial lesions to manifest lesions.

5.2.1 Caries in relation to previous caries experience (Paper I)

A strong relationship was shown between caries prevalence at 20 years of age and caries experience during childhood and adolescence. The onset of caries before 3 years of age was predictive not only of further caries development in the primary dentition, but also of caries development in the permanent dentition. It was also found that caries experience at 3 years of age was more predictive of caries prevalence at 20 years of age than caries experience at 6 years of age.

There are few longitudinal studies on dental health in Swedish young adults followed from early childhood. A Swedish register study by Ekbäck et al. (Ekbäck et al. 2012) reported poor correlation between active caries in the primary dentition and active caries at 19 years of age. However, there was a correlation for total caries prevalence. A relationship between caries at an early age and caries later in life has previously been reported (Li and Wang 2002, Mejare et al. 2004, David et al. 2006, Mattila et al. 2008). The follow-up periods in these studies ranged from 6 to 15 years, compared with 19 years in the present study. An earlier study of the same cohort as in the present study disclosed a strong relationship between early childhood caries and caries prevalence at 15 years of age (Alm et al. 2007). In the same

cohort, the caries increment between 3 and 6 years of age was 5 times higher for children with manifest caries at 3 years than for those who were caries free at this age (Wendt et al. 1999). Individuals who had been caries-free at 3 and 6 years of age, but had manifest caries at age 15 years, developed few new initial lesions on approximal surfaces between 15 and 20 years of age. There was, however, an increase of manifest caries lesions, which indicates continuing disease progression, from initial to manifest lesions, during this period. This is consistent with the findings of Mejare et al. (Mejare et al. 2004) who reported few new approximal caries lesions between the ages of 12 and 15 years. The same trend was shown in the study by Hugoson et al. (Hugoson et al. 2008), with a threefold increase of manifest approximal lesions between 15 and 20 years of age, but few new initial approximal lesions.

A noteworthy finding concerned individuals who had manifest caries at 3 and 6 years of age, but exhibited no approximal caries at 15 years of age: at 20 years of age, their approximal caries experience was comparable to the 20 year-olds who had been caries free at 3, 6 and 15 years of age. This means that if a child is caries-active at 3 and 6 years of age, but changes behaviour and become caries free at 15 years, there is a high likelihood that at 20 years of age caries prevalence will remain low. Despite the statement that early childhood caries is the best predictor of future caries prevalence (SBU 2007, Tagliaferro et al. 2008) it shows that there is a potential to change a predictive development.

Another interesting subgroup comprised those who were caries free at 3 and 6 years of age, but had developed initial or manifest approximal lesions by age 15: at 20 years of age their caries experience was comparable with those with caries onset before 3 years of age. As previously mentioned, few new initial lesions develop between 15 and 20 years of age. However, there is a trend that initial lesions progress to manifest. It is therefore clear that it is of outmost importance to maintain the individual caries free up to 15 years of age.

5.2.2 Caries in young adults in relation to overweight and obesity

Overweight and obesity was found in 26 percent of the individuals. Young adults with overweight or obesity had statistically significantly higher mean values for caries lesions than normal weight individuals. These findings are in accordance with earlier studies showing higher caries prevalence in overweight or obese individuals (Alm et al. 2008a, Modéer et al. 2010,

Gerdin et al. 2008). A number of factors may contribute. A review by Harrington (Harrington 2008) indicated a relationship between the increase in adolescent obesity and the concurrent increase in consumption of sugar-sweetened beverages.

Obesity and dental caries have some common risk determinants. A multidisciplinary approach involving both medical and dental health aspects is therefore needed to analyse contributory factors and initiate appropriate preventive measures. Strategies for individuals at risk at an early age are crucial to promote a healthy lifestyle in the future. This is of particular importance during the formative years.

5.2.3 Caries in relation to parental, socio-economic, psychosocial factors and life style (Paper IV)

The mother's estimation of her own oral health care seems to affect the child's standard of oral hygiene. Thus, dental behaviour and attitudes of the mother during childhood seem to affect dental habits in the young adult. Infrequent oral health habits during early childhood are predictive of poor dental health in 10 year-olds (Mattila et al. 2005a). The parental influence on dental behaviour in adolescence is also described by Åström et al. (Åstrom and Jakobsen 1996), with significant associations with respect to tooth-brushing. The family is an important mediator of socialization, with the parents as social models for the child. It is therefore important to support the parents with respect to both their own and the child's dental health habits.

