Dental caries among adolescents

Implications for planning oral health services
in India and Norway

Jamil David

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Department of Oral Sciences - Pedodontics

Faculty of Dentistry

and

Centre for International Health

University of Bergen, Norway

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"Having a dream is what keeps you alive. Overcoming the challenges make life worth living"

Mary Tyler Moore, 1936

Kadinamkulam beach, Kerala (Photo by Jamil David)

This thesis is dedicated to all those involved in the endeavour to improve public health

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List of publications

Paper 1. David J, Wang NJ, Astrøm AN, Kuriakose S

Dental caries and associated factors in 12-year-old schoolchildren in
Thiruvananthapuram, Kerala, India.
International Journal of Paediatric Dentistry 2005; 15(6): 420-428.

Paper 2. David J, Astrøm AN, Wang NJ

Prevalence and correlates of self-reported state of teeth among schoolchildren in
Kerala, India. BMC Oral Health 2006; 6(1): 10.

Paper 3. David J, Raadal M, Wang NJ, Strand GV

Caries increment and prediction from 12 to 18 years of age: A follow-up study.
European Archives of Paediatric Dentistry 2006; 7(1): 31-37.

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1.   Introduction

1.1   Dental caries

Dental caries is one of the most prevalent oral diseases of public health concern affecting adolescents [1]. This disease is ubiquitous in nature [2] and progresses over time in those affected [3], if timely preventive measures are not undertaken. Untreated caries can result in pain and adversely affect the individual's quality of life [4-6].

Present studies suggest that dental caries is a multifactorial disease, caused by a web of factors like micro-organisms, substrate, host, factors related to the teeth and time [7-9]. In addition, sociobehavioural and environmental factors have been shown to be risk indicators for dental caries among adolescents in both developing and developed countries [10-12].

A developing country is defined, "as a country with a relatively low standard of living, undeveloped industrial base, and moderate to low Human Development Index (HDI)" [13] and a developed country "as one with a relatively high standard of living derived through an industrialized, diversified economy and very high HDI" [14].

The prevalence and distribution of dental caries is different in developed and developing countries. A decline in the level of dental caries has been observed over the past four decades in developed countries [15-17]. This reduction has been attributed to the use of fluorides, changes in life styles, improved oral hygiene practices, preventive dental services and changes in diagnostic criteria [1, 17-19]. However, in developed countries variations in caries experience exist among subgroups of the population [1, 20, 21]. Some researchers now suggest that the average dental caries experience in adolescents has reached a plateau [22],

while others believe that it is gradually rising in young children of some developed countries [23, 24].

The prevalence of caries is high in some developing countries and low in others, when compared to developed countries [1]. Increased consumption of sugar has been stated as one of the causes for the increase in caries prevalence in developing countries [1, 25].

1.2 Adolescents

The World Health Organisation (WHO) defines "adolescents" as individuals between the age of 10 and 19 years [26]. This age group constitutes 20% of the world's population [27].

Adolescence is deemed important for oral health, as individuals during this period gain independence in making personal and diet related choices. In addition, oral health behaviours are established and habits are formed during adolescence, heavily influenced by the social environment related to peers [28]. Adolescents are considered as an important target group for oral health promotional activities due to two main reasons. Firstly, behaviours and attitudes formed during adolescence may last into adult life [29] and secondly, most adolescents attend schools, therefore, it is easy to organise and target preventive care for this age group.

1.3 Diagnostic criteria for dental caries

In epidemiological studies different diagnostic criteria have been used to identify dental caries [30-34]. One of the major differences between the various diagnostic criteria is that some studies include only cavitation stages [31], while others include initial lesions in order

to diagnose dental caries [30, 32]. In this thesis, cavitation or manifest caries represent dentin caries, while initial lesions correspond to enamel caries.

The prevalence of caries is under-reported when using the WHO (World Health Organisation) criteria. The approach recommended by the WHO to diagnose dental caries is based on the idea that, only manifested lesions require treatment, and excludes initial lesions from the diagnostic criteria due to concerns over reliability [8]. Though some researchers have raised doubts regarding the reliability of using pre-cavitation lesions in determining caries prevalence [8, 35], others have found that an acceptable reliability can be achieved [34, 36]. A study in Norway showed that in 12 years olds, when caries lesions in the enamel (D_{1-2}) were added to the mean number of teeth, that were missing, filled and with dentin caries ($D_{3-5}MFT$), the total caries experience increased from 2.2 ($D_{3-5}MFT$) to 6.2 ($D_{1-5}MFT$) [34]. Similar studies showed that with the inclusion of initial lesions, the caries experience doubled or tripled, and, as a result, decreased the proportion of the population having no caries experience [24, 36-38] .

Including initial lesions in epidemiological surveys helps in early detection of caries and in identifying individuals that need interceptive caries management [39-41]. Caries levels may be underestimated when recording only dentine lesions but this is considered to be adequate when planning services in a developing country with limited available resources. In research, the choice of a diagnostic criteria depends on the aims of a project [42]. In developing countries the diagnostic criteria often used is the WHO-criteria. With low caries experience in developed countries, use of sensitive diagnostic criteria other than the WHO-criteria, is essential [31]. The main reason for using different criteria in diagnosing dental caries is because the resources available for treatment vary.

