

# **Caries risk indicators in preschool children**

Maternal and family conditions in pregnancy and early childhood and  
dental caries development in preschool children

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”Man kan ikke være forsiktig nok i valg av foreldre”

Erik Pontoppidan



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# CONTENTS

<b>CONTENTS.....</b>	<b>V</b>
<b>ACKNOWLEDGEMENT.....</b>	<b>VII</b>
<b>LIST OF PAPERS .....</b>	<b>IX</b>
<b>INTRODUCTION .....</b>	<b>1</b>
Caries aetiology.....	1
Caries prevalence in preschool children .....	2
Caries diagnostic criteria .....	4
Caries prevention .....	5
<i>Preventive strategies</i> .....	6
Caries risk indicators .....	8
<i>Community-level</i> .....	8
<i>Child-level</i> .....	8
<i>Family-level</i> .....	9
<b>PURPOSE.....</b>	<b>15</b>
<b>MATERIALS AND METHODS.....</b>	<b>16</b>
Study design .....	16
<i>Cross-sectional study</i> .....	16
<i>Longitudinal study</i> .....	17
Material.....	17
<i>Cross-sectional study - Sample 1</i> .....	18
<i>Longitudinal study - Sample 2</i> .....	19
Method.....	20
<i>Cross-sectional study</i> .....	20
<i>Longitudinal study</i> .....	21
<i>Variables</i> .....	22
<i>Intra and inter-examiner agreement</i> .....	24
<i>Statistical methods</i> .....	24
<i>Ethical considerations</i> .....	25

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<b>SUMMARY OF RESULTS.....</b>	<b>26</b>
Paper I .....	26
Paper II .....	27
Paper III .....	28
Paper IV .....	29
<b>DISCUSSION.....</b>	<b>30</b>
Methodological considerations.....	30
Main results.....	34
<i>Caries prevalence and distribution</i> .....	34
<i>Caries risk indicators</i> .....	36
Future research .....	41
<b>CONCLUSIONS .....</b>	<b>42</b>
<b>REFERENCES .....</b>	<b>43</b>
<b>APPENDIX 1 .....</b>	<b>53</b>
1a. Invitation letter.....	53
1b. Informed consent .....	54
<b>APPENDIX 2 .....</b>	<b>55</b>
2a. Registration form used in clinical examination of the children .....	55
2b. Additional registration form used in the cross-sectional study .....	56
<b>APPENDIX 3 .....</b>	<b>57</b>
3a. Questionnaire to the parents.....	57
3b. Additional questionnaire used in the cross-sectional study .....	58
<b>PAPERS I - IV</b>	

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*Tove I Wigen  
Oslo, May 2011*





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## LIST OF PAPERS

- Paper I Wigen TI, Wang NJ. Caries and background factors in Norwegian and immigrant 5-year-old children.  
Community Dent Oral Epidemiol 2010; 38: 19-28.
- Paper II Wigen TI, Skaret E, Wang NJ. Dental avoidance behaviour in parent and child as risk indicators for caries in 5-year-old children.  
Int J Paediatr Dent 2009; 19: 431-7.
- Paper III Wigen TI, Espelid I, Skaare A, Wang NJ. Family characteristics and caries experience preschool children. A longitudinal study from pregnancy to 5 years of age.  
Community Dent Oral Epidemiol 2011; 39:311-317.
- Paper IV Wigen TI, Wang NJ. Maternal health and lifestyle and caries experience in preschool children. A longitudinal study from pregnancy to 5 years of age.  
In manuscript \*

\*A revised version of the manuscript has been accepted for publication in Eur J Oral Sci



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# INTRODUCTION

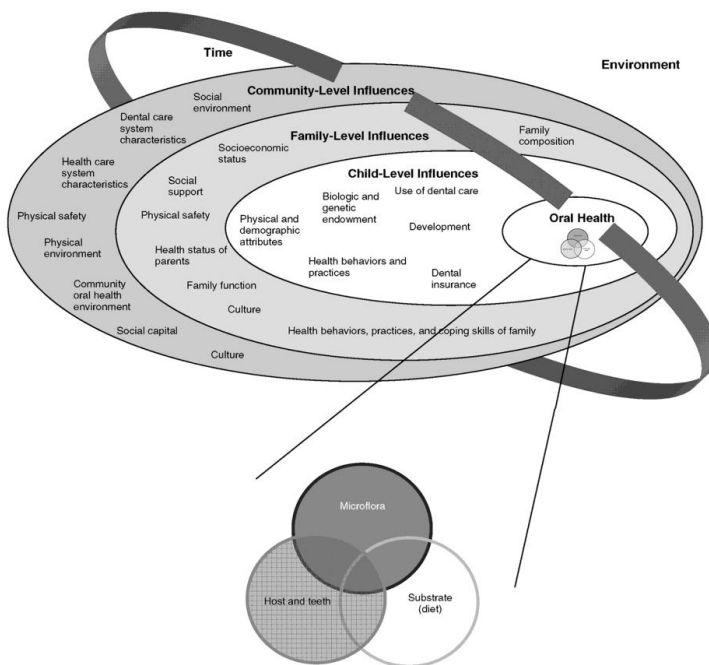
Dental caries is a common disease in children (1, 2). Untreated dental caries can affect body weight, growth and quality of life in preschool children (3). Caries experience in early childhood has been linked to caries experience in the permanent dentition in several studies (4-7). The burden of dental caries lasts a lifetime because once the tooth structure is destroyed, it will usually require restoration and on-going maintenance throughout life. Early identification of children at risk of developing caries will make it possible to direct resources towards the parents, to enable them to make better and more healthy choices regarding their children's dental care.

## Caries aetiology

Historically, researchers have focused on biological and dietary effects on children's oral health to explain caries development. In recent years, interest has increased in exploring children's oral health outcomes using a broader framework, which incorporates psychosocial and environmental predictors as well as the biological and dietary effects (8-10). These frameworks generally classify conditions associated with disease into five broad domains: genetics and biology, social environment, physical environment, health-influencing behaviours and medical care (10, 11). These background variables are relevant to explain why some children, despite widespread use of fluoride and abundant information about caries prevention, develop carious lesions. To visualize the biological and environmental effects on caries development, caries models have been developed (12, 13), and later modified with increasing knowledge in the field (10) (Fig 1). The caries models give a description of how environmental factors can be considered the driving forces triggering the caries process, described by Keyes' triad (14), to develop.

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The caries model by Fisher-Owens and co-workers includes different levels of the environment that can affect caries development: child-level; family-level; and community-level (Fig 1).



**Figure 1.** Caries model depicting environmental factors that can affect caries development in children (10).

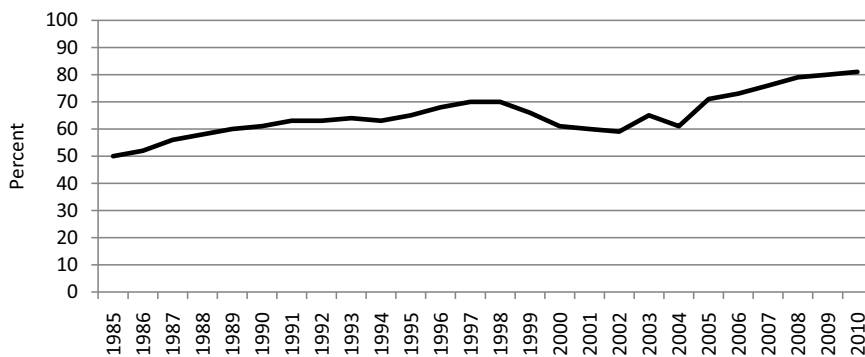
## **Caries prevalence in preschool children**

Caries prevalence in children has declined during the last 20 years (15-18). As caries prevalence declines in child populations, the distribution of dental caries is reported to be increasingly skewed, with a smaller proportion of the children having many lesions, and a greater proportion having no lesions (19). In Norway, the reported proportions of 5-year-

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olds with caries experience has decreased from 50% with caries experience in 1985 to 19% with caries experience in 2010 (20) (Fig 2).

Caries localization in the deciduous dentition has mainly been reported in populations with relatively high caries prevalence, and radiographs are seldom included (21-24). At the age of 5 years, localization of caries in the dentition has changed over the years from affecting smooth surfaces to predominately affecting pit and fissure surfaces, and shifted from anterior teeth to the molars (25, 26). In populations where caries prevalence in deciduous teeth is low, limited information is available to describe the severity and localization of caries in the dentition.



**Figure 2.** Proportions of 5-year-olds in Norway without caries experience from 1985 to 2010 (20).

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## **Caries diagnostic criteria**

When reporting caries in a population, the choice of method with which caries lesions are registered will affect the reported caries experience. Several sets of caries diagnostic criteria have been developed for registration of caries. The use of different systems and different diagnostic thresholds can dramatically influence the reported caries experience and severity of dental caries (27, 28).

When designing a study, choice of caries diagnostic criteria has to be made at an early stage. Information to be considered when choosing diagnostic criteria includes: the aims of the study, the sample size, whether an epidemiological or a clinical study, number of examiners, caries prevalence in the study population, and whether the dental examinations will be performed in a dental clinic using radiographs and explorer on dry teeth, or under field conditions with dental examinations outside the dental clinic.

Several different caries diagnostic criteria have been used in the literature. In a review from 2004, 29 caries diagnostic criteria systems were included; 13 from the UK (England and Scotland), 3 were from the USA, 2 from the Netherlands, 2 from the World Health Organization (WHO), 4 from Denmark, 2 from Sweden, 1 from Norway, 1 from Switzerland and 1 from Canada (27). The review revealed substantial differences in reporting of caries experience.

The caries diagnostic criteria described and recommended by WHO are widely used (29). The WHO index registers cavitated lesions, based on the belief that it is not possible to obtain reliable diagnoses at the non-cavitated stage, and that only cavitated lesions need restorative treatment (29). The national statistics describing the caries situation among children in Norway are based on the WHO criteria, and only lesions in need of restorative treatment are reported (30).

Two caries diagnostic criteria are recently developed, the Significant Caries Index (SIC) and the International Caries Detection and Assessment System (ICDAS). The ICDAS criteria were introduced in 2007 and the aim was to develop one standard system for caries detection and assessment in caries research where caries was recorded at all stages

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from the earliest enamel lesion through to cavitation. The ICDAS records caries on a six-point scale (31). The SIC-index was introduced in 2000, with the intention on focusing attention on individuals with the highest caries scores in a population when caries distribution is skewed (32), and it reports caries experience in the one-third of the population with the highest caries experience. It is actually not an index, but rather is a form of data presentation to give a better picture of the situation in populations with skewed distribution.

In Norway, the Public Dental Services uses a 5-graded index to register caries lesions where both enamel and dentine lesions are registered (30, 33, 34). Some previous studies from Norway, reporting caries data for 5-year-olds from selected dental clinics in Oslo and Bergen, have used a 5-graded index and shown a high frequency of enamel lesions (26, 35).

## **Caries prevention**

Caries prevention is important in child oral care, and efforts towards prevention of dental caries should, according to law, be given higher priority in the Public Dental Services than restorative treatment (36). Caries prevention in children can be organized in different ways. The risk of developing caries has to be considered when planning preventive oral care for children.

Risk is defined as the probability that a particular event will occur within a given period of time (37, 38). The term is used to express the probability that a particular outcome, often a disease, will occur following an exposure (39). In epidemiological research the terminology may be confusing as different definitions of risk terms are used.

Risk factor – the term is defined as an environmental, behavioural or biological factor confirmed by temporal sequence, which, if present, directly increases the probability of a disease occurring. Risk factors are part of the causal chain, and are identified in longitudinal studies (40).

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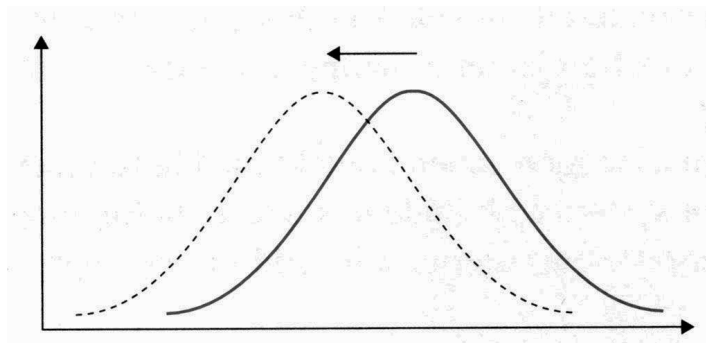
Risk indicator – the term is defined as a condition associated with a disease. Risk indicators are established in cross-sectional studies, in which correlations between various conditions and disease are investigated (37). A risk indicator may be a risk factor if validated in longitudinal studies (40).