It was found that tooth-brushing once a day or less at 3 year of age was significantly associated with higher caries experience at 20 years of age. Studies by Mattila et al. (Mattila et al. 2005a, Mattila et al. 2005b) showed that infrequent tooth-brushing at 3 years of age was associated with poor dental health at 7 and 10 years of age. Furthermore, a stabilisation of children's dental health habits seems to occur around 10 years of age, at the change from the primary to the permanent dentition. The present study showed that plaque on maxillary incisors at 1 year of age did not seem to have an impact on the caries prevalence at 20 year of age. Of the individuals with high caries prevalence at 20 years of age, 34 percent had plaque on maxillary incisors at 1 year of age, compared to 20 percent of those who did not have plaque at 1 year. In previous studies of this cohort, plaque on maxillary incisors at 1 year was found to be associated with caries experience at age 3 (Wendt), and age 15 (Alm) (Wendt et al. 1994, Alm et al. 2008b). However, at 20 years of age this association was not statistically significant.

The present study confirms an association between frequent high sucrose intake (consumption of juice) at 3 years of age and approximal caries at 20 years. This is in accordance with findings from earlier studies of the present cohort which showed that early establishment of such behaviour as frequent consumption of caries-risk products was associated with caries prevalence at 6 and 15 years (Wendt et al. 1996, Alm et al. 2008a). Early established habits of high sucrose intake are assumed to persist throughout childhood, adolescence and in young adulthood (Alm et al. 2012). We could confirm the assumption that dietary habits of high sucrose intake, established in early childhood, increase the risk for persistent cariogenic dietary habits and dental caries in young adulthood. In today's society, sugar-containing snacks and beverages are easily accessible at all hours and at a low cost. The consumption of these products is widespread across all ages, with the parents acting as providers for their children and will become a part of the lifestyle of adolescents and young adults. Thus with respect to dietary habits there is a need to offer the parents support to make a change in consumption pattern.

Previous studies of the same cohort have disclosed that children who failed to attend the 1-year examination had significantly more caries at 3 (Wendt et al. 1992) and 15 years (Alm et al. 2008b). The present study confirms that this is also true for young adults. As parents are responsible for ensuring that young children keep dental appointments (Kleiman 1982, Herbertt and Innes 1979), the family's structure and general socioeconomic situation (Gustafsson et al. 2010) need to be taken into account, when coping with families where children fail to attend dental appointments. In a report from the Swedish National Board on Health and Welfare it has been pointed out that parental and socioeconomic factors are associated with children's non-attendance at dental visits (Socialstyrelsen 2013). A Norwegian study by Wigen et al. (Wigen et al. 2009) showed that failing to keep dental appointments and parents' dental avoidance behaviours were related to dental caries in 5-year-old children. A cooperative effort is required, involving both the Public Dental Service and Child Welfare Centres, in order to manage the problem of failure by parents to keep the child's dental appointments.

There was no statistical association between approximal caries prevalence at age 20 and the educational level of the parents, when the child was 1 year of age. This is in accordance with previous studies on the same cohort (Alm et al. 2008b). In the present study, young adults whose fathers had a high educational level had less caries lesions than those whose fathers had less education, but the difference was not statistically significant. A study by Julihn et al. (Julihn et al. 2006), reported a similar pattern between caries prevalence at 19 years of age and the fathers' educational level. In contrast to

our findings, a relationship between dental caries in children and the parents' educational background has been reported. This relationship was particularly strong if the caries prevalence was high (Petersen 2005). The differences may be explained by the low caries experience in the present study.