1.4 Prevalence and severity of dental caries

Prevalence of dental caries is usually expressed as the percentage of population affected, while the severity or experience is calculated based on the number of decayed (D), missing (M) and filled (F) teeth. Severity of dental caries (DMFT) is categorised according to the WHO classification; very low (0.0 - 1.1 DMFT), low (1.2 - 2.6 DMFT), moderate (2.7 - 4.4 DMFT), high (4.5 - 6.5 DMFT), very high (> 6.6 DMFT). The mean caries experience of 12-year-olds in the Americas, Europe, Africa and Asia are 3.0, 2.6, 1.6 and 1.3, respectively [43, 44].

The dental caries experience was high in developed countries when compared to developing countries during the late 60's, but a reversal in the levels of caries appears to be occurring since the late 90's [15, 16, 22, 23, 45, 46]. In developed countries, changes in diagnostic criteria is reported to contribute to the decline in caries prevalence [47]. With the prevalence of caries decreasing in developed countries, a pattern seems to have emerged, where majority of the caries is seen within a subgroup of the population [48-51]. Even though the severity of dental caries has declined in developed countries, it still affects almost 60 - 90% of the schoolchildren [1], whereas in developing countries of South-East Asia 36 – 80% are affected. [43].

The average severity of dental caries in different countries of South-East Asia range from 0.5 to 3.0 DMFT [43, 52-55]. At present, the severity of dental caries in 12-years-old children in South-East Asia is lower than the global goal set by WHO and FDI (Federation Dentaire International) World Dental Federation for the year 2000, which is 3 DMFT [56]. With lifestyle changes, especially nutritional transitions, the current level of caries in developing countries is expected to rise [25, 27].

Previously, data on prevalence and severity were used to describe the presence of dental caries within a population. In 2003, the WHO, in collaboration with the FDI and the International Association for Dental Research, set new global goals for oral health to be achieved by year 2020. The goals included aspects of oral diseases other than dental caries, such as dental pain and the impact of oral diseases on quality of life [57].

1.5 Dental caries in India

Several oral epidemiological studies have been conducted among adolescents from different regions of India (Table 1). Yet, the results of these studies are not comparable due to socio-cultural disparities [58]. Majority of the studies followed the WHO-criteria for diagnosing caries.

Table 1. Studies reporting DMFT in 12 year olds from different states of India during 1986 to 2005

Region State	Reference	Year of study	N	Age	% with caries	Mean DMFT	Area
North India							
Punjab	Gauba et. al.	1986	173	12	86	3.8	R
Punjab	Chawla et. al.	2000	223	12	55	1.3	U
West India							
Dharavi	Damle and Patel	1994	367	12	80	3.8	US
Sevagram	Bhowate et. al.	1994	802	11-15	54	1.2	U
Mumbai	Rodrigues and Damle	1998	358	12	63	1.2	U
Bhiwandi	Rodrigues and Damle	1998	256	12	55	1.1	U
Goa	Mascarenhas	1999	1189	11-15	78	2.8	U
Bhopal	Christensen et. al.	2003	599	11-13	35	0.6	U, R & US
East India							
Orissa	Tewari et. al.	1991	333	12	64	2.1	U & R
Calcutta	Subrata and Subrata	1996	1043	12	64	3.4	U & R
South India							
Varkala	Retnakumari	1999	119	12	67	2.1	U
Moodbidri	Rao et. al.	1999	771	11-12	67	1.3	U
Puttur	Goel et. al.	2000	121	12-13	60	1.9	U
Thiruvananthapuram	Gopinath	2001	482	12	71	2.1	U
Pondicherry	Saravanan et. al.	2003	1013	12	22	0.6	U
Mangalore	Sudha et. al.	2005	171	11-13	83	1.8	U
Chennai	Maheshkumar et. al.	2005	600	12	80	3.9	U

R = rural, U = urban, US = urban slum, n = number of participants. [53, 59-74].

Oral health services in India

Ninety per cent of the dentists in India are private practitioners located either in urban or rural areas. On an average there is one dentist for every 36,538 inhabitants in India [75], but the rural average is one for every 350,000 [76]. The high costs of dental services in India, as in other developing countries, make it impossible for the majority of the population including children and adolescents to afford dental care [27].

In urban areas of India, there are few dental clinics that provide subsidised oral health service [1, 76], while, in rural areas no such facility is available [1, 76]. A nominal fee is charged in dental services run by the government.

Private dentists and pedodontic departments in dental schools offer dental service to children and adolescents, but these services are unattainable to the majority due to unaffordability or inaccessibility. Private practitioners focus mainly on restorative care, whereas dental schools offer preventive services in addition to restorative care. In order to raise oral health awareness among children, dental campaigns are conducted by some dental associations without any coordination or long time strategy.

