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**Dental caries in children aged 3-10 years**  
**Longitudinal and cross-sectional studies**

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# **1 List of the papers constituting the basis for the present thesis**

1. Skeie MS, Espelid I, Skaare AB, Gimmestad A. Caries patterns in an urban, preschool population in Norway. *Eur J Paediatr Dentistry* 2005; 6 (1):16-22.
2. Skeie MS, Riordan PJ, Klock KS, Espelid I. Parental risk attitudes and caries-related behaviours among immigrant and western native children in Oslo. *Community Dent Oral Epidemiol* 2005; accepted.
3. Skeie MS, Raadal M, Strand GV, Espelid I. Caries in primary teeth at 5 and 10 years of age : a longitudinal study. *Eur J Paediatr Dentistry* 2004; 5 (4): 194-202.
4. Skeie MS, Raadal M, Strand GV, Espelid I. The relationship between caries in the primary dentition at 5 years of age and permanent dentition at 10 years of age – a longitudinal study. *Int J of Paediatr Dentistry* 2005; accepted.



## 2 Introduction

### **2.1 Time trends of the caries disease**

Repeatedly epidemiologic studies and reports have confirmed a substantial decline in dental caries among children in Western Europe during the 1970s and early 1980s (38, 187, 196).

Among proposed explanatory factors for the reduction are widespread use of fluoride, school-based prevention programs and dental care activities at child welfare centres (18, 20, 177, 188, 215). Changes in diagnostic criteria and a more conservative treatment philosophy have also been listed as contributory factors (54).

It is widely accepted that countries, which have achieved a low mean level of dental caries appear to be resistant to further decline (177). Among preschool children, a tendency to stagnation in caries reduction was reported as early as the end of the 1980s (81, 188), and since then similar reports about the same age group have been published (38, 150). Among 5-yr-olds, some researchers suggest even a caries increase (70, 128, 144) (Abstract. Armfield J, Spencer AJ. Increases in caries experience in Australian children. 81<sup>st</sup> General Session of the IADR. 2003).

Trends towards static caries levels have been noticed in both primary and permanent teeth among 6- and 7-yr-olds (110, 147, 197), but most dental health reports covering 12-yr-olds describe a continuing caries decline. Inter-country differences exist (27), and within this age group, there are populations in which the caries reduction has bottomed out (108, 197).

Not unexpectedly, when cohorts of children were followed to elucidate time trends in caries increment during age spans, the same caries patterns emerge. In Denmark, during the period 1988-1994, a slight decrease in caries increment was noticed the first years in both the

deciduous (3 to 6 yr) and permanent dentition (7 to 15 yr), but at the end of the period, no additional decrease was found from one cohort to the next (147).

Times trends in caries prevalence among children are important as they may give some indication of the disease in the future (38); such a documented increase naturally would cause concern (70). In spite of the halt in caries improvement, the populations referred to still might be described as low-caries communities (221) in comparison with other contemporary groups.

A most striking change in caries prevalence during the latest 20 years is skewness in the distribution of caries among children (6). This polarisation is particularly marked among the youngest where it is suggested to be increasing (16, 38, 188). According to a Finnish study of 5-yr-old children, eight percent of them were responsible for 76 percent of all decayed teeth (204). Similar findings are reported in 2-5-yr-old children by a recent US study (106). Caries today thus seems to be mostly limited to underprivileged population subsets; this is in contrast with former times when privileged populations bore the main burden of caries (43, 87, 91, 163). In some populations caries is accepted to be almost impossible to control (30). Early Childhood Caries (ECC) and Severe Early Childhood Caries (S-ECC), both terms describing caries at young age (<3 yr, alternatively <5 yr) (39), are mainly confined to groups with low socioeconomic status and/or minority ethnic backgrounds (88, 216, 217). In immigrant children, ECC has been reported to be 3 times (and S-ECC 6 times) more frequent than in European native born (49).

Skewness is not only a characteristic feature of the population distribution. Caries is also unevenly distributed on different dental sites (6). For many years different hierarchies of

caries susceptibility in children's teeth and surfaces have been described (9, 56, 149). The observed caries reduction has influenced the caries pattern differently (9, 177); the least caries susceptible sites (approximal and smooth) showed higher caries reduction compared with the surfaces with highest caries susceptibility (occlusal) (9, 113). Caries in low-caries populations is therefore mostly limited to pits and fissures (6, 113). Simultaneously, studies of various dental health reports from Nordic countries have found caries on approximal- and incisor-surfaces to be substantially reduced (208), a trait that accompanies improved dental health in highly developed countries (97). The lower anterior teeth and canines belong to the least susceptible of all sites (9). As a reservation, it should be noted that these findings are based on studies in which enamel caries was not recorded and radiographs not always used. When enamel caries is recorded (with radiographs) on the approximal surfaces of the deciduous molars, caries has been found to be frequent as early as at 5 years of age (4, 22, 46, 164). Approximal lesions (cavitation criteria) are also reported to predominate the caries increment during the late primary dentition (80).

High caries risk subgroups are characterized by a higher proportion of buccal, lingual and approximal carious lesions in relation to the total index than children with lower risk (9). In spite of the fact that the extent and severity of frank lesions have diminished in many child populations (48), deep frank lesions are not uncommon among children in the subgroups with high caries risk. A high number of active lesions is another indication of caries activity (167).

Evidence today strongly supports that the rate of caries progression is slow, except in the case of a high caries minority (114, 140, 143). In the presence of a preventive program, and over time, it is found that approximal enamel remains more static compared with dentin caries

(109). It is even claimed that with appropriate preventive measures, the rate of progression on approximal enamel surfaces in permanent teeth can be controlled (48).

The shape of the carious lesion itself seems to have changed along with the different occurrence in children. In contrast to the morphology seen in the past, today frank lesions mostly appear only when considerable destruction of underlying tissue has taken place (139), thereby making caries detection and diagnosis more difficult (33, 142).

## ***2.2 Trends in caries prevention and treatment***

The dynamics of the carious disease process alternating between de- and re-mineralization, provides a basis for future caries prevention and treatment in paediatric dentistry. The essential aims are to postpone, arrest and heal the carious lesion at an early stage (125, 165). The time is now ripe for moving from operative to non-operative preventive care in the management of dental caries (137). Operative restorative treatment most often leads to loss of sound tooth substance and a weakened tooth, and in permanent teeth, a life long need for restorations and their regular replacement (117). Furthermore, harmful psychological effects after experiencing pain and discomfort during invasive restorative treatment, may lead to dental fear and odontophobia (168, 180). Restorative treatment cannot prevent the occurrence of new lesions when the disease is not under control (191). Finally, it should not be forgotten that the parents' rights include information about balance of benefit and harm associated with healthcare (141, 181).

## ***2.3 Caries prevalence and increment in the primary dentition***

Many epidemiologic studies about dental health of toddlers and preschool children come from Sweden (Table 1). In particular, the theses of Wendt (213) and Grindefjord (59) from 1995

have influenced our present knowledge and insight. Caries in children up to 3 years of age is mainly found on the maxillary incisors (60, 217), especially on labial surfaces (217). Also caries located on approximal surfaces, affecting 18% of the children in the study by Wendt and al. (217), was mainly limited to upper incisors. At age 3.5 years, Grindefjord reported in her thesis that the occlusal surfaces of the second molars were the most caries affected surfaces (59).

The proportion of 4-yr-old children with 10 or more dmfs constituted 6% in a recent Swedish study (188). At surface level the distribution of caries is skewed: a contemporary Norwegian study of 5-yr-olds showed that 4% of surfaces accounted for all caries (53). The same study documented that almost one half (45%) of the dentin lesions was located to approximal surfaces. A study among 5-yr-old children eight years earlier, reported that the second molars are the teeth with highest dmft values and the approximal surfaces of the molars are the sites with the highest prevalence of decay (5).

*Table 1. Various Nordic caries surveys in preschool children up to 5 yrs, published since 1991.*

Author (Year)	Country	Age Month / Year	Caries prevalence (%)	Mean dmfs
Wendt et al. (1991) (216)	Sweden	12-14 mo	1	
Alaluusua & Malmivirta (1994) (2)	Finland	19 mo	8	
Schröder et al. (1994) (171)	Sweden	18 mo	1	
Hallonsten et al. (1995) (67)	Sweden	18 mo	2	
Pienihäkkinen et al. (2004) (134)	Finland	2 yr	3*	
Wendt et al. (1991) (216)	Sweden	23-26 mo	8	0.5 <sup>1</sup>
Grindefjord et al. (1993) (60)	Sweden	30 mo	11	0.2 <sup>1</sup>
Nielsen & Estmark (1992) (122)	Denmark	30-36 mo	17*	1.0 <sup>2*</sup>
Wendt et al. (1992) (217)	Sweden	36 mo	28	2.0 <sup>1</sup>
Paunio et al. (1993) (129)	Finland	36 mo	18	0.4 <sup>1</sup>
Scröder et al. (1994) (171)	Sweden	36 mo	28	
Alaluusua & Malmivirta (1994)(2)	Finland	36 mo	14	1.0 <sup>1</sup>
Hugoson et al. (2000) (82)	Sweden	3 yr	28	1.2 <sup>2</sup>
Mattila et al. (2001) (111)	Finland	3 yr	8*	
Karjalainen et al. (2001) (94)	Finland	37 mo	8*	0.2 <sup>1*</sup>
Grindefjord et al. (1995) (61)	Sweden	42 mo	37	1.5 <sup>1</sup>
Stécksen-Blicks et al. (2004) (188)	Sweden	4 yr	46	2.0 <sup>3</sup>
Gimmestad & Holst (2003) (53)	Norway	5 yr	56	3.6 <sup>3</sup>
Amarante et al. (1998) (4)	Norway	5 yr	71	5.4 <sup>3</sup>
Hugoson et al. (2000) (82)	Sweden	5 yr	52	3.7 <sup>2</sup>
Mattila et al. (2001) (111)	Finland	5 yr	28*	
Pienihäkkinen et al. (2004) (134)	Finland	5 yr	23*	

Caries diagnoses based on cavitation level are marked \*. Caries index at surface level: 1) ds-index 2) dfs-index 3) dmfs index.

A current trend is that much caries in preschool children is left untreated (38, 124, 132), without any accompanying evidence that more preventive care has been provided. In some countries this trend is more striking than in others (159), and some authors have even



questioned the necessity of treatment (192). Yet, from Sweden it has been published that replacement of restorations constitutes a substantial proportion of the treatment procedures in primary teeth of children during 7-12 years of age, especially between 7 and 9 yr (3). The authors here indicated that more restorative treatment in primary teeth was performed after 6 years of age than before (3).

Caries pattern has been and still is age specific (116). A pattern of caries on free buccal and lingual smooth surfaces is typical of the caries seen in early childhood (154), and after 5 years of age this constitutes a minor problem (194). The peak of pits and fissure caries increment (recorded using the cavity as criterion) in primary molars has been shown by Greenwell et al. (58) to occur soon after the molars have come into occlusion, but declined from 4 years of age. Concerning caries increment on molar-approximal surfaces, it remained constant during the period 4.0-6.5 years (58).

Children with early caries onset are more likely to develop caries during the subsequent years than children with no caries experienced at early age (62, 218). Significantly more caries was found among 6-yr-olds with initial carious lesions at age 3 yr than among those who then were caries-free (218). Likewise, most of the children (92%) with initial and/or manifest (dentin) carious lesions at 2.5 years of age developed new manifest carious lesions one year later (61).

Concerning the late primary dentition, only treatment patterns are published (3). Yet, Mejäre et al. have found the distal surface of the primary second molars to be especially prone to enamel or dentin caries; this affected 64% of the 9-yr-old children examined (114). There is today a need for detailed longitudinal epidemiological studies of caries (including enamel

caries) in the late primary dentition. As caries in the primary dentition also constitutes a major health problem for some groups (39, 132), there have recently been an increased recognition that a better understanding of caries in the primary dentition is needed (102).

