On Dental Caries and Caries-Related Factors in Children and Teenagers

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Abstract

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Dental caries is still a common disease among children and adolescents. The aims of the present thesis were therefore: 1) to investigate the approximal caries prevalence in posterior teeth in 15-year-olds, 2) to study past caries experience in the primary dentition in relation to future caries development and need for treatment, 3) to investigate factors during early childhood which are associated with caries development later in life, and 4) to study the association between age-specific body mass index (isoBMI) and approximal caries status in 15-year-olds.

Paper I has a retrospective design and the analyses were based on record data from a randomly selected sample. Papers II, III and IV are based on radiographic analyses of posterior teeth in 15-year-olds followed longitudinally from 1 to 15 years of age. The data for these studies were selected from examinations, interviews and questionnaires from early childhood and school health care records at 15 years (isoBMI values).

The result showed that the approximal caries prevalence in 15-year-olds is underestimated in official caries data, since initial caries lesions are not included in these statistics. Two thirds of all 15-year-olds had approximal caries and initial caries constituted 86% of the total number of caries lesions. There was a strong relationship between caries in early childhood and approximal caries prevalence in the posterior teeth at 15 years of age. Children with caries experience at 6 years received significantly more treatment in the primary dentition during the period from 7 to 12 years compared with children who were caries free at the same age. Further, it was pointed out that parents' attitudes to dental health and psychosocial factors during early childhood have an effect on approximal caries in 15-year-olds. Additionally, plaque on primary incisors at 1 year of age and infrequent toothbrushing at 3 years of age were associated with a high caries experience at 15 years. It was also demonstrated that adolescents with overweight and obesity had a significantly higher approximal caries prevalence than those of normal weight. Furthermore, it was shown that children's unfavourable snacking habits at 1 and 3 years of age were associated with approximal caries at 15 years.

The main conclusions from this thesis are that: 1) epidemiological caries data should include initial caries lesions on approximal tooth surfaces, in order to show the actual caries prevalence, 2) there is a strong relationship between caries in early childhood and approximal caries prevalence in the posterior teeth at 15 years of age, 3) the psychosocial environment in which children live during their childhood has an impact on dental health later in life, 4) good oral hygiene habits including the use of fluoride toothpaste, established in early childhood, provide a foundation for good dental health in adolescence, and 5) future preventive programmes should include, at a multidisciplinary level, strategies to prevent and reduce both dental caries and obesity at an early age.

Key words: Adolescents, approximal caries, caries experience, early childhood caries, oral hygiene, fluoride toothpaste, plaque, psychosocial factors, snacking habits, body mass index

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Contents

Original papers

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

I. Alm A, Wendt LK, Koch G: Dental treatment of the primary dentition in 7-12 year-old Swedish children in relation to caries experience at 6 years of age. Swed Dent J 2004;28:61-66.

II. Alm A, Wendt LK, Koch G, Birkhed D: Prevalence of approximal caries in posterior teeth in 15-year-old Swedish teenagers in relation to their caries experience at 3 years of age. Caries Res 2007;41:392-398.

III. Alm A, Wendt LK, Koch G, Birkhed D: Oral hygiene and parent-related factors during early childhood in relation to approximal caries at 15 years of age. Caries Res 2008;42:28-36.

IV. Alm A, Fåhraeus C, Wendt LK, Koch G, Andersson-Gäre B, Birkhed D: Body adiposity status in teenagers and snacking habits in early childhood in relation to approximal caries at 15 years of age. Int J Pediatr Dent 2008;18:189-196.

Paper I in this thesis is published with the permission of the editor of the Swedish Dental Journal, Papers II & III with the permission of the publisher S. Karger AG (Caries Research) and Paper IV with the permission of the publisher Blackwell Publishing Ltd (International Journal of Paediatric Dentistry).

Abbreviations and Definitions

The following terminology has been used in this thesis:

Caries prevalence/caries experience = caries status (caries lesions including restorations), caries score on one occasion

def-s appr = decayed, extracted and filled approximal tooth surfaces on primary molars and canines at 6 years of age
def-s tot = decayed, extracted and filled tooth surfaces (all surfaces included) on primary molars and canines at 6 years of age

Early primary dentition = primary dentition from 1 to 6 years of age
Late primary dentition = primary dentition from 7 to 12 years of age

Early childhood caries = caries development before 3 years of age
Late childhood caries = caries development between 3 and 6 years of age
Caries-free childhood = children without caries and restorations at 3 and 6 years of age

Caries-free group = children free of initial and manifest caries at 3 years of age
Initial caries group = children with initial caries but without manifest caries at 3 years of age
Manifest caries group = children with manifest caries lesions or fillings at 3 years of age

D_ia = initial caries – an approximal caries lesion in the enamel that has not reached the enamel-dentine junction or a lesion that reaches or penetrates the enamel-dentine junction, but does not appear to extend into the dentine (counted on molars and premolars at 15 years of age)
D_ma = manifest caries – an approximal caries lesion that clearly extends into the dentine (counted on molars and premolars at 15 years of age)
$D_{i+m}Fa$ = approximal initial and manifest caries lesions or fillings in molars and premolars at 15 years of age
DFa = $D_{i+m}Fa$

"Caries-promoting factors" = factors associated with the development of the caries disease
"Caries-inhibiting factors" = factors associated with the prevention of the caries disease
"Caries indicators" = is a characteristic or an exposure that co-exists with an increased probability of developing a disease

Significant Caries Index (SiC index) = the mean value of the third part of the population with the highest caries scores [Bratthall, 2002]

BMI = body mass index (kg/m^2)
isoBMI = body mass index (kg/m^2), calculated using the international classification system for childhood obesity recommended by the International Obesity Task Force cut-off values [Cole 2000]
Low-normal weight = isoBMI < 25
Overweight = isoBMI 25-29.9
Obesity = isoBMI ≥ 30

Standard deviation (SD) in this thesis is given as ± SD according to Papers II, III and IV.

Introduction

Dental health in children and adolescents

Dental caries is one of the most prevalent chronic diseases in man, worldwide. It is a multifactorial disease that starts with microbiological shifts within the complex biofilm (dental plaque). Caries is affected by the consumption of dietary sugars, salivary flow, exposure to fluoride and preventive behaviours [Selwitz et al., 2007]. Epidemiological studies have reported a decline in caries among children in Western Europe during the last decades [Marthaler, 2004; Downer et al., 2005; Hugoson et al., 2008]. However, among pre-school children, a tendency towards a stagnation in caries decline has been reported since the end of the 1980s [Hugoson et al., 1986, 1995, 2005; Stecksén-Blicks et al., 2004]. Furthermore, there is a trend in many developed countries for the prevalence of dental caries to increase again, especially among young children [Haugejorden & Birkeland, 2002]. As a result, dental caries is still common among children and adolescents [Nithila et al., 1998; Marthaler, 2004] and affects 46% of 4-year-old children [Stecksén-Blicks et al., 2004] and 80% of 15-year-olds [Hugoson et al., 2008]. In the Jönköping study, the mean number of decayed and filled tooth surfaces (DFS), including initial lesions at 15 years of age, was 6.4, while the distribution by type of surface for the proximal, occlusal and buccal/lingual was 3.0, 1.5 and 1.9, respectively. Moreover, dental caries is a public health problem because it is a widespread condition that is costly to treat and has an impact on the quality of life of children of all ages [Low et al., 1999; Filstrup et al., 2003; Ismail, 2004]. It is therefore of the utmost important to prevent the caries disease, but this will not be successful unless the available scientific knowledge relating to ways of changing the etiological factors of the disease is applied. However, there are still a number of issues and conditions associated with caries in children and adolescents which are not completely understood and it is important to evaluate them in order to increase the basis for evidence-based prevention such as:

- Approximal caries prevalence in the permanent posterior teeth in adolescents
- Past caries experience in the primary dentition in relation to future caries development and treatment needs

- Factors during early childhood which are associated with caries development and dental health later in life
- Overweight and obesity in relation to caries prevalence.

Approximal caries prevalence in permanent teeth

In Sweden, data relating to dental caries in individuals 3 to 19 years of age are available in annual reports from 1985 to 2005 and are given as the percentage of children who are free from manifest caries [Socialstyrelsen, 2006]. However, initial caries lesions are not included in these data. Consequently, the national reports often underestimate the true prevalence of caries [Amarante et al., 1998; Machiulskiene et al., 1998]. In studies by Moberg Sköld et al. [1995, 2005a, b], approximal initial lesions have been reported to constitute 80-90% of the total number of caries lesions in teenagers. This is in accordance with a study conducted by Forsling et al. [1999]. They studied the prevalence and distribution of approximal initial and manifest caries among 19-year-old Swedish patients and found that initial caries lesions constituted 90% of all lesions. Additionally, Poorterman et al. [2002] reported from a Dutch population that 23% of the 14-year-olds were caries free on the approximal surfaces if initial (enamel) lesions were included. The corresponding value for 17-year-olds was 18%.

Owing to the potential risk of initial lesions progressing to manifest caries lesions [Mejàre et al., 1999; David et al., 2006], the prevalence of initial caries and its significance for further caries development ought to be a reason for finding new strategies for caries prevention. This is in line with Nyvad [2004], who concluded that "the time is now ripe for a move from operative to non-operative care in the management of dental caries with the essential aims of arresting and healing the caries lesions at an early stage". The intention should be primary prevention, i.e. to prevent even non-cavitated approximal initial caries lesions [Raadal et al., 2001; Pitts, 2004].

Furthermore, reporting approximal initial caries lesions is very important, since it shows the actual caries prevalence in the population. For the early diagnosis of approximal caries lesions, the bitewing radiograph is an important diagnostic tool [Kidd & Pitts, 1990; Espelid et al., 2003; Clark & Curzon, 2004]. According to Kidd and Pitts [1990], the bitewing radiograph is particularly important in the detection of the initial lesion, which may be managed preventively rather than operatively. There is, however, a need to ensure that radiographic exposures are minimised. The need for radiographs

should therefore be balanced with the ethical issues associated with failing to make use of an established diagnostic aid. Lith and Gröndahl [1992] suggested that it ought to be possible to use previous caries experience as a method for individualising the planning of future radiographic procedures. More studies and regular national reports with special emphasis on approximal caries including initial caries lesions are needed to obtain a real picture of the caries situation in the permanent teeth.