1.6   Dental caries in Norway

Reports from the WHO show that in the year 2000, 52% of 12-year-old adolescents in Norway had dental caries with a mean caries experience of 1.5 DMFT [43]. Figure 1 shows the caries experience in 12 and 18-year-olds in Norway from 1985 to 2004.
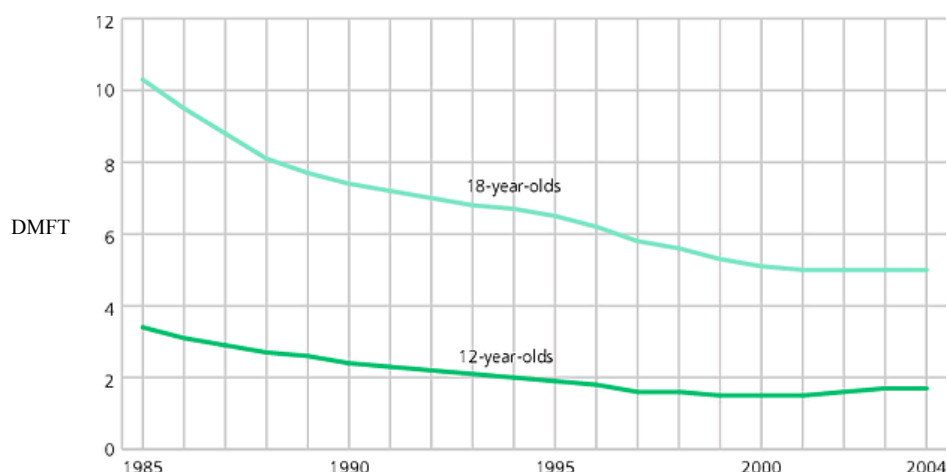
Figure 1. Mean number of teeth with caries experience (DMFT) in 12 and 18-year-olds [77]

Since the 1980's the mean caries experience and proportion of 12 and 18-year-olds with dental caries have declined [22]. After 2000, the caries prevalence has been stable [78].

Oral health services in Norway

In Norway all children and adolescents from birth to the age of 18 years are offered comprehensive and systematic dental care free of charge [79]. The services for children are provided by dentists and dental hygienists within the public health services [80]. Adolescents are provided with the required preventive care by the dentist and future appointments are planned based on the need of the individuals. The National Oral Policy recommends all individuals to brush their teeth twice a day with fluoride toothpaste and to use fluoride supplements by those who are at risk of dental caries [81, 82]. Commonly used fluoride vehicles are the following; fluoridated toothpaste, fluoride supplements and fluoride varnish.

1.7   Facts of India and Norway

Table 2 summarizes facts and figures of Norway and India. In addition, information on the state of Kerala where the present study was conducted has also been included.

Table 2. Facts and figures from India, Kerala and Norway

	India	Kerala	Norway
Population	1,080,264,388	31,841,374	4,593,041
GDP per captia (in US dollars)	$3,400	$629	$42,400
DMFT at 12 years	2.0 (average all studies)	2.1 [71]	1.5 [43]
Coverage of dental services for adolescents	Data not available	Data not available	100%
Payment for dental services during adolescents	Nominal fees in government facilities	Nominal fees in government facilities	Free until 18 years of age
Dentists to population ratio	1 : 36,538	Data not available	1.3 : 1000
Literacy rate	59	95	100
Birth rate/1000 population	22	18	12
Life expectancy at birth	64	74	79
Infant mortality rate deaths/1000 live births	56	12	4
Total fertility rate children born/woman	3	2	2
Death rate/1000 inhabitants	8	6	9

1.8 Risk of dental caries

In epidemiology, the term "risk" is defined as the probability that an event will occur within a given period of time [83].

Risk indicators

Variables associated with dental caries are categorized as risk indicators and risk factors [12, 84]. A risk factor is a variable that causes disease and the exposure to which leads to disease occurrence. Longitudinal studies are required to demonstrate causal relationship. [12]. A risk indicator is a variable that correlates with disease occurrence and might be studied in cross-sectional studies [84]. In the cross sectional study presented in this thesis, correlates of dental caries have been denoted risk indicators. Some of the important risk indicators used in the study are introduced in the following paragraphs.

Socio-economic status has been shown to be associated with caries experience both in developing as well as developed countries. Studies in Kerala [68] and other countries, have

shown that low socioeconomic status is associated with high caries experience [10, 11, 21, 27, 46, 85], although the opposite has been observed in Africa [6].

Mother's education is a risk indicator frequently used as a measure of socio-economic status. It has been shown that mother's with high education have children with less caries experience than mother's with low education [46, 52, 65, 86-89].

In many developing and developed countries higher caries prevalence have been reported in urban compared to the rural areas [6, 52, 90-93]. However, a study in India has reported no difference in caries experience between children living in urban and rural areas [66], a finding similar to that reported by Al-Shammery from Saudi Arabia [94]. But, higher caries levels have been found in children living in urban slum areas compared to children living in urban and rural areas, in India [66].

Girls have higher caries experience than boys, both, in developed and developing countries [70, 85, 93, 95, 96], on the other hand, a study from Sweden has shown no difference in caries experience between the genders [97].

A number of studies suggest that frequency of sugar consumption is associated with caries experience [88, 98-102]. Yet, one systematic review [103] showed that this association is weak, nevertheless, frequent intake of sweet is still considered to be a risk indicator for dental caries [104].