### ***Preventive strategies***

In health promotion and caries prevention, two types of strategies may be used: population strategy and high-risk strategy (41).

#### **Population strategy**

Use of a population strategy implies offering standardized interventions to all individuals without considering the actual risk of disease development in the individual. In situations where the goal is to lower the prevalence of a disease, a population strategy will be beneficial (Fig 3). In situations where most of the individuals are without risk of disease, efforts and resources may be wasted.



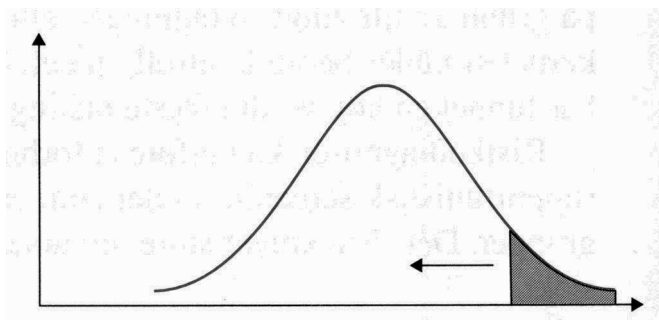
**Figure 3.** Population strategy, directing intervention towards all individuals.



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### High-risk strategy

Use of a high-risk strategy to prevent disease implies offering interventions to individuals identified as being at risk of developing disease. In situations where disease prevalence is low, and parts of the population can benefit from intensified interventions, a high-risk strategy may be beneficial (Fig 4).



**Figure 4.** High-risk strategy, directing intervention towards individuals with high risk of disease.

As a consequence of the decrease in and polarisation of caries prevalence in preschool children, it has been proposed that individualized care to prevent caries development should be offered to children at high risk of developing caries, instead of targeting standardized caries preventive measures to the whole population (42). Both the population strategy and the high-risk strategies have strengths and weaknesses. Use of high-risk strategies is dependent on the possibility of identifying individuals at risk of disease (43, 44). It has been recommended that in prevention of caries, combining the two strategies is the optimal approach (44).

### Preventive strategies in the Public Dental Services

In Norway, both population strategy and high-risk strategy are used in caries prevention in children. All children are offered regular, free, comprehensive dental care in the Public

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Dental Services (population strategy), while the recall intervals are individualised (high-risk strategy). This gives the opportunity to deliver intensified caries preventive efforts to families with children identified as being at risk of developing caries.

When using a high-risk strategy in caries prevention, functional risk indicators must be identified. Although several studies have been published in recent years, there is limited knowledge regarding risk indicators for caries development in preschool children. The multifactorial nature of dental caries, and the fact that the disease is dynamic but not continuous, can progress and/or regress, makes studies on risk assessment complex. A multitude of variables influence the prediction at different times during the life of an individual (45), and make it difficult to construct risk models in which future caries experience can be accurately predicted (46).

## **Caries risk indicators**

In a review article from 2004, 106 risk indicators were associated with caries development in children (47). Risk indicators may be classified according to levels as illustrated in Figure 1, page 2.

### ***Community-level***

Children's oral health is likely to be better in a community that values good oral health (48). Cultural aspects and the neighbourhood may have implications for caries development (10, 49). The dental care system and amount of dental care available may affect oral health and the development of caries in preschool children.

### ***Child-level***

Research on risk indicators for caries in preschool children have focused on child oral health habits associated with caries development in children, child-level influences (Fig 1).

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Visible plaque (50, 51), early colonisation by caries-related bacteria (52), the presence of mutans streptococci (53-56), frequent intake of sweetened drinks (51, 57, 58), infrequent tooth brushing (59), illness and use of antibiotics (60, 61) have all been associated with caries development in preschool children. Children with dental anxiety and behaviour management problems are reported to have more carious surfaces and more missed dental appointments than other children (62-65), and missing dental appointments has been associated with dental caries in children (66).

### ***Family-level***

This thesis focuses on risk indicators for caries development in children from pregnancy to the age of 5 years. In early childhood, family influences are important in child development. Table 1 gives an overview of European research from 1990 to 2010 dealing with parental factors as risk indicators for caries in preschool children. As shown in Table 1, 50% of the studies are from the Nordic countries. Family level characteristics associated with caries risk in children included in this thesis are:

- demographic factors of the family
- parental oral health behaviours and attitudes
- dental anxiety and dental attendance
- maternal health and lifestyle in pregnancy and early childhood.

**Table 1.** European studies on parental factors as risk indicators for caries development in children from 1990 to 2010.

Author	Year	Country	Focus
Ekman et al	1990	Sweden	Immigrant status, parents dental status
Petersen	1992	Denmark	Education, Income
Verrips et al	1992	The Netherlands	Immigrant status
Wendt et al	1992	Sweden	Immigrant status, dental attendance
Grindejord et al	1993	Sweden	Immigrant status, plaque,
Paunio et al	1993	Finland	Illness, antibiotics, diet, tooth brushing
Verrips et al	1993	The Netherlands	Immigrant status, education
Grindejord et al	1995	Sweden	Immigrant status, education
Kinirons et al	1995	UK	Education, dental attendance
Wendt et al	1995	Sweden	Mental health, family interaction, life events
Grindejord et al	1996	Sweden	Immigrant status, education,
Wang	1996	Norway	Immigrant status
Wendt et al	1996	Sweden	Illness, use of medication
Freeman et al	1997	UK	Dental attendance, attitudes
Gibson et al	1999	UK	Social class, tooth brushing, diet
Wendt et al	1999	Sweden	Immigrant status
Mattila et al	2000	Finland	Family-related factors
Williams et al	2000	UK	Parental and maternal smoking
Vanobbergen et al	2001	Belgium	Socioeconomic background
Milsom et al	2003	UK	Dental anxiety, dental attendance
Sundby et al	2003	Denmark	Immigrant status
Pine et al	2004	UK	Parental attitudes
Stecksèn-Blichs et al	2004	Sweden	Immigrant status, tooth brushing
Stevens et al	2004	UK	Mother-child interaction
Skeie et al	2005	Norway	Immigrant status
Willems et al	2005	Belgium	Socioeconomic background, neighbourhood
Wogelius et al	2005	Denmark	Dental attendance
Poutanen et al	2006	Finland	Parental influence
Skeie et al	2006	Norway	Parental attitudes
Conway et al	2007	UK	Immigrant status
Poutanen et al	2007	Finland	Parental influence
Declerck et al	2008	Belgium	Visible plaque and sugary drinks, education
Leroy et al	2008	Belgium	Parental smoking
Menghini et al	2008	Switzerland	Immigrant status, dental hygiene
Skeie et al	2008	Norway	Parental attitudes
Stecksèn-Blichs et al	2008	Sweden	Immigrant status
Campus et al	2009	Italy	Immigrant status, education, preterm birth
Vanagas et al	2009	Lithuania	Parental attitudes
Wang et al	2009	Norway	Dental attendance
Christensen et al	2010	Denmark	Socioeconomic background
Christensen et al	2010	Denmark	Immigrant status, education, income
Elfrink et al	2010	The Netherlands	Immigrant status, hypomineralization
Ferro et al	2010	Italy	Social class and immigrant status

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### **Demographic factors of the family**

The social environment influences child development (67). Social conditions experienced in early childhood, such as parents' educational level and socioeconomic status at child birth has been shown to be associated with child dental health (59). The influence of social conditions on dental health has been shown to be stronger for preschool children than older children (68).

Parental educational level and national background has been connected with caries development in children in several studies (Table 1) (26, 69-84). Family income and father's occupational status at child birth has been linked to preschool child oral health (59, 85, 86). Mother-child interaction (87), and family function (9) have, in some studies, been related to caries development in children. Studies of the association between maternal age at child birth and caries experience in the child have shown conflicting results (88-90). Few children in the family have been reported to be associated with less caries in children (68). Change in family status from a traditional two-parent family to single parent families may influence the parent's ability to give the child appropriate oral care. A Finnish study showed that children living in families where relationships were complicated had higher risk of having caries experience at the age of 5 years (88). Limited information exists on the associations between family status and the probability of caries development in young children; this is particularly the case for studies including longitudinal data (47).

### **Parental oral health behaviours, beliefs and attitudes**

Children are dependent on their environment to establish favourable health behaviours (67, 69), and young children's dental health relies on the parents' involvement. Oral health habits established during early childhood are maintained and associated with oral health conditions later in life (91).

Parents' own tooth brushing habits have been associated with caries experience in children (88, 92, 93). The age of the child when the parents' start to brush the child's

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teeth (94-96) and parents' own dental health (97) have all been shown to be associated with caries development in children.

Frequent sugar intakes in children have been associated with caries development in many studies. Children's dietary intake has been shown to be strongly associated with their mothers' dietary intake (98) and with children's own dietary habits developed early in life (99, 100). Limited information exists on parental dietary habits and caries development in preschool children.

Behaviours usually, but not always, reflect established beliefs and attitudes (101). Attitudes towards the behaviours and social norms produce intentions that are said to determine behaviours (102). Parental attitudes towards oral health related behaviours may influence whether the behaviours will occur in children (49). In some studies, parental beliefs and attitudes towards oral health have been associated with caries development in children (103-106). Limited information exists on parental beliefs and attitudes towards oral health and caries experience in children.

### **Dental anxiety and dental attendance**

Dental anxiety is associated with avoidance of dental treatment (107) and poorer dental health (108, 109). For both dental anxiety and behaviour management problems, pain and negative experiences with dental treatments are often considered as major reasons for avoiding dental care (110). It has been reported that a mother's attitudes and beliefs about dental care are major determinants of whether or not she takes her child to the dentist (111). Mother's dental anxiety and dental attendance pattern have been proposed as predictors of preschool child dental health and for taking the child to the dentist (112), but the relationship is still unclear and needs to be further explored.

### **Maternal general health and lifestyle**

The development of the child *in utero* has been used as explanation for risk of adult disease, such as cardiac disease, respiratory disease and diabetes (113). Development of

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the foetus is influenced by several factors, including genetic endowment, nutrition and other biological influences, maternal health conditions and lifestyle.

In addition to a biological explanation for disease in children, maternal health and lifestyle in pregnancy and early life may also influence mothers' ability to take appropriate care of their children's health, including oral health. Maternal weight has been shown to be associated with the child's birth weight (114). Associations between child's birth weight and dental caries have been explored in several studies, with conflicting results (115-117). In a recent study, maternal weight early in pregnancy was associated with caries increment during the teenage period (118). Maternal obesity in pregnancy and parental smoking have been shown to be related to respiratory health in early childhood (119, 120). An association between parental smoking and caries in primary teeth has been demonstrated in several studies (121-123). Knowledge regarding associations between maternal health and lifestyle in pregnancy and the child's early life, and caries development in preschool age is limited.

### **Dental health services for preschool children**

All children in Norway are, by law, offered free dental care, including preventive care, free of charge, in the Public Dental Services from birth. The first regular dental examination in the Public Dental services is at around age 3 years. Before 3 years old, preventive dental care is mainly given by primary care personnel, who are advised to give information about dental care for children to the parents as part of their general health care promotion (124).

Primary health care personnel have information about the family and the child from pregnancy. Characteristics of the family that could serve as risk indicators for caries in preschool children are often known to the primary health care personnel. These characteristics could be used to identify children at risk of developing caries, before clinical caries occurs. There is little available knowledge about caries risk indicators in preschool children, and this limits the ability of primary health care personnel to give

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preventive information and to refer risk children to dental personnel; this issue requires further study.



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# PURPOSE

This work focuses on caries experience in 5-year-old children, and its associations with characteristics of parents and families during pregnancy and in early childhood.

The main purpose was to explore aspects contributing to early identification of children at risk of developing caries.

Specifically, the aims were:

- To describe the caries situation among 5-year-old children in a low caries population in Norway, including the distribution and severity of caries at tooth and surface level;
- To study associations between caries experience in 5-year old children and family characteristics such as:
  - parents' education, national origin, oral health behaviours and attitudes,
  - dental avoidance behaviour and dental anxiety in parents and children,
  - structural characteristics of the family during pregnancy and in early childhood, and
  - maternal health and lifestyle during pregnancy and in early childhood.

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# MATERIALS AND METHODS

## Study design

This thesis consists of studies using cross-sectional study design (Paper I and II) and longitudinal study design (Paper III and IV). An overview of the papers, samples, focus of interest, designs and study populations is shown in Table 2.