#### **2.4 Caries prevalence and increment in the young permanent dentition**

In the permanent dentition, occlusal caries (pits and fissure) usually occurs many years in advance of approximal caries (41, 205). An eight-year Finnish follow-up study, focusing the permanent first molars in children from 7 to 15 years of age, found the caries attacks were most prevalent on occlusal surfaces between seven and nine years of age, and on approximal surfaces, at the ages of 12 and 13 (cavitation criteria) (205). An association between caries experience on the mesial surface of permanent first molars and on the adjacent surface has been reported by many authors (17, 115, 201). Furthermore, Mejäre et al. (114) have shown that the rate of progression from the inner half of the enamel to the outer half of the dentin on the mesial surface of the permanent first molar was almost 4 times faster in a young age group (6-12 yr) than in an older (12-22 yr). At the age of 12, this surface accounted for the majority of approximal lesions in the permanent dentition (114).

Various studies (cavitated lesion criteria) have investigated the relationship between caries in the primary and permanent dentitions and found caries experience in primary teeth to be associated predominantly with pit and fissure decay in the young permanent dentition (103, 130, 166, 175). Children whose primary dentitions are caries-free are less susceptible to caries in the young permanent dentition (80, 103, 130).

It is debateable whether the caries data of Mejäre et al. regarding young permanent teeth of children, born more than thirty years ago, are still applicable to today's children (114).

Undoubtedly, there is a need for more updated knowledge of caries prevalence and incidence for both noncavitated and cavitated carious lesions (86). Regarding caries prevalence, the ratio of noncavitated to cavitated lesions has been shown to vary between countries. In developed countries it is found to be higher than in developing countries (86).

## **2.5 Caries risk and prediction**

Previously, when dealing with caries and children, the commonly focused caries risk factors were mostly part of or interfered with the local caries process itself; sugar consumption, plaque and hygiene regime and fluoride. The caries disease is, however, linked with many factors outside the oral cavity (44), and it is claimed that these extra-oral factors have been somewhat neglected during the 20<sup>th</sup> century (83).

As with caries itself, the distribution of risk factors is skewed (137). They are confirmed to be accumulated in families with low socioeconomic status, often living in low status housing areas (76) and over represented in minority ethnic groups (30, 34, 136). Links between high caries experience in preschool children and low maternal education (206) or single mother status (21) have been revealed. In Norway, almost a quarter (22%) of children are living with one parent (157), and in this group, one child out of five has a parent who receives social security support (223). Wendt et al. (220) have also pointed at the consequences of crises in families on oral health in infants and toddlers. Medical conditions and illness in infancy have additionally been discussed as indicators for increased caries risk (199, 219). Due to the fact that mostly sugar-free medicines are prescribed for children in Scandinavian countries, medicine use constitutes a minor problem for dental health (219).

Consistent with the above description, the caries risk in a child, as other health risks, cannot be considered in isolation from the disease risk of the population to which it belongs (51, 156,

162), and the strength of association between social class and caries experience is beyond doubt (52, 76). Socioeconomic factors may be even more related to caries during preschool years than later in life (21, 76, 112). Consequently, it is important to monitor and quantify all changes taking place within communities, according to population groupings, life-styles and prevailing trends and norms (99). Prevailing caries risk factors constitute new changing challenges throughout the entire lifetime (112, 142, 170). Children of today live under quite different surroundings than children a generation ago (74). In Scandinavia, the parents are mostly working outside their homes, and the proportion of women in the workforce in Norway has never been so high (76.2%) (79). Kindergarten therefore constitutes the every-day life of the majority of preschool children (83.5% of Norwegian 3-5-yr-olds in 2002) (155, 183), which implies the parents cannot control the caries risk factors to which their children are exposed during the day. Food manufacturers, by adding sugar to earlier traditionally tooth-friendly foods (e.g. sugared milk), additionally make it increasingly difficult to get an overview of the ingredients in the commercially prepared foods (200). A survey performed in 2000 among 4-yr-old Norwegian children confirmed a high sugar intake, showing that more than 80% of them had a higher energy proportion intake from sugar than recommended by nutrition experts (above 10%) (145). Older children, being under advertising and peer influence (160), are especially viewed as a major market force by the beverage industry (189). Vending machines, providing fizzy drinks for pupils during school hours, have become widespread (85). Other factors under change and presumably related to every-day lives of children are family structure and life-style (157), meals pattern (200), diet ("fast food") (200), sugar consumption ("snacking and fizzy drinks' culture") (119), child rearing and parenting norms (92, 160), parental attitudes (more democratic) (92), consumption pressure (160) and "pocket money" (160). Some possible caries related explanatory factors may be more typical for Norwegian background conditions; parents belonging to the so-called "fluoride generation

“without first-hand caries knowledge”, a history of doubt and uncertainty regarding fluoride program policy, prolonged “check-ups” intervals resulting in reduced caries focus, and economic incentives in some regions of the Public Dental Health Service which do not benefit the primary teeth (19, 47).

Nevertheless, to monitor earlier, well-known caries risk factors is still important. For example, widespread extensive fluoride exposure has modified the rôle of sugar in some populations (28) while in subgroups without the same fluoride protection, sugar acts as a potent risk factor as before (225). Simultaneously, in order to get the best possible overview, knowledge about the distribution of the risk factors should be accounted for. One reason is that the more widespread the risk indicators/factors are, the less it is possible to discriminate between them (161).

Through the years many studies have aimed at identifying risk factors, yet only longitudinal study designs are considered reliable for the purpose. Studies with other designs can only investigate caries predictors, which might be looked upon as putative risk factors (69). The focus on cost-efficiency in dentistry has led to great interest in prediction, in order to canalize limited economic resources to children who actually are in need of preventive strategies (126, 224). One precondition for a such design to be cost-effective is that the target population is small enough to justify the efforts and necessary expenses. Risk groups exceeding 30% of the population are therefore seen upon as unworkable (73).

Multifactorial modelling has proved to be superior in the field of prediction, which is natural due to the complex aetiology of the disease (44). Risk factors do not operate alone, but show interrelations and interactions (226) and are additive in nature (62, 143). However, the most

powerful known single predictor for future caries development has been shown to be past caries experience (151). Regarding the young permanent dentition, past caries experience of primary teeth has been shown to have good predictive value, and caries status of the most recently/exposed surfaces of primary molars is the most appropriate measure (151). Models spanning shorter periods, used among very young children, tend to be the most accurate (151).

The age period 5 to 10 years, with its own set of risk variables, is one in which teeth of both dentitions coexist, sharing exposures related to caries occurrence. Restorative treatment during the period is rather frequent. A Finnish study has documented that between 10% and 25% of all permanent molars were filled in the year of tooth emergence (101). The restoration rate plateaued once 60-80% of the permanent first molars had been filled, 5-8 years after eruption (101). The age span 5-10 years is especially crucial for the initiation and progression of caries on the mesial surface of the permanent first molar (114). The period is also important for children's future relationship with dental health services.

In spite of this, few previous studies have followed children during the age period 5 to 10 years for predictive purposes, especially using risk model groupings (175). To our knowledge, with regard to this period there are no such studies that include calibrated examiners, detailed caries diagnostic systems and radiographs at both sessions.

## ***2.6 Parental dental beliefs, attitudes and behaviours towards child dental care***

It is well known that beliefs and attitudes have impact on how parents perform dental care for their children (112, 135). Nevertheless, studies focusing the influence parental attitudes have on children's dental health are scarce. Concerning dental matters, preschool children are completely dependent on parents or other family members (34), but a study by Mattila et al.,

conducted on 10-yr-old children, also showed that children of this age still had parents as role models for their dental health (111). In modern societies where the majority of women are working outside their homes, fathers have increasingly taken a more active role in the daily care of their children (21, 95, 112).

The process by which caregivers manage their child's dental health seems to be complex (31). Parents are far from homogeneous, and they usually follow the behavioural and cultural norms of their religious or ethnic groups, which do not necessarily reflect material circumstances (161, 172, 178). Therefore, any investigation about the influence parental beliefs, attitudes and dental behaviours have on the oral health of their children, has to be considered in the context of cultural and ethnic variations.

## **2.7 Immigrants**

One of the most important demographic changes to have taken place during recent years in Scandinavia is immigration, transforming many populations from mono- to multicultural (228). Hitherto, the population of Norway has been relatively homogenous (195), but in Oslo, this is no longer the case. Here, immigrant children and adolescents constitute 27% of the age group 0-17 yr, and 94% are of non-western origin (203). In the Municipality of Copenhagen, approximately 25% of children under the age of 18 have a non-Danish ethnic background (190). Especially among immigrants of non western origin, there is high unemployment and high dependence on social security funds (105, 184). The families of 47% of children with non-western backgrounds required social security funds in Norway in 2001 (223). The study of Wennhall et al. (221) documented a very high caries prevalence among immigrant children from a low socio-economic, multicultural, urban background (Table 2). However, the immigrants living in Scandinavia constitute a heterogeneous group (190, 221), and not all

immigrant children grow up in families of low socioeconomic status. Most of the existing surveys have concentrated on caries in immigrant children from deprived areas (13), but it is now seen as important to clearly state if the catchment areas of the immigrant children studied are deprived or not (107).

Habits such as prolonged bottle feeding, frequent use of commercial weaning foods, ready availability of sweets and sweet drinks and insufficient use of fluoride toothpaste have been documented to be associated with a high level of caries in the group (37). Furthermore, religion and mother's ability to speak the language of the host country have been documented as risk indicators for the occurrence of caries (12, 16, 37).

It is well acknowledged that there exist both general and oral health disparities between children with immigrant and native backgrounds (30, 198, 219, 227). Immigrant status is known to discriminate between the prevalence of *Streptococcus mutans*, dietary habits and oral hygiene as early as at one year of age (62). The difference in oral health is most evident for the primary dentition (15, 37, 190, 209). Immigrant children not only suffer from higher caries experience than indigenous children, but are also found to have higher rates of untreated caries (202), higher frequency of dental pain, and more extensive destruction of the dentition when they are affected (40). Children from non western countries are seen to be at the forefront of caries disease disadvantage (108, 190, 221), and among the non-western countries, children originating from Eastern Europe and Asia have a high caries prevalence (12, 24, 32, 190). Two to three year old children of Turkish, Pakistani, Ex-Yugoslav and Albanian origin have been noted as having high caries prevalence (131, 190). However, there is no evidence that inherent differences in caries susceptibility among children of different



ethnic origin exist (27). For the Municipality of Copenhagen, the extent of stagnation in improvement of oral health among the 5-yr-olds has been suggested to be related to the increasing number of immigrant children (190).