Adolescents from Uganda who had visited a dentist frequently had higher caries experience than adolescents who had visited only once [105]. Similar results have also been documented in Asian adolescents [106].

An association between regular tooth brushing and low caries experience has been reported [85]. Some studies suggest that caries experience does not differ with the use of different types of dental aids [52, 92]. Nonetheless, the use of toothbrush along with fluoridated toothpaste is understood to lower caries experience [100, 107].

Low caries experience has been reported among children who performed well in school [85, 108-110].

Caries prediction

As the proportion of the population with caries decreases, the need to predict individuals at risk of developing caries increases. In this way preventive services can be allocated to those at risk [111, 112]. Moreover, the use of predictors to identify risk groups has gained prominence due to increased costs of dental services on the one hand, and the importance of providing cost-effective dental services on the other [113-115].

In order to estimate the accuracy of prediction, the commonly used measures are sensitivity and specificity; false positive rate and false negative rate [112]. Generally a 100% sensitivity and specificity is desired to identify the optimal predictor, but this is usually not achievable. The least expected sum of sensitivity and specificity in a risk model which is useful in the clinic, is suggested to be 160% [116]. Although risk models help in predicting individuals at risk of dental caries, it should be recognised that as dental caries is multifactorial in nature, the accuracy of predicting it becomes difficult [112]. When planning to divert resources to prevent disease in a risk group, it is imperative that the percentage affected should not exceed 40%, because a percentage above that level indicates that the disease is not

concentrated within a sub-group of the population. In such cases a whole-population strategy would be preferable [117].

Approximal caries

Approximal surfaces are prime areas after occlusal surfaces where the biofilm (plaque) is allowed to stagnate and cause dental caries [9]. Restorative treatment of caries on the approximal surfaces usually requires two surface restorations, and consequently leads to excessive loss of healthy tooth structure [118]. Furthermore, at later stages, the restorations may have to be replaced due to secondary caries or fracture which in turn weakens the tooth [119, 120]. So, it is of primary importance to diagnose initial caries on these surfaces in order to be able to prevent or arrest lesions before they need restorations [39].

In general, the prevalence of caries on the approximal surfaces have been reduced with a decline in the overall caries experience [121-123]. However, evidence suggests that adolescents with past caries experience on the approximal surface during early adolescence have a relatively higher risk of caries experience at late adolescence than those with no caries experience [124, 125]. An increase in the risk of approximal surface caries in adolescents has also been observed within a few years after the formation of approximal contacts [126]. Moreover, the progression of caries on these surfaces has been shown to be more pronounced during early adolescence rather than late adolescence or adulthood [126, 127]. These reasons make caries on the approximal surfaces at early adolescence a suitable indicator for identifying individuals at risk of more advanced caries on these surfaces later in life.

1.9 Self-reported oral health

Information regarding health and dental needs is imperative for planning health services [128]. Traditionally, the need for dental care is assessed by dentists using clinical measures.

Assessing needs based entirely on a normative point of view raises concern, as it does not consider the functional, social and psychological consequences of the status of teeth and mouth [129, 130]. This has led researchers to acknowledge that, in addition to the normative dental needs, subjective or perceived oral health status should also be considered when planning oral health care services [130-133].

Many subjective oral health indicators have been developed in dentistry, ranging from single item indicators to complex inventories [134-140]. Most of the indicators developed have been used to evaluate oral health outcomes in adults and older populations [131, 135, 138, 141]. Some studies have used single item [136, 137, 142] and others multi-item indicators [134, 143, 144] to evaluate the impact of oral health on quality of life of children. Currently, a positive research trend seems to exist in order to collect information on self-reported oral health of children. This is mainly due to two reasons; firstly, because there is evidence that adolescents have the cognitive ability to provide valid and reliable reports of their oral health when using age-specific questionnaires [140, 143, 145], secondly, the impact of oral disorders on quality of life is more pronounced in children than among adults [146].

While some studies have found only a weak association between professionally recorded and self-reported oral health status [129, 136, 138, 147, 148], others have shown the association to be strong [137, 142, 144]. This may suggest that valid reports can be acquired when using subjective measures to evaluate oral quality of life. However, the use of a method low in sensitivity might probably direct services towards an undeserving population [149].

In research, single-item indicators like self-reported oral health may help in monitoring outcomes of oral health, recognising risk factors, and identifying individual priorities. These characteristics of single-item indicators aid in planning tailored programmes [150]. The need

to use single-item indicator is accentuated in countries where the oral health system is not well developed [151] and where running costs of dental services are relatively high [152].

The significance of subjective perspectives has also been recognised by the WHO, and it has highlighted improvement of oral quality of life as one of the goals for the year 2020 [57].

2. Aims of the study

General objective

The aim of the thesis is to provide information useful for planning preventive oral services in two different settings; in India, which is a developing country, and Norway, which is a developed country.

The overall objective of the research was to study aspects of dental caries and related factors/predictors in adolescents in India and Norway that may be valuable for the planning of oral health services for this age group.