**Table 2.** Papers, samples, focus of interest, designs and study populations in the thesis.

Paper	Sample	Focus of interest	Design	Study population (n)
I	1	Caries distribution, parents' education and national background	Cross-sectional	523
II	1	Dental anxiety and dental attendance	Cross-sectional	523
III	2	Structural characteristics of the family in early childhood	Longitudinal	1366
IV	2	Maternal health and lifestyle in pregnancy and early childhood	Longitudinal	1366

### *Cross-sectional study*

Paper I and Paper II are based on data from a cross-sectional study of 5-year-old children in the county of Akershus.

In Paper I, the distribution of caries experience in 5-years-old children was described, and associations between parents' education, national background, oral health behaviours and attitudes, and caries experience in 5-year-old children were studied.

In Paper II, associations between dental avoidance behaviour and dental anxiety in parents and children, and caries experience in 5-year-old children were studied.

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## ***Longitudinal study***

Paper III and Paper IV are based on data from prospective longitudinal observational study collected during the period from pregnancy until the child was 5 years old.

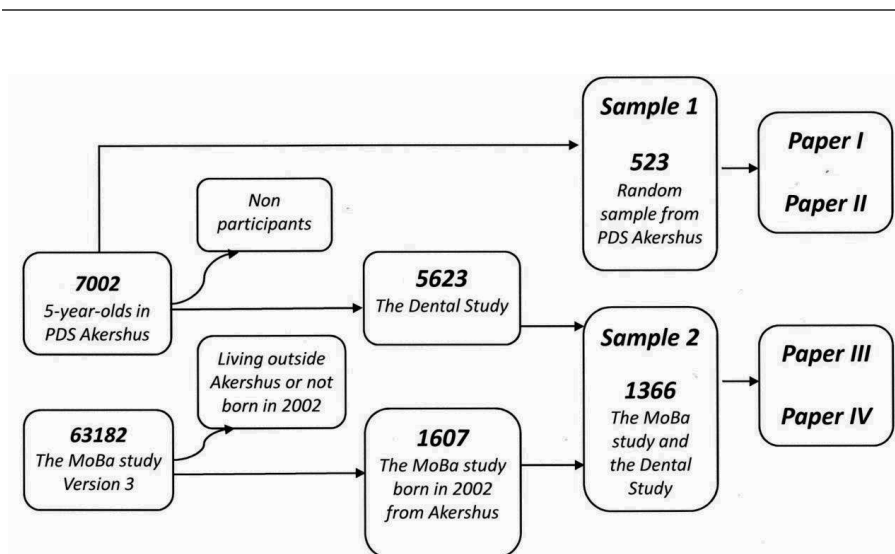
In Paper III, associations between structural characteristics of the family in pregnancy and early childhood, and caries experience in 5-year-old children were studied.

In Paper IV, associations between maternal health and lifestyle in pregnancy and early childhood, and caries experience in 5-year-old children were studied.

## **Material**

In this thesis, 5-year-old children born in 2002 in the county of Akershus were studied. The sample (Sample 1) used in the cross-sectional studies was a random sample of children born in 2002 enrolled in the Public Dental Services in Akershus.

The sample (Sample 2) used in the longitudinal studies consisted of children participating in the Mother and Child Cohort Study (MoBa) born in 2002 in Akershus and also participating in the Dental Study (Fig 5).



**Figure 5.** Overview of sampling procedure and study populations.

## ***Cross-sectional study - Sample 1***

### **Random sample of children**

In 2007, about 8% of the 5-year-old children enrolled in the Public Dental Services in Akershus were invited to participate in the cross-sectional study (Appendix 1a). Power calculation was performed based on a caries prevalence of 20%, precision of 0.05 ( $\alpha = 0.05$ ) and a power of 80% ( $\beta = 0.20$ ) suggesting a sample size of 275 children for bivariate analyses. To allow multivariable analyses and based on practical considerations, the target sample size was increased to approximately 500 children. The numbers selected in each of the 32 dental clinics in Akershus were proportional to the total numbers of 5-year-olds enrolled in each clinic.

A total of 536 children were selected randomly and invited to participate in connection with their scheduled clinical recall examinations. Twelve families with 13 children refused to participate. The proportions of children with caries experience were not significantly different between non-participating and participating children (31% and 34%,  $p = 0.82$ ). The final sample in the cross-sectional study included 523 children.

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## ***Longitudinal study - Sample 2***

### **The Mother and Child Cohort Study (MoBa)**

The MoBa study is a prospective cohort study including more than 100 000 pregnancies recruited from 1999 to 2009 (125). The primary goal of the study is to identify environmental and genetic factors, or interaction among these, for diseases in pregnancy and childhood, aiming at prevention. Participants were recruited by postal invitation in connection with the routine ultrasound examination offered to all pregnant women in Norway at 17-18 weeks of gestation. The overall participation rate was 44%. The study was established in Western Norway in June 1999. In 2000, 7% of the pregnant women were invited to participate, and in 2006 about 71% of all pregnant women were invited to participate. In 2002, 34% of all pregnant women were invited to participate, and 46% of the invited women participated (126). Data were collected by questionnaires and by blood and urine samples during pregnancy and delivery.

The longitudinal studies included in this thesis used questionnaire data based on quality-assured data files (version 3) released for research in 2007. The final sample included only children born in Akershus, 1607 children.

### **The Dental study**

All children born in 2002 and enrolled in the Public Dental Services in Akershus were invited to participate in the Dental Study as part of their regular dental examination closest to the age of 5 years (Appendix 1a and 1b). All children in Norway are, by law, offered free regular and comprehensive dental care in the Public Dental Services from birth. In 2007, 96% of the 5-year-olds were enrolled in the services.

The county of Akershus has more than 500 000 inhabitants, 11% of the Norwegian population. The dental health of the 5-year-olds in the county was slightly better than the national average in 2007 and 80% did not receive restorative treatment (20).

Data were collected in 2007 and 2008, and 20% of the 7002 children enrolled in the Public Dental Services, did not participate in the study; they were mostly children whose parents refused to participate and children that did not show up for the routine

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dental examination. Data on caries experience ( $d_{3-5mft}$ ) was obtained from 244 (18%) of the non-participating children. Caries experience was higher in these children (32% with  $d_{3-5mft} > 0$ ), than in the participating children (16% with  $d_{3-5mft} > 0$ ) ( $p < 0.001$ ). The final sample included 5623 children.

### **The MoBa study and the Dental study**

In Norway all residents have a unique 11-digit National Registration Number. This number is recorded in health registries and health records, and permits linkage between different registries. Of the 1607 children participating in the MoBa study, 1366 also participated in the Dental Study. The final sample in the longitudinal study included 1366 children with data both from the MoBa study and the Dental Study.

## **Method**

The Methods used in this thesis were clinical dental examination of the children and questionnaire data.

### ***Cross-sectional study***

#### **Clinical examination**

The clinical dental examinations were performed by one trained paediatric dentist (TIW). The examination was performed in fully equipped dental clinics using plane mirrors and sharp probes after the teeth had been dried with air. Two registration forms were completed by the examiner as part of the dental examination in the cross-sectional study (Appendix 2a and 2b). Bitewings were taken in accordance with the Public Dental Services' standard routines (bitewings when visual inspection of approximal surfaces is impossible) and were used as an adjunct to the clinical caries registration.

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## **Questionnaire**

Two questionnaires were completed by the accompanying parent at the time of the oral examination. The questionnaires contained sections about socioeconomic status, children's oral health habits, dental anxiety and behaviour management problems (Appendix 3a). In addition the questionnaire included variables measuring parents' oral health, oral health habits, dental anxiety and dental attendance (Appendix 3b).

## ***Longitudinal study***

### **Clinical examination**

The clinical dental examination of the children in the Dental Study was performed by 44 dental hygienists as part of the regular dental recall examination in the Public Dental Services. The examinations were always performed in fully equipped dental clinics using plane mirrors and sharp probes after the teeth had been dried with air. Registration forms were completed by the examiner as part of the clinical examination (Appendix 2a). Bitewings were taken when indicated.

### **Questionnaire**

Questionnaires were completed by the mothers during week 15, 22 and 30 in pregnancy, and when the child was 6, 18 and 36 months old as part of the MoBa study. The questionnaires in the MoBa study can be found at <http://www.fhi.no>. The questionnaires cover a variety of issues regarding parents and children, with detailed questions on health, socioeconomic status, nutrition, environmental exposures, and familial and psychological factors before, during and after pregnancy. Pregnancy and birth records from the Medical Birth Registry of Norway (127) are included in the MoBa database.

In addition a questionnaire completed by the accompanying parent at the dental examination of the 5-year-old children was used. This questionnaire included information

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about socioeconomic status, the children's oral health habits, dental anxiety and behaviour management problems (Appendix 3a).

## ***Variables***

### **Caries experience**

The caries experience of the children at the age of 5 years was the dependent variable in the analyses.

Caries was registered with the surface as the unit of measurement. Surfaces were given a code according to status: sound (s), decayed (d), filled (f) or missing due to caries (m). The clinical record was checked when there was doubt about whether a tooth was missing because of caries or dental trauma. Molars extracted or indicated for extraction due to caries were counted as five missing surfaces and incisors as four missing surfaces because only teeth with serious caries were extracted rather than filled in this population. Five caries grades were recorded ( $d_1$  to  $d_5$ ) (33). Grades  $d_1$  and  $d_2$  were enamel lesions and grades  $d_3$ ,  $d_4$  and  $d_5$  were dentine lesions. In the analyses, grades  $d_1$  and  $d_2$  were summed and categorised as enamel caries, and grades  $d_3$ ,  $d_4$  and  $d_5$  were summed and categorised as dentine caries. Using the same criteria, caries experience was also noted with the tooth as unit of analysis and the results are presented as decayed, filled and missed teeth or surfaces (dmft or dmfs).

In Paper I, the term "caries" includes both enamel and dentin caries ( $d_{1-5}$ mft) and the term "dentine caries" is used when only caries extending into dentine was included ( $d_{3-5}$ mft). In Paper II, III and IV, only caries lesions extending into dentine ( $d_{3-5}$ mft) were analysed and named caries.

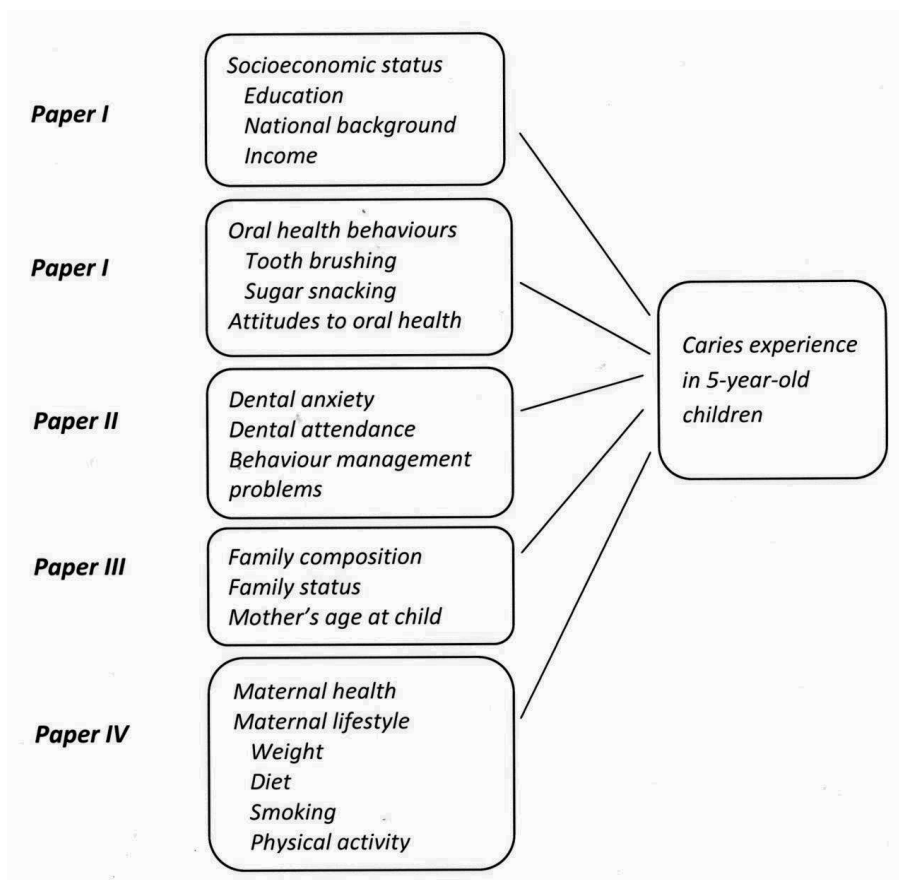
In the analyses of associations between caries experience and the independent variables, children were classified as having caries experience ( $d_{1-5}$ mft > 0 or  $d_{3-5}$ mft > 0) or not having caries experience ( $d_{1-5}$ mft = 0 or  $d_{3-5}$ mft = 0).