Caries in the primary dentition and treatment needs in the late primary dentition

There are many epidemiological studies relating to the dental health of toddlers and pre-school children from the Nordic countries [Wendt et al., 1991, 1992, 1999; Grindefjord et al., 1993, 1995b; Hallonsten et al., 1995; Mattila et al., 1998, 2000; Raadal et al., 2000; Karjalainen et al., 2001; Stecksén-Blicks et al., 2004; Skeie et al., 2005b; Hugoson et al., 2008]. In particular, the theses by Wendt [1995a] and Grindefjord [1995a] have provided knowledge about the complexity of the caries disease among pre-school children. Caries is primarily found on the buccal, lingual and proximal tooth surfaces of the maxillary incisors up to 3 years of age [Grindefjord et al., 1993; Wendt et al., 1992]. After 3 years of age, other tooth surfaces are affected. Grindefjord et al. [1995b] reported that the occlusal surfaces of the second molar were the most affected surfaces at 3.5 years of age. In a Norwegian study, Skeie et al. [2004] found that molar approximal lesions dominated the caries increment in the primary dentition between 5 and 10 years of age. Consequently, molar approximal surfaces might be the main problem in the late primary dentition.

In Sweden, epidemiological data for the primary dentition are only available at 3 and 6 years of age [Socialstyrelsen, 2006]. No longitudinal epidemiological study of dental health in the primary dentition of children 7 years of age and older has been published in Sweden in the last decade. The most recent Swedish longitudinal investigation concerning the prevalence of dental caries in the primary dentition of children older than 6 years of age is currently about 30 years old [Holm, 1978]. However, recent studies [Mejàre & Stenlund, 2000; Edblad et al., 2001] have found a high caries prevalence in selected groups of children and selected tooth surfaces in the primary dentition in children aged 7 years and above. Mejàre and Stenlund [2000] reported that 64% of 9-year-old children had caries (initial or manifest) in one or more distal surface

of the second primary molar. Consequently, there appears to be a need for treatment, including a need for preventive treatment in the primary dentition after 6 years of age. This is in agreement with the thesis by Skeie [2005a], who concluded that the caries increment is considerable for the majority of children during the age period 5-10 years. These studies indicate the importance of a treatment approach that places a high priority on preventive and interceptive treatment of caries in the primary dentition even after 6 years of age.

There are various reasons why interceptive treatment should be applied to caries in the primary dentition. Painful treatment is one of the most commonly mentioned causes of anxiety and non-attendance for dental treatment and it is therefore important to avoid this in children [Skaret et al., 1998a, 1999; Raadal et al., 2002]. Furthermore, restorations in the primary teeth are known to have a shorter lifetime than those in permanent teeth [Qvist et al., 1997]. In a study by Wendt et al., [1998] the frequency of replacements was twice as high in the primary dentition as in the young permanent dentition. Combined with the relatively high percentages of initial caries lesions in the primary dentition [Amarante et al., 1998; Skeie et al., 2005b], these facts highlight the importance of focusing greater interest on the interceptive treatment approach when it comes to the management of caries in the primary dentition. There is also a need for more studies of caries prevalence in the late primary dentition. As things stand, we do not have enough knowledge of caries prevalence and past caries experience in relation to future caries development and the need for treatment in the primary dentition.

Past caries experience in relation to future caries development

A recent systematic review by the Swedish Council on Technology Assessment in Health Care [SBU, 2007] stated that past caries recording is the single best predictor of future caries development among pre-school children, school children and adolescents. This is in accordance with another systematic review [Powell, 1998] which concluded that clinical variables, especially past caries experience, are confirmed as the most significant predictors of future caries development. The relationships between caries in the primary teeth in early and late childhood and between caries in the primary and permanent teeth have been studied. Consequently, several authors have pointed out that children who have caries in their primary teeth during infancy or as toddlers tend to develop additional decay in their primary teeth during their pre-school years [Demers et

al., 1992; Grindefjord et al., 1995b; Wendt et al., 1999; Pienihakkinen et al., 2004]. Other studies have shown that children who have caries in their primary teeth during pre-school years continue to run a high risk of developing new caries lesions in their permanent dentition [Helfenstein et al., 1991; Raadal & Espelid, 1992; Mejàre et al., 2001; Vanobbergen et al., 2001; Li & Wang, 2002; Peretz et al., 2003; Vanderas et al., 2004; Leroy et al., 2005; Skeie et al., 2006a]. Studies have also shown that past caries experience had a predictive value when it came to an increment in approximal caries in permanent teeth [Lith & Gröndahl 1992; Lith et al., 2002; Stenlund et al., 2002]. However, there is a need for more longitudinal studies of caries prevalence, including initial lesions from early childhood to adolescence.

Caries risk assessment

Identifying risk in individuals or populations is difficult when it comes to chronic diseases that are caused by multiple factors that develop over a long period of time. Multifactorial modelling has been shown to be superior in the field of prediction, which is natural due to the complex aetiology of the disease [Anderson, 2002; Eriksen & Dimitrov, 2003]. Aetiological factors do not operate alone but display inter-relations and interactions [Fejerskov, 2004] and are additive in nature [Pitts, 1998]. Previously, the caries risk factors which attracted most interest were factors associated with the local caries process itself, such as the consumption of sugar, plaque, hygiene regimen and the host. According to Burt [2005], these factors should be extended. He stated that "we should broaden our view of risk to include social determinants of health and population health". Risk factors are often discussed in the literature and one of the most important questions is whether the factor is "causal" or "associated". Three types of factor related to dental caries have been defined: 1) risk factor, 2) risk indicator, 3) risk inhibitor.

Risk factor is a characteristic or an exposure that plays an essential role in caries development. According to Burt [2005], "any definition of risk factor must clearly establish that the exposure has occurred before the outcome, or before the conditions are established to make the outcome likely". For this reason, prospective studies are needed to evaluate risk factors.

Risk indicator is a characteristic or an exposure that co-exists with an increased probability of developing a disease or may lead to a measurable change in health status

[Paulander, 2004]. Furthermore, a risk indicator can be helpful in identifying groups at risk. In line with Burt [2005], an exposure which is associated with an outcome in cross-sectional data is called a *risk indicator*. Sometimes, the terms risk factor and risk indicator are used inappropriately. For example, regular toothbrushing with fluoride toothpaste is important for the prevention of caries. Perhaps the term *risk inhibitor* or *health factor* might be better for variables with these characteristics. This is in line with the so-called "salutogenic theory" presented by Antonovsky [1987] in order better to understand the emergence of health. According to this model, more attention should be focused on children and adolescents who maintain good dental health. In other words, interest should focus on health factors rather than risk factors. More knowledge is needed about the complexity of the caries disease and the inter-relations between factors that inhibit or promote caries. In this thesis, these factors will be called: *"caries-inhibiting factors"* and *"caries-promoting factors"*. The term *risk indicator* will also be used.

Sugar consumption as a caries-promoting factor

Dental caries has been defined as a dietary "carbohydrate–modified bacterial infectious disease" [van Houte, 1994]. A sucrose-rich diet increases the growth rate of many oral bacteria and changes the composition of the microflora in a caries-promoting manner [Marsh & Nyvad, 2001]. Acid-producing micro-organisms, such as the mutans streptococci in dental plaque, play an essential role in the caries process [van Houte 1994; Caufield et al. 2005]. The high and frequent consumption of sugar has been known to be an aetiological factor in caries for several decades [Moynihan et al., 2003]. However, a systematic review has shown that today, with frequent fluoride exposure, the relationship between sugar consumption and caries experience is not consistent [Burt & Pai, 2001]. Sundin [1994] concluded that nowadays the consumption of sweets and other sugary products does not seem to be a strong factor for the occurrence of caries. However, for subjects with a combination of poor oral hygiene, the consumption of sweets has been shown to be particularly harmful. This is in line with Zero [2004], who pointed out that, in subgroups without the same fluoride protection, sugar still acts as a potential risk. Studies have also shown that the frequent consumption of caries-risk products, candy and sugar-containing beverages, particularly sweetened liquid in a

feeding bottle, during the first years of life was associated with caries development during pre-school years [Wendt & Birkhed, 1995b; Grindefjord et al., 1996].

In addition, Guthrie and Morton [2000] showed that sweetened drinks constitute the primary source of added sugar in children's daily diet. Marshall et al. [2003, 2007] have suggested that contemporary changes in beverage intake, particularly the increase in soda pop consumption, have the potential to increase dental caries rates in children. According to Sheiham [2001], "sugars, particularly sucrose, are the most important dietary aetiological cause of caries and the main strategy to further reduce the levels of caries, is reducing the frequency of sugars intakes in the diet". Continued action to promote good dietary habits is necessary for both dental and general health. However, more knowledge is needed about the establishment of dietary habits from early age and the effect on caries development later in life.

Psychosocial and socio-economic factors as risk indicators

When it comes to dental health, socio-economic status has been recognised as a main factor for inequality [Locker, 2000]. In children, important social risk indicators are low socio-economic status and immigrant background, factors that indirectly influence oral hygiene standards and attitudes to dental care [Wendt et al., 1994; Hjern et al., 2001; Källestål & Wall, 2002]. Additionally, Powell [1998] stated that sociodemographic variables are most important in caries prediction models for young children.

In recent decades, Sweden has gradually become more multicultural as a result of immigration and several studies have reported that this has consequences for the dental health of children and adolescents [Grindefjord et al., 1996; Wendt et al., 1999; Stecksén-Blicks et al., 2004; Julihn et al., 2006; Skeie et al., 2006b]. This is in line with a study by Wennhall et al. [2002] which documented a very high caries prevalence among 3-year-old immigrant children from a multicultural society with a low socio-economic status.