Specifically, the objectives were:

- To describe the dental health status of 12-year-old schoolchildren in Thiruvananthapuram, India, and
    - o to identify sociodemographic factors, oral health behaviours, attitudes and knowledge associated with dental caries experience.
- To assess the prevalence of self-reported state of teeth among these children, and
    - o to identify correlates of self-reported state of teeth.
- To describe in detail the development of dental caries from 12 to 18 years of age in Norway, and
    - o to explore the possibilities for predicting caries increment from 12 to 18 years of age based on caries experience at 12 years.

3.   Materials and methods

This thesis is based on two separate surveys (Table 3). One study was carried out in Thiruvananthapuram, Kerala, India and the other in Bergen, Norway.

Table 3. Summary of the studies

Country	Paper	Focus of interest	Design	Age	Location	Year of examination
India	Paper 1	Dental caries and associated factors	Cross-sectional	12 yrs	Thiruvananthapuram	2003
	Paper 2	Self-reported state of teeth and correlates	Cross-sectional	12 yrs	Thiruvananthapuram	2003
Norway	Paper 3	Caries increment and prediction	Longitudinal	12 and 18 yrs	Bergen	1993 and 1999

Paper 1 describes the caries experience of adolescents in India using the DMFT (decayed, missing and filled teeth) index [31]. The paper also describes the association of dental caries with sociodemographic factors, oral health behaviours, attitudes and knowledge.

Paper 2 assesses the factors correlated with self-reported state of teeth among adolescents in India. This study considers functional, social and psychological aspects of the oral health status.

Paper 3 describes the caries experience of adolescents at 12 and 18 years of age in Norway, based on the follow-up of one cohort. The study also describes the caries increment and possibilities of predicting caries increment from 12 to 18 years of age.

The material and methods used in India and Norway will be described separately.

3.1 The Indian study

Study area

The state of Kerala is situated in the South-West corner of India (Figure 2) and is one of the smallest states in India. The Gross Domestic Product (GDP) per capita is low when compared with the rest of the country [153]. About 30% of its population is below the age of 14 years [154]. Ninety-five per cent of the adolescents in the state are literate [155].
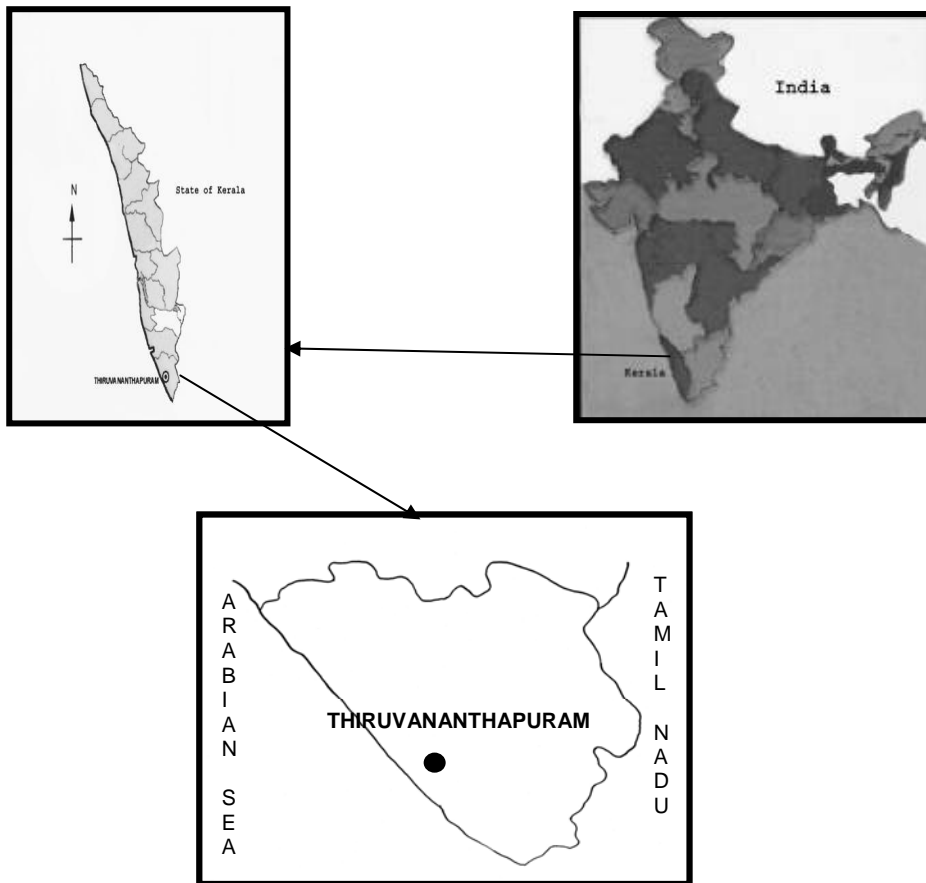

Figure 2. Thiruvananthapuram district, State of Kerala and India

Thiruvananthapuram is situated at the southern tip of Kerala (Figure 2). The district is divided into three geographical zones for administrative purposes (Neyyattinkara,

Thiruvananthapuram, Attingal). Sixty-six per cent of the population live in rural areas where approximately 80% of the upper primary schools are situated. Agriculture is the primary occupation of the people in this district. The state government runs a dental school and 3 multi-speciality dental clinics in Thiruvananthapuram district. Nearly 300 dentists practice in the urban parts of the district and are mainly private practitioners [71]. Ninety-nine per cent of water samples from Kerala had less than 1 ppm (parts per million) fluoride per litre [43].