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## The independent variables

The independent variables used to explore associations with caries experience were all related to the parents and the family during pregnancy and in early childhood, see Figure 1, page 2. An overview of the independent variables in Papers I to IV is shown in Figure 6.



**Figure 6.** Overview of dependent and independent variables included in Papers I to IV.

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### ***Intra and inter-examiner agreement***

Intra-examiner agreement of the main investigator (TIW) was measured using extracted teeth, radiographs and re-examination of 34 children after a 30-day interval. Cohen's kappa for intra-examiner agreement was 0.61 (extracted teeth), 0.85 (radiographs) and 0.88 (examination of children).

Intra- and inter-examiner agreement in the Dental Study was measured using 20 bitewing radiographs of deciduous molars including eight approximal surfaces in each radiograph. Caries in the radiographs was registered three times during the examination period with an interval of about 90 days. The registrations by the main investigator were regarded as the "gold" standard and compared with the registrations of the 44 dental hygienists' to calculate inter-examiner agreement. The mean inter-examiner Kappa-value was 0.86, and the mean intra-examiner Kappa-value was 0.85.

The obtained agreement (Kappa values) were defined as "substantial to almost perfect" according to the scale of Landis and Koch (128).

### ***Statistical methods***

The statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, Inc. Chicago, IL, USA, version 16). Inter- and intra-examiner agreements were calculated using Cohen's kappa. Bivariate and multivariable logistic regression analyses were conducted with children's caries experience as dependent variable. Multivariable logistics regression analyses were conducted to determine associations between the independent variables towards the presence of caries in the participants, controlled for the other variables included in the analyses. Results were reported using frequencies, odds ratios (OR), 95% confidence intervals (95% CI) and p-values (p). Spearman's Rank correlation was used to test relationships between the independent variables before multivariable analyses were conducted. The level of significance was set at 5%.

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### ***Ethical considerations***

Written, informed consent was obtained from all parents (Appendix 1b). The investigation was approved by the Regional Committee for Medical Research Ethics and the Norwegian Social Science Data Services. The MoBa is also approved by the Norwegian Data Inspectorate.

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# SUMMARY OF RESULTS

## Paper I

The purpose of this study was, firstly, to describe the caries situation among 5-year-old children in a low caries population, including the distribution and severity of caries at tooth and surface level and, secondly, to study associations between parents' education, national origin, oral health behaviours and attitudes, and children having caries experience at 5 years of age.

Caries experience was low; 34% of the children had caries experience ( $d_{1-5mft}$ ), and 18% of the children had dentin caries experience ( $d_{3-5mft}$ ). Caries experience was skewed; 10% of the children had five or more teeth affected by caries experience ( $d_{1-5mft}$ ). For all children, the average number of deciduous teeth affected by caries ( $d_{1-5mft}$ ) was 1.3 (SD = 2.7), and the average number with dentine caries was 0.6 (SD = 1.9). The Significant Caries Index (SIC) was 3.9 (SD = 3.5) and, for dentine caries experience, the SIC was 1.9 (SD = 2.9). Both enamel caries and dentine caries experience were most frequent in the molars, and accounted for 85% of the total caries experience. Caries experience ( $d_{1-5mfs}$ ) was most frequently registered in the occlusal surfaces of the second molars. The highest proportion of surfaces with dentine caries experience ( $d_{3-5mfs}$ ) was registered in the distal surfaces of the first molars, and the occlusal surfaces of the second molars. Surfaces with enamel caries constituted 49% of all surfaces with caries experience.

The results from the multivariable analyses showed that having one or both parents of non-western origin (OR = 3.6), both parents (OR = 1.9) and one parent (OR = 1.7) of low educational level was associated with a higher probability of having caries experience ( $d_{1-5mft} > 0$ ) at the age of 5 years. Education level had stronger associations with the probability of having caries experience in participants of non-western origin than in western children, indicating that the real high-risk group is children of non-western origin with parents with low education.

Adjusted for the other variables included in the multivariable analysis, the following variables were associated with a higher probability of having dentine caries

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experience ( $d_{3-5mft}$ ) at the age of 5 years: having one or both parents of non-western origin (OR = 4.8); both parents (OR = 3.0) or one parent (OR = 2.1) with low educational level; parental laxity about tooth brushing (OR = 2.8); parents who brushed their own teeth less frequently than twice a day (OR = 2.2); and, parents who had frequently consumed sugar (OR = 1.8). Parent-related factors explained 22% of the variance in the probability of having dentine caries experience ( $d_{3-5mft} > 0$ ) in the 5-year-olds.

## Paper II

The aim of this study was to explore associations between dental avoidance behaviour and dental anxiety in both parents and children, and children having caries experience at 5 years of age.

In the bivariate analyses, having caries experience at the age of 5 years was associated with the child having missed one or more dental appointments, the child having behaviour management problems during previous dental visits, child dental anxiety and parents reporting not having their own dentist.

Multivariable analysis was performed with parents' dental attendance, the child having missed at least one dental appointment, child dental anxiety and behaviour management problems during previous dental visits entered as explanatory variables. Parents' educational level and national origin were entered as control variables. The results showed that, having one or more missed dental appointments (OR = 4.0) and parents reporting behavior management problems before the age of 5 years (OR = 2.4) were associated with having caries experience at the age of 5 years. Variables included in the analyses explained 24% of the variance in the probability of having caries experience at the age of 5 years.

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## Paper III

The purpose of this study was to explore associations between structural characteristics of the family during pregnancy and in early childhood and having caries experience at 5 years of age with longitudinal data.

The results showed that caries experience in the 5-year-old children was low; 89% had no caries experience ( $d_{3-5mft} = 0$ ). Caries experience was skewed, two-third of the children (62%) had one or two teeth with caries experience and 18% were severely affected by caries, with five or more teeth with caries experience. For all children the average number of teeth with caries experience was 0.3 (SD = 1.2) and, for children with caries experience, the mean was 2.7 (SD = 2.3) teeth. The SIC index was 0.9 (SD = 1.8). In the bivariate analyses, having caries experience at the age of 5 years was associated with having one or both parents of non-western origin (OR = 5.0), having had a change in family status from pregnancy to the age of 5 years (OR = 2.2), having a mother with low education (OR = 2.0) and having a young mother at child birth (OR = 1.9)

Multivariable analysis were conducted to explore the associations between children having caries experience and mothers' age at child birth, family status, family size, family income, mothers' education and parents' national origin. Gender and child age at dental examination were entered in the analysis as control variables. The results from the analyses showed that having caries experience at the age of 5 years was associated with having one or both parents of non-western origin (OR = 3.4), having had a change in family status from two parents to one parent from pregnancy to the age of 5 years (OR = 2.0), and having mother with low education (OR = 1.9).

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## Paper IV

The aim of this study was to explore associations between maternal health and lifestyle in pregnancy and early childhood and children having caries experience at 5 years of age.

The results from the bivariate analyses showed associations between caries experience in children at the age of 5 and having one or both parents of non-western origin (OR =5.0), having mother defined as obese (OR = 2.4) or overweight (OR = 1.5), with low education (OR = 2.0), who smoked at child age 6 months (OR = 1.8), who smoked during pregnancy (OR = 1.6), who consumed more sugar than recommended (OR = 1.6) and having mother without allergy (OR = 1.4).

Multivariable analysis was conducted to explore associations between children having caries experience and maternal health, maternal diet, maternal weight, maternal smoking, maternal physical activity, child birth weight, child born premature controlled for maternal education, parental origin and child age at dental examination. The results from the multivariable analysis showed that having a mother defined as obese (OR = 2.1) or overweight (OR = 1.6) and having a mother who consumed more sugar than recommended (OR = 1.6) were related to having caries experience at the age of 5 years, in addition to having parents' of non-western origin (OR = 4.6) and having mother with low education (OR = 1.5).

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# DISCUSSION

## Methodological considerations

This thesis included 5-year-old children from a low caries area, the county of Akershus. The caries prevalence of 5-year-old children in Akershus was, in 2007, slightly lower than the national average in Norway, 80% versus 76% 5-year-olds without caries experience (20).

### Cross-sectional study

The study population in Paper I and Paper II included a random sample of children scheduled for recall examination in the Public Dental Services in 2007. The proportion of non-participants in this study was low (2%), and the majority explained the reason for non-participation to be lack of time to complete questionnaires and dental examinations. Based on the participation rate, the sample is considered to be representative of those 5-year-old children in Akershus who were examined in the Public Dental Services in 2007.

According to national statistics (20), 20% of children in the county of Akershus examined in 2007 had dentine caries experience, while dentine caries experience was registered in 18% of the children in the study population in Paper I and Paper II. As a result of needs-based recall-intervals longer than 12 months in the Public Dental Services, 35% of the 5-year-olds were not recalled to the Public Dental Services in the calendar year 2007. These results showed, as expected, a slightly higher caries prevalence in children scheduled for examination in 2007 compared with all 5-year-old children in the county of Akershus.

### Longitudinal study

The study population in Paper III and Paper IV included children participating in the MoBa study and the Dental Study.



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A total of 80% of the 5-year-olds enrolled in the Public Dental Services in Akershus participated in the Dental Study. Non-participants in this study were children that did not want to participate (3%), children that did not show up for the routine dental appointment (2%), and children that were not invited to participate by the dental personnel (15%). Reasons that children scheduled for routine examination were not invited are not known, but most likely include failure to notice, administrative practical reasons and lack of time. It has been documented that children that do not show up for dental appointments have higher caries experience than children that do show up (66), while there is no reason to assume that the majority of the non-participating children, the children that were not invited to participate, differed from the participating children. This indicates that caries prevalence of participants in the Dental Study may be slightly lower than in the 5-year-olds enrolled in the Public Dental Services.

Caries prevalence among 5-year-old children from Akershus participating in the MoBa study and the Dental Study was lower than among 5-year-old children included in national statistics for Akershus in 2007, 89% versus 80% without caries experience (20). This is probably caused by higher participation in the MoBa by mothers that reported no smoking and used folic acid supplements before/during pregnancy, indicating healthier lifestyle behaviours, and lower participation by mothers with lower age at child birth than the Norwegian average (126). This is consistent with the general finding that attrition of study participants and low participation rate in prospective longitudinal studies may cause selection-bias and systematic errors in such studies (37). Typically, bias in longitudinal studies is found in the prevalence of exposure and outcomes, but bias is less in relative risk estimates of exposure-outcome associations. A recent analysis of exposure-outcome associations in the MoBa study reports no statistically significant differences in association between variables in the MoBa study and in the total population (126).

Measures regarding prevalence in Paper III and Paper IV are therefore representative only for children participating in the MoBa study and the Dental Study and can not be generalized to a larger population. Results regarding exposure-outcome associations may be generalised to Norwegian children at the same age.

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## Clinical examinations

The clinical data collection in the cross-sectional study was performed by one experienced dentist and the Kappa intra-examiner agreement was considered “substantial” to “almost perfect” according to the scale of Landis and Koch (128).

The clinical data collection in the longitudinal study was performed by dental hygienists in the Public Dental Services as part of the routine dental examination of the children at the age of 5 years. The Public Dental Services has written guidelines regarding caries registration and the clinicians are regularly calibrated. The caries diagnostic criteria used in the Dental Study were identical to the criteria the personnel used in routine examinations. According to Landis and Koch, the Kappa values for registration of enamel and dentine caries lesions indicated “substantial” to “almost perfect” intra- and inter-examiner agreement (128). In spite of the large number of examiners (44 dental hygienists performed examinations), the levels of intra-and inter-examiner agreement indicate reliable caries registration.

While most national and international caries data in children are based on recordings only of dentine caries, information regarding both enamel and dentine caries is useful to give the total frequency of the caries disease in a population and to estimate the requirement for preventive dental services (129, 130). In this low caries population, enamel caries was found to constitute half of the total caries experience among the 5-year-olds. This result is in line with previous findings in populations with higher caries prevalence (25, 35). This study showed that as the caries prevalence decreases, the proportions of enamel and dentine caries lesions remain constant and indicate that, by recording only dentine caries, a fairly reliable estimate of the total caries prevalence can be calculated.