According to Burt [2005], it is important to look not only at the mean values for caries but also at the frequency distribution in a population. Similarly to the caries disease, the distribution of factors associated with risk is skewed [Pitts, 2004]. These factors are confirmed to be accumulated in families with a low socio-economic status, often living in low-status housing areas [Hjern et al., 2001]. A relationship has been revealed between high caries experience in pre-school children and single mother status

[Bolin et al., 1997] or the low education level of the parents [Verrips et al., 1993; Mattila et al., 2005a]. It is also well known that parental attitudes have an impact on the establishment of oral health habits in children [Adair et al., 2004; Pine et al., 2004; Skeie et al., 2006b]. As a result, children's dental health habits and behaviour are associated with the dental health behaviour of their parents [Poutanen et al., 2006, 2007] and their important role persists in a significant manner during childhood [Mattila et al., 2000, 2005a, b], as well as during adolescence [Åstrøm & Jakobsen, 1996]. The parents' function as role models for their offspring into adolescence has been studied by Åstrøm & Jakobsen [1996] and Åstrøm [1998]. These studies showed that the family is an important mediator of socialisation and the development of health-related behaviours even during adolescence. Nicolau et al. [2007] discussed a life-course approach and stated that "the development of oral hygiene habits may be sensitive to the socioeconomic environment in which the people live during their childhood". Although the aetiological mechanisms, risk inhibitors and risk indicators for dental caries are well known, the early life events which may contribute to caries are not completely understood.

Toothbrushing and fluoride toothpaste as caries-inhibiting factors

Daily toothbrushing with fluoride toothpaste is believed to be the primary reason for the caries decline that has been observed since the 1970s [Nyvad, 2003]. Fluoride has a well-documented effect in caries prevention and this is primarily due the topical effect of different fluoride vehicles after tooth eruption. All over the word, fluoride toothpaste is by far the most widely used method of applying fluoride [Ellwood & Fejerskov, 2003]. In addition, a current Swedish systematic review of caries prevention methods [SBU, 2002] and a Cochrane report [Marinho et al., 2003] stated that there is strong scientific support for the efficacy of fluoridated toothpaste. Studies have shown that the frequency of toothbrushing had a significant association with caries prevalence [Wendt et al., 1994; Stecksén-Blicks et al., 2004; Julihn et al., 2006; Mattila et al., 2005a]. Good oral hygiene habits established at an early age and maintained during pre-school age, appear to be essential to achieve good oral health in infants and pre-school children [Grytten et al., 1988; Wendt et al., 1994]. However, very little information is available

about the maintenance of good oral health factors over time, from early childhood to adolescence, and its effect on caries development later in life.

Overweight and obesity in relation to caries prevalence

Body adiposity status is determined by calculating body mass index (BMI= weight/height^2). The cut off points for overweight and obesity are body mass index of 25 kg/m^2 and 30 kg/m^2, respectively. In childhood, body mass index changes substantially with age, therefore the international classification system for childhood obesity (isoBMI) is recommended by the International Obesity Task Force [Cole et al., 2000]. The prevalence of overweight and obesity in children is rapidly increasing in many countries around the world, including those in Europe [WHO, 2000; Lobstein & Frelut, 2003]. The Word Health Organisation (WHO) has compared this marked change in body weight to a "global epidemic disease". According to the American Academy of Pediatrics, Committee on Nutrition [2003], overweight and obesity are now the most common medical conditions of childhood. The potential health problems associated with overweight/obesity in children are numerous. They include insulin resistance, hypertension, orthopaedic complications, adult obesity and effects on quality of life [Whitaker et al., 1997; WHO, 2000]. A recent study of 10-year-olds, conducted in the western part of Sweden, revealed that 18% were overweight and 3% were obese. This corresponds to a two-fold increase in overweight and a four-fold increase in obesity from 1984 to 2000 [Mårild et al., 2004]. Another Swedish study of 15-year-old adolescents, based on data collected from 2000 to 2002, reported that 15% of the girls and 18% of the boys were overweight and a total of 3% of the girls and 4% of the boys were obese [Neovius et al., 2006].

The aetiology of childhood obesity is multifactorial and includes social and cultural factors. A low socio-economic level in terms of living area appears to be related to a higher prevalence of obesity [Blomquist & Bergström, 2007]. Global changes over the past decade have led to serious behavioural changes in populations, such as the increased consumption of soft drinks and fast food, which, together with more sedentary lifestyles [Andersen et al., 1998], has contributed to the increasing number of overweight people worldwide [Romito, 2003]. The amount of time spent watching TV is positively correlated with obesity [Andersen et al., 1998] and the increased consumption of soda [Giammattei et al., 2003]. Studies have also shown a relationship

between the consumption of sugar-sweetened drinks and childhood obesity [Ludwig et al., 2001; James & Kerr, 2005]. Preventive messages at an early age appear to be necessary, as obese children tend to become obese adults [Whitaker et al., 1997; Freedman et al., 2002]. Studies point to the fact that parental BMI has a positive association with childhood obesity [Whitaker et al., 1997; Burke et al., 2001; Mårild et al., 2004] and that familial behaviour can predict the risk of obesity.

Dental caries and obesity are both multifactorial diseases with a complex aetiology and both are associated with dietary habits. A sugar-rich diet, including beverages, is associated with various health problems such as obesity, dental caries and poor diet quality [Bawa, 2005; Kantovitz et al., 2006]. In a study by Larsson et al. [1995], the relationship between dental caries (DFS; decayed, filled surfaces) and risk factors for atherosclerosis in Swedish adolescents was evaluated. It found that adolescents with a high DFS score (≥ 9) had a significantly higher BMI and diastolic blood pressure than caries-free adolescents.

Relatively few studies of the relationship between overweight/obesity and dental caries have been published and a systematic review revealed contradictory results [Kantovitz et al., 2006]. Recently published studies have also reported conflicting results. A study by Bailleul-Forestier et al. [2007] assessed caries experience in an adolescent population being treated for severe obesity and found that there was a significant association between BMI and DMFT in the severely obese group. Furthermore, Hilgers et al. [2006] and Willerhausen et al. [2004, 2007a, b] reported an association between high weight and high caries frequency in children and adolescents, while Macek & Mitola [2006], Pinto et al. [2007] and Kopycka-Kedzierawski et al. [2008] found no significant association between weight and caries. In most of these studies, dental caries recordings were performed by oral examination and diagnosed at cavity level. Only one study diagnosed approximal caries including initial caries lesions using bitewing radiographs [Hilgers et al., 2006]. Recent studies of the relationship between overweight/obesity and dental caries are presented in Table 1. Further studies are needed to evaluate a possible relationship between caries (including approximal initial caries lesions) and overweight/obesity.

Table 1. Studies on the relationship between dental caries and BMI

First author	Year	Study design	Age, years	BMI	Method of caries diagnosis	Association between BMI and caries
Bailleul-Forestier	2007	CS	12-18	BMI for age IOTF	Oral examination DMFT	Association between BMI and DMFT
Chen	1998	CS	3	> 95th percentile	Oral examination dft	No association between BMI and dft
Dye	2004	CS	2-5	≥ 85th percentile adjusted for age and gender	Oral examination dfs	No association between BMI and dfs
Hilgers	2006	CS	8-11	BMI for age IOTF	Bitewing radiographs (including initial carious lesions)	Association between BMI and approximal caries in permanent molars
Kantovitz	2006	Systematic review	3- ≥ 65	Mainly ≥ 85th percentile for age and gender	Various	Contradictory results
Kopycka-Kedzierawski	2008	CS	2-18	≥ 85th percentile	Data from NHANES III 1988-1994 and NHANES 1999-2002 dft/DMFT	No evidence that overweight children run an increased risk of dental caries
Larsson	1995	CS	15	> 90th percentile	Oral examination and bitewing radiographs DFS	Positive correlation between BMI and DFS
Macek and Mitola	2006	CS	2-17	≥ 85th percentile	Data from NHANES 1999-2002 dft/DMFT	No association between weight and caries
Moreira	2006	CS	12-15	Growth standards for age and gender*	DMFT	No association between dental caries and obesity
Pinto	2007	CS	Mean age 8.7	BMI percentile/age and gender adjusted scales	Oral examination ds/DS	No correlation between dental decay in obese and non-obese children
Tuomi	1989	CS/RS	5-13	> 97.5%	Local centre health files	Obesity does not predict caries
Willershausen	2004	CS	6-11	BMI for age IOTF	Oral examination dft/DFT	Association between BMI and dft/DFT
Willershausen	2007	CS	6-11	BMI for age IOTF	Oral examination dft/DFT	Association between BMI and dft/DFT
Willershausen	2007	CS	6-11	BMI for age IOTF	Oral examination dft/DFT	Association between caries frequency and BMI

NHANES: National Health and Nutrition Examination Surveys.
IOTF: International Obesity Task Force.
*National Center for Health Statistics growth charts: Monthly Vital Statistics Report, National Center for Health Statistics 1976;25.
CS = Cross sectional.
RS = Retrospective study.

Aims

The overall aim of this thesis was to collect knowledge and provide a foundation for caries prevention and dental health care planning during a period from childhood to adolescence. In more detail, the aims of this thesis were:

- To investigate the approximal caries prevalence in the posterior teeth in 15-year-old adolescents followed from 1 year of age
- To study past caries experience in the primary dentition in relation to future caries development and treatment needs
- To investigate factors during early childhood associated with caries development and dental health later in life
- To study the association between age-specific body mass index (isoBMI) and approximal caries status in 15-year-old teenagers

Material and Methods

The material in the present thesis is based on two parts (Table 2). Part 1 (Paper I) was performed in the County of Jönköping and Part 2 (Papers II, III, IV) in the Municipality of Jönköping. The children from both populations were born in 1987, which means that some children from the Municipality of Jönköping participated in both studies.

The study protocols were approved by the Ethics Committee at the University of Linköping. In addition, informed consent for their children's participation was obtained from the parents when the children were 1 and 3 years of age.