Maternal dental anxiety was not found to influence the anxiety of the 20 year old. This is in contrast to the findings by Milgrom et al. (Milgrom et al. 1995), who reported that children (5–11 years of age) with dentally anxious parents were more likely to be anxious. In studies by Goettems et al. (2011, 2012) maternal dental anxiety seems to be related to the child's caries prevalence (Goettems et al. 2012, Goettems et al. 2011). It was also found that 20 year-olds in the present study with anxious mothers had high approximal caries prevalence. Thus maternal dental anxiety should be considered as an important risk factor in early childhood caries.

5.3 Dental erosion in young adults (Paper II)

Previously reported prevalence of dental erosion is lower than in the present study (Jensdottir et al. 2004, Hasselkvist et al. 2010, Mulic et al. 2013). This may be due to differences in definitions of dental erosion and/or the scoring systems used. A new scoring system, the so called BEWE, Basic Erosive Wear Examination index (Bartlett et al. 2008), has recently been presented in order to make clinical research on dental erosion more comparable. Unfortunately, this scoring system had yet to be been introduced when the present study was initiated in 2006. In the present study we used a modified scoring system in order to facilitate comparisons. A new definition, namely "extensive erosion", has been used in the present study: this is a better description of an erosive condition than high scores for individual tooth surfaces.

In the present study, about 35 percent of the subjects showed no erosion or only mild erosion in molars, 63 percent had moderate erosion i.e. one or more cuppings, and only 2 percent had severe erosion. This is in general agreement with results reported by Hasselkvist et al. (Hasselkvist et al. 2010) and Mulic et al. (Mulic et al. 2013). The minor differences can be explained by different tooth groups studied and/or scoring systems used. It is debatable whether an individual with minor cupping in molars should be regarded as "diseased": this condition might be regarded as a normal variation in a healthy population.

In the present study, 75 percent of the subjects had signs of dental erosion. This is in accordance with a study by Fares et al. (Fares et al. 2009) in which

around 77 percent of 21-year-olds had at least one surface with exposed dentine. In that study, and in some other studies (Hasselkvist et al. 2010, Arnadottir et al. 2010), males had significantly more wear in dentine than females. Jensdottir et al. (Jensdottir et al. 2004) found a trend towards higher erosion scores in molars in males. This male predominance, however, was not statistically significant. Our findings are in agreement with Jensdottir et al.: we were unable to demonstrate a gender difference.

5.3.1 Dental erosion in relation to caries and salivary factors (Paper II)

A significant statistical association between caries and dental erosion was disclosed. This is in agreement with the results reported by Mulic et al. (Mulic et al. 2013). O´Sullivan et al. (O'Sullivan and Curzon 2000) demonstrated that individuals with erosion have salivary characteristics that more closely match those of caries-active individuals. The present study confirms this: MS were more prevalent in individuals with extensive erosion. The high MS count in individuals with extensive erosion may be of interest when analysing contributory factors in individuals with tooth wear.

The significant association between MS and dental erosion may be due to lifestyle factors, e.g. high intake of sweet products such as soft drinks, which are known risk factors for both caries and erosion. Barkeling et al. (Barkeling et al. 2002) found that the MS count correlated with both BMI and a high intake of sweet foods. Furthermore, the prevalence of erosion has been found to be higher in adults with diagnosed gastroesophageal reflux disease than healthy controls. The association between MS count and carious teeth, is, however, less frequent in individuals suffering from GORD than in healthy controls (Correa et al. 2012). Whether this applies to the individuals in this cohort with self-assessed gastric reflux, warrants further clarification.

Low buffer capacity has been reported to be the most significant salivary factor for the development of erosion in individuals 3 to 16 years of age (O'Sullivan and Curzon 2000). The present study, however, disclosed no association between the buffer capacity of stimulated saliva and erosion. This may be because the study population was quite healthy, with normal salivary secretion rates, which in turn increases the bicarbonate concentration in saliva. There are, however, also published reports in which no association between dental erosion and salivary buffer capacity was proven (Jaeggi and Lussi 2004).

5.3.2 Dental erosion in relation to behavioural factors and general health (Paper II)

In the present thesis, young adults with extensive erosion showed frequent consumption of soft drinks. Previous studies have reported a similar association in young adults (Jensdottir et al. 2004, Bartlett et al. 2011, Okunseri et al. 2011, Johansson et al. 1997). In a study of Icelandic young adults (19-22 years old) significantly higher erosion scores were found on molars in subjects who drank more than 1 litre of carbonated drinks per week compared to those who drank less than 1 litre (Jensdottir et al. 2004). The consumption of soft drinks in Sweden has tripled over the last 50 years (Jordbruksverket 2012, Birkhed et al. 1989) and in the USA it increased almost 300 percent between 1977 and 1996 (Cavadini et al. 2000).

A higher proportion of individuals with extensive erosion reported tooth-brushing only once a day or less, compared to individuals with no erosion. This is in accordance with data reported by Mulic et al. (Mulic et al. 2012), of an association between erosion and tooth-brushing once a day or less. It has been suggested that prolonged and frequent tooth-brushing might increase the risk of tooth wear (Lussi 2006). Ganss et al. (Ganss et al. 2007, Ganss et al. 2009) however, showed that neither the frequency of tooth brushing nor the brushing force increased substance loss of eroded dentin.

In this thesis, no relationship was found between self-assessed gastric reflux or frequency of physical activity and dental erosion. Gastric reflux, confirmed by medical diagnosis, has been reported to be a significant factor in the development of dental erosion (Holbrook et al. 2009, Marsicano et al. 2013). It has been suggested that in young physically active males, consumption of soft drinks and gastric reflux during exercise are contributing factors to dental erosion (Myklebust et al. 2003). In the present cohort, consumption of soft drinks during physical activity was infrequent among the young adults, who preferred water as a thirst quencher. This should reduce the risk for dental erosion during physical activity. As discussed by Holbrook et al. (Holbrook et al. 2009), there appear to be strong links between gastric reflux and the presence of tooth erosion, especially in molars. In the present study, there were only 8 individuals (1.6 percent) with severe erosion of the molars, thus no conclusions about the causes should be drawn.

In the present study, a high frequency of erosion was found in young adults with high BMI. This is in agreement with McGuire et al. (McGuire et al. 2009). that obese children have a greater risk for erosive tooth wear than normal weight children. Childhood overweight/obesity has been associated

with the number of daily servings of soft drinks. In addition, abdominal obesity may be associated with oesophageal dysfunction and increased acid exposure and reflux symptoms which in turn may lead to a higher risk for dental erosion (Anggiansah et al. 2013). The above is in agreement with our findings on the association between dental erosion and obesity.

Dental plaque has been found to inhibit dental erosion of enamel *in vitro* and *in vivo* (Ganss et al. 2009, Cheung et al. 2005). In the present study no such association could be found. This is in accordance with data reported by El Aidi et al. (El Aidi et al. 2011). Furthermore, no association between erosion and gingivitis could be demonstrated in the present study.

5.3.3 Dental caries, dental erosion, overweight/obesity and lifestyle

The present thesis reveals a number of etiological relationships between dental caries, dental erosion, overweight/obesity and lifestyle factors. In short, it seems that lifestyle is a determinant of the development of these conditions. To manage this complicated and multifactorial situation a broad multi-professional approach is necessary.

6 CONCLUSIONS

The caries prevalence in 20-year-olds in the present thesis is in close agreement with national and local epidemiologic data. There is a strong relationship between caries prevalence at 3, 6, 15 and 20 years of age in the studied cohort.

A high prevalence of dental erosion (75 percent) was found among young adults but this was mostly of low severity. Very few had severe erosion. A significant association was found between dental erosion and caries, lifestyle factors and overweight/obesity.

Overweigh/obesity was found in 26 percent of the cohort. These subjects had a statistically significantly higher mean caries prevalence than normal weight individuals.

Parental, socioeconomic and psychosocial factors at 3 years of age have an effect on approximal caries in 20 year-olds. Dental avoidance and parental dental anxiety at 1 year of age were associated with caries experience in the young adult.

7 FUTURE PERSPECTIVES

Parental, socioeconomic and psychosocial factors during infancy and lifestyle factors seem to exert a strong influence on the prevalence of dental caries, dental erosion and overweight/obesity in young adults. To prevent this unfavourable development in infancy and early childhood, there is a need for multidisciplinary preventive measures. This will require a multiprofessional research approach.

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