One aim in this thesis was to describe caries experience in 5-year-old children, and in Paper I both enamel caries and carious lesions extending into dentine were studied. In Papers II, III and IV, children with caries lesions extending into dentine were chosen as the risk group in the analyses. In some children, 16%, only enamel caries lesions were registered and these children, without dentine caries, were classified as having no caries

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experience in the analyses in Paper II, III and IV. The results from Paper I showed that associations between caries prevalence and the independent variables were fewer and weaker when children who had enamel lesions only were included. This indicates that children with dentine caries are easier to identify than a large group with both enamel and dentine caries. The explanation could be partly that among children who have only enamel lesions, children with active enamel lesions, children with previously active lesions and children that had changed their oral health behaviours were included. Restorative dental treatment in preschool children is challenging, time consuming and may result in dental anxiety in the children. Enamel lesions are, in Norway, usually treated by non-restorative treatment; fluoride supplement and oral hygiene advice. In this thesis, the aim was to identify indicators associated with risk for development of caries requiring restorative treatment, that is, carious lesions extending into dentine, in the first 5 years of life.

Bitewing radiographs were taken as an adjunct to clinical examinations in these studies, so that “all” carious lesions on approximal surfaces in molars were registered. Some of these lesions would have been missed without radiographs. This is in contrast to most other large scale epidemiological studies which do not include radiographs and care must be taken when comparing the present results with studies not including radiographs.

### **Questionnaires**

Information from the parents was collected by questionnaires in the MoBa study and at the dental examinations. The longitudinal study design, with data collection several times during pregnancy and early childhood, reduces bias due to parents’ poor recollection of past events. Information was collected before the outcome, caries experience at the age of 5 years, was recorded and possible bias in the data because parents or examiners knew whether the child would develop caries or not (information bias) was reduced.

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The validity of questions in the MoBa study has been tested previously. Statistically significant associations between exercise activities reported in the MoBa study and objectively measured physical activity have been found (131). The food frequency questionnaire used in the MoBa study have been shown to give reasonably valid intake estimates and it has been reported to be a valid tool by which to rank the mothers' according to low and high intakes of energy, nutrients and food (132).

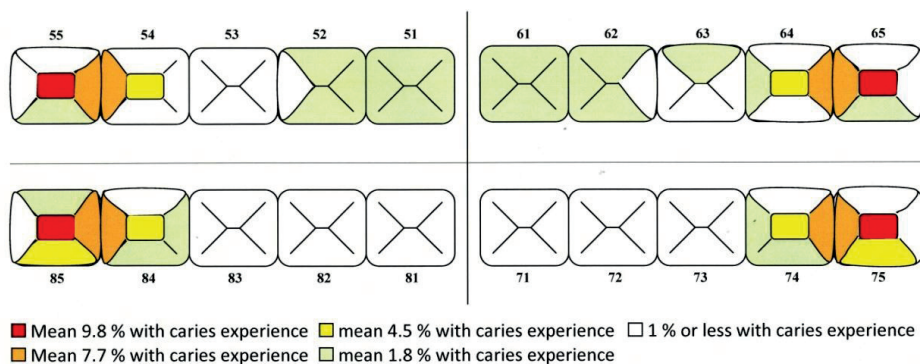
The questionnaires filled in at the dental examination were pilot tested in parents and adjusted according to comments prior to data collection. The questions regarding attitudes to oral health behaviours have previously been validated and used in international studies (133), and dental anxiety in parents was reported using Corah's dental anxiety scale, which has been widely used and psychometrically evaluated, including in Norwegian populations (134).

## **Main results**

### ***Caries prevalence and distribution***

In the cross-sectional study, the majority of the 5-year-olds, 82%, had no dentine caries experience (Paper I). This has major implications for the planning of dental services for children, including estimating the quantities and types of dental personnel necessary. Enamel caries was registered in 29% of the children, and enamel carious lesions i enamel constituted 50% of all registered caries lesions (Paper I). In 16% of the children, only enamel carious lesions were registered. This result indicates that preventive dental care targeted at preschool children and their families is required. The results showed that a relatively low proportion of children required restorative care and suggest that dental hygienists could provide most of the primarily preventive dental care for this child population (135, 136).

Figure 7 depict the localisation of the caries experience in the dentition of 5 year old children in a low caries area (a version of Figure 2 in Paper I).



**Figure 7.** Caries localisation in the deciduous dentition of 5-year-old children.

Previous studies have reported caries localisation in the deciduous dentition in populations with higher caries prevalence (21-24). This study showed that the major pattern of caries was similar in low and high caries populations. Further, in this low caries population, many teeth and surfaces never or very seldom had caries and the vast majority of the dentine caries lesions were one-surface lesions, mainly located on molars. The results indicated that the majority of the carious lesions were one-surface lesions, and that the molars accounted for 85% of the carious lesions (Paper I). These results have implications for the provision of preventive advice regarding brushing and flossing for children and their parents.

Caries experience in the preschool population was highly skewed. While 82% had no dentine caries experience, children with dentine caries experience had on average three teeth with dentine caries experience (Paper I). This indicates that a only small proportion of children (about 20%), needs restorative dental care before the age of 5 years. Increased knowledge regarding risk indicators for caries development in early childhood would help to identify these children at risk of developing caries before clinical caries develops.

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## ***Caries risk indicators***

In this thesis, it was shown that several family characteristics were associated with the presence of caries at the age of 5 years.

### **Demographic factors of the family**

The results in this thesis showed that structural characteristics of the family in pregnancy and early childhood were associated with caries development in children before the age of 5 years (Paper I and Paper III).

A social gradient in dental health in preschool children was demonstrated when social level was measured by parents' education and national background. In addition to confirming the effect of educational level (51, 54, 68, 72, 73, 84, 86, 95, 112, 137-139), the results showed that, in non-western children, the association between parental education and caries was stronger than in western children, suggesting that the real high risk group is non-western children whose parents have low education (Paper I).

Change in family status from pregnancy to when the child turned 5 years was found to be related to caries prevalence at the age of 5 years (Paper III). A change in family status, such as separation or divorce, causes emotional stress on the parents, and may lead to changes in daily routines. This may influence the parents' ability to give the child appropriate dental care and so increase the risk of developing caries. Stability of family structure in early life seems, therefore, to be associated with caries development in preschool children. A Swedish study, including seven families with children who had developed caries before two years of age, showed that all families had experienced at least one life event that had put the family into crisis (9). A Finnish study showed that living in families where family relationships are complicated was associated with risk of developing caries in children (88).

Many mechanisms have been suggested to mediate the association between social conditions and caries experience. Low educational level has been associated with reduced ability to adopt to health promoting behavior (140). It has been well documented that immigrant children have higher caries prevalence than other children (26, 54, 68, 71,

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72, 74-82, 94, 97, 139, 141, 142) but the reasons for the high caries prevalence among non-western children are debated. A higher probability of developing caries among immigrant children has been associated with “cultural” differences in child rearing and immigrant parents’ beliefs and attitudes towards dental health (96). The strong and consistent finding of associations between educational level and national background and early development of caries indicate that among parents with immigrant background and low education intensified health promotion in early childhood are necessary.

The results from this thesis showed that even in Norway, where the child dental service is comprehensive and individualized and the aim is to remove health inequalities in children, family conditions such as parental education level, parental background and family status are decisive for the development of caries in preschool children.

#### **Parental oral health behaviours, beliefs and attitudes**

Parental habits regarding tooth brushing and parental beliefs and attitudes towards tooth brushing were related to caries prevalence in children (Paper I).

These results are consistent with the findings of previous studies which have reported that parental tooth brushing frequency (88, 92, 93) and that parental attitudes towards tooth brushing were associated with children’s caries status (103-106).

Attitudes and beliefs can be considered as long-term individual characteristics which shape behaviours and can be acquired through primary socialisation (101, 102). Several conditions can influence the establishment and maintenance of beliefs and attitudes. These include knowledge in the field of interest, social and cultural background and society. Beliefs and attitudes are modifiable and can differ between individuals from the same background (101). Changing peoples’ beliefs and attitudes is considered complicated. There are several theoretical models explaining how beliefs and attitudes regarding health-related behaviours can be modified, but there is no consensus in the literature about which model to choose (101). Considering parental oral health behaviours and attitudes could be an important part of caries prevention in preschool children, as children develop their oral health behaviours on the basis of health habits in

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the family (67, 69). Targeting preventive care based on parental oral health behaviours, beliefs and attitudes could be expected to improve the efficacy of the preventive advice given to preschool children and their families.

### **Dental anxiety and dental attendance**

Caries prevalence in children at the age of 5 years was associated with missed dental appointments and behaviour management problems in early childhood (Paper II).

When children do not attend for scheduled dental appointments, it is usually due to the parents not bringing the children to the dental service. This behaviour may reflect parents' negative beliefs and attitudes toward dental care (111). It may also be due to ignorance of the dental care system for children or to a parent's fear of the consequences of taking time off work. Missed dental appointments have been related to caries prevalence in older children (66, 143), and reported to be associated with dental treatments due to toothache in children (64). The results from this thesis signify the importance of establishing early contact with parents of children who do not show up for scheduled appointments to explore possible obstacles to bringing their children to the dental services. Strategies aimed at changing parental behaviours may represent an important part of caries prevention for preschool children. Focusing on prevention of further missed dental appointments in preschool children may be less resource consuming than performing more complicated dental treatments as a result of caries a few years later (144).

The reasons for behaviour management problems in the dental situation are numerous (145), from immaturity in the child to more complex problems, such as a burdensome life or family situation (146). The findings support the importance of giving young children with behaviour management problems appropriate care including caries prevention, rather than waiting for child development and maturity (65). As the reason for behavioural management problems in preschool children may be caused by a burdensome family situation these children and their families require special support from the Public Dental Services to prevent further caries development in children.



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## **Maternal general health and lifestyle**

Maternal weight close to the beginning of the pregnancy, maternal sugar consumption in pregnancy and frequent parental intake of sugar containing drinks at 5 years of age was associated with the risk of caries prevalence in 5-year-old children (Paper I and Paper IV).

Sugar is important in caries development (14), and children's sugar consumption is related to caries development (51, 57, 58). The Public Dental Services has routines regarding information for parents and children about children's sugar consumption and risk of caries development as part of the dental examinations of children (147). The results from these studies indicate that the information given about sugar consumption and risk of caries development in children should also include information about maternal sugar consumption and the benefits of reducing this, particularly with respect to the reduced risk of caries development in children. Efforts towards reducing maternal high sugar consumption could start during pregnancy, to enable the mothers to change their habits before child birth, as the mothers are likely to introduce their dietary habits to the children (98).

The relationship between maternal obesity and caries development in children may be linked with biological development and dietary habits. Maternal obesity during pregnancy has been considered to influence appetite control in children (148) and the probability of an increased number of meals which may influence caries development. Maternal obesity has been related to reduced possibility of breastfeeding, and thereby associated with high sugar consumption in children (149). This indicates that information given to the mothers during pregnancy regarding diet, dietary habits and sugar consumption should include information about the risk of caries development in preschool children.

## **Clinical implications**

Such information could be used to identify children at risk of developing caries and opens the possibility of targeting preventive oral care to children at risk of developing caries and their families. Usually the primary health care personnel know the major caries risk

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indicators associated with caries for 5-year-old children (education, national background, maternal weight and family situation) when the mother is pregnant or soon after the birth.

Pregnant mothers with unfavourable oral health behaviours or with one or several of the family structural characteristics identified as risk indicators for caries should be referred for dental care, to enable oral health promoting activities to be instigated. Dental care for children younger than 3 years of age is in Norway partly provided by primary care personnel in general health care units. Further development of the collaboration between the Public Dental Services and primary care personnel in health care units, regarding dental care for children at risk of developing caries, could be ensured by establishing routines based on the risk indicators that have the potential to prevent caries development.

Children that do not attend for to dental appointments and children who have behavioural management problems in early dental visits require special attention from the Public Dental Services. By offering these children and their families intensified preventive dental care caries prevalence in 5-year-old children could be reduced further.

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## **Future research**

In this thesis, risk indicators for caries development in preschool children were identified. As a follow-up, a fields study has been initiated in the Public Dental Services in the county of Vestfold to use the identified risk indicators in primary care units for preschool children as criteria for referring children to the Public Dental Services. The number and characteristics of the children will be registered and the referred children will be given intensive preventive care.

Collecting data on oral health in these 5-year-old children as they grow up will make it possible to see whether the indicators for caries at the age of 5 years persist as caries indicators during later childhood and adolescence. In addition, the material used in this thesis includes information that can be analysed further to learn more about dental health behaviours and how aspects of the Public Dental Services influence the dental health of preschool children.

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## CONCLUSIONS

This thesis aimed at describing caries experience and distribution in the dentition of 5-year-old children in a low caries population, and to explore associations between caries prevalence in 5-year-old children and parent-related factors during pregnancy and early childhood.