*Table 2. Various Nordic caries surveys from 1991, comparing native and immigrant preschool children up to 5 yrs.*

Author (Year)	Country	Immigrant origin	Age Year/ Month	Caries prevalence (%)		Mean dmfs	
				Native	Immigrant	Native	Immigrant
Wendt et al. (1992) (217)	Sweden	Mixed	24 mo	5	22 <sup>1</sup>		
Grindefjord et al. (1993) (60)	Sweden	Mixed	30 mo	8	14 <sup>1</sup>		
Nielsen & Esmark (1992) (122)	Denmark	Pakistan	30-36 mo			0.7*	4.7 <sup>3*</sup>
		Yugoslavia					3.5 <sup>3*</sup>
		Turkey					5.6 <sup>3*</sup>
		Morocco					1.7 <sup>3*</sup>
Wendt et al. (1992) (217)		Mixed	3 yr	22	51 <sup>1</sup>		
Wennhall et al. (2002) (221)		Mixed	3 yr		85 <sup>2</sup>		4.4
Stécksen-Blicks et al. (2004) (188)	Sweden	Mixed	4 yr			1.5	6.8 <sup>1</sup>
Sundby & Petersen (2003) (190)	Denmark	Turkey	3 yr	10 *	21 <sup>3*</sup>	0.3*	1.5 <sup>3*</sup>
		Pakistan	3 yr		26 <sup>3*</sup>		3.1 <sup>3*</sup>
		Albania	3 yr		38 <sup>3*</sup>		1.8 <sup>3*</sup>
		Somalia	3 yr		22 <sup>3*</sup>		1.8 <sup>3*</sup>
		Arabia	3 yr		14 <sup>3*</sup>		0.8 <sup>3*</sup>
Grindefjord et al. (1995) (59)	Sweden	Mixed	3.5 yr	29	44 <sup>3</sup>		
Stécksen-Blicks et al. (1997) (186)	Sweden	Bosnia	5 yr				28.4 <sup>3</sup>
Sundby & Petersen (2003) (190)	Denmark	Turkey	5 yr	35 *	46 <sup>3*</sup>	1.6*	4.7 <sup>3*</sup>
		Pakistan	5 yr		33 <sup>3*</sup>		1.0 <sup>3*</sup>
		Albania	5 yr		78 <sup>3*</sup>		9.2 <sup>3*</sup>
		Somalia	5 yr		42 <sup>3*</sup>		4.1 <sup>3*</sup>
		Arabia	5 yr		49 <sup>3*</sup>		3.7 <sup>3*</sup>

Caries diagnoses based at cavitation level are marked \*. Immigrant definition according to 1) if at least one parent was born outside Sweden 2) foreign language spoken at home 3) country of origin. Missed teeth were included in the mean caries index for children aged 4 or more.

Literature dealing with immigrant parental beliefs and attitudes towards children's dental health, is hitherto found to be scarce. Nevertheless, it has been claimed that emphasis should be placed on improving immigrants' attitudes towards oral health (16). For instance, indulgent attitudes towards oral health behaviours are reported to be more frequent among some ethnic groups than others (121). In a study from the UK, comparing parents of Pakistani and resident population to 3- and 5-yr-olds, the majority (72%) of the Pakistani parents (n=116) considered it too stressful to say 'no' when their child wanted sweets, while only 33% of the native parents (n=88) felt similarly (Abstract. Shadid S, Csikar J, Malik A, Williams S. Perceived parental control in oral health promotion among young Bradford children of Pakistani and white origin. 81<sup>st</sup> General Session of the IADR. 2003). Also other studies have reported differences in dental attitudes between parents with and without immigrant background (42, 131). Positive attitudes to prevention were found to be less frequent in parents of immigrant children (131).

In light of a probable increase in immigration in the near future (108), it is evident that a more detailed mapping of oral health status among preschool immigrant children is needed. The current socio-cultural transition of the child population simultaneously demands in depth insight into and knowledge of immigrant backgrounds. To date, little is known regarding the self-reported oral health behaviours of minority ethnic groups (13). Both better understanding of dental attitudes and of cultural influences among immigrant parents are needed (1, 30, 153). Oral health equality is also emphasised in the UN-priority list (132).

In such a traditionally monocultural country as Norway, the work of improving oral health in immigrant children becomes a real challenge for established health services.

## **2.8 The aims**

The present thesis aimed to explore different aspects related to dental caries in groups of children aged 3, 5 and 10 years. The overall aim was:

- to collect data and gain knowledge to provide a basis for caries prevention and dental treatment planning

More specially, the work aimed to explore

- Caries experience, distribution and severity in 3 and 5 yr olds according to ethnicity
- Caries increment from 5 to 10 yr in primary and permanent dentition
- Prediction of future caries at 5 yr of age for the following 5 yr period
- Parental beliefs, attitudes and behaviour in relation to immigrant status and the caries experience of 3 and 5 yr olds

### 3 Material and methods

The present thesis is based on two separate surveys (Table 3), one in Oslo (Study I, Sample A) and the other in Bergen (Study II, Sample B).

*Table 3. Overview of the two studies.*

	Paper	Focus of interest	Sample	Age group	Location	Year of examination
Study I	1	Dental health and dental health disparities according to immigrant status and age.	A	3 and 5 yr	Oslo	2002
	2	Dental health. In the context of ethnic variations, also parental beliefs, attitudes and behaviours towards their children's dental health.		3 and 5 yr	Oslo	2002
Study II	3	Caries increment in primary dentition.	B	5-10 yr	Bergen	1993, 1998
	4	Relationship between caries in primary and permanent dentition.		5-10 yr	Bergen	1993, 1998

#### 3.1 Ethical approval

The study protocols were approved by the Regional Committee for Medical Research Ethics and the Norwegian Data Inspectorate. Additionally, written informed consent for their children's participation was obtained from the parents.

#### 3.2 Study design

Study I had a cross-sectional design, and the analyses were based on clinical data from caries examinations together with parental responses from a questionnaire (Appendix I). The study

started February 2002 at seven Public Dental Health Service clinics in Oslo. Most of the data were collected before April 1.

Study II had a prospective longitudinal design, and the follow-up period extended from the initial examination in 1993 to 1998. The whole cohort attended three Public Dental Health Service clinics in Bergen where free annual check-ups and treatment were provided from the age of 3 years. The two caries examinations for the study took place when the children were 5 and 10 years of age. The majority of the children were examined for caries during the last four months of the year.

### **3.3 Sample sizes**

#### **3.3.1 Study I**

A sample size calculation for comparing means was performed under the assumption that type I (alpha) and type II (beta) errors were 0.05 and 0.2 respectively. The standard deviation used in sample size calculation was based on an adjustment between indigenous and immigrant child populations at both age levels. The desirable sample size was estimated to be 524, but was increased to 900, to allow for defections and unevenly sized subgroups.

#### **3.3.2 Study II**

The baseline sample size in this study was already settled in a previously published study by Amarante et al. (4, 5), comprising 217 5-yr-old children in 1993.

### **3.4 Study sample**

The sample in Study I (Table 4 and 5) was drawn from seven different clinics, and the individuals were grouped in a 3-yr-old group (mean age; mo: 35.5, SD=1.7, yr: 3.0, SD=0.1)

and a 5-yr-old group (mean age; mo: 57.0, SD=3.1, yr: 4.8, SD=0.3). The selection criteria were clinics with a high proportion of immigrant children in their catchment area or clinics with a wide socioeconomic base. The local dental health profile and availability of clinics and dental hygienists were also taken into consideration. At each clinic, the children were randomly selected. From the original sample, a total of 775 attended for clinical examination, while 735 also completed parental questionnaires. In case of twins in the last group, only one was selected. Age of the children was approximately calculated by subtracting dates of birth from a chosen date during the study period (1.03.02).

*Table 4. Number of children in Study I ( Sample A. WN=western native, IM=immigrant).*

Age	Original sample (n)	Clinically examined (n)			Clinically examined and completed questionnaire (n)		
		NW	IM	Total	NW	IM	Total
3 yr	450	327	44	371	313	40	353
5 yr	450	360	44	404	341	41	381
Total	900	687	88	775	654	81	735

*Table 5. Number of children and countries of origin in the IM-group (Sample A, the extended group, where not all had completed questionnaire).*

Country	Clinically examined (n)	Country	Clinically examined (n)	Total
Pakistan	21	Brazil	1	
Sri Lanka	10	Czech Republic	1	
Turkey	8	Romania	1	
Thailand	6	Tanzania	1	
Somalia	5	Slovenia	1	
Arabia	4	Philippines	1	
Vietnam	3	Kurdistan	1	
Iran	3	Gambia	1	
Morocco	3	Syria	1	
Iraq	2	Poland	1	
China	2	Former Yugoslavia	1	
India	2	Ethiopia	1	
Bosnia	2	Kroatzia	1	
Uganda	1	Origin unknown	2	
Korea	1			
Total	73		15	88

The sample in Study II (Table 6) in Bergen covered catchment areas which were intended to include several socio- economic backgrounds. All 5-yr-old children at the actual clinics were invited to participate in 1993. The educational level of the parents had previously been reported to be above the average for Norway (5, 164).

*Table 6. Children in Study II (Sample B).*

Sex	Baseline group (5 yr) Children (n) examined in 1993	Drop-outs (n)	Follow-up group (10 yr) Children (n) examined in 1998
Boys	108	18	90
Girls	109	13	96
Total	217 (100%)	31 (14.3%)	186 (85.7%)

The parents in both Study I and Study II received information about the actual studies in advance. The letter for Study I contained information about the purpose of the study, confidentiality and a promise of a gift for children who participated. A request to complete a questionnaire was also included. Both the information paper and the questionnaire were sent by mail to the parents with a request to return it at the examination session. Interpreter assistance at the clinics was offered to immigrant parents with difficulties completing the questionnaire. The recall letter in Study II contained information and a short questionnaire about the amount and level of the parent's education, also to be returned at the examination date of their child. As in Study I, a gift as incentive was given to each child.

### **3.5 *The immigrant definition***

Study I discriminates between children belonging to the immigrant- and western native-group.

A child was assigned to the immigrant group (IM-group) if the mother was of non-western origin, which meant origin from Eastern Europe, Asia, Africa, Turkey, South and Central America (203). This definition assumed that the mothers were first generation immigrants. Children in the western native group (WN-group) had mothers from the Nordic countries, Western Europe, North America, Australia and New Zealand (203). Two children had mothers where home-countries could not be identified, but by name and hygienists' knowledge, they were of non-western origin.

Study II does not group the children according to ethnic background, due to the low number of immigrant children.



## **3.6 Drop-outs**

### **3.6.1 Study I**

Participation and response rates in Study I were respectively 86.1% and 81.6% for the whole group of children. The corresponding rates for the IM-group alone were 67.7% and 62.3%.

The non-respondents were sent reminders, first by mail and then by phone. We have no further information about the reasons for the drop-outs, but the dental staff at the actual clinics with immigrants, reported that moving residence was a common occurrence in the immigrant group. The most frequent explanations for not completing the questionnaire, given orally by the parents during the clinical examination of their children were: questionnaire too long or time consuming, uncertainty about confidentiality or merely unwillingness to participate.

### **3.6.2 Study II )**

Thirty-one children failed to respond to the several recall reminders, so as stated in Table 6, the participation rate was 85.7%. Moving and unwillingness to participate were the main reasons for drop-outs.

## **3.7 Calibration**

### **3.7.1 Study I**

Prior to the onset of the study, a calibration course and training of the seven dental hygienists were provided, including 12 hours of lectures and training on extracted teeth, clinical pictures and radiographs. The training program also included exercises on a specially designed computer software program (Abstract. Espelid I, Tveit A. Computer assisted training in caries calibration. 4<sup>th</sup> Congress of European Academy of Paediatric Dentistry. 1998). Specific feedback was given for each diagnosis based on the available radiographs and clinical pictures of sound and carious teeth. The course concluded with a clinical

training program and an inter-examiner reliability test, in which preselected tooth surfaces in sixteen 10-year-old children were examined. In the 8 first patients, consensus about the caries diagnoses was reached. In the last 8 patients the recorded caries diagnoses were used in the reliability test (Test I). During the middle of the project period, another calibration and reassessment of examiner-reproducibility was undertaken (Test II), in which 2-5 patients in the respective clinics were examined according to the same procedure as before the study. Both reliability tests represented a comparison of pooled scores of the dental hygienists with the author M.S.S. The inter-examiner reliability was expressed as Cohen's kappa score (weighted and unweighted). For weighted kappa, 66% and 33% credit was given for scores deviating one or two caries grades respectively.

### ***3.7.2 Study II***

The inter- and intra-examiner reproducibility (Cohen's kappa, unweighted and weighted) between the five examiners in 1993 have previously been published by Amarante et al. (4). The examiners worked in the selective Public Dental Health Service clinics. An intensive calibration program for the examiners was undertaken before the study began, consisting of both radiographic and clinical sessions. Also a group of 20 children, randomly selected, was re-examined by each examiner, and Cohen's kappa scores were calculated between each of the local dentists and the first author (Amarante E). At the follow-up examination in 1998 only one dentist carried out the clinical examination of the children. The dentist had clinical and radiographic calibration training before being calibrated against two clinically trained professors. The unweighted intra-examiner reproducibility was based on the dentist's re-examination of a group of 20 children.

In both studies (Study I and Study II) the kappa statistics did not contain any scores regarding missing teeth or fillings.

### **3.8 Oral examinations**

A five-graded caries diagnosis system, based on written descriptions (4) and photographs (Fig. 1, Appendix II), was used in the two studies. Caries is denoted  $d_{1-5}$  where the subscript indicates the caries grade. The two incipient grades of caries (1 and 2) are denoted enamel or “initial” lesions and the others dentin or “manifest” lesions. Teeth restored due to trauma were registered as sound. When a tooth was extracted or indicated for extraction due to caries, the tooth was counted as two surfaces in the dmfs-index. When an intact fissure sealant covered an occlusal surface, the surface was counted as sound, while a preventive resin restoration was counted a filling. When there was doubt about the type of restoration, the decision was taken after re-examination of the dental records (Study II).

The caries status of deciduous teeth (excluding incisors) that had been exfoliated before 10 years of age was recorded based on notes in the dental records (Study II). This involved a total of 341 canines and 347 molars, 30.8 % of the total number of these teeth present at the age of 5 years.

The standard conditions for clinical facilities included good artificial light, dental probes, mouth mirrors and compressed air and cotton rolls. Three years old was the only age when bitewing radiographs were not taken, otherwise this diagnostic aid was used whenever the approximal surface could not be inspected clinically. The procedure to polish with prophylactic paste prior to the examination was accomplished in Study II while in Study I this was done only when debris was visible. Caries registration was recorded into dental diagrams

in a computer program (Opus Dental, version 3) in Study I, and on a paper record form (dental diagram) in Study II.

### **3.9 Questionnaire construction and development (Study I)**

The questionnaire completed by the parents was self-administered, structured and standardised. The front cover design was pleasant and printed in colour (Appendix I). The main part of it (104 main items, Part A-E) was constructed by an international research team (135) while an additional part (23 items) was the product of a Norwegian research consortium (Part F).

The international part of the questionnaire was used in the international collaborative study, carried out in 17 countries around the world (135). This common part (Part A-E) consisted of items that measured present and past dietary and tooth-brushing habits, parental dental attendance, family structure and other demographic conditions. A section contained questions on belief and attitudinal issues (49 items), developed by health psychologists and based on theoretical models regarding the psychology of health behaviour (136). The explanatory working model behind these items is that certain beliefs and attitudes about a particular behaviour might predict the certain behaviour (31). The 49 items were all related to oral hygiene and sugar snacking, due to a recent review of risk factors (69).

The parents answered the items according to a psychometric 5-point Likert scale (from strongly disagree to strongly agree), so both direction and strength of the statements were measured. The direction of the scale (1 to 5) was determined before analyses were performed, and for the regression analyses the midpoint of “neither degree nor disagree” was excluded. The whole international part of the questionnaire was translated to Norwegian and reverse translated by an independent bilingual person to ensure comparability with the original form.

Here appropriate wordings concerning Norwegian conditions were selected to enhance semantic and conceptual balance. Some items were excluded as they were not appropriate for Norwegian conditions (e.g. chewing sticks). The part of the questionnaire developed in Norway (Part F) was tailored for Norwegian conditions. It included items regarding use of fluoride, the Public Dental Health Service and demographic items which were not covered by the demographic items in the international study. The applicability of the questionnaire was not pilot tested for Norwegian conditions.

Studies about reliability and validity of belief and attitudinal items in the international part of the questionnaire had been published previously by the international research team (136). The questionnaire was constructed so as to reveal inconsistency in the responses. The same topics were covered by several items in alternative forms, and the items were not chronologically ordered.

### ***3.10 Constructed variables – questionnaire (Study I)***

Many of the variables were inter-related, so groups of variables were constructed, such as parental attitudinal variables concerning oral hygiene, diet and indulgence to these behaviours. Positive scores were responses favourable to oral health, and negative score were those unfavourable. The sum of these scores then formed a quantitative expression of parents' attitudes to those factors, and the most favourable attitudes had the highest total. These composite variables were given titles based on the content of the included statements. For example, the indulgence variable included items which showed permissiveness ("It is often too stressful to say 'no' to my child when he or she wants sweets"). Table 1 in Paper 2 shows the items on which the different composite variables are based.

As a proxy for socio-economic status, the variable “Social Status” was chosen as an expression of the combined educational level of both parents. High “Social Status” was defined as both parents having university level educational backgrounds. Middle “Social Status” was the category in which one parent had university level education or when both of the parents had reached high school level. Remaining responding parents were classified as low “Social Status”. The variable “Frequent Sugar” classified high sugar-related intake (eating/drinking) every day as a negative dietary behaviour, and other responses were classified as positive dietary behaviour. Parental regular dental attendance was positive behaviour and going sporadically to the dentist was negative behaviour for the variable “Parental Dental Attendance”. A question about the appropriate amount of toothpaste for children was seen as a proxy for whether dental care directives were appropriately communicated and understood by the recipients. In spite of its limitations, “Acquired Dental Knowledge” was established as a marker for acquired practical hygiene guidelines. An answer in agreement with appropriate toothpaste use was positive for dental behaviour, and the opposite response was negative. The variable “Religion” was based on the main official religion of the country of origin. It was constructed due to the close association of Islam with strict hygiene regime on one hand (176), and on the other, the link between caries and religious background (16, 37). The variable differentiated between “Muslim” or “non-Muslim”. Not all questions were completed for every item so analyses and the results presented are based on a varying number of completed questions.

### **3.11 Constructed risk groups at 10 yrs of age – related factors at 5 yrs (Study II)**

#### **3.11.1 Risk group, primary dentition**

For the purpose of analysing caries increment in the primary dentition during the age period from 5 to 10 years, a risk group of children was defined according to the following criteria: 1)

the total dmfs increment was more than one SD above the mean for the whole group, and/or 2) one or more teeth had been extracted due to caries, and/or 3) the increment of dentin lesions and fillings on the approximal surfaces of the molars was more than one SD above the mean for the whole group. After having tested a number of hypothesized caries predictors at 5 years of age for assignment to the risk group, the following were found to be significantly related in a bivariate analysis: “Total  $d_{1-5}mfs$  more than one SD above the mean”; “At least one caries lesion ( $d_{1-5}fs$ ) on the approximal surfaces of the molars”; and “At least one carious lesion ( $d_{1-5}fs$ ) on anterior teeth (incisors and canines) more than one SD above the mean”.

### ***3.11.2 Risk group, permanent dentition***

A risk group of children with the most severe caries pattern in permanent teeth at 10 years of age was also constructed. The criteria for inclusion were: 1) those with one or more dentin or filled lesions on the mesial surface of permanent first molars, and/or 2) same type of lesions on any incisor, and/or 3) total  $D_{1-5}MFS$  more than one SD above the mean (premolars and permanent second molars not included in  $D_{1-5}MFS$ ). As was done in the primary dentition, a range of hypothesized caries predictors at 5 years was tested for belonging to the risk group. After bivariate regression analyses, various variables based on the primary molars were shown to be significantly related to the risk group. Those were: At least one carious lesion,  $d_{1-5}fs$ , in “Primary second molars”; At least one carious lesion,  $d_{1-5}fs$ , in “All primary molars”; At least one approximal carious lesion,  $d_{1-5}fs$ , in “Primary first molars”; At least one approximal carious lesion,  $d_{1-5}fs$ , in “All primary molars”; At least one approximal carious lesion,  $d_{1-5}fs$ , in “Primary second molars”; At least one carious lesion,  $d_{1-5}fs$ , in “Primary first molars”.

### **3.12 Data management**

In both studies, the data were first plotted in the data base program MS Access and then exported to SPSS, version 11.0 (SPSS Inc, Chicago IL). In Study I, the data were systematically reviewed by two independent research fellows, to confirm that errors from the files did not conflict with the true content of the questionnaire. One person read in the questionnaire while the other checked the paper transcripts of the files. The checking of data input from the caries records was done by the author alone in both Study I and II, using standardized procedures in MS Excel to reveal inconsistency.

### **3.13 Statistical methods**

All analyses were performed using MS Excel and the SPSS programs. In the different studies and papers different statistical tools were used to measure differences between groups; chi-squared statistics, independent-sample *t*- tests, relative risk (RR), Kruskal-Wallis test and Lorenz curves (Table 7). To assess the associations between caries experience in the two dentitions, as well as relationship between caries experience and parental educational levels, Spearman's rank correlation coefficient was chosen. Pearson correlation coefficient was alternatively used when looking for association between caries among immigrant children and an attitudinal item from the questionnaire. Cronbach's alpha ( $\alpha$ ) measured internal consistency of the belief and attitudinal items. A consensus behind the construct of the international part of the questionnaire was that items with low internal reliability were excluded (1). After measuring the internal consistency of the 49 items under Norwegian condition, one item ("Bringing our child to the dentist on a regular basis is the best way to prevent tooth decay") revealed a negative internal reliability and was thus excluded from the analyses. Cronbach's  $\alpha$  of each composite constructed attitudinal variable was measured.



The caries increment in primary teeth during the follow-up period was calculated by subtracting the  $d_{1-5}mfs$  value at 5 years from that of the 10-yr-old children after including exfoliated canines and molars and excluding the incisors. Data on caries prevalence in the permanent dentition included all erupted permanent teeth, but erupted premolars and permanent second molars were not included in the risk group calculation or in the analyses of association or prediction. These teeth were excluded because they were not present in the majority of the children.

Regression models were constructed in both studies. Several possible caries risk indicators (predictors) were tested in both studies and given the value 1 for an expected positive relationship to the chosen dependent variable and 0 if the relationship was negative. Only statistically significant caries risk indicators (predictors) were allowed to enter the multivariate models. Odds ratios (OR) with 95% CIs were the outcome measurements.

For prediction the following measures were calculated: odds ratios (OR), values of sensitivity, specificity, positive and negative predictive values, proportion of children correctly classified (crude hit rate) and receiver operating curves (ROC curves).

The level of statistical significance was set at 5 per cent.

*Table 7. Statistical methods used presented.*

Statistical tests and outcome measures	Paper 1	Paper 2	Paper 3	Paper 4
Cohen's kappa	+	+	+	+
Cronbach's alpha		+		
Lorenz curves	+			
Chi-squared	+	+	+	+
Logistic regression (OR)		+	+	+
Relative risk		+		
One-way ANOVA		+		
Independent-sample <i>t</i> -test	+	+	+	+
Kruskal-Wallis test		+		
Pearson correlation coefficient		+		
Spearman's rank correlation coefficient		+		+
Sensitivity, specificity, positive and negative predictive values				+
Proportion correctly classified (crude hit rate)				+
ROC-curves (receiver operating curves)				+

## 4 Results

### **4.1 Reliability of caries examinations**

Test 1 (after prestudy calibration) showed unweighted and weighted (linear) Cohen's kappa values of 0.49 and 0.68. The corresponding values for Test 2 (during the study) were 0.67 and 0.75 (Paper 1 and 2, Study I). In Study II (Paper 3 and 4), unweighted (linear) Cohen's kappa values at age 5 varied between 0.71 to 0.90, while the value reached 0.62 when 10-yr-old children were examined 5 years later.

### **4.2 Caries experience, distribution and severity according to age (3 and 5 yr) and ethnicity (2002, Study I)**

Sample A in the extended group where not all had completed the questionnaire, consisted of 371 children, aged 3 years and 404, aged 5 years.

#### **4.2.1 3-yr-olds (Sample A, Paper 1)**

Eighty percent of the children (80.1%) were caries-free, and 12.7% had only initial lesions. Four individuals (1.1%) had restorations and none had had extractions. The respective  $d_{1-5mft}$  and  $d_{1-5mfs}$  values were 0.76 (2.14) and 1.04 (3.51), and the corresponding  $d_{3-5mf}$  indexes at tooth and surface level were 0.32 (1.40) and 0.51 (2.75).

Caries experience, but not prevalence, was significantly associated with sex, boys had higher levels of caries experience ( $d_{1-5mfs}$ ) and were overrepresented in the group with the highest caries experience (Fig.1). In that group,  $d_{1-5mfs} \geq 6$  ( $n=21$ ), 9 of the 16 boys were of immigrant origin, and they made up 37.5% of the whole 3-yr-old group of immigrant boys.

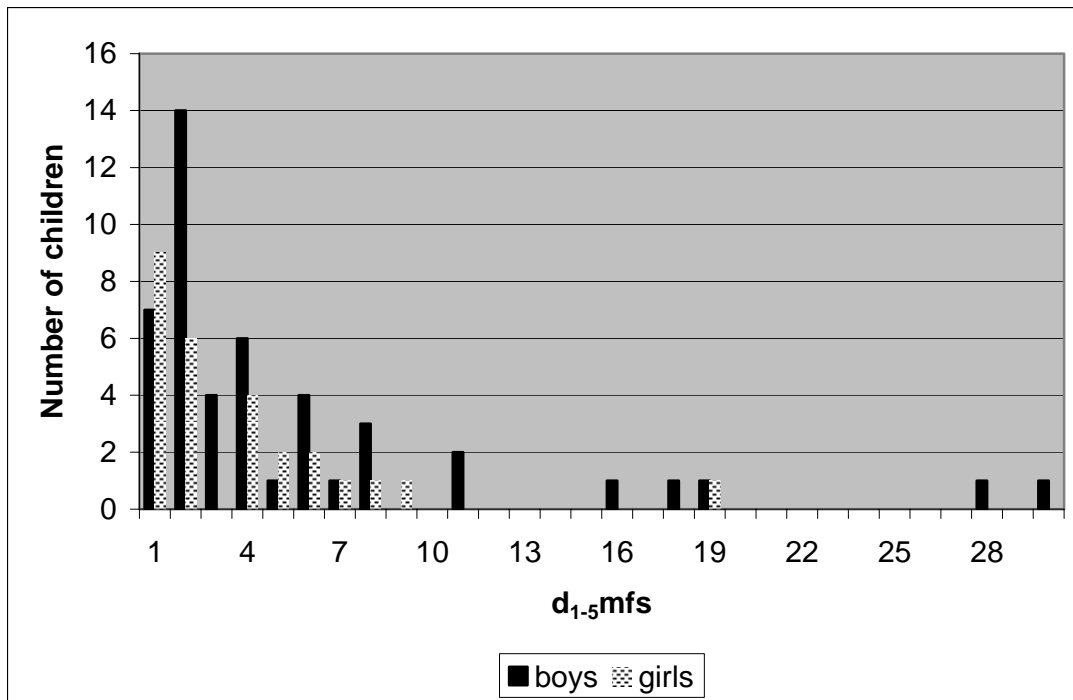


Fig. 1. Distribution of  $d_{1-5}mfs$  in 3-yr-old children with caries (24 out of 164 girls, 48 out of 207 boys).

In general, the proportion of enamel carious lesions exceeded that of dentin lesions at surface level (52.0% vs 48.0 %), but not in anterior teeth (37.3% vs 62.7%). Caries experienced ( $d_{1-5}mfs$ ) in the anterior teeth constituted 57.4% of the total caries experience. Caries on approximal surfaces, affecting 6.5% of the children, was also mostly limited to anterior teeth.

Of the group of children with caries experience ( $d_{1-5}mfs > 0$ ), 70.3% had caries on occlusal surfaces, 48.6% on smooth (buccal/lingual) surfaces and 5.4% had clinically visible approximal caries in molars.

Lorenz curves (Fig 2, Paper 1) show that there were dental health disparities between the western native (WN) and the immigrant (IM) group. The most marked skewness in caries distribution was seen within the WN-group, where 6.4% (n=21) of the children were

responsible for 76.9% of the caries ( $d_{1-5}mfs$ ). Compared with the IM-group, the WN-group contained significantly more caries-free children (84.1% vs 50.0%). Fewer than 4% in the WN-group had restorations and/or dentin lesions while this proportion was 34.1% among the IM-children. Figure 2 shows that the first primary molars contributed more to total caries experience in the IM-group than in the WN-group. Almost three-quarters (72.7%) of those in the IM-group who had caries experience ( $d_{1-5}mfs > 0$ ) experienced caries in anterior teeth, while 48.1% of WN-group with caries experience did so.

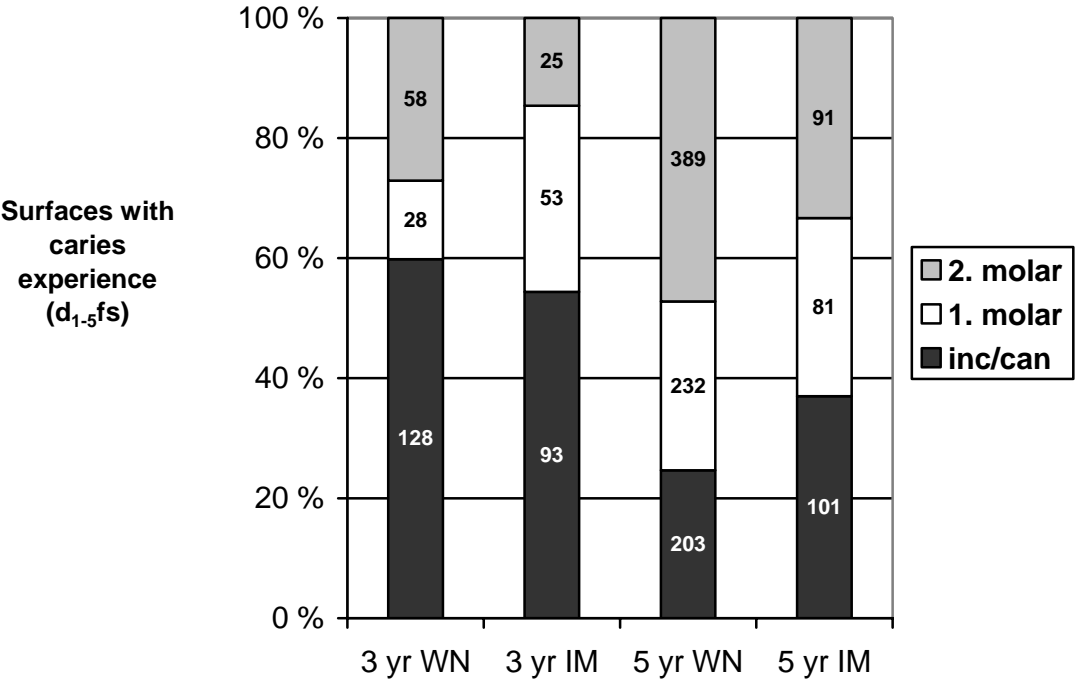


Fig. 2. The distribution of surfaces with caries experience in the western native group (WN) and immigrant group (IM). Numbers in column denote numbers of lesions.

**4.2.2 5-yr-olds (Sample A, Paper 1)**

There were no sex differences in caries experience among the children at the age of 5. Forty-eight percent of the 5-yr-old children were caries-free, and the  $d_{1-5}mft$  and  $d_{1-5}mfs$  values of the whole group were 2.18 (3.22) and 2.77 (4.77). Corresponding  $d_{3-5}mft$  and  $d_{3-5}mfs$  values were 1.03 (2.36) and 1.39 (3.64). A quarter of the children (25.5%) experienced only enamel lesions. Thirty-nine children (9.6%) had restorations, predominantly occlusal

(2/3 of total restorations), with a slight overweight in primary first molars. Eight children had had extractions (n=12). The second molar constituted the tooth with the highest caries experience. As among the younger age group, the number of enamel carious lesions exceeded dentin lesions. On the molar-approximal surfaces, the proportions of enamel versus dentin lesions were 58% versus 42%. Concerning the children with caries experience ( $d_{1-5mfs} > 0$ ), 76.2% had occlusal caries, 40.0% had approximal caries in molars and 33.8% had caries on smooth surfaces.

The proportions of caries-free children were 52.5% in the WN- and 11.4% in the IM-groups, respectively. Restorations and/or dentin lesions were found in 21.1% of the WN- and in 70.5% of the IM-group. Caries in anterior teeth made up a higher proportion of total caries experience in the IM-group than in the WN-group (Fig 2).

Only a small caries increment in anterior teeth was noted from 3 to 5 years of age, but the increment was considerably higher on other tooth surfaces (Fig. 1, Paper 1). Among the individuals with caries experience ( $d_{1-5mfs} > 0$ ), there were only small differences between the mean number of carious surfaces among the 5-yr-olds compared with the 3-yr-olds ( $d_{1-5mfs}$ ; 5 yr: 5.34, 3 yr: 5.20). The same tendency was also seen when caries was recorded at the tooth level.

#### ***4.2.3 Children from Pakistan (Sample A, Paper 1)***

When the age groups were pooled, there were 21 children with mothers from Pakistan. These children had a mean caries experience (mean age=3.9 yr,  $d_{1-5mfs}$ =7.05) five times higher than children with mothers from Norway (n=649, mean age=3.9 yr,  $d_{1-5mfs}$ =1.43). Their

mean  $d_{1-5}mfs$  value was also higher, though not statistically significantly higher than the rest of the IM-group (mean age=3.9 yr,  $d_{1-5}mfs=5.38$ ).

### **4.3 Caries increment 5-10 yrs of age (1993-1998, Study II)**

#### **4.3.1 Primary dentition (Sample B, Paper 3)**

There was no significant difference in caries increment between the sexes. About half (48.9%) of all children had caries at 5 years of age with a further caries increment during the period 5-10 years, while 15.6% acquired caries experience during the period although free of caries at age 5. The rest of the group either remained free of caries or their caries experience stayed constant, or they experienced caries reversals. The mean caries increment ( $d_{1-5}mfs$ ) of the whole group (n=186) was 3.05 (incisors excluded, other exfoliated primary teeth included). Children with caries experience at 5 years of age had slightly higher increment ( $d_{1-5}mfs=3.22$ ) than those without ( $d_{1-5}mfs=2.67$ ), but the difference was not statistically significant. However, the caries status at 5 years was associated with both the severity of caries increment and the distribution of the lesions (Table 4 and 5, Paper 3). All children (n=24) with one or more teeth extracted during the period belonged to the group that had caries experience at baseline.

The majority of new lesions in primary teeth during the period were located on molars, most frequently on the distal surfaces of the primary second molars. The number of carious lesions on smooth surfaces showed a net decline during the study period.

#### **4.3.2 Permanent dentition (Sample B, Paper 4)**

At 10 years of age, all incisors, 36.6% of the canines, 23.7% of premolars, all permanent first molars and 3.6% of the permanent second molars had erupted. Seventy one percent (70.9%)

of all caries ( $D_{1-5}MFS$ ) was found in 33.8% of the children. When only manifest caries ( $D_{3-5}MFS$ ) was considered, the same proportion (70.9%) of recorded caries affected 17.2% of the study group. Caries experience was not significantly associated with sex.

The proportion of children without caries experience in permanent teeth ( $D_{1-5}MFS=0$ ) was 24.7% ( $n=46$ ) while 41.9% ( $n=78$ ) had dentin caries and /or restorations ( $D_{3-5}MFS$ ). The  $D_{1-5}MFT$  and  $D_{1-5}MFS$  values were 2.43 (1.97) and 3.52 (3.47) respectively. No extractions were recorded.

The permanent first molars had almost the total caries burden (91.8% of  $D_{1-5}MFS$ ). Sixty-one children (32.8%) had caries on all four permanent first molars while 27 (14.5%) had three affected molars. Caries on mesial surfaces was found in 85 children (45.7%), and on these surfaces the prevalence of enamel lesions dominated dentin lesions (87.9% vs 12.1%). Table 8 and 9 give an overview of the caries distribution in permanent first molars.

*Table 8. Mean caries experience ( $D_{1-5}MFS$ ) in the permanent first molars, distributed on surface locations.*

Location of lesions	
All surfaces	Mean (SD)
Occlusal	1.47 (1.57)
Approximal	1.02 (1.40)
Bucc/ling	0.75 (1.12)
$D_{1-5}MFS$	3.24 (3.08)



*Table 9. Mean caries experience (D<sub>1-5</sub>MFS) in the permanent first molars, distributed into its separate DMFS components.*

Lesion severity	
Surfaces	Mean (SD)
D <sub>1-2</sub> S	2.09 (2.25)
D <sub>3-5</sub> S	0.35 (0.88)
FS	0.80 (1.45)
D <sub>1-5</sub> MFS	3.24 (3.08)

#### **4.4 Relationship between caries experience at 5 and 10 yrs of age (1993-1998, Study II)**

##### **4.4.1 Primary dentition (Sample B, Paper 3)**

A statistically significant relationship was found between three putative caries predictors at 5 years of age and belonging to a defined caries risk group at 10 years of age (n=58, 31.2%). In the bivariate regression analysis with attainment of the risk group as the dependent variable, the baseline predictor “Total d<sub>1-5</sub>mfs more than one SD above the mean” obtained the highest odds ratio value (OR=8.6). In the final multiple stepwise logistic regression analysis, the predictor “At least one carious lesion (d<sub>1-5</sub>fs) on the approximal surfaces of the molars” gave the highest odds ratio (OR=4.4).

##### **4.4.2 Permanent dentition (Sample B, Paper 4)**

At 5 years of age, caries experience (d<sub>1-5</sub>mfs) in the whole primary dentition or solely in the primary second molars (d<sub>1-5</sub>fs), was found to be statistically significantly associated with caries experience (D<sub>1-5</sub>MFS) in the permanent dentition at age 10 (r=0.5). The great majority (92.2%, n=71) of children with dentin and/or filled carious lesions and/or extractions at baseline had caries in the permanent dentition at 10 years of age, while 61.4% (n=35) of the

children with no caries at baseline (n=57) experienced at age 10 years caries in permanent teeth.

The risk group of children at 10 years constituted 24.2% of the sample (boys, n =19, girls, n=26), and had a mean  $D_{1-5}MFS$  of 7.96 (SD=3.28) and a mean  $D_{3-5}MFS$  of 3.36 (SD=3.04). Statistically significant relationships between a number of potential predictors at 5 years of age and inclusion in the risk group were found. The variable “Primary second molars” (at least one carious lesion,  $d_{1-5}fs$ ) had the highest odds ratio (OR=12.3) in the bivariate analyses and also remained in the model in the final analysis (multiple stepwise logistic regression).

Two variables were found to be useful predictive test variables at 5 years of age for belonging to the risk group at 10 years of age: “Primary second molars” (at least one carious lesion,  $d_{1-5}fs$ ) and “All primary molars” (at least one carious lesion,  $d_{1-5}fs$ ). The variable “Primary second molars” gained the highest sum of sensitivity and specificity (148%), achieved when the cut-off point was set to more than two lesions. Sensitivity then amounted to 76%, and the percentage of correctly classified children, 73%. When “All primary molars” was the predictor and the same cut-off point was used, a slightly lower sum of sensitivity and specificity was reached (146%). The areas under the respective ROC curves (Fig. 2, Paper 4), however, were almost equivalent for the two predictors ( $A_1$  of “Primary second molars”: 0.75, CI=0.67-0.82,  $A_2$  of “All primary molars”: 0.76, CI=0.76-0.84).

## **4.5 Other caries risk indicators than past caries experience (Study I)**

### **4.5.1 The questionnaire (Sample A, Paper 2)**

Cronbach's  $\alpha$  was measured to 0.86 when responses of the whole group were checked and to 0.88 when only the IM-group was considered. The variable "Attitude to Hygiene", based on a bivariate logistic regression model, was found significantly to be associated with the dependent variable "Supervised Brushing", twice daily or not. Similarly, the variable "Attitude to Diet" showed significance according to the dependent variable "Frequent Sugar".

### **4.5.2 Parental attitudes or behaviours (Sample A, Paper 2)**

After testing a range of significant caries risk indicators for the presence of caries ( $d_{3-5}mfs > 0$ ) in a multiple logistic regression model, the following caries indicators were shown to have the highest odds ratio values : among the 3-yr-olds, "Immigrant Status", "Sugary Drink to Bed" and "Social Status", and among the 5-yr-olds, "Immigrant Status", "Parental Indulgence", "Attitude to Diet", "Attitude to Hygiene", "Social Status" and "Age started Brushing". The variable "Supervised Brushing", twice daily or not, and the constructed variable "Frequent Sugar" did not show high odds ratio values in regression analyses at any age.

Considering the pooled sample of 3- and 5-yr-olds, parents with two unfavourable dental attitudes ("Attitudes to Hygiene and to Diet") had children ( $n=32$ , mean age=4.0 yr) with definitely more caries, almost five times higher  $d_{1-5}mfs$ , than parents whose attitudes to these variables were defined as favourable ( $n=547$ , mean age=3.9 yr).

### **4.5.3 Children of western native- vs immigrant background (Sample A, Paper 2)**

Parents of immigrant children showed a significantly lower response rate than those of other children (62.3% vs 84.9%). The majority (78.5%) of the children had mothers who had lived

in Norway for more than 5 years. These children (n=51, mean age=4.0 yr) had 2.3 times as high caries experience ( $d_{1-5}mfs$ ) than children of mothers with more recent arrivals (n=14, mean age=3.5 yr).

The most persistent factors associated with the caries status in the total IM-group, were “Attitude to Hygiene” and “Parental Indulgence” (dependent variable= $d_{3-5}mft > 0$ ). When only the 5-yr-olds (n=34) were included, the variables “Age started Brushing” and “Parental Indulgence” were the most important. The questionnaire item “It is often too stressful to say ‘no’ to my child when he or she wants sweets” was shown to be the item most strongly correlated with  $d_{1-5}mft$  ( $r=0.5$ ) in the 5-yr-old IM-group (n=37).

When the same regression model was run for only the WN-group, the dominant caries risk indicators were “Parental Dental Attendance” and “Social Status” for the 3-yr-olds and for the 5-yr-olds, “Parental Indulgence”, “Attitude to Diet” and “Social Status”.

The responses concerning the caries risk indicators were in general differently distributed in the WN- and IM-groups (Table 4 and 5, Paper 2). Also the demographic profile was different (Table 2, Paper 2). The educational level was significantly lower among Muslim mothers than among other mothers in the IM-group. The educational level of mothers or fathers in IM-group was not correlated with their caries experience to the extent it was in the WN-group.

Inter-group variations in distribution of parental dental attitudes were revealed. The proportion of parents with Muslim background (54.3% of the IM-group) with unfavourable “Attitude to Hygiene” or/and “Attitude to Diet” was significantly higher than among parents in the rest of the IM-group.

## 5 Discussion

### 5.1 Methodological issues

Considering that the clinical examinations were carried out by a high number of dental hygienists and dentists, the inter-observer reliability values in the two studies was within an acceptable range, from moderate to almost perfect (100).

None of the two samples was truly randomized. It might be assumed in Study I that the most common factors exposing dental health were represented, due to the substantial spread of clinics concerning caries prevalence and socioeconomic location and the high number of participating children. The average educational level of the mothers was shown to be similar to the maternal educational level for the age group 30-39 years in Oslo (185), which is above the average educational level for the rest of the country (185).

The findings of Study II cannot be fully generalized to the Norwegian child population. In spite of the fact that the parental educational level was above the mean for the general population (5, 164), the caries prevalence (cavitation level) was comparable with the national data of 5-yr-old children in 1992 (5).

The response rate gained in Study I was above 80% and noted as high (169). Both participation and response rate were much lower when only the IM-group was analysed, though still above 60% (67.7% and 62.3%). A lower response rate among immigrants is in accordance with literature on dental attendance (8, 35). This implies that the IM-group could be affected by selection bias, as drop-out groups with immigrant background have usually

higher caries experience than those taking advantage of free regular dental care (8, 152). In Study II, the drop-outs were not believed to have affected the results, as at baseline their caries experience was not found to be significantly higher than that of the study group.

The immigrant definition used in Study I was restricted to children whose mothers were first generation immigrants from non-western countries (203). No distinction between refugee- and immigrant status was set. Because of small numbers of responders in subgroups, it was difficult to highlight disparities within the IM-group itself in a more appropriate way (16, 107). The variable “Religion” differentiated between “Muslim” and “non-Muslim” on the assumption that parents from countries that are predominately Muslim actually are Muslims. The variable “Religion” was thus treated as an ecological variable, which is imprecise.

Test-retest reliability and internal consistency measures of the attitudinal international part of the questionnaire have been previously reported to be excellent and very good (136), and the attitudinal items, described as robust (1). A limitation is that the applicability of the questionnaire was not tested in the form of a pilot test for Norwegian conditions.

Nevertheless, the finding that the internal consistency (Cronbach’s  $\alpha$ ) of the present responses to the attitudinal items was similar to the values gained by the international study ( $\alpha=0.86$  vs  $\alpha=0.89$ ) is consistent with the questionnaire having good reliability (29). No requests for interpreter assistance from immigrant parents were received, which may indicate that the language barrier in this sample was small problem (23). Internal consistency, based on tests for the IM-group, was found to be even higher than in the WN-group. These results should be treated with caution, as the internal consistency results were based on responses from only those parents who had responded to the total numbers of the items. The low number ( $n=48$ ) doing so in the IM-group may indicate responses only from those parents with the best

language skill, and omit those who might have lowered the results. However, the fact that the findings in the present study were consistent with the caries literature dealing with child populations, further strengthens the validity of the questionnaire.

## **5.2 Oral health status (Study I)**

### **5.2.1 3-yr-olds (Sample A, Paper 1)**

Age in months does matter for caries experience and prevalence in children aged 5 and younger. This should be taken into consideration when epidemiologic studies among small children are compared and may explain some of the variations in caries data seen among the Nordic studies in Table 1. For children aged about 3 years, clinical examination without the use of BW-radiographs usually does not reduce the validity of caries assessment, as approximal caries then is mainly limited to upper incisors (217).

The average age in months of the children, studied by Wendt et al. (36.2 mo) (217), is comparable with the mean age of the children in the present study (35.5 mo) (Table 1). The caries prevalence noted was somewhat higher than in the present survey, both when enamel lesions were included (28% vs 20%), and when they were not (16% vs 7%). Higher level of caries experience (enamel caries included) was similarly reported (2.0 vs 1.0). However, in the light of the facts that the proportion of immigrants in the Swedish study is three times higher and that 10 years differentiate the studies in time, the findings from the two studies are reasonably comparable. Caries epidemiologic studies of other Nordic children with comparable ages, show commensurable values of caries prevalence and caries experience with the present study (Table 1).

Lorenz curves (Fig 2 and 3, Paper 1) are considered as useful supplementary tools for analysing data (148), here showing differences in distribution between the IM- and WN-groups. From these curves the exact proportion of the children, responsible for the caries burden can be seen, and this is of special interest when planning high-risk prevention strategies. The finding that skewness was most marked among the youngest age group and especially in the children of western native origin, was anticipated and in accordance with the literature (106, 204). The caries prevalence reported by Wendt et al. (217) concerning immigrant children was consistent with the present IM-group (51% vs 50%) and underlines that caries even at early age constitutes a problem, both for the child and the dentist (123). The finding that the present immigrant children, originating from Pakistan, had an especially high caries experience was in accordance with reports from Copenhagen (122, 190). Otherwise, the high caries prevalence in anterior teeth among immigrant children was in line with previous findings that this pattern is a common occurrence among immigrant children (49).

The present study reveals a higher caries experience among boys than girls, and there was an excess of immigrant boys among the children with the highest caries experience. This supports the anecdotal reports from the practising hygienists that in some immigrant families the young boys are treated as “princes”, and that the parents treat them with the over-indulgence, associated with increased caries experience (45, 66). In the literature it has been suggested that some Asian parents may treat their sons and daughter differently (153), and one study among young Asian children has also found boys to have a higher caries experience than girls (10). Another study (122) which found more boys among preschool children with high caries experience, speculated that boys might have a higher level of physical activity which rendered tooth-brushing more difficult (122).



### **5.2.2 5-yr-olds (Sample A, Paper 1)**

The caries prevalence (52%) and experience ( $d_{1-5}mfs=2.8$ ) of present 5-yr-olds were lower compared with previously Norwegian studies from 1993 (4) and 2003 (53) (Table 1). The 5-yr-olds in the study of Amarante et al. (4) were examined in the last four months of the year, so their mean age was probably higher than that of the present children (4.8 yr). This age effect may provide a logical explanation as to why the caries data of the present study are lower. Another explanatory factor may be a generally reduced caries prevalence taking place from 1993.

The present caries data are not comparable with the national public data (cavitation criteria) of 5-yr-olds. The recent trend towards extended recall intervals and selective recall of children considered to be at high caries risk, results in “worse than average” children being disproportionately represented when caries epidemiology is based on recall examinations. In Oslo in 2001, only 39% of the 5-yr-old children were examined for caries (127, 182). Nevertheless, the caries data of the present children may be interpreted as being in line with the other caries epidemiologic data of the Nordic 5-yr-olds (Table 1).

The decreasing number of spaces between molars from 4 years of age (77) is important for plaque accumulation and caries development, as is the time of inter-molar contact (17). As a consequence, molar-approximal caries of the study of Amarante et al. (5, 164) was found to be more frequent than in the present study. As reported in the literature (78, 89, 210), the proportion of enamel lesions in the two studies was higher than dentin lesions. Enamel lesions in the present study made up 58% of the total  $d_{1-5}S$ -index on molar-approximal surfaces,

which endorses previous recommendations that bitewings radiographs should be used in caries registration in 5-yr-olds (4, 7, 46, 75). In a review about caries trends in primary teeth of Scandinavian children during 1973-1993, the proportion of enamel surfaces was especially large among Norwegian 5-year-olds (146). As reported by Amarante et al. (5, 164), the second molars in the present survey constituted the teeth with highest caries experience at the age of 5.

Caries affected almost all the children in the IM-group (89%) at 5 years of age, but it was common for the WN-group as well (48%). Still at 5 years the carious lesions in anterior teeth constituted a considerable proportion in the IM-group, which is also described by others (49). There was a marked difference in the frequencies of fillings and/or dentin lesions in the IM- and WN-groups (70.5% vs 21.1%). Characteristic traits for the IM-group were high caries prevalence and caries experience, and a more severe type of the disease. These findings support existing literature (37, 40, 60, 170).

### ***5.2.3 Subjects 3- vs 5 yr-olds (Sample A, Paper 1)***

Caries measured by the dmfs index of caries experience is cumulative over time, and it was therefore an interesting finding that the group with caries experience ( $d_{1-5}mfs > 0$ ) at both ages had an average caries experience almost of same magnitude. The explanation may be that the children affected by caries very early in life, usually also suffer from a large number of carious lesions, a general trait of children with ECC (211). Caries progression is also more rapid in these children due to a combination of unfavourable dietary habits (66, 212) and newly erupted teeth with poor posteruptive maturation (98, 173).

### **5.3 Caries increment from 5-10 yrs (Study II)**

The statistical methods used for calculation of caries increment, did not account for the discrepancy in timing of tooth emergence and exfoliation (84, 96). This lack of consideration of time at risk of caries is undoubtedly a study weakness (93). In 1993 these statistical methods were not well-known option among dental researchers.

#### **5.3.1 Primary dentition (Sample B, Paper 3)**

Since this study also followed the fate of caries experience in exfoliated teeth, the caries increment cannot directly be compared with previous follow-up studies covering the period (80, 111). The fact that the net sum of caries on free smooth surfaces ended up negatively, illustrates the dynamics of the caries disease, in which lesions may either reverse, be arrested or progress. Such lesions are considered to be readily amenable to prevention (193). Similar findings have previously been documented in the young permanent dentition, where three-quarters of the most frequent enamel lesions on free smooth surfaces on permanent molars either remained static or had regressed at the end of a 2-yr- period (120).

In accordance with previously published studies of caries increment in the late primary dentition (80), approximal caries increment ( $d_{1-5fs}$ ) in molars in the present study was found to predominate, particularly on the distal surfaces of primary second molars (114). These surfaces usually first get their first carious lesions when the permanent molars erupt.

Half of the children who were without caries at 5 years of age developed caries during the period, and regarding their approximal lesions, more than a half them were in dentin or had been filled. These findings challenge today's practices of long recall intervals based on the presence or absence of caries at time of examination. Extended recall intervals may run the

risk of new carious lesions not being seen while they are still at a reversible stage and thus they may be allowed to progress to frank cavitation.

Caries status at baseline in the follow-up study was related to the severity of caries increment during the study period, which indicates that the children with established caries at age 5 years also experienced the most invasive types of caries treatment during the period. They not only had all the extractions, but also had the highest mean number of molar-approximal lesions in need of restorative treatment. The years during the late primary dentition have also in the literature been described as a period of extensive need for treatment (3).

### ***5.3.2 Permanent dentition (Sample B, Paper 4)***

First of all, the study revealed that the caries increment was substantial in the permanent dentition during the period, and affected three-quarters of all children at the age of 10. The permanent first molars, responsible for the caries burden (114, 222), had a high proportion of enamel lesions (Table 9). The proportions of enamel and dentin lesions found on mesial surfaces were in accordance with the proportions found in a Swedish study of 12-year-old children (the present study: 88% vs 12%, the Swedish study: 80% vs 20%) (50). This supports previous findings that lesions progress more slowly in permanent than in primary teeth (115, 133).

Due to the lack of representativity our findings should not be extrapolated to other populations. Nevertheless, we believe that this study gives new and detailed information about the magnitude of the caries increment and its distribution from 5 to 10 years of age in the permanent dentition. In the light of the current state of knowledge of the carious process

and principles of prevention, it is a notable finding that as many as eighty-five children (46%) had caries on the mesial surfaces of their permanent first molars. Operative procedures on these approximal surfaces, as in primary molars, are invasive, complicated and frequently painful. Evidence also exists that restorative treatment during childhood is a risk factor for dental anxiety orders later in life (104, 168).

In some countries healthcare information is included in the legal rights of patients and caregivers (141, 181). The caries description, outlined in Table 9, indicates that at the age of 10 years it is still possible to provide preventive care for the permanent first molars, to arrest or retard caries progression. It is therefore timely to discuss whether patients and caregivers are fully informed about the importance for future dental health of keeping the permanent first molars caries-free. The responsibility lies on the dentists to inform about the importance of prevention, but few dental schools provide dentists with adequate training in health education and health promotion. As debates focusing on healthy lifestyles and health prevention often are discussed in media, many caregivers today have developed their own views and preferences for dental disease prevention (141).

#### **5.4 Caries risk indicators among 3- and 5-yr olds (Study I, Paper 2)**

Ethnic differences in caries experience, reported by many authors, may decrease or disappear when adjustment is made for socioeconomic variables (16, 30, 206). The findings from the present study suggest that immigrant status is associated with high caries experience also after this adjustment. The strongest caries risk indicators for the 3-yr-old children, immigrant status, consumption of sweet drinks in bed at night and social status, are in accordance with previously published studies (63, 214). Among 5-yr-olds, the strongest caries indicators were immigrant background, parental indulgence, attitude to diet, attitude to oral hygiene, social

status and age of starting to brush the teeth. Variables such as “Supervised Brushing”, twice daily or not, and the constructed variable “Frequent Sugar”, did not at any age belong among the strongest caries indicators. It therefore seems that the parental attitudes among the 5-yr-olds are more closely associated with caries experience of the children than the dental behaviours reported by the parents, such as “Attitude to Hygiene” vs “Supervised Brushing”. This may be explained in two ways: firstly, that “Supervised Brushing” is so common that the variable is unable to discriminate between children (161) or, secondly, that most parents give the answer which they think reflects the acceptable norm, twice daily brushing, and lie about the actual behaviour (179). The acceptable answers in the composite variables (sequence of many attitudinal items) may not be equally predictable, and the source of bias is thereby reduced. In the light of this finding, it may be that “social desirability” (179) should be taken more into account when dental health is discussed with parents of young children. In the hectic morning routines of many young families where both parents are working outside their homes (95), appropriate tooth-brushing to assure sufficient intra-oral fluoride levels for children may be difficult. Probably, many children in need of additional preventive programs are not reached.

Parental attitudes were found to be closely associated with caries experience, and this was highlighted when groups with two favourable and unfavourable attitudes were compared (“Attitude to Hygiene and to Diet”). Caries experience (based on pooled samples) was almost 5 times higher in the group where both attitudes were unfavourable, which seem to be noteworthy findings.

### **5.5 Children of western native- vs immigrant background (Study I, Paper 2)**

Though it is somewhat surprising, the finding that children of mothers who had lived for some period in the country had worse dental health than did the children of recently arrived mothers is in line with previous literature (37). In this case, having lived more than five years in Norway may mean greater family income and the ability to buy more soft drinks, sweets and sticky products than do recent arrivals. Most probably is this adaptation part of the acculturation process (32, 107, 118). Simultaneously, both surrounding stress factors according to immediate problems of resettlement (174) and low level of dental knowledge (30) may overshadow tooth care. This finding should, however, be interpreted with caution, due to the small sample sizes.

Within the IM-group, the parental attitudes related to oral hygiene and indulgence were the caries risk indicators most closely associated with high caries experience. As suggested in the literature, differences within the IM-group were taken into account (107), by considering religious background as a possible caries risk indicator (16, 37). Islam regards personal hygiene as having great importance (176), which is of interest, because it offers motivational arguments for good dental health. However, our results did not find this variable to be associated with better attitudes to oral hygiene; the contrary was more often the case. Bedi & Elton (14) also found poor oral cleanliness to be a problem among Muslim children.

The finding that immigrant parents were more indulgent than the other parents have also previously been reported (121). With respect to indulgence, there was no significant difference between parents with and without Muslim background, while an unfavourable attitude to diet was more closely related to Muslim- than non-Muslim parents. Having a sugar-rich diet has been described as being related to Muslim origin (12, 153).

A review of transcultural oral health care by Dhawan & Bedi (37) indicates that parents of minority ethnic communities use fluoride-containing toothpastes less frequently on their children's teeth than the indigenous population. The present difference between WN- and IM-parents at which age they started tooth-brushing of their children was evident (Table 5, Paper 2). Among the western natives, 77% of the parents started before their child was one year old, but this was the case in just 39% of the immigrant parents. This reveals that the intra-oral fluoride concentration may be insufficient among many immigrant children, if no other fluoride source is available. In a high caries risk multicultural area in Sweden, children without daily fluoride supplements or fluoridated toothpaste were shown to have significantly more caries compared with those that used fluoride in the toothpaste (221). A more substantial reduction in caries of 5-yr-old children from materially socially deprived areas compared with affluent ones, has also been reported by a British investigation into water fluoridation (158). Likewise, a positive effect on dental health has recently been documented by a supervised tooth-brushing program (fluoride toothpaste) in a socially deprived high ethnic population in London (90).

As also reported in literature (37, 55), the habit of prolonged bottle-feeding (after 1 yr) is more common in the IM-group than in the WN-group (77% vs 52%) (Table 5, Paper 2), as also is the habit of taking sugary drinks to bed (37% vs 9%). The IM-mothers were less likely to be employed in full time jobs (Table 2, Paper 2) than indigenous mothers (31% vs 56%), and the proportion of immigrant children in kindergarten was lower (43% vs 82%). Among some minority ethnic communities there exists a general acceptance of decay in primary teeth (121), and it is easily understandable that to reach parents with this attitude with caries prevention programs is difficult. However, in Oslo, much interest is attached to a



current dental health program (65). The project educates women from the minority ethnic groups in dental care in order to make them into dental helpers, to assist parents of their own culture. It may be that this mode of assistance will more easily gain the confidence of the newcomers.

In accordance with previous literature (37), the parents of the IM-group in the present study distinguished themselves by having many attitudes and behaviours that are associated with poorer dental health outcomes. As these attitudes and behaviours were more frequent within the IM-group, they may also to some extent be seen as proxies for immigrant status.

Nevertheless, when the WN-group was analysed separately, the caries indicators “Parental Indulgence” and “Attitude to Diet” were still shown to be the strongest among the 5-yr-old children.

Concerning the IM-group, well-known relationships, such as the one between the children’s caries experience and maternal educational levels (64, 207), did not show statistical significance. In caries literature related to immigrant populations, maternal levels of education have actually been shown to have an effect contrary to that normally expected (55). However, it has to be accepted that hitherto not all pathways that link immigrant status to poor dental health have been revealed.

### ***5.6 Prediction of caries from 5 to 10 yrs of age (Study II, Paper 3 and 4)***

It is desirable that scientifically based recommendations can be applied clinically (138). This view influenced our construction of the present risk groups of the two dentitions, while it also

made it more challenging than the more traditional caries/no caries design (any risk model). In the primary dentition, caries increment was mainly found on approximal surfaces, so one of the risk group criteria at 10 years was having at least one incremental severe caries lesion (dentin caries and/or filling) on a molar approximal surface. Likewise, in the permanent dentition, one of the risk group criteria was to have at least one severe carious lesion on a mesial surface of a permanent first molar. These considerations were to assure that among all children with various caries risk group criteria (severe types), the children suffering from severe approximal caries were present. It is the author's opinion that caries not only should be considered a disease confined to the oral cavity, but also the potential source of serious dental anxiety disorders if invasive operative treatment is needed. It is also the author's opinion that this factor has been underestimated in previously described risk group constructions and model buildings. Also the view that children at high caries risk continued to get on permanent first molars sealants during the study period was taken into consideration. In order to reduce this possible predictive bias (6, 25), occlusal surfaces were excluded in two of three risk group criteria. Additionally, efforts were made to limit the size of the group to the recommended size for practical reasons (below 30% of the study population) and to be cost-effective for preventive care (72). However, regular dental care for the children at caries risk was not discontinued during the period, due to ethical considerations and their legal entitlements (171).

Not unexpectedly and in accordance with the literature (57, 103), caries experience in primary molars at 5 years of age was most tightly associated with caries in permanent teeth. Caries experience ( $d_{1-5fs}$ ) in the primary second molars achieved both the highest correlation value with  $D_{1-5}MFS$  in permanent teeth and the highest OR value in the regression analysis. Here the dependent variable was inclusion in the risk group at age 10 years, based on severe caries

in the permanent dentition. At a cut-off point higher than two carious lesions, the sum of sensitivity and specificity of the primary molars in the predictive study was the highest reached. For the predictor “Primary second molars” this sum was found to be identical with the corresponding average sum in a literature review (72, 151), based on thirty multifactorial prediction models. Usually, single parameters are considered inadequate and inferior to multivariable predictive methods (170). This opens up to possibilities of higher values if more predictors are added in the predictive models (11, 36, 170). As shown by Grindefjord et al. (62), the probability of predicting dental caries development at 3.5 years of age was highest when all the predictors in 1-yr-old children were present.

Inter-study comparisons of predictive values are not easy to perform (36, 62). The most comparable with the present study using a high risk group model, may be a Finnish predictive study from 1989 (175). This study evaluated the power of past caries experience in primary dentition at 6 years to predict caries in children in the upper quartile of caries experience at the age of 13 years. Baseline data were obtained from previous records of the Public Dental Care (radiographs were not routinely used), and enamel caries was not included. The sensitivity and specificity of caries in primary teeth were found to be 57% and 85%, respectively.

According to Hausen (71), few studies with the size of a risk group within the range 20-30% have attained sensitivity values above 60%. As sensitivity in the variable “Primary second molars” (at a threshold level above two lesions) achieved 76%, the variable may be classified as reasonably powerful (72, 151). From a clinical point of view, it may be argued that high sensitivity values are of greater importance than high values of specificity (26). The problem of providing more extensive preventive programs to children at low risk is not as serious as

overlooking children at high risk. However, if the specificity values get too modest, the danger is that the future preventive programs may collapse for insufficient resources.

As an addendum to the other predictive measurements, the ROC diagram in Fig. 2, Paper 4, documents the predictive strength of the two analysed predictors (“Primary second molars”, “All primary molars”). Indices of predictive power are the calculated estimates under the curves, which may vary from 0.5 (no apparent accuracy) to 1.0 (perfect accuracy). The test results of both these predictors support predictive strength, as the confidence intervals of neither  $A_1$  nor  $A_2$  included 0.5 (68). The two predictors were found almost equal in predictive power.

In accordance with many other studies (57, 103, 130, 166, 175) the present study revealed that caries experience in primary teeth, molars in particular, is related to caries experience later in life. The validity of this documentation should be considered good, as the degree of association was endorsed by many measures: correlation coefficient, odds ratio, sensitivity and specificity and the proportion correctly classified. Due to the well documented risk of developing caries on surfaces adjacent to a carious lesion (115, 201), children who experienced caries on the distal surfaces of primary second molars, are also assumed to be more susceptible to caries on the mesial surface of the permanent first molar. Concerning the prediction of inclusion into the risk group at 10 years of age, the number of carious lesions in the four primary second molars is estimated as more practical for clinical use than including all eight molars.

As a consequence of these easily applicable results, a practitioner should inform the child and parents at an early age that primary second molars should be given particular attention when

brushing the teeth. However, it is naive, in the light of the complex aetiology of dental caries (44) to think we could identify at 5 years of age all children included in a risk group 5 years later (170). The cumulative effect of underlying factors during the relatively long study period makes the ideal stability needed for prediction impossible (72). Factors as fading parental control, access to money, vulnerability to advertising, peer influence and a trend towards a more democratic attitude within the family unit (160) contribute to an increased consumption on sweets, snacks and soft drinks than ever before (119). When taking into account the additional reasonable size of the high risk group and the fact that only past caries experience has been used as predictor, the present findings may be estimated as “almost acceptable”.

### ***5.7 Future implications***

The findings in this thesis have confirmed that non-cavitated lesions constitute a substantial part of the caries burden among children. By continuing to neglect non-cavitated lesions, the national health reports underestimate the caries prevalence, thereby leading politicians and patients to consider caries to be less a problem than it is (191). The present studies contribute to produce a detailed basis for planning caries prevention and treatment planning at the society level.

The study carried out in Oslo shows almost a dramatic difference in dental health status between the immigrant and indigenous children, already at the age of 3 years. As shown in the study, the immigrant group is far from homogeneous, implying that caries high-risk subgroups should be identified and receive extra attention (12). Hopefully, the caries data gained would provide the basis for future development of various hypotheses to be evaluated within randomised controlled trials.

The present findings about oral health disparities indicate that future research is needed to get more knowledge about the different cultural norms and expectations within ethnic communities and investigate how they impact on oral health. Motivation for providing appropriate dental care for their children or views on the importance of primary teeth may deviate from the prevailing norms among the native parents. Native dental health workers may even fail to propose the right questions. Therefore, in-depth interviews should be encouraged, in which the parents themselves are allowed to define their facing problems with regard to tooth-care of their children. Such interviews should precede any prevention strategy, because a better basis of knowledge than available today is essential before targeted programs are effectuated. Preventive programs should also, if possible, be designed in collaboration with the targeted minority ethnic communities (190), start shortly after arrival in the country (32), and the health information should be given in the most cultural sensitive way (37, 174).

Additionally, the parental attitudinal variables, documented to be significantly associated with caries experience of the children in the two groups (NW, IM), open up for future intervention preventive studies. If parents in Oslo attending child health care clinics or even future parents are asked some key dental attitudinal questions, those with the likelihood of getting or having children developing caries, might be identified before the disease process has reached an irreversible stage.

Recently, the dental health among Norwegian preschool children has been paid publicity and concern (19, 70). The present longitudinal study provides evidence for a clear relationship between dental caries in the primary and permanent dentition. It also documents a substantial caries increment in the primary teeth from the age of 5 up to 10 yr. Because of this recently ongoing debate, in Norway, it is as timely as ever to disseminate the dental health message to

both policy makers and caregivers that primary teeth during the late primary dentition should be given priority. Especially important it is to prevent caries in the primary second molars during these years.

## **5.8 Main findings**

- The most marked caries skewness was seen in the western native subgroups, especially at 3 yr of age.
- Immigrant children showed a considerably higher caries prevalence and caries experience, were more often affected by severe caries, and experienced an earlier onset of the disease than the other children.
- Immigrant status was the strongest caries indicator among preschool children.
- Other caries indicators were: among 3-yr-olds: consumption of sweet drinks at bed and social status; among 5-yr-olds, parental indulgence, attitude to diet, attitude to oral hygiene, social status and age of starting to brushing teeth.
- The strongest caries indicators within the IM-group were parental attitudes to oral hygiene and indulgence.
- Dental parental attitudes were more closely associated with caries experience than the behaviours to which they were related.
- The caries increment in primary teeth is large during the period from 5 up to 10 years, especially on molar-approximal surfaces.
- Children with approximal lesions in molars at 5 yrs of age were more likely than other children to be included in the risk group of the primary dentition at 10 yr of age.
- The substantial caries increment in permanent teeth from 5 to 10 years of age was mainly limited to the permanent first molars. The high proportion of enamel caries indicates a great potential for non-operative treatment.
- Significant relationship in the occurrence of caries between the dentitions was found. More than two surfaces with caries experience in the primary second molars is suggested as a clinically useful predictor at 5 yrs of age for being at high risk at age 10 years.



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## **7 The papers**

### **7.1 Paper 1**

### **7.2 Paper 2**

### **7.3 Paper 3**

### **7.4 Paper 4**

## **8 Appendix I**

### **8.1 *The questionnaire***

## **9 Appendix II**

### **9.1 *The criteria for the caries diagnosis system used***