Study sample and design

The study population consisted of 12-year-old schoolchildren attending private and government upper primary schools (grade 7) in urban and rural areas of Thiruvananthapuram district. This sample is considered representative of 12-year-olds in the district, as 95% of all children attend schools. The methods used for collecting data were clinical examination and questionnaire.

The data was collected between June and November 2003. The study had a cross-sectional design and was of analytical type. A stratified, two stage random cluster sample design was applied using schools as the primary sampling unit. The sample size was estimated allowing for a design factor of 2, caries prevalence of 60% [68] and precision of 0.05. The required sample size calculated was 738. Fifteen percent was added in order to compensate for non-response. The total population to be included in the study was rounded off to 840 schoolchildren.

For the survey, the schools were stratified according to area (urban and rural) and type of school (government and private). At stage 1, 30 schools (3 urban private, 5 urban government, 14 rural private, 8 rural government) were selected using a unified sampling fraction from the list of schools in the area. The decision to include only 30 schools was

based on financial and logistical constraints. At stage 2, 28 schoolchildren were randomly selected from each school selected at stage 1, on the day of the survey with the help of the school register. In three schools the required number of adolescents was not available. In such cases 12-year-old adolescents from neighbouring schools were included, yielding a total sample size of 838.

Data collection

Clinical oral examination

Oral examinations were conducted in classroom settings (Figure 3) where all the students (838) were examined by one dentist (Jamil David) and an assistant entered the recordings into a form. The students were examined while lying down on a bench and the observations were carried out using plane mouth mirrors, WHO periodontal probes and torch light. Neither radiographic examination nor drying of the teeth was carried out. Dental examinations were conducted based on the guidelines set by the WHO (Appendix 1) [31]. The criteria used to identify caries teeth, have been discussed in Paper 1. A tooth was considered missing due to caries when the child gave a history of bleeding, pain or swelling in the affected area. A tooth filling was considered to be the consequence of caries. Care was taken to identify teeth restored with tooth coloured restorations.

Oral hygiene status was measured using the Oral Hygiene Index – Simplified (OHI-S index) (Appendix 1) [156]. The index has two components, (debris index - simplified (DI-S) and calculus index - simplified (CI-S). Oral debris and calculus was estimated by running the side of an explorer along the tooth surfaces examined. The surfaces and teeth examined were,

buccal aspects of the upper first molars (16, 26), lingual aspects of the lower first molars (36, 46), and labial aspects of the upper right (11) and lower left (31) incisors.

Debris and calculus are graded on a numeric scale from 0 to 3 (see Appendix 1), depending on the severity and extent of the deposits. The debris scores are totaled and divided by the number of surfaces scored for each individual, giving the debris index score. The same methods were used to obtain the calculus index score. The average age-group debris and calculus index scores were combined to obtain the simplified oral hygiene index (OHI-S). The OHI-S scores range from 0 to 6 and are categorized as good (score 0.0 to 1.2), fair (score 1.3 to 3.0) and poor (score 3.1 to 6.0).

Figure 3. Oral examination carried out in a school

Training and calibration exercises to examine dental caries were undertaken by one researcher (Jamil David) at the Faculty of Dentistry in Bergen. The intra-examiner reliability of the caries registration was based on examining two adolescents from each school twice and was evaluated by calculating Cohen's Kappa [157]. Inter-examiner and intra-examiner calibrations were not feasible for the OHI-S Index.

Questionnaire survey

The questionnaire was initially constructed and administered in English. As schoolchildren had difficulty in understanding the language, the questionnaire was translated into the local language (Malayalam). To check for language accuracy the questionnaire was translated back into English. Selections of appropriate and simple words were considered. On the day of the survey, after clinical examination the adolescents were asked to fill in the questionnaire. The questionnaire was administered by the main researcher (Jamil David) along with two assistants. During the survey, the questions were read to the schoolchildren one by one providing them with ample time to answer the questions. Teachers were not present in the classrooms when children answered the questionnaire so as to ensure confidentiality and to reduce response bias. The questionnaire was re-introduced to 108 schoolchildren in seven schools. The test-retest time ranged from 7 to 19 days.

Figure 4. Adolescents filling in the questionnaires

3.2   The Norwegian study

Study area

The city of Bergen is situated on the South-West coast of Norway. Norway is one of the countries with the highest GDP per captia in the world [158], with a literacy rate of 100%.