The studies showed that:

- more than 80% of the 5-year-old children had no dentine caries experience, and 10% of the children had 5 or more teeth with enamel or dentine caries experience
  - caries experience was mainly registered in the molars, in the occlusal surfaces
- A social gradient in caries prevalence in 5-year-old children in Norway was found
  - the real high-risk group was children of non-western origin with parents with low education
  - change in family situation before 5-years of age represented risk of caries development in preschool children
- Parental tooth brushing habits and attitudes to tooth brushing in children were associated with caries prevalence in children
- Missed dental appointments in children and behaviour management problems at early dental visits were related to caries prevalence in preschool children
- Maternal weight and sugar consumption in pregnancy were associated with caries prevalence in preschool children

The caries risk indicators identified in this thesis may increase the possibility to target preventive care at the children with the highest risk of dental caries.

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# APPENDIX 1

## 1a. Invitation letter



UNIVERSITETET I OSLO  
DET ODONTOLOGISKE FAKULTET

### Forespørsel om å delta i en undersøkelse av hull i tennene hos småbarn

"Kariesprediksjon hos småbarn"

I forbindelse med den vanlig rutineundersøkelsen i Tannhelsetjenesten i Akershus vil vi invitere din femåring til å delta i en studie.

#### Hensikt

Undersøkelsen kan komme fremtidige barn til gode ved å øke mulighetene til å oppdage risiko for hull i tennene tidlig og gjøre det mulig å tilby forebyggende behandling til barn med høy risiko for hull.

#### Deltagelse er frivillig

Opplysning om barnets tannhelse vil bli registrert. Opplysninger vil bli samlet ved undersøkelsen av barnets tenner. Undersøkelsen vil bli gjennomført på samme måte som ved den ordinære tannhelsekontrollen som barnet innkalles til i Den offentlige tannhelsetjenestene i Akershus. I forbindelse med tannhelsekontrollen vil du bli bedt om å fylle ut et spørreskjema. Det inneholder spørsmål om bakgrunnsopplysninger, tannhelsevaner og bruk av tannhelsetjenesten.

Deltagelse i undersøkelsen vil ikke medføre noen konsekvenser for deg eller barnet. Opplysningene skal kun benyttes til forskning og vil inngå i doktorgradsarbeidet til stipendiat Tove Wiggen ved Universitetet i Oslo. Deltagere vil da få samme behandling som de som ikke deltar i undersøkelsen og kan når som helst trekke seg fra videre deltagelse. Barn som fyller 5 år i 2007 kan delta i undersøkelsen.

#### Personopplysninger

Alle som arbeider med undersøkelsen har taushetsplikt og opplysningene behandles konfidensielt. Tannhelseopplysninger fra barnets tannhelsejournal og svar på spørsmål vil bli aidentifisert før de utleveres til forskere, det vil si at data uten identifikasjon benyttes og kodenøkkel oppbevares separat. Prosjektet avsluttes innen utgangen av 2010. Det er ikke satt tidsbegrensning for hvor lenge opplysningene kan lagres. Det er mulig at det vil bli aktuelt å gjennomføre en oppfølgingsundersøkelse. I så fall vil du motta ny informasjon og ny forespørsel om å delta. Ved 18 års alder vil barna motta informasjon om at data lagres og må aktivt samtykke til videre oppbevaring. Prosjektet er vurdert av Regional etisk komité og tilrådd av Personvernombud for forskning ved Norsk samfunnsvitenskapelig datatjeneste.

#### Til de som er med i Mor og barnundersøkelsen

Dersom barnet ditt deltar i Mor og barnundersøkelsen i regi av Nasjonalt Folkehelseinstitutt vil vi be om samtykke til at opplysningene som samles inn ved tannhelsekontrollen kobles til spørreskjemadata (opplysning om tannhelseatferd, helse, sosio-økonomi og andre opplysninger som er vist å påvirke tannhelse) som er innsamlet. Informasjonen benyttes i aidentifisert form (uten personopplysninger). Deltagelse i tannhelseprosjektet er frivillig og påvirker ikke videre deltagelse i Mor og barnundersøkelsen.

#### Studien gjennomføres av:

Universitet i Oslo, Det odontologiske fakultet, Institutt for klinisk odontologi, Pb 1109 Blindern, 0317 Oslo  
Den norske Mor og barnundersøkelsen, Nasjonalt Folkehelseinstitutt, Pb 4404 Nydalen, N-0403 Oslo  
Den offentlig tannhelsetjenesten i Akershus, Schweigaardsgt 2, 0136 Oslo

Dersom du har spørsmål om undersøkelsen kan disse rettes til prosjektleder, førsteamanuensis Nina J Wang, Institutt for klinisk odontologi – avdeling for pedodonti og adferdsfag, Det odontologiske fakultet, Pb 1109 Blindern, 0317 Oslo, tlf 22 85 22 70.

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## 1b. Informed consent



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DET ODONTOLOGISKE FAKULTET

### Samtykkeerklæring

Jeg samtykker i at mitt barn deltar i undersøkelsen av hull i tennene hos småbarn "Kariesprediksjon hos småbarn".

Jeg har lest informasjonen om studien og samtykker i at min sønn/datter vil delta i tannhelseundersøkelsen.

Dersom din sønn/datter deltar i Mor og barnundersøkelsen: Jeg samtykker til at opplysningene fra tannhelsestudien kobles til Mor og barnundersøkelsens opplysninger.

Barnets navn: \_\_\_\_\_

Barnets fødselsnr (11 siffer): \_\_\_\_\_

Dato: \_\_\_\_\_

Underskrift: \_\_\_\_\_

Jeg har lest informasjonen om studien og ønsker **ikke** at min sønn/datter skal delta i tannhelseundersøkelsen:

Dato: \_\_\_\_\_

Underskrift: \_\_\_\_\_



# APPENDIX 2

## 2a. Registration form used in clinical examination of the children

**Fylles ut av tannklinikken – registreringskjema**

1 Klinik 2 Behandler 3 Pasient  
[ ][ ][ ] [ ][ ][ ] [ ][ ][ ]

4 Undersøksdato: \_\_\_\_\_

5 Distrikt:  Asker og Bærum  Nedre Romerike  
 Follo  Nordøstre Romerike

6 Antall ikke-møtt besøk i alderen 3 til 5 år: \_\_\_\_\_

7 Barnet ble registrert som risikopasient ved 3-års kontroll?  Nei  Ja

8 Tid fra forrige kariesundersøkelse: \_\_\_\_\_ måneder

9 Pasient ikke møtt til undersøkelse:

----- **Avslutt her dersom pasienten ikke har møtt**

10 Tid til neste kariesundersøkelse: \_\_\_\_\_ måneder

11 Røntgen BW tatt:  Ja  
 Nei, fordi:  Barn eller mor ønsker ikke  
 Ikke nødvendig

12 Gjennomføring av undersøkelsen?  
 Klinisk kariesregistrering uten problem  
 Klinisk kariesregistrering etter overtalelse  
 Delvis klinisk kariesregistrering  
 Ikke mulig å gjennomføre klinisk kariesregistrering

Opus

Altk: B	Gruppe P2	
ST: B	DS: B	DS + B
DT: B	MS: B	FS + B
MT: B	FS: B	Approx. I, D, F: B
FT: B	DPS: B	Approx. II, D1, D2: B
DTF: B	DMFS: B	Antall decid. tenner: B
DMFT: B		

Hverst: B

Egen editer: Flus: [ ] Div: [ ] Risiko: [ ]  
Kosthold: [ ] CRIN: [ ]  
Hygiene I: [ ] Chikaprøvdokt: [ ]  
Hygiene B: [ ] Oralpasstg: [ ]

Alle svarte bokser skal være registrert i Opus


Tannhelsedata for 5 åringer skrives ut fra Opus: Se eget ark for fremgangsmåte

Utskriften stiftes sammen med dette registreringskjema og spørreskjema og samtykkeskjema

## 2b. Additional registration form used in the cross-sectional study

Utvalgsundersøkelse

**Tilleggsskjema – fylles ut av stipendiaten**

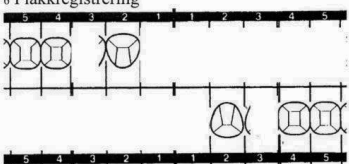


1 Klinik 2 Behandler 3 Pasient

4 Undersøkesdato: \_\_\_\_\_

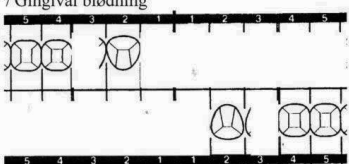
5 Barnets personnummer: \_\_\_\_\_ / \_\_\_\_\_

6 Plakkregistrering



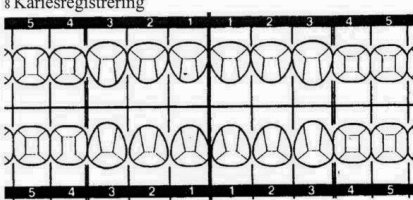
Indikatorflater:  
55 b,m, 54d, 52 b,p,  
75 l,m, 74d, 72b,l

7 Gingival blødning



Indikatorflater:  
55 b,m, 54d, 52 b,p,  
75 l,m, 74d, 72b,l

8 Kariesregistrering



BW ikke tatt  
 Årsak: \_\_\_\_\_

9 Tannstillingsfeil:

Åpent bitt       Overbitt  
 Kryssbitt       Underbitt  
 Ikke tvangsføring  
 Tvangsføring  
 Trangstilling

Nei  
 Smokk  
 Sluttet ved \_\_\_\_\_ år  
 Fingersuging  
 Sluttet ved \_\_\_\_\_ år  
 Vet ikke

10 Mineraliseringsforstyrrelser \_\_\_\_\_

1=Velavgrenset opacitet  
 2=Diffus opacitet  
 3=Hypoplasi

12 Erosjon til dentin Tann \_\_\_\_\_  
 Kode \_\_\_\_\_

Indikator-tann: Alvorligst affisert tann av de primære molarer  
 Kode: Grad 3: Mindre enn 1/3 av flaten har blottlagt dentin  
 Grad 4: 1/3 – 2/3 av flaten har blottlagt dentin  
 Grad 5: Mer enn 2/3 av flaten har blottlagt dentin

Tove Wigen UIO  
 Januar 2007

# APPENDIX 3

## 3a. Questionnaire to the parents

### Tannhelse hos 5-åring – spørreskjema til foresatte

Barnets personnummer (11 siffer): \_\_\_\_\_ - \_\_\_\_\_

Mors personnummer (11 siffer): \_\_\_\_\_ - \_\_\_\_\_

#### 1. Kjønn:

- Gutt  
 Jente

#### 2. Har noen av barnets foreldre utenlandsk opprinnelse?

- Ja, mor; land: \_\_\_\_\_  
 Ja, far; land: \_\_\_\_\_  
 Nei

#### 3. Antall år med utdanning etter grunnskole:

Med antall år menes antall år med fullført utdanning etter ungdomsskole.

\_\_\_\_\_ år, mor  
\_\_\_\_\_ år, far

#### 4. Hvor ofte børstes barnets tenner?

- 2 ganger per dag eller mer  
 1 gang per dag  
 Av og til  
 Aldri

#### 5. Brukes fluortannkrem på børsten?

- Nei  
 Av og til  
 Ja, vanligvis

#### 6. Får barnet ofte hjelp med tannpuss?

- Aldri  
 Av og til  
 Daglig  
 2 ganger per dag

#### 7. Bruker barnet fluortabletter?

- Nei  
 Av og til  
 Ja, daglig fra \_\_\_\_\_ måneders alder

#### 8. Barnet bor sammen med:

- Mor og far  
 Delt samvær  
 Mest hos mor  
 Mest hos far  
 Annet

#### 9. Hvor ofte drikker eller spiser barnet følgende?

	Sjeldnere enn en gang per uke	En gang per uke	Flere ganger i uken	Flere ganger per dag
a. Sukkerholdig saft/nectar/leskedrikk/brus	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. Sukkerfri saft/leskedrikk/lettbrus	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c. Kjeks/boller/vafler	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d. Smågodt, seigmann, sjokolade etc	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

#### 10. Tannlegebesøk:

	Svært enig	Enig	Verken enig eller uenig	Uenig	Svært uenig
a. Barnet gleder seg til tannlegebesøk	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. Barnet viser redsel/bekymring for tannlegebesøk	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c. Barnet har hatt problemer med tannlegebesøk tidligere	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d. Barnet har hatt smerter på grunn av hull	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>


#### 11. Min sønn/datter deltar i Mor og barn undersøkelsen:

- Ja       Nei       Vet ikke

Lever skjema til tannpleier/tannlege!