Table 2. The thesis is based on the following studies

	Paper	Focus of interest	Age group (years)	Year of birth	Sample
Part 1	I	Dental treatment in the late primary dentition in relation to caries experience at 6 years	6-12	1987	Randomly selected sample in the County of Jönköping
Part 2	II	Approximal caries prevalence at 15 years in relation to childhood caries	3, 6, 15	1987	Unselected, longitudinal followed sample in the Municipality of Jönköping
	III	Early childhood factors in relation to approximal caries at 15 years	1, 3, 15	1987	Unselected, longitudinal followed sample in the Municipality of Jönköping
	IV	isoBMI in adolescents and early childhood snacking habits in relation to approximal caries at 15 years	1, 3, 15	1987	Unselected, longitudinal followed sample in the Municipality of Jönköping

Study design (Part 1)

This study has a retrospective design and the analyses were based on record data from a randomly selected sample in the County of Jönköping. The study was planned in 2000 and the data were collected in 2001.

Study population (Part 1)

This study was conducted in the County of Jönköping, which has approximately 333,000 inhabitants. The registers from the Public Dental Service (PDS) clinics (n = 36) in Jönköping County were used randomly to select 10% of all the children (n = 433) born in 1987. Of these, 381 had been treated annually at the PDS clinics in the county between 6 and 12 years of age and were thus included in the investigation. The main reason for non-inclusion was that the child had moved into or out of Jönköping County during the study period and had thus not been examined regularly throughout the 6-year period. Other reasons were lack of epidemiological data at 6 years of age or treatment at private clinics.

Methods (Part 1)

The records, including radiographs, were collected from each of the clinics in the county. Epidemiological data at 6 years of age and number of dental treatments between 7 and 12 years of age were extracted and entered on a form designed for data processing. The following data relating to the primary canines and molars were collected from the records:

- Decayed, extracted, and filled surfaces (defs) at 6 years of age. Only caries lesions involving the dentine (manifest caries lesions) were included
- Number of dental treatments between 7 and 12 years of age

When it came to the treatments, the following information was collected:

- New restorations
- Replacement of restorations
- Other treatments, such as extraction or disking

The restorations were registered regardless of whether they involved one surface (Class I and V) or two or more surfaces (Class II). Record information regarding clinical examination, preventive dental care and behaviour-shaping procedures was not registered because of difficulty distinguishing whether these treatments related to the primary or permanent dentition. Furthermore, extractions for orthodontic reasons were excluded.

Study design (Part 2)

The present study has a prospective longitudinal and cross-sectional design. The children have been followed from 1 to 15 years of age. The study was planned in 2003 and the data were collected in 2004.

Study population (Part 2)

This radiographic study of 15-year-old teenagers was conducted in the Municipality of Jönköping, which had 122,000 inhabitants in 2007. Jönköping is an administrative centre for the County of Jönköping, as well as a centre for education, transportation, industry and commerce. These 15-year-old teenagers have been followed longitudinally from 1 year of age. All children (n = 671) who were 1 year of age in 1988 and living within the districts of four of the thirteen child welfare centres in the Municipality of Jönköping were invited to participate [Wendt et al., 1991, 1992, 1999]. The four districts included towns, suburbs and rural areas and were chosen to reflect the socio-economic levels of the population living in this part of Sweden.

The parents were informed by letter about the purpose of the study and, before the start of the study, informed consent was obtained from the parents. They were also informed that they could leave the study whenever they wanted. The total number of invited children was 671, which was about half of all the 1-year-olds living in the Municipality of Jönköping. The children underwent clinical examinations (by the same dentist) at 1, 3 and 6 years of age. The prevalence of caries, including initial caries, was diagnosed by clinical examinations and also radiographically if approximal contacts existed in primary molars. In all, 632 children (94%), 319 boys and 313 girls, were examined at 1 year of age. The response rate at 3 and 6 years of age was 94% and 86% respectively.

From the age of 1 year, the children had followed the regular dental care programme for the County of Jönköping, including dental check-ups and special preventive care for children at risk of developing caries lesions. Furthermore, the majority of all caries-free permanent molars were fissure sealed as soon as possible after eruption.

At 15 years of age (in 2002), the adolescents were treated at 10 different PDS clinics in the Municipality of Jönköping, where dental examinations including bitewing

radiographs were carried out by the children's ordinary dentist. These radiographs were collected and analysed for the present study (see radiographic analyses below).

Of the original population (671 individuals), 17 adolescents were treated in private practice, two had died, 74 had moved from the municipality and 10 were excluded for technical reasons. The number of dropouts between 1 and 15 years of age totalled 103. As a result, 568 children, 282 boys and 286 girls, were finally included in the study. Due to movements in and out of the municipality or failure to attend during the period from 1 to 15 years of age, some of the children were unable to take part in all the examinations (Table 3, Fig. 1).

Table 3. Number of children in different analyses and papers (Part 2)

Examination	Number of subjects	Paper
15 years	568	II, III
1 and 15 years	539	III
3 and 15 years	555	II, III
3, 6 and 15 years	514	II
15 years and isoBMI values	402	IV

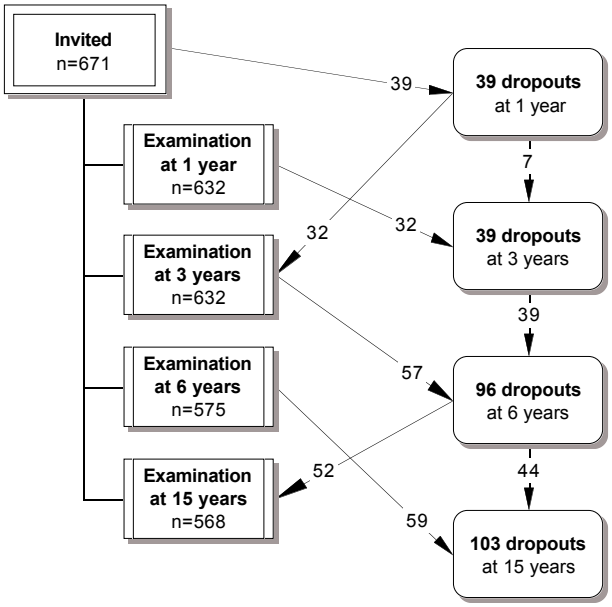

Fig. 1. Distribution of the population from 1 to 15 years of age (Part 2).

Methods (Part 2)

The data for the present study were selected from examinations at 1, 3, 6 and 15 years of age, interviews at 1 and 3 years, questionnaires at 1 year and school health care records (isoBMI) at 15 years (Table 4).

Table 4. Design of Part 2

Paper	Examination				Interview		Questionnaire	isoBMI values
	1 yr	3 yrs	6 yrs	15 yrs	1 yr	3 yrs	1 yr	15 yrs
II		X	X	X				
III	X	X		X	X	X	X	
IV				X	X	X		X

Radiographic analysis at 15 years of age

The bitewing radiographs were analysed by one dentist (the principal investigator, A.A.). The films were examined using a magnifying viewer [Mattsson, 1953] and light desk. The approximal surfaces from the distal surface of the first premolar to the mesial surface of the second molar (a total of 24 surfaces) were evaluated. If no posterior bitewings were available or if they were not readable (for example, due to fixed orthodontic treatment) at 15 years of age (21%), the bitewings from 14 years of age (10%) or from 16 years of age (11%) were used for analyses. There were no significant differences in caries prevalence between radiographs taken at 15 years of age compared with radiographs taken at 14 and 16 years of age.

Before the start of the study, the examiner was calibrated to a specialist at the Department of Oral Radiology, Skövde, Sweden, for reading sound and caries tooth surfaces. In order to calculate intra-examiner reproducibility, 10% of the radiographs were analysed twice with an interval of two months. The intra-examiner agreement produced Cohen's kappa values of 0.95.

Caries was registered on approximal tooth surfaces as initial or manifest caries according to the National Board of Health and Welfare [Socialstyrelsen, 1988] as follows:

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

Groups at 15 years of age

According to the caries experience at 15 years of age, the children were stratified into the following four groups according to total approximal caries prevalence and fillings, (D_{i+m}Fa = DFa): 1) DFa = 0, 2) DFa > 0, 3) DFa ≥ 4 and 4) DFa ≥ 8. It should be noted that the DFa ≥ 4 and DFa ≥ 8 groups are subgroups of the DFa > 0 group.

Body adiposity status

Data concerning the weight and height of the 568 adolescents were obtained from school health care records when the teenagers were 13.5 to 16.4 years of age. Information was not available for 166 teenagers owing to: 1) no data available in the records (n = 120), 2) the teenagers did not want to check their weight (n = 24) and 3) computer broke down (n = 22). As a result, 402 teenagers were finally included in the analyses of body mass index in relation to approximal caries. Body adiposity status was determined by calculating BMI (kg/m^2) using the international classification system for childhood obesity (isoBMI) recommended by the International Obesity Task Force cut-off values [Cole et al., 2000]. The teenagers were divided into four groups according to this classification system: 1) low-normal weight (isoBMI < 25), 2) overweight (isoBMI 25-29.9), 3) obesity (isoBMI ≥ 30) and, 4) overweight/obesity (isoBMI ≥ 25).

Data from examinations at 1, 3 and 6 years of age

All erupted tooth surfaces were examined for initial and manifest caries at 3 years of age. At 6 years of age, caries (initial and manifest) recorded on all surfaces of the primary molars and cuspids was used in the analyses. Dental plaque at 1 year of age was registered when plaque was visible on the buccal surfaces of the maxillary incisors and scored as: 1) no visible plaque and 2) visible plaque (on one, some or all tooth surfaces).

Oral hygiene at 3 years of age was registered according to the criteria suggested by Schröder and Granath, [1983] as: 1) good (clean teeth with practically no plaque), 2) intermediate (gingivitis without bleeding on the lingual surfaces of the mandibular molars and on the buccal surfaces of the maxillary molars) and 3) poor (thick plaque covering large areas of the buccal and the lingual surfaces, brushing leads to bleeding).

Groups at 3 years of age

At 3 years of age, the children were divided into three groups as follows: 1) caries-free group (children free from initial and manifest caries), 2) initial caries group (children with initial caries but without manifest caries) and 3) manifest caries group (children with manifest caries lesions or fillings)

In the longitudinal comparison between 3, 6 and 15 years of age, the children were divided into three subgroups according to the age of caries debut and caries experience as follows: 1) early childhood caries (children with caries development before 3 years of age), 2) late childhood caries (children with caries development between 3 and 6 years of age) and 3) caries-free childhood (children caries free at 3 and 6 years of age).