About 20% of the population is below 14 years of age. Seventy-four per cent of the people work for the public services [158]. There is no fluoride content in the natural as well as public drinking water supply.
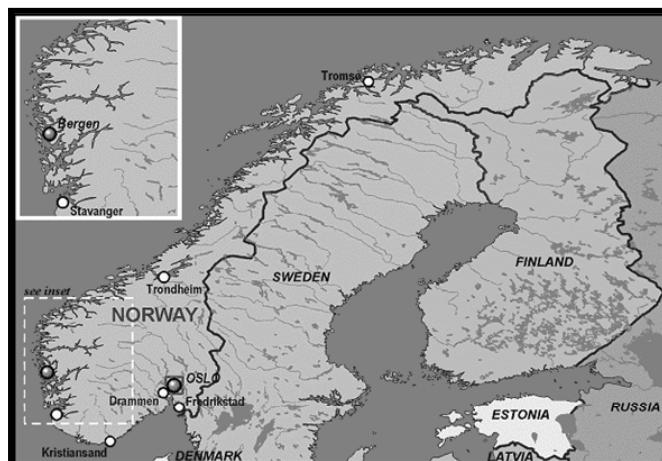
Figure 5. Study area in Bergen, Norway

Study sample and design

The current research work was a follow-up of the study carried out by Amarante and co-workers [34, 159] and was based on available data.

Twelve-year-old children, examined in 1993 [34, 159], were re-examined at the age of 18 years in 1999. The study had a prospective longitudinal design.

In 1993 all 12-year-old children receiving routine dental check-ups in three public dental clinics in the city of Bergen, were invited to participate in the study and 159 children were examined. The adolescents were then invited to be re-examined at the age of 18 years in 1999, and 112 (70%) of them participated.

Data collection

The study included clinical examination and a questionnaire survey.

Clinical oral examination and calibration

In 1999, when the adolescents were 18-years-old, one examiner (Gunhild V. Strand) carried out the oral examination. A diagnostic criteria of five caries grades (D_1 to D_5) was used to identify caries progression with the help of bitewing radiographs (Appendix 2) [32, 160]. The detailed description of caries examination has been discussed in Paper 3.

The examiner was subjected to clinical and radiographic training and was calibrated against two well trained examiners. The intra-examiner reliability was calculated based on the examination of 20 adolescents and was expressed as Cohen's Kappa.

Questionnaire

A questionnaire, written in Norwegian language, was sent to the adolescents when they were 12 and later when they were 18-years-old. The questionnaire was mailed along with an invitation letter asking them to participate in the survey.

3.3 Data management and statistical methods

The statistical softwares used were, Statistical Package for Social Sciences (SPSS), version 12.0 and 13.0 (SPSS Inc, Chicago IL), EPI INFO ^{TM} version 6.0 and STATA version 9.0. During analysis, some of the variables that were initially ordinal or nominal were dichotomised in order to carry out the final analysis. In some instances scores were totalled and then categorised into groups. Data from both the studies were first entered into recording

sheets and then entered into the computer. The data was later explored to correct any errors or missing data.

Majority of the analyses were performed by the SPSS program. To calculate the cluster design effect, the STATA program was used. Sample size for the Indian study was calculated using EPI INFO software package. The statistical methods and tests used in the three papers are summarised in Table 4.

Table 4. Statistical methods and tests used in this thesis

Statistical test/method used	Papers		
	I	II	III
Chi-square test	√	√	
Independent two sample t-test		√	√
Cohen's Kappa	√	√	√
Logistic regression	√	√	
Sensitivity and specificity			√
Efficiency of the test			√
Proportion in the risk group			√

The Indian study: The primary sampling unit used in this study was the schools in the district and individual children were the unit of enquiry. To adjust for potential cluster effects, analyses were performed with STATA (9.0) allowing for the cluster design and showed that the initial results provided by unadjusted analyses were left essentially unchanged.

The Norwegian study: The caries increment during the follow-up period was calculated by subtracting the approximal mean $D_{3-5}FS$ values at 12 years from that of 18 years. In order to predict adolescents at risk of developing approximal manifest caries lesions ($D_{3-5}FS_{approx}$) from 12 to 18 years, the predictive values of indicators at 12 years of age ($D_{1-5}FS_{approx}$) were used. The best predictors at 12 years of age were identified based on values of sensitivity, specificity, efficiency of the test and actual proportion of the population at risk. Cut-off

points of caries increment $D_{3-5}FS > 0$, 1, 2, 3 and 4 on approximal surfaces were used for defining risk groups.

Ethical clearance

The studies were approved by the Regional Committee for Medical Research Ethics and the Norwegian Data Inspectorate, Ethical Committee at the Thiruvananthapuram Medical College and the Directorate of Public Instruction, Kerala. In Kerala a written consent was requested both from the leader of the school and the children who participated in the study. In Norway all adolescents at 18 years of age gave a written consent to participate in the study.

4. Results

4.1 Paper I

Dental caries and associated factors in 12-year-old schoolchildren in Thiruvananthapuram, Kerala, India

The prevalence of dental caries (DMFT > 0) was 27% and the mean caries experience was 0.5 (SD = 0.9). The major portion of the DMFT was of decayed teeth (91%), while the remaining was missing (5%) and filled (4%) teeth. The proportion of children with dental caries experience was higher in the urban than in rural areas (33% versus 25%, p < 0.013). A statistically significant higher caries experience was found among children having visited a dentist, not using tooth brush, consuming sweets often, being dissatisfied with teeth and reporting poor school performance when compared to their counterparts. The multivariate analysis showed that children living in urban areas (OR = 1.5), who did not use a brush (OR = 1.9), consumed sweets (OR = 1.4) or had poor school performance (OR = 1.7) had greater probability of having dental caries experience at the age of 12 years than other children.