## 3b. Additional questionnaire used in the cross-sectional study

Utvalgsundersøkelse



**Tilleggsspørsmål – til foresatte**

**1. Har barnet noen sykdom?**  
 Nei  
 Ja, hva: \_\_\_\_\_

**2. Bruker barnet noen medisiner?**  
 Nei  
 Ja, Medikament: \_\_\_\_\_

**3. Hva gjør barnet på dagtid?**  
 Er i heldags barnehage/dagmamma  
 Er i barnepark  
 Er hjemme med mor/far eller andre  
 Annet; hva \_\_\_\_\_

**4. Når begynte du/dere med tannpuss av barnets tenner?**  
 Under 1 år  
 Mellom 1 og 2 år  
 Mellom 2 og 3 år  
 Husker ikke

**5. Barnets vekt:** \_\_\_\_\_ kg

**6. Er du fornøyd med tilbudet barnet ditt får fra Den offentlige Tannhelsetjenesten?**  
 Ja  
 Nei, hvorfor ikke? \_\_\_\_\_

---

*Så noen spørsmål til deg, om DIN tannhelse.*

**7. Hvem følger barnet?**  
 Mor  
 Far  
 Annen; \_\_\_\_\_

**8. Hvor ofte børster du tenner?**  
 2 ganger per dag eller mer  
 1 gang per dag  
 Av og til  
 Aldri

**9. Hvor ofte går du til tannlege?**  
 Har fast tannlege, får regelmessig innkalling  
 Har fast tannlege, tar selv kontakt ved behov  
 Har ikke fast tannlege, tar kontakt ved smerter/behov  
 Aldri

**10. Har du hatt problemer med tennene?**  
 Ja  
 Nei

**11. Har du hatt hull i tennene?**  
 Ja  
 Nei

**12. Hvis ja, hvor mange tenner har du fyllinger i?**  
 1-4  
 5-10  
 Mer enn 10

**13. Er du fornøyd med tennene dine?**  
 Ja  
 Nei, hvorfor ikke? \_\_\_\_\_

**14. Hvor ofte drikker eller spiser du følgende?**

	<i>Sjeldnere enn en gang per uke</i>	<i>En gang per uke</i>	<i>Flere ganger i uken</i>	<i>Flere ganger per dag</i>
a. Saft/nectar/leskedrikk/brus <u>med</u> sukker	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. Saft/leskedrikk/brus <u>uten</u> sukker	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c. Kjeks/boller/vafler	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d. Smågodt, seigmann, sjokolade etc	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**15. Holdninger**

	<i>Svært enig</i>	<i>Enig</i>	<i>Verken enig eller uenig</i>	<i>Uenig</i>	<i>Svært uenig</i>
a. Vi prøver å kontrollere hva barnet spiser/drikker mellom måltidene	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. Det er viktig for oss å kontrollere hva barnet spiser/drikker mellom måltidene	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c. Det er bare uflaks hvis barnet får hull i tennene	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d. Det er ikke bryet vært å kjempe med barnet om tannpuss	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
e. Det er ofte for stressende å si nei til sotsaker når barnet vil ha det	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Tove Wiggen UiO  
Januar 2007

SNU

#### 16. Angst og ubehag ved tannbehandling

Nedenfor er det fire spørsmål med 5 svaralternativer for hvert spørsmål.

Les spørsmålet og kryss av i den boksen som står foran svaret som du synes passer best for deg.

1. Dersom du skulle til tannlegen i morgen, hva ville du føle?

- a. Jeg ville se frem til det som en ganske hyggelig opplevelse
- b. Det ville være det samme for meg, ikke bety noe
- c. Det ville gjøre meg litt urolig
- d. Jeg ville bli redd for at det skulle bli ubehagelig og vondt
- e. Jeg ville bli svært redd med tanke på hva tannlegen kanskje skulle gjøre

2. Når du venter på tannlegens venteværelse, hvordan føler du deg da?

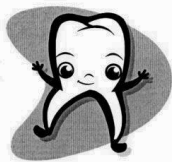
- a. Avslappet
- b. Litt urolig
- c. Anspent, nervøs
- d. Redd, engstelig
- e. Så redd at jeg av og til begynner å svette eller nesten føler meg syk

3. Når du sitter i tannlegestolen og venter på at tannlegen skal begynne behandlingen, hvordan føler du deg da?

- a. Avslappet
- b. Litt urolig
- c. Anspent, nervøs
- d. Redd, engstelig
- e. Så redd at jeg av og til begynner å svette eller nesten føler meg syk

4. Tenk at du sitter i tannlegestolen og skal få temene rensset og pusset. Hvordan føler du deg mens du sitter og venter på at tannlegen skal finne frem instrumentene som skal brukes til å skrape og pusse med?

- a. Avslappet
- b. Litt urolig
- c. Anspent, nervøs
- d. Redd, engstelig
- e. Så redd at jeg av og til begynner å svette eller nesten føler meg syk



TAKK FOR HJELPEN !





















# **Maternal health and lifestyle and caries experience in preschool children. A longitudinal study from pregnancy to age 5 yr**

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**Running title:** Maternal lifestyle and caries in children

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*Wigen TI, Wang NJ.*

Maternal health and lifestyle and caries experience in preschool children. A longitudinal study from pregnancy to age 5 yr

*Eur J Oral Sci;*

### **Abstract**

In this study, associations between maternal health and lifestyle in pregnancy and early childhood and caries experience in preschool children were explored. The study is based on the Norwegian Mother and Child Cohort study conducted by the Norwegian Institute of Public Health and on data from the Public Dental Services. A total of 1348 children were followed from pregnancy to age 5 yr. Clinical dental examination was performed at age 5 yr. Questionnaires were completed by the mothers during pregnancy and the first 18 months of life, and as part of the dental examination. The results from the multivariable logistic regression analysis showed that having a mother defined as obese (OR 2.1, CI 1.1-4.1), or overweight (OR 1.6, CI 1.0–2.6), having a mother with a diet containing more sugar than recommended (OR 1.6, CI 1.1-2.4), having one or both parents of non-western origin (OR 4.6, CI 2.0-10.5) and having a mother with low education (OR 1.5, CI 1.0-2.3), were statistically significant risk indicators for caries experience at age 5 yr. In conclusion, maternal weight and sugar intake in pregnancy were associated with caries experience in preschool children.

**Keywords:** caries risk indicators, dental caries, obesity, social determinants, sugar consumption

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Identification of children at risk of developing caries in early childhood is of interest in populations with low prevalence of dental caries. Identification of children can be performed by primary health care personnel that have contact with the families during pregnancy and in early childhood. It is well accepted that the environment can affect the carious process and caries development in children (1, 2). In a conceptual model, several levels of the environment have been described by Fisher-Owens and co-workers: child-level; family-level and community-level (3). At the family level, possible risk indicators are structural relationships in the family and maternal health and lifestyle. It is known that socio-demographic factors such as parental national background and education (4-7), family status (8, 9), family income (7, 10) and maternal age at child birth (7, 8, 11) are associated with development of dental caries in young children. Knowledge regarding associations between maternal health and lifestyle in pregnancy and early childhood, and caries development in preschool age is scarce.

Maternal lifestyle habits such as diet, physical activity, weight and smoking habits influence the children and the establishment of children's oral health behaviours. Children's dietary intake has been shown to be strongly associated with their mothers' dietary intake (12), and the children's own dietary habits developed early in life (13, 14). Relationship between parental intake of sugar-containing beverages and caries experience in 5-yr-old children has been shown (4). Maternal weight early in pregnancy has been associated with caries increment during the teenage period (15). Associations between birth weight and dental caries have been explored in several studies, with conflicting results (16-18). Association between parental tobacco smoking and caries in primary teeth has been demonstrated in several studies (19-21).

In Norway, children are, by law, offered free dental care in the Public Dental Services. The first regular contact with the Public Dental Services is at age 3 yr. Caries prevalence in

preschool children is low and the caries experience is skewed (22). Identification of children at risk of developing caries should preferably be performed before clinical caries is visible so that preventive strategies may be put in place. We have previously demonstrated associations between parents' oral health behaviours and access to dental care and caries experience in children in a cross-sectional study (4, 23), and associations between maternal education, parental national background and family status, and caries experience in preschool children in a longitudinal study (9). In this study, we explore associations between maternal health and lifestyle in pregnancy and early life and caries experience in preschool children using longitudinal data. Based on previous research, it was hypothesized that maternal general health and lifestyle in pregnancy and children's early life were associated with caries experience in early childhood.

### **Material and methods**

This study is based on the Norwegian Mother and Child Cohort Study conducted by the Norwegian Institute of Public Health (24, 25) and data from dental examination of 5-yr-old children (The Dental Study).

The Mother and Child Cohort Study is a prospective pregnancy cohort study including more than 100 000 pregnancies recruited from 1999 to 2009. Participants were recruited by postal invitation in connection with routine ultrasound examination offered to all pregnant women in Norway at 17-18 wk of gestation; 44% of all invited pregnant women agreed to participate. Data were collected by questionnaires completed by each mother in pregnancy, and when the child was 6, 18 and 36 months old. The current study was based on quality-assured data files (version 3) released for research in 2007, and included 1607 children born in 2002 in the county of Akershus.

All children born in 2002 enrolled in the Public Dental Services (PDS) in Akershus were invited to participate in The Dental Study as part of their regular dental examination, as close as possible to the age of 5 yr. In 2007, 96% of the 5-yr-olds were enrolled in the PDS. The county of Akershus has more than 500 000 inhabitants, making up 11% of the Norwegian population. The dental health of the 5-yr-olds in the county was slightly better than the national average with 80% without need of restorative treatment in 2007 (22). The data were collected in 2007 and 2008, and 5623 (80%) of the 7002 children enrolled in the PDS participated in the study.

In Norway, each resident has a unique 11-digit National Registration Number. This number is recorded in health registries and health records, and permits linkage between different registries. Of the 1607 children participating in the Mother and Child Cohort Study, 1366 also participated in The Dental Study. Eighteen children lacked data from Mother and Child Cohort Study questionnaires and were excluded from these analyses. The final study population consisted of 1348 children with data both from the Mother and Child Cohort Study and The Dental Study.

The clinical dental examination of the children was performed by 44 dental hygienists as part of the regular dental recall examination in the PDS. The examination was performed in a fully equipped dental clinic using plane mirror and sharp probe after the teeth had been dried with air. Bitewings were taken when indicated in accordance with standard routines in the PDS (bitewings when visual inspection of approximal surfaces is impossible), and were used in 68% of the children as an adjunct to the clinical caries registration.

Caries experience was registered as the sum of teeth recorded as decayed, filled or missing due to caries. Five caries grades were initially recorded both in clinical examination and in the radiographs (26), with the tooth surface as the unit of measurement. In this study,

the term “caries” was used to denote carious lesions extending into dentine. In the analyses, children were categorized as having or not having teeth with caries experience.

Intra- and inter-examiner agreement in the dental study was tested using 20 bitewing radiographs of deciduous molars including eight approximal surfaces in each radiograph. The first author was previously calibrated (4), and the registrations by the first author were used as a standard and compared with the dental hygienists’ registrations. Intra- and inter-examiner agreement was calculated using Cohen’s kappa. The mean inter-examiner Kappa-value was 0.86 (SD 0.10) and the mean intra-examiner Kappa-value was 0.85 (SD 0.12). Details on intra- and inter-examiner agreement have been described earlier (4, 9).

Exposure data was obtained from questionnaires answered during pregnancy and the first 18 months of life, and from a questionnaire completed by the accompanying parent at the dental examination. The questionnaires included information about maternal health and lifestyle habits: whether mother had had any long lasting diseases, her diet, weight and height, physical activity and smoking habits.

Maternal disease was reported if she had had any long-lasting chronic disease: asthma, allergy, diabetes, coronary disease, rheumatism, cancer, psychiatric disorders or other unspecified diseases. The diseases were categorized into allergy (including asthma), psychiatric disorders and somatic diseases. Maternal body mass index (BMI) was calculated as  $\text{weight/height}^2$  ( $\text{kg/m}^2$ ) on the basis of reported weight and height before pregnancy (27). BMI was categorized as normal ( $< 25$ ), overweight (25-29) and obese ( $>29$ ).

Physical activity was reported four times in the period from three months before pregnancy until the child was 18 months old. How often the mother was physically active during work and in leisure time was registered. Physical activity was dichotomized into physically active once a week or more often and being physically active less than once a week at all four registrations. Maternal smoking was reported as smoking or not smoking at four

points in time: at the beginning of the pregnancy; during pregnancy and at child age 6 months and 18 months.