Data from Interviews at 1 and 3 years of age

As an integral part of the examination at 1 and 3 years of age, the accompanying parent was interviewed by the same person who performed the clinical examination. Interpreter assistance was offered when necessary. Using a semi-structured form, the parent was asked questions about the normal oral hygiene frequency, use of fluoride toothpaste and dietary habits (intake frequency of caries-risk products) during the last year. In addition, the parents were asked about country of birth. The questions are presented in the appendix.

Questionnaires at 1 year of age

Both parents answered a questionnaire in conjunction with the examination at 1 year of age. The response rate for the 539 children who were examined at 1 and 15 years of age was 81% (based on whether mother, father or both parents had answered the questionnaire). The questionnaire contained a series of questions and covered several topics, such as psychosocial, socio-economic, behavioural and attitudinal factors. Socio-economic status and behavioural factors were described in terms of the parents' civil

status, age, educational level, social situation and responsibility for the child in the family. Attitudes to dental care were described in terms of "self-estimation of oral health care". The questions are presented in the appendix.

Dropouts

There was a significant difference in mean manifest caries prevalence at 3 years of age between the 555 children examined at both 3 and 15 years of age and the 77 children who dropped out between 3 and 15 years of age and were thus not examined at 15 years of age (0.65 ± 2.88 vs. 2.23 ± 5.97; $p < 0.05$; Paper II).

At 15 years of age, there was a difference, albeit not significant, in mean D_mFa for the 74 children with early childhood caries examined at 3, 6 and 15 years and the 7 children with early childhood caries who had moved and were therefore not examined at 6 years of age but had moved back and were examined at 15 years of age (1.02 ± 1.77 vs. 3.86 ± 3.72; Paper II).

The 20 children who failed to attend the examination at 1 year of age had a mean DFa of 6.95 ± 5.36 at 15 years of age compared with 3.13 ± 3.87 for children who were examined at 1 year of age ($p < 0.01$; Paper III).

When it came to non-respondents to the socio-economic questionnaire, there was no statistically significant difference in caries experience (DFa) at 15 years of age among adolescents whose parents had answered (n = 439) the questionnaire compared with those who had not (n = 100); the mean ± SD in these two groups was 3.01 ± 3.64 and 3.64 ± 4.41, respectively (Paper III).

The 24 teenagers who did not want to check their weight had a mean of 3.67 ± 4.39 $D_{i+m}Fa$ and 0.75 ± 1.70 D_mFa compared with 3.21 ± 3.95 $D_{i+m}Fa$ and 0.42 ± 1.13 D_mFa for the 402 teenagers who had checked their weight at 15 years of age. These differences were not statistically significant (Paper IV).

Statistical methods

All the analyses were performed using the Statistical Package for Social Science (SPSS, versions 2.0 and 12.0 for Windows). Descriptive methods were used to describe the population and different subgroups: mean, standard deviation (SD), range and median. In the different studies and papers, various statistical methods were used to measure

differences between groups: for non-parametric data, the Mann-Whitney U-test and, for parametric data, an unpaired two-sample t-test and Analyses of Variance (ANOVA) with Scheffé's test (for multiple comparisons). Differences between proportions in different groups were tested using approximate normal distribution with continuity correction.

Univariate and stepwise multivariate logistic regression models were constructed in Part 2. Several possible caries risk indicators were tested in the univariate analyses. Only univariate statistically significant caries "risk indicators" were allowed to enter the multivariate models, in which corrections for gender were also included. Odds ratios (OR) with 95% confidence intervals (95% CI) were the outcomes presented. The stepwise logistic regression analyses were performed in order to compare caries-free teenagers, DFa = 0, and teenagers with DFa > 0, DFa ≥ 4 and DFa ≥ 8, respectively.

Cohen's kappa was calculated in order to test intra-examiner reproducibility after re-analysing bitewing radiographs.

The term "positive odds ratio" (POR) [Ejlertsson et al., 2002] has been used in the discussion in the thesis in order to predict health (i.e. remaining caries free at 15 years of age). A logistic regression analysis was carried out in order to calculate the probability (POR) of remaining approximally caries free at 15 years, compared with the probability of having approximal manifest caries at this age, for caries-free children at 3 years of age compared with children with manifest caries at 3 years.

In all the analyses, the level of statistical significance was set at 5 per cent.

Results

Approximal caries at 15 years of age (Paper II)

Of the 568 adolescents examined at 15 years of age, 67% (n = 381) had approximal initial and manifest caries lesions or fillings ($D_{i+m}Fa$) in their molars and premolars, 22% (n = 123) had approximal manifest caries lesions or fillings (D_mFa) and 66% (n = 375) had approximal initial caries lesions (D_ia). The mean number of D_ia, D_mFa and $D_{i+m}Fa$ was 2.78 ± 3.37, 0.45 ± 1.20 and 3.23 ± 3.98, respectively. Initial caries lesions (D_ia) constituted 86% of the total caries experience ($D_{i+m}Fa$). About 33% (n = 189) had 4 or more initial and manifest carious lesion or fillings ($D_{i+m}Fa$) and 14% (n = 79) had 8 or more initial and manifest carious lesions or fillings ($D_{i+m}Fa$). Ten per cent of the 15-year-olds had 74% of all the approximal manifest caries lesions and 38% of all the approximal initial caries lesions.

Caries development and treatment needs in relation to past caries experience (Papers I and II)

Approximal caries in the permanent dentition at 15 years of age in relation to caries experience in the primary dentition at 3 years of age. Children with manifest caries at 3 years of age (n = 81) had a mean of 1.27 ± 2.13 manifest caries lesions and fillings (D_mFa) and 5.94 ± 5.52 initial and manifest caries lesions and fillings ($D_{i+m}Fa$) at 15 years of age compared with 0.25 ± 0.67 and 2.52 ± 3.18, respectively for children who were caries free (n = 408) at the same age ($p < 0.001$ for both comparisons; Table 1, Paper II).

About 41% of the children with manifest caries experience in their primary teeth at 3 years of age developed approximal manifest caries in their permanent posterior teeth compared with 17% of the children who were caries free at the same age ($p < 0.001$). Furthermore, children who were caries free at 3 years of age more frequently remained caries free at 15 years of age compared with children with manifest caries at 3 years of age (37 vs. 17%; $p < 0.001$, Fig. 2, Paper II).

Approximal caries in the permanent dentition at 15 years of age in relation to caries experience in the primary dentition at 3 and 6 years of age. About 39% of the children with early childhood caries (children with caries development before 3 years) had manifest caries experience at 15 years of age compared with 27 and 12% for children with late childhood caries (children with caries development between 3 and 6 years) and children who were caries free during childhood, respectively. At 15 years of age, the mean number of initial and manifest approximal caries and fillings ($D_{i+m}Fa$) was 5.65 ± 5.21, 3.82 ± 4.01 and 2.0 ± 2.65 for children with early childhood caries, children with late childhood caries and children who were caries free during pre-school years, respectively. These differences were statistically significant (Table 5).

Table 5. Mean (SD) number of initial and manifest approximal caries lesions and fillings at 15 years of age, distributed according to the caries experience at 3 and 6 years of age

	Caries experience at 3 and 6 years of age					
	Early childhood caries (children with manifest caries at 3 years)		Late childhood caries (children caries free at 3 and manifest caries at 6 years)		Caries-free childhood (children caries free at 3 and 6 years)	
	n=74		n=149		n=291	
Caries experience	Mean	SD	Mean	SD	Mean	SD
15 years $D_{i+m}Fa$	5.65	5.21	3.82	4.01	2.0	2.65
15 years D_mFa	1.02	1.77	0.44	0.94	0.15	0.44

Early vs. late childhood caries, $p < 0.01$ for $D_{i+m}Fa$ and $p < 0.001$ for D_mFa.
Early childhood caries vs. caries-free, $p < 0.001$ for $D_{i+m}Fa$ and D_mFa.
Late childhood caries vs. caries-free, $p < 0.001$ for $D_{i+m}Fa$ and $p < 0.01$ for D_mFa.
ANOVA with Sheffé for multiple comparisons

Treatment needs in the late primary dentition in relation to caries experience at 6 years. Children with caries experience at 6 years of age required a mean of 3.5 times more treatment between 7 and 12 years of age compared with caries-free children (4.2 vs. 1.2). The median number of treatments was 3.0 and 0.0 respectively ($p < 0.001$). Of the children who had been caries free (def-s tot = 0) at 6 years of age, 34% (n = 73) underwent treatment in the primary dentition during the period compared with 87% (n =

144) of the children with caries experience (def-s tot > 0) at 6 years of age (Fig. 2, Paper I).

Replacements of restorations were frequently performed in the primary dentition between 7 and 12 years of age among children with previous caries experience. In caries-free children (def-s tot = 0), 0.1 of 0.7 Class-II restorations were replacements compared with 0.7 of 2.3 in children with previous caries experience (def-s tot > 0). In children with 4 or more proximal def-s, 2.1 of 3.8 Class-II restorations were replacements (Fig. 2 and Fig. 4, Paper I).

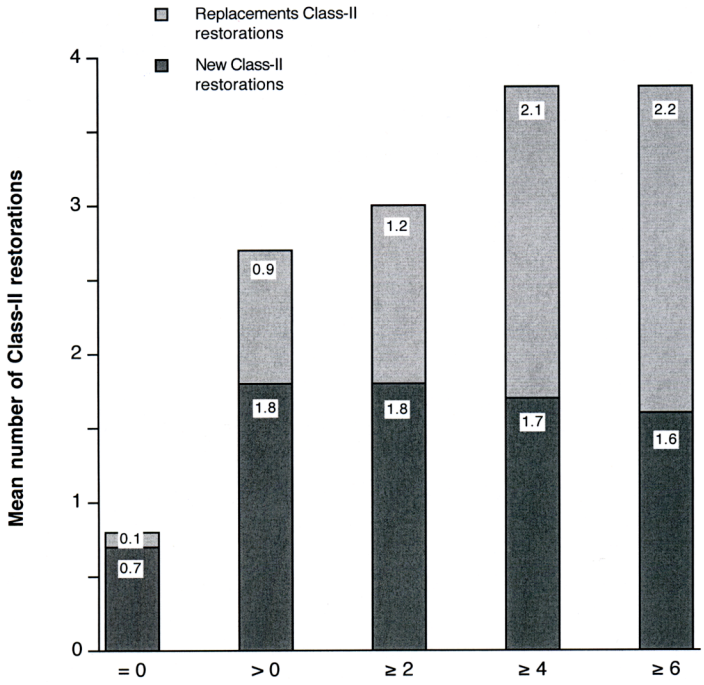

Fig. 2. Mean number of Class-II restorations including replacements performed between 7 and 12 years in relation to approximal def-s at 6 years of age.

Caries-promoting factors (Papers II and III)

Plaque. Univariate logistic regression analyses were carried out to identify the predictor variables. Comparisons were made between caries-free teenagers and teenagers with different caries experience, i.e. DFa > 0, DFa ≥ 4 and DFa ≥ 8 respectively (Table 3, Paper III). The variables "plaque on maxillary incisors at 1 year of age" and "poor oral hygiene at 3 years" were significantly associated in all the analyses. In the analyses of

DFa ≥ 4 and DFa ≥ 8, the variable "intermediate oral hygiene at 3 years" was also significantly associated with caries.

Plaque on maxillary incisors at 1 year remained significant in the final multivariate logistic regression analysis and strongly predicted caries at 15 years of age for DFa ≥ 4 (Table 5, Paper III).

Snacking habits. Snacking habits in early childhood were significantly associated with caries experience at 15 years of age. Children who consumed caries-risk products more than three times a day at 1 year of age had significantly more caries ($D_{i+m}Fa$) at 15 years of age than children who consumed caries-risk products 3 times a day or less (5.35 ± 5.35 vs. 2.98 ± 3.70; $p < 0.05$). Children who consumed sweets more than once a week at 3 years of age had a higher caries experience ($D_{i+m}Fa$) at 15 years of age compared with children who ate sweets once a week or less (3.66 ± 4.37 vs. 2.64 ± 3.34; $p < 0.05$; Table 3, Paper IV).

Caries-risk indicators (Paper III)

Psychosocial and socio-economic factors. Univariate logistic regression analyses were carried out to identify the predictor variables. Comparisons were made between caries-free teenagers and teenagers with different caries experience, i.e. DFa > 0, DFa ≥ 4 and DFa ≥ 8, respectively (Table 4, Paper III). The variables "mother who was a single parent when the child was 1 year old", "mother's self-estimation of her oral health care being less good to poor" and "both parents born abroad" were significant in all analyses. In the analyses of DFa ≥ 4, the following variables were also significantly associated with caries: "father's self-estimation of his oral health care being less good to poor" and "father less satisfied with his social situation". In the analyses of DFa ≥ 8, the following variables were significantly associated with caries as well: "father less satisfied with his social situation" and "mother answering that she was the only person in the family with responsibility for the child". In the final multivariate logistic regression analyses, the following variable remained statistically significant and predicted caries in all the analyses: "mother's estimation of her own oral health care as being less good to poor". In the analyses of DFa ≥ 4, the variable "father less satisfied with his social situation" also remained significant (Table 5, Paper III).

There was a significant difference in caries prevalence (DFa) at 15 years of age between the group in which both parents were born abroad compared with the group in

which both parents were born in Sweden (Table 6). In the high-risk group (DFa ≥ 8), 27% of the teenagers whose parents were born abroad belonged to the high-risk group (DFa ≥ 8) at 15 years compared with 12% in teenagers whose parents were born in Sweden (Table 2, Paper III).

Children who failed to attend the examination at 1 year had a significantly higher caries experience at 15 years of age compared with children who participated at 1 year of age (Table 6). About 40% of the children who failed to attend the examination at 1 year belonged to the high-risk group (DFa ≥ 8) at 15 years compared with 13% for children who were examined at 1 year (Table 2, Paper III).

Table 6. Mean (SD) approximal caries experience (DFa) in 15-year-olds

Groups	Number of children	DFa	
		Mean	SD
All	568	3.23	3.98
Male	282	2.99	3.89
Female	286	3.48	4.05
Examined at 1 and 15 years	539	3.13	3.87
Failed to attend at 1 year, examined at 15 years	20	6.95	5.36
Both parents born in Sweden	449	2.93	3.74
Both parents born abroad	49	4.76	4.83

An unpaired two-sample t test was used to test differences in mean DFa between groups.
Children examined at 1 and 15 years vs. children who failed to attend at 1 year; $p < 0.01$
Both parents born in Sweden vs. both parents born abroad; $p < 0.05$

Caries-inhibiting factors (Paper III)

Oral hygiene. Good oral hygiene and toothbrushing twice a day at an early age were factors associated with good dental health at 15 years of age. Univariate logistic regression analyses were carried out to identify the predictor variables. Comparisons were made between caries-free teenagers and teenagers with different caries experience, i.e. DFa > 0, DFa ≥ 4 and DFa ≥ 8, respectively, (Table 3, Paper III). Less frequent toothbrushing was significantly associated with "presence of caries" in most of the analyses, except for the variable toothbrushing sometimes/never at 3 years of age for DFa > 0 and DFa ≥ 4. In the analyses of DFa ≥ 4 and DFa ≥ 8, the following variables were also significantly associated with caries: use of fluoride toothpaste once a day and

sometimes/never versus twice a day or more at 3 years of age. Less frequent toothbrushing with fluoride toothpaste (once a day or less) at 3 years remained significant in the final multivariate logistic regression analysis and strongly predicted caries at 15 years of age for DFa ≥ 8.

Relationship between age-specific body mass index (isoBMI) and approximal caries in teenagers (Paper IV)

Adolescents with overweight and obesity (isoBMI ≥ 25; n=64) had a significantly higher approximal caries experience ($D_{i+m}Fa$) than low-normal weight individuals (isoBMI < 25; n = 338); the mean ± SD in these two groups was 4.64 ± 5.15 vs. 2.94 ± 3.62 ($p < 0.05$). Individuals with obesity (isoBMI ≥ 30; n=14) had more than twice as many approximal caries lesions and fillings compared with low-normal weight individuals (isoBMI < 25); the mean ± SD in these two groups was 6.29 ± 5.04 vs. 2.94 ± 3.62 ($p < 0.05$; Fig. 3). In the "high caries experience group" ($D_{i+m}Fa \geq 8$), 30% of the adolescents were overweight/obese (isoBMI ≥ 25) and 11% were obese (isoBMI ≥ 30) compared with 15% and 2% in the caries-free group ($D_{i+m}Fa = 0$), respectively ($p < 0.05$ for both comparisons).

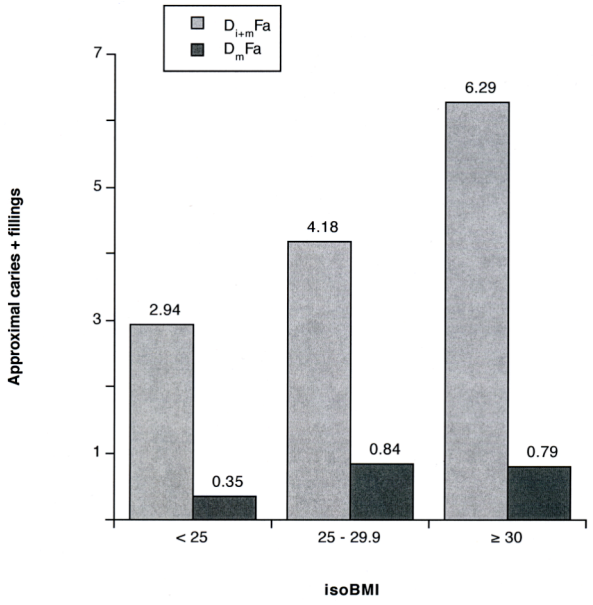

Fig. 3. Distribution of mean numbers of approximal (a), initial (i), and manifest (m) caries lesions and fillings ($D_{i+m}Fa$ and D_mFa) at 15 years of age distributed according to age-specific body mass index (isoBMI).

Discussion

The main findings in the present thesis were that there was a strong relationship between caries in early childhood and approximal caries prevalence in the posterior teeth at 15 years of age. Furthermore, good oral hygiene habits, including the use of fluoride toothpaste, established in early childhood, provide a foundation for a low prevalence of approximal caries in adolescence. In addition, the psychosocial environment in which children live during their childhood could influence dental health later in life. Moreover, it was found that adolescents with overweight and obesity have a higher approximal caries prevalence than normal-weight adolescents.

Methodological considerations

The material in the present thesis is based on two populations, one from the County of Jönköping and one from the Municipality of Jönköping. The children from both populations were born in 1987. Some children from the Municipality of Jönköping participated in both studies.

Part 1. One weakness in this study is that bitewing radiographs were lacking for about 10% of the children at 6 years of age, which means that the number of children with caries experience at that age could have been higher. This might explain the unexpected need for treatment among some of the children classified as caries free at 6 years of age (Fig. 2, Paper I). It could be argued that many different dentists were involved in the treatment decision process. However, the purpose was to register the amount of treatment performed and not to have a standpoint about the diagnosis and dental care. The study is based on analyses of records of the children and the reading was performed by the principal investigator (A.A.).

Part 2. A retrospective study has potential problems. First of all, it could be difficult to collect the dental records and bitewing radiographs from several different PDS clinics in the municipality. Considering that this is an unselected population followed from 1 to 15 years of age, the number of drop-outs, 103 of 671, must be regarded as an acceptable

range. The time span of 14 years and adequate methods for data collection in this longitudinally followed population make this study unique.

One limitation of the present study is that it is a radiographic study and that the caries situation was only recorded on the approximal tooth surfaces of premolars and molars. It is possible that the exclusion of caries diagnosis on the occlusal surfaces might affect the outcome and conclusions of this study. However, the children in the present study generally had fissure sealants applied to all permanent molars as soon as possible after eruption [Wendt et al., 2001b]. The caries prevalence on the occlusal surfaces was therefore very low and, consequently, approximal caries might be the main problem for the 15-year-olds in the present thesis. All the bitewing radiographs were examined by one person (the principal investigator, A.A.) and the intra-examiner re-test produced high agreement (Cohen's kappa values of 0.95).

Recently, Bratthall [2000] presented the so-called Significant Caries Index (SiC Index), which means that one third of the population with the highest caries scores should be analysed separately (as a risk group). In the present study, the DFa ≥ 4 group corresponds to one third of the population and is thus in line with the SiC Index. In Scandinavia, the 10-15% of the population with the highest caries scores are usually regarded as a "risk group". This corresponds to DFa ≥ 8 in the present study and represents 14% of the population. These cut-off points were therefore used in the present study.

The response rate is often discussed when questionnaires are used in studies. According to Bryman [2002], a response rate of 85% should be regarded as "excellent", 70-85% as "good", and 60-70% as "acceptable". Consequently, the response rate of 81% for the 539 children examined at 1 and 15 years of age and whose parents answered the questionnaire when the children were 1 year of age was on a "good" level (based on whether the mother, the father, or both parents had answered the questionnaire). The separate response rate for the mothers and fathers was 74% and 70%, respectively. Non-responders were not believed to have affected the results as there were no statistically significant differences in caries experience among adolescents whose parents had answered the socio-economic questionnaire compared with those who did not answer. From a general standpoint, questionnaires are useful in biomedical research and provide support for the long-term effects of health behaviour and psychosocial risk factors on poor self-ratings of health [Svedberg et al., 2006].

In epidemiological caries studies, means are most often used to describe the distribution of the caries disease, since these values provide more useful information about caries experience in different groups. Subsequently, means were also chosen in these studies and t-tests and ANOVA were therefore used in the analyses.

According to the "salutogenic theory" presented by Antonovsky [1987], more attention should be focused on children and adolescents who maintain good dental health. Ejlertsson et al. [2002] presented the so-called "Positive Odds Ratio" (POR) in order to predict health. The POR was calculated to test the probability of remaining caries free (i.e. to predict health) at 15 years of age. This method was used in the present thesis. The probability of remaining approximally caries free at 15 years of age compared with the probability of having approximal manifest caries at this age (POR) was 5.1 (95% CI 2.6-10.2; $p < 0.001$) for caries-free children at 3 years of age compared with children with manifest caries at 3 years.

Caries prevalence in teenagers

In Paper II, it was found that two thirds of all 15-year-olds had approximal caries lesions/fillings and that approximal initial caries lesions at 15 years of age constituted 86% of the total number of approximal caries lesions. This is in accordance with recent studies by Moberg Sköld et al. [2005a; b], showing that more than 90% of the new approximal lesions between 13 and 16 years of age consisted of initial caries lesions. Furthermore, Gustafsson et al. [2000] found that 86% of the total number of approximal caries lesions among Swedish 16-year-olds were enamel lesions. In the Västerhaninge study [Mejàre et al., 1998], the mean number of approximal enamel lesions for 16-year-olds was 6.1 ± 4.6 compared with 1.4 ± 2.6 for approximal dentine lesions, indicating that 81% of all caries lesions on the approximal surfaces were initial lesions.

In the present study, the mean number of total approximal caries experiences ($D_{i+m}Fa$) in the posterior teeth was 3.2 for the 15-year-olds. This is in accordance with a recently performed study in Jönköping, Sweden [Hugoson et al., 2008], which showed that the mean number of total proximal DFS was 3.0 (initial caries lesions included) among 15-year-olds. In all these studies, initial caries lesions were included, as different from Swedish reports by the National Board of Health and Welfare, which only report manifest caries lesions and fillings [Socialstyrelsen, 2006]. Including initial lesions in epidemiological studies is thus essential, as it is generally accepted that the arrest of

initial, non-cavitated caries lesions can occur [Raadal et al., 2001; Fejerskov et al., 2003].

In agreement with a study by Forsling et al. [1999], the present study showed that the distribution of caries was highly skewed on the manifest level, since 10% of the 15-year-olds had 74% of the approximal manifest caries lesions and fillings. However, initial caries lesions were more uniformly distributed. Although caries prevalence is declining in the official data, approximal caries lesions (initial and manifest) still remain a health problem for individuals and for public health care.

Sheiham and Fejerskov [2003] discussed population contra high-risk preventive strategies and pointed out that even a small decrease in the average level of a "risk factor" in the population may result in a considerable reduction in the incidence of a health problem. The fact that two thirds of all 15-year-olds have approximal caries experience and that initial caries lesions were more uniformly distributed in this group highlights the need for public interventions and a population-based preventive strategy in order to prevent the development and progression of caries lesion in a large group of teenagers.

Caries development and treatment needs in relation to past caries experience

Approximal caries in the permanent dentition at 15 years of age in relation to caries experience in the primary dentition at 3 and 6 years of age. In Paper II, a strong relationship was found between early childhood caries and caries development in the permanent posterior teeth up to mid-teenage. Similar results have previously been presented [Gray et al., 1991; Raadal & Espelid, 1992; Mejàre et al., 2001; Li & Wang, 2002; Vanderas et al., 2004; Skeie et al., 2006a]. The follow-up periods in these studies were between 2 and 8 years compared with 14 years in the present study. The findings in the present study also showed that early childhood caries experience had a greater predictive value than late childhood caries when it came to caries prevalence at 15 years of age. In a previous study of the same population, it was shown that the caries increment between 3 and 6 years of age was 5 times as high for children with manifest caries at 3 years compared with children who were caries free at the same age [Wendt et al., 1999]. So early childhood caries predicts not only further caries development in the primary dentition but also caries development in the young permanent dentition. These

findings highlight the importance of the early detection of caries disease in the primary dentition in order to avoid further caries development. Several studies have shown that preventive programmes in early childhood [Holm, 1979; Peyron et al., 1992; Gisselsson et al., 1994; Wendt et al., 2001a] and also during pregnancy [Gomez et al., 2007] are effective in preventing dental caries.

It is important to use the knowledge that prior caries experience is the best single predictor of future caries development among pre-school children, schoolchildren and adolescents [SBU, 2007]. Based on the present findings, it seems reasonable to conclude that individualised prevention at *an early age* should play an important role in paediatric dentistry and that the early prevention of the caries disease is the key to optimal oral health later in life.

Treatment needs in the late primary dentition in relation to caries experience at 6 years of age. Studies of caries experience and the need for treatment in the late primary dentition are sparse. However, a recent Norwegian study [Skeie et al., 2004] which followed children from 5 to 10 years of age found that the need for restorative treatment in the primary dentition during this period was considerable. During this time span, the approximal molars accounted for the largest increment. This is in line with the result from Paper I and a previous study from the same population [Alm et al., 2003], where it was shown that the need for treatment was extensive during the period from 7 to 12 years of age and that replacements, mainly Class-II restorations, were frequently performed in the primary dentition at these ages. Replacements in the primary dentition were also discussed in a study by Wendt et al. [1998], which found that 33% of the restorations had failed at least once in 8-year-old children.

Children with caries experience at 6 years of age required significantly more treatment in the primary dentition between 7 and 12 years of age than children who were caries free at 6 years. This is in accordance with a study by Holt [1995], which followed children from 5 to 9 years and found that new caries lesions were seen most often in children with previous disease experience. In addition, Skeie [2004] showed that one or more approximal lesions at 5 years were the strongest predictor of inclusion in a caries-risk group at 10 years. Studies have also shown that caries in the late primary dentition is associated with caries development in the permanent dentition [Mejàre et al., 2001, Leroy et al., 2005]. Consequently, Mejàre et al. [2001] found that the caries rate for the mesial surfaces of the first molar was dependent on the status of the distal

surface of the primary second molar and increased 15 times if this surface had caries in the enamel/enamel-dentine border compared with a sound distal surface. In addition, Leroy et al. [2005] studied cavity formation in the permanent first molars and found that it was clearly influenced by the status of the adjacent primary molars. These findings underline the importance of the early detection of caries in the primary dentition. The prevalence and activity of dental caries in the primary dentition after 6 years of age is so far not available in annual national reports. Further studies are recommended in order to evaluate caries prevalence and the need for treatment in the late primary dentition.

Caries-promoting factors and caries-risk indicators

As shown in Papers III and IV, the following factors in early childhood are associated with caries at 15 years of age: plaque, unfavourable snacking habits, psychosocial and socio-economic factors (including parents' attitude to dental care habits). These caries-promoting factors (plaque, snacking habits) and risk indicators (psychosocial and socio-economic factors) are discussed below.

Plaque. In Paper III, it was found that visible plaque on the maxillary incisors at 1 year of age and poor oral hygiene (i.e. thick plaque covering large areas of the buccal and lingual surfaces) at 3 years were associated with higher caries experience at 15 years of age. This is in accordance with a study by Mattila et al. [2005a], which showed that visible plaque on teeth at 3 years of age was significantly associated with poor dental health at 10 years of age. Furthermore, studies by Mattila et al. [1998] and Wendt et al. [1994] showed that plaque at an early age was associated with higher caries prevalence two years later. Dental professionals should use this knowledge and should already start to examine the maxillary primary incisors for visible plaque at 1 year of age. When plaque is present, the parents should be informed and instructed on how to brush their children's teeth.

Snacking habits. Paper IV confirmed that there is an association between the frequent consumption of caries-risk products during infancy and approximal caries at 15 years of age. This is in accordance with a previous long-term Finnish study by Mattila et al. [2001]. They reported that the daily intake of sweets at the age of 3 years was associated with caries increment between 7 and 10 years. Ruottinen et al. [2004] followed children's sucrose intake from infancy to 10 years of age and found that, once a high sucrose intake is adopted in early childhood, changes later in life are unlikely.

Furthermore, previous analyses of caries-related factors in the same population as in the present study showed that caries-associated dietary habits during infancy are maintained throughout early childhood [Wendt et al., 1996]. The result from Paper IV indicates that snacking habits that begin during early childhood might be maintained throughout adolescence.

The role of diet, especially the frequent consumption of fermentable carbohydrates, in the aetiology of dental caries is well established [Moynihan et al., 2003]. However, there are studies that have failed to demonstrate the relationship [Sundin, 1994]. One reason for the difficulty involved in showing a strong association is probably the frequent use of fluoride, which has changed the role of sugars [Duggal et al., 2001]. In modern society, sugar-containing products and beverages are easily accessible and consumption is extensive in many groups of children and adolescents. In a recent study from northern Sweden, caries-risk profiles in 2-year-old children were studied. The authors concluded that the sugar consumption was strikingly high and that daily help with toothbrushing was not a daily routine in 22% of the families [Stecksén-Blicks et al., 2007]. These findings highlight that, even today, patients with a high intake of caries-risk products and/or insufficient fluoride exposure need personal advice and recommendations related to the use of sugars, sweets, sweet juices and soft drinks from early childhood.

Psychosocial and socio-economic factors. It has been demonstrated that social, economic and environmental factors have a fundamental impact on oral health [Locker, 2000; Watt & Sheiham, 1999]. Furthermore, Newton and Bower [2005] have discussed the complexity of life social process and the causal networks between social structure and dental disease. The interaction between these factors could presumably explain why children who failed to attend the 1-year examination had significantly more filled and decayed surfaces at 15 years of age than those who attended (Paper III). This is in agreement with an earlier study from the same population, which showed that children who did not attend the examination at 1 or 2 years had significantly more caries at 3 years [Wendt et al., 1992]. A recent study by Foster et al. [2006] confirmed that children who did not attend their immediate follow-up appointment after dental treatment with general anaesthesia may be more likely to develop new caries lesions. Furthermore, Skaret et al. [1998b] have shown that teenagers with missed appointments had significantly higher mean DMFT compared with the rest of the group. In this

context, it could be important to discuss reasons for non-attendance. Studies have pointed out that dental fear and anxiety are common reasons for non-attendance for dental treatment and that painful treatment is one of the most commonly mentioned reasons for anxiety [Skaret et al., 1998a, 1999; Raadal et al., 2002]. One conceivable reason for the children's non-attendance at one year of age could therefore be the parents' dental fear and anxiety.

Moreover, a strong relationship between caries in childhood and the socio-economic status of the family has been demonstrated in western countries [Verrips et al, 1993; Gibson and Williams, 1999; Hjern et al., 2001]. This was also confirmed in the present study. The study by Hjern et al. [2001] revealed that there is considerable social inequality in oral health and the use of dental care in Swedish children. In the present study, it can be pointed out that there was a significant difference in caries prevalence at 3 years of age between the 555 children examined at both 3 and 15 years of age and the 77 children who dropped out (moved) between 3 and 15 years of age and were therefore not examined at 15 years of age. This is in line with Dong et al. [2005], who discussed childhood residential mobility and multiple health risks during adolescence.

In Paper III, it was found that the parents' immigrant background, especially when both parents were born abroad, was associated with a higher caries experience at 15 years of age. Even though these teenagers had lived in Sweden from early childhood and had received the same dental health education and treatment as those with Swedish-born parents, the cultural background factors still appear to have an effect on caries prevalence. An earlier study from the same population showed that the caries increment between 3 and 6 years of age was considerably higher in the "immigrant group" [Wendt et al., 1999]. Other Nordic studies have also reported a significantly higher caries prevalence and caries with an earlier onset in immigrants compared with non-immigrants [Wendt et al., 1992, 1999; Grindefjord et al., 1996; Sundby & Petersen, 2003; Skeie et al., 2006b]. There are different factors that could interact and affect this situation. The question of whether parental attitudes towards children's oral health are impacted by cultural and ethnic variety has been discussed [Adair et al., 2004; Skeie et al., 2006b]. Poor knowledge about the caries disease could be one explanation why dental care, especially in the primary dentition, is not always given priority. This is supported by an earlier study from the same population, which showed that parents born

in Sweden brushed their children's teeth more frequently and with an earlier onset than "immigrant parents" [Wendt et al., 1994].

Some other factors associated with a high caries prevalence at 15 years of age were "father not satisfied with his social situation", "mother who was a single parent when the child was 1 year old" and "the mother feeling that she was alone with the responsibility for the child in the family". This is in accordance with Freire et al. [2002], who reported a strong association between mothers' sense of coherence and their adolescent children's oral health. Furthermore, Skeie et al. [2006b] found that there was a relationship between a father who accompanied the child to the clinical examination and low caries prevalence in the child. This indicates that the family situation is important and that responsibility shared by both parents could have a positive impact on good oral health.

The factor "mother's estimation of her own oral health care as being poor" remained significant in the final multiple logistic regression and was strongly associated with a high caries prevalence at 15 years of age. These findings point to the fact that oral hygiene habits are transferred from parent to child and that parents constitute an important social model for their children, even at an age when the children are particularly open to other socialising factors. This is in accordance with a study by Åstrøm and Jakobsen [1996], which indicated that the toothbrushing habits of the parents and their adolescent offspring are significantly associated. Nicolau et al. [2007] discussed a life-course approach and stated that "the development of oral hygiene habits may be sensitive to the socioeconomic environment in which the people live during their childhood". As a result, extra attention at an early age should be paid to children and their families when the social situation is complicated.

Caries-inhibiting factors

Oral hygiene. As shown in Paper III, toothbrushing with fluoride toothpaste (twice a day or more) is important for the prevention of caries. Teenagers who were caries free were more likely to brush their teeth twice a day at 3 years of age compared with teenagers with caries experience. Furthermore, children from the same population as in the present study who were free from caries at 3 years of age had their teeth brushed more frequently at 1 and 2 years of age than children with caries [Wendt et al., 1994]. This is in accordance with other studies, showing that toothbrushing behaviour,

established during infancy, is often maintained during early childhood [Wendt et al., 1996; Grytten et al., 1988; Mattila, 1998] and even throughout adolescence into adulthood [Åstrøm & Jakobsen, 1998]. This is in line with a Cochrane report [Marinho et al., 2003], which concluded that, in the case of self-administered care, fluoride toothpaste is the most powerful intervention for caries prevention because of its high clinical effectiveness and social acceptability. The term "caries-inhibiting factors" or health factors is in line with the so-called "salutogenic theory", which was presented by Antonovsky [1987]. According to this model, more interest should be focused on good dental health habits in children and adolescents – in this context, by maintaining good oral hygiene habits, including the use of fluoride toothpaste from an early age.

Overweight and obesity in relation to caries prevalence

Paper IV shows that adolescents with overweight and obesity have a higher approximal caries prevalence (mainly initial caries) than normal-weight adolescents. Both dental caries and obesity are multifactorial diseases and have common "promoting factors" that increase the likelihood of both diseases [Bawa, 2005]. For example, both diseases are related to dietary habits [Marshall et al., 2003] and to lower economic status [Wennhall et al., 2002; Lobstein and Frelut, 2003; Blomquist and Bergström, 2007]. In a recently preformed study, Marshall et al. [2007] found that caries and obesity co-exist in children of low socio-economic status. Obesity develops when energy intake exceeds expenditure for a considerable time. Several characteristics in today's society are contributing to the widespread childhood obesity problem. Changes in the environment that are promoting a sedentary lifestyle and a high consumption of energy-dense foods and drinks have resulted in a larger number of children becoming obese [Blomquist and Bergström, 2007].

In the present study, 24 teenagers did not want to check their weight. One reason for this could be that they had a higher isoBMI. Consequently, these 24 teenagers were analysed separately in relation to approximal caries experience. The teenagers who had not wanted to check their weight had somewhat higher caries experience values than the study group, even if they were not significant. Other studies have shown that non-participation is associated with deprivation of health. For example, Mårild et al. [2004] studied the correlation between parental and child body mass index and found that the

prevalence of obesity or being overweight appeared to be higher in children whose parents did not participate in the study.

Recent studies have also identified an association between dental caries and obesity in childhood/adolescence and have suggested that obese children run an increased risk of caries development [Hilgers et al., 2006; Bailleul-Forestier et al., 2007; Willerhausen et al., 2007a; 2007b]. However, other studies have not provided evidence to suggest that overweight children run an increased risk of dental caries [Macek & Mitola, 2006; Moreira et al., 2006; Pinto et al., 2007; Kopycka-Kedzierawski et al., 2008]. In most of the studies, dental caries was diagnosed at cavity level (initial caries not included). Furthermore, like the present study, these studies were cross-sectional in nature and were therefore unable to investigate causality. Longitudinal studies (including initial carious lesions) are therefore needed in order to obtain more knowledge about causative factors and the possible relationships between dental caries and overweight/obesity in children. Knowledge of these relationships could lead to preventive health measures designed to reduce the prevalence of both obesity and dental caries.

Since both dental caries and obesity are related to dietary factors, health professionals should work in a multidisciplinary manner with the whole family with the aim of establishing good dietary habits.

Conclusions

The finding from Papers I-IV can be summarised as follows.

- The approximal caries prevalence in 15-year-olds is underestimated in official caries data, since initial caries lesions not are included in these data. Initial caries lesions constituted 86% of the total number of caries lesions. (Paper II)
- Children with previous caries experience at 6 years of age received significantly more treatment in the primary dentition during the period from 7 to 12 years of age compared with children who were caries free at the same age. (Paper I)
- There is a strong relationship between caries in early childhood and (manifest) approximal caries prevalence in the posterior teeth at 15 years of age. (Paper II)
- Good oral hygiene habits, including the use of fluoride toothpaste, established in early childhood, are a "caries-inhibiting factor" and provide a foundation for good dental health in adolescence. (Paper III)
- Parental dental attitudes and psychosocial factors during early childhood could have an influence on dental health later in life. (Paper III)
- Adolescents with overweight and obesity have a higher approximal caries prevalence (mainly initial caries) than normal-weight adolescents. (Paper IV)

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