4.2 Paper II

Prevalence and correlates of self-reported state of teeth among schoolchildren in Kerala, India

The percentage of schoolchildren reporting bad state of teeth was 23%. A higher proportion of children who performed poorly in schools reported the state of teeth as bad compared to those who performed well in schools (41% versus 19%, p < 0.05). More children who reported to have bleeding gums and bad breath stated to have bad teeth than those who reported not to have bad breath (29% versus 21%, p < 0.05) and bleeding gums (37% versus 16%, p < 0.05).

The logistic regression analysis established that children who performed poorly in school (OR = 2.5), who had bad breath (OR = 2.4), who visited a dentist (OR =1.6), those dissatisfied with appearance of teeth (OR = 4.2) and who experienced caries (OR = 1.7) were more likely to report the state of teeth to be bad.

4.3   Paper III

Caries increment and prediction from 12 to 18 years of age: a follow-up study

At 12 years of age the mean $D_{1-5}MFT$ was 5.3 and at 18 years it was 8.9. The corresponding $D_{3-5}MFT$ (manifest caries) were 1.9 and 6.1. Ten and one per cent of the children were caries-free ($D_{1-5}MFT$) at 12 and 18-years of age respectively. The caries increment from 12 to 18 years of age was 4.2 $D_{1-5}MFT$. Of the surfaces with caries increment ($D_{1-5}FS$), the majority was on the occlusal surface of the first (35%) and second molars (40%). Forty-seven per cent of the adolescents had manifest caries increment ($D_{3-5}FS$) on the approximal surfaces from 12 to 18 years of age and the majority of these lesions were on the premolars (40%). The two predictors at 12 years of age of approximal caries increment ($D_{3-5}FS_{approx}$) from 12 to 18 years of age with the highest predictive power were caries experience on the approximal surfaces of the premolars and second molars at the age of 12. The group of adolescents (12%) who developed four or more approximal surfaces with manifest caries between 12 and 18 years of age were the easiest to identify, and this group experienced 62% of the total number of caries increment of this kind.

5.   Discussion

In the following section the main findings of the studies are discussed. This section ends with the conclusion and future implications of the studies in terms of planning dental services.

5.1   Methodological issues

The methodological issues of the studies conducted in India and Norway are discussed separately. The data collected in India used a sample survey methodology, where the group to be studied is chosen by suitable statistical methods and represents a given population [161]. Use of this method, rather than inclusion of the total population reduces the over all costs for conducting a survey, and provides an acceptable level of accuracy [161]. Nevertheless, various sources of errors (sampling error, non-coverage error, non-response error, measurement error) may influence the validity of the results leading to false conclusions [162]. The study sample selected in Norway was of convenience. This method of sampling reduces the external validity of the results and obscures true estimates.

5.2   Reliability

Reliability is synonymous to repeatability and reproducibility [163]. A reliable diagnostic procedure is one that gives the same result, within acceptable ranges, on repeated measurements of the same variable. It is also linked to precision of a procedure [164]. In this thesis reliability was measured using the Kappa statistics [165] .

Study in India

In the study conducted in India, the intra-examiner agreement of the caries examination was determined by randomly re-examining 60 schoolchildren. The Kappa value for intra-examiner agreement was 0.88, which is considered to be very good [157].

To test the reliability of the questionnaire data, 108 schoolchildren were selected to complete the questionnaire for the second time. As the schools were busy with their own schedule it was not possible to lengthen the time between test and retest, although that was desirable [166]. The Kappa values for test-retest of the questionnaire variables ranged from 0.56 (use of tooth brush) to 0.94 (visit to a dentist) in Paper 1, and from 0.55 (oral health knowledge) to 0.97 (wealth index) in Paper 2. The results of these Kappa values are considered to represent moderate to substantial agreement [165].

Study in Norway

The Kappa values for intra and inter-examiner reliability of the caries examination at 12 years of age ranged from 0.71 to 0.90 [34]. The Kappa value for the intra-examiner reliability at 18 years was 0.62. On both occasions, the values revealed a moderate to substantial Kappa agreement [165].

5.3   Validity

A measure is said to be valid if it measures what it claims to measure [166]. Internal validity deals with questions of whether a true measure of the variable or attribute is obtained for the study subjects, whereas external validity relates to whether it is acceptable to generalise the findings to a wider population [161].

Internal validity

Study in India

Though the test-retest reliability of the caries examination was very good, the internal validity of the results can be questioned, as dental caries might have been misclassified and under-reported in the study conducted in India. The reasons for under-reporting were mainly because the dental examinations were not performed under ideal clinical conditions; the study was conducted under field conditions without cleaning and drying of the teeth, and devoid of bitewing radiographs. Previous studies have shown that excluding initial lesions from the diagnostic criteria underestimates the caries experience to a large extent [33, 34]. Nevertheless, in order to conduct high standards of dental caries examination, calibration exercises were performed prior to the start of the fieldwork. Moreover, the diagnostic criteria (excluding initial lesions) selected for the study in India was based on the guidelines adopted by the WHO so as to make the data globally comparable [31].

The adolescents were subjected to a questionnaire