Maternal diet was recorded by mothers completing a food frequency questionnaire in pregnancy. The information was used to calculate daily intake of nutrients (28, 29). In this study, intake of sugar, intake of fat and total energy intake were used to calculate the proportion of total energy intake from sugar and fat. In Norway, the health authorities have made recommendations on nutrition based on the Nordic Nutrition Recommendations (30). Intake of sugar should be less than 10% of total energy intake, and energy from fat in the diet should be less than 35% of total energy intake (31). Sugar in the diet in this study was dichotomized as less than 10% of total energy intake and 10% or more of total energy intake. Intake of fat was dichotomized as less than 35% of total energy intake and 35% or more of total energy intake.

The child's birth weight was dichotomized as less than 2500 g and 2500 g or higher. Preterm birth was defined as being born before wk 35 in pregnancy.

Maternal education was reported in pregnancy including completed and ongoing education. More than 12 yr at school was defined as high education and 12 yr or less was defined as low education. National background was recorded according to mother's and father's country of birth. Mother's and father's national background were combined into one variable and dichotomized into both parents with western origin and one or both parents of non-western origin. Non-western origin included parents born in Asia, Africa, South America, Central America and Eastern Europe.

The statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, Inc. Chicago, IL, USA), version 16.0. Bivariate and multivariable logistic regression analyses were conducted with children's caries experience as the dependent variable. Spearman's Rank correlation was used to explore associations between the

independent variables before the multivariable analysis was conducted. Spearman's rho was lower than 0.7 for all associations. Multivariable logistic regression using backward stepwise selection was performed. P-value for removal was set at  $p > 0.10$ . In the model, the key exposure variables: disease, smoking, physical activity, diet, birth weight and prematurity, as well as the background variables: education, national origin and child age at dental examination, were entered simultaneously. Results were reported using frequencies, odds ratios (OR) and 95% confidence intervals (CI).

Four of the independent variables (smoking at child age 6 and 18 months and physical activity at child age 6 and 18 months) had 10% or more missing answers. Missing answers in these variables were replaced by multiple imputations to reduce the loss of cases in the multivariable analysis. The level of statistical significance was set at 5%.

Written, informed consent was obtained from all parents. The investigation was approved by the Regional Committee for Medical Research Ethics, The Norwegian Social Science Data Services and The Norwegian Data Inspectorate.

## **Results**

The caries experience in the 5-yr-old children was low, only 11% of the children had any caries experience. Details of caries experience have been presented earlier (9). The distributions of parents and children according to maternal health, maternal diet, maternal lifestyle and family characteristics are presented in Table 1.

### *Bivariate analyses*

The results from the bivariate analyses are presented in Table 1. Statistically significant associations were found between caries experience in the children and having one or both parents of non-western origin (OR 5.0), having a mother defined as obese (OR 2.4) or

overweight (OR 1.5), with low education (OR 2.0), who smoked at child age 6 months (OR 1.8), who smoked during pregnancy (OR 1.6), who consumed more sugar than recommended (OR 1.6) and having a mother with asthma or allergy (OR 1.4).

### *Multivariable analysis*

The results of the multivariable logistic regression analysis, exploring associations between caries experience in the children and maternal health, maternal diet, maternal BMI, maternal smoking habits, maternal physical activity, maternal education, parental national origin, children's birth weight, children born preterm, children's age at dental examination, are given in Table 2.

Maternal weight and amount of sugar in the diet were statistically significantly related to caries experience in the child at 5 yr of age, in addition to maternal education and parental origin. Children whose mother was defined as obese had a 2.1 times higher probability of having caries experience at the age of 5 yr than children whose mother was defined as being of normal weight. Children whose mother consumed more sugar in the diet than recommended had 1.6 times higher probability of having caries experience at the age of 5 yr than children whose mothers had consumed less sugar in the diet. Children having one or both parents of non-western origin had a 4.6 times higher probability of having caries experience at the age of five than children both of whose parents were of western origin, and children with mother with low education had 1.5 times higher probability of having caries at the age of five than children with mother with high education (Table 2).

### **Discussion**

The aim of this prospective study was to explore associations between dental caries in children at the age of 5 yr and maternal health and lifestyle in pregnancy and early childhood.

The main results were that children with an obese or overweight mother, or one whose diet was rich in sugar early in pregnancy, had higher odds of having caries at age 5 yr than other children.

This study was based on data from the Norwegian Mother and Child Cohort Study. The cohort study design with data collection several times during pregnancy and early childhood reduces bias caused by parents' recall. The food frequency questionnaire used in this study produces reasonably valid intake estimates and is considered to be a valid tool by which to rank the mothers according to low and high intakes of energy, nutrients and food (28), and significant positive association between the measures of self-reported exercise activities and objectively measured physical activity has been found (32). Generally non-participation among invited subjects and low participation in prospective studies may cause selection bias and systematic errors in prevalence results (33). However, analyses have shown no statistically significant relative differences in association measures between participants in the Mother and Child Cohort Study and the total population regarding exposure-outcome associations (34). Results regarding exposure-outcome associations may therefore be generalised to the Norwegian population.

Maternal weight close to the beginning of the pregnancy was related to caries experience in children at 5 yr of age in this study. Maternal obesity has previously been associated with child obesity, and has also been linked to long-term detrimental consequences for child health, such as development of cardiac disease, obesity and diabetes later in life (35). One explanation of the link between maternal obesity and child obesity is the "developmental over-nutrition hypothesis". This states that maternal glucose, free fatty acids and amino acid concentrations result in permanent changes in appetite control, neuroendocrine function and energy metabolism in the developing fetus, leading to adiposity in later life (36). Lack of



appetite control in children may influence dietary habits, leading to increased numbers of meals which again is associated with development of dental caries.

In this study, maternal intake of sugar in pregnancy was related to caries experience in children at age 5 yr. Mothers whose diet is rich in sugar are likely to introduce the same diet to the children, leading to high sugar consumption in children (12). It has been shown that children whose diet is rich in sugar in early life may continue with a diet rich in sugar during childhood and adolescence (13, 14, 37). A study from Finland has shown that children with a diet rich in sugar exceeded the recommended sugar intake as early as the age 2 yr (37). An association between a diet rich in sugar in early childhood and caries experience at age 10 yr has been reported (38). The results indicate that information about maternal sugar intake during pregnancy and early childhood, and efforts towards changing maternal unhealthy diet, should be considered when planning preventive dental care for preschool children.

Maternal smoking in pregnancy and at child age 6 months were statistically significantly related to caries experience in children in the bivariate analyses, but did not reach statistical significance in the final multivariable analysis. A low, but significant correlation between the smoking variables at different point in time, between smoking and maternal weight and between smoking and education was found in the analyses. One explanation may be that in this child population with low occurrence of caries, high education level among the mothers' and few mothers who reported smoking, the study lacked the power to demonstrate an association between maternal smoking and caries experience. An association between mothers' smoking habits and caries experience in preschool children has previously been shown in several studies (19-21). Five yr olds whose parents' reported smoking received less help with tooth brushing, brushed less frequently and received more between-meals snacks and drinks at night than children who grew up in a smoke-free environment (19).

A reverse association between mothers who had allergies and caries experience in children was demonstrated in the bivariate analyses. This may be explained by such mothers being strict with the children's diet to protect the children from developing allergy, and thereby lowering the caries risk of the children. This association was not statistically significant when controlling for the other variables in the multivariable analysis.

Socioeconomic indicators such as education and national background are known risk indicators for caries development in preschool children (4-7). Education and national background influences lifestyle and general health and were included in the multivariable analysis. Even though education and national background were adjusted for in the analyses, maternal obesity and sugar consumption in pregnancy were related to caries experience in the child at age 5 yr. These analyses confirmed that caries experience in preschool children was associated with maternal education and national background.

In conclusion, maternal lifestyle in pregnancy and the early childhood were associated with caries experience in children before age 5 yr. Obesity and a diet rich in sugar in the mother can be considered risk indicators for caries in preschool children, and could be included as risk appropriate indicators identifying children at risk of developing caries and could be used to target preventive dental care for children before age 5 yr.

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Table 1. Description of independent variables for all children and children with caries experience. Bivariate logistic regression analyses with caries experience in children as the dependent variable.

	All children (n = 1348)		Children with caries (n = 147)		Bivariate logistic regression	
	%	(n)	%	(n)	OR	95% CI
<b>Maternal disease</b>						
Allergy						
Yes	63	(846)	70	(103)		
No	37	(502)	30	(44)	<b>1.4</b>	<b>1.0 – 2.1</b>
Psychiatric disorders						
No	92	(1236)	93	(137)		
Yes	8	(112)	7	(10)	0.8	0.4 – 1.5
Somatic disease						
No	77	(1032)	75	(110)		
Yes	23	(316)	25	(37)	1.1	0.8 – 1.7
<b>Maternal smoking</b>						
<b>Pre pregnancy</b>						
No	69	(893)	67	(98)		
Yes	31	(394)	33	(44)	1.1	0.8 – 1.7
<b>During pregnancy</b>						
No	90	(1173)	85	(120)		
Yes	10	(134)	15	(21)	<b>1.6</b>	<b>1.0 – 2.7</b>
<b>6 months after birth</b>						
No	88	(1015)	80	(90)		
Yes	12	(142)	20	(22)	<b>1.8</b>	<b>1.1 – 3.0</b>
<b>18 months after birth</b>						
No	84	(898)	80	(83)		
Yes	16	(175)	20	(21)	1.3	0.8 – 2.1
<b>Maternal physical activity</b>						
<b>Pre pregnancy</b>						
Less than once a week	25	(319)	20	(27)		
Once a week or more often	75	(963)	80	(105)	1.3	0.9 – 2.1
<b>During pregnancy</b>						
Less than once a week	42	(528)	41	(53)		
Once a week or more often	58	(721)	59	(76)	1.1	0.7 – 1.5
<b>6 months after birth</b>						
Less than once a week	25	(172)	22	(15)		
Once a week or more often	75	(524)	78	(54)	1.1	0.6 – 1.8
<b>18 months after birth</b>						
Less than once a week	28	(285)	29	(28)		
Once a week or more often	72	(743)	71	(70)	1.0	0.6 – 1.5
<b>Maternal diet</b>						
<b>Sugar (% of energy intake)</b>						
< 10	62	(791)	53	(72)		
≥ 10	38	(484)	47	(65)	<b>1.6</b>	<b>1.1 – 2.2</b>
<b>Fat (% of energy intake)</b>						
< 35	78	(1000)	74	(102)		
≥ 35	22	(275)	26	(35)	1.3	0.9 – 1.9
<b>Maternal BMI</b>						
Normal	70	(867)	58	(73)		
Overweight	21	(261)	25	(32)	<b>1.5</b>	<b>1.0 – 2.4</b>
Obese	9	(116)	17	(21)	<b>2.4</b>	<b>1.4 – 4.1</b>
<b>Child's birth weight (g)</b>						
≥2500	96	(1292)	94	(138)		
<2500	4	(53)	6	(9)	1.7	0.8 – 3.6
<b>Child born preterm</b>						
No	98	(1287)	97	(141)		
Yes	2	(28)	3	(4)	1.4	0.5 – 4.0
<b>Child's age at dental examination (months)</b>						
48-59	31	(419)	35	(52)		
60-71	65	(881)	60	(88)	0.8	0.5 – 1.1
72-80	4	(48)	5	(7)	1.2	0.5 – 2.8
<b>Maternal education</b>						
High	65	(876)	50	(73)		
Low	35	(468)	50	(72)	<b>2.0</b>	<b>1.4 – 2.8</b>
<b>Parental origin</b>						
Both western	96	(1294)	87	(128)		
One or both non-western	4	(54)	13	(19)	<b>5.0</b>	<b>2.8 – 8.9</b>

Table 2. Multivariable logistic regression analysis of associations between caries experience in children and maternal health, maternal diet, maternal BMI, maternal smoking, maternal physical activity, children's birth weight, children born preterm, maternal education, parental origin and children's age at dental examination (n = 1043).

	OR	95% CI
Sugar (% of energy intake)		
< 10 (ref)		
≥ 10	<b>1.6</b>	<b>1.1 – 2.4</b>
Maternal BMI		
Normal (ref)		
Overweight	<b>1.6</b>	<b>1.0 – 2.6</b>
Obese	<b>2.1</b>	<b>1.1 – 4.1</b>
Maternal education		
High (ref)		
Low	<b>1.5</b>	<b>1.0 – 2.3</b>
Parental origin		
Both western (ref)		
One or both non-western	<b>4.6</b>	<b>2.0 – 10.5</b>

ref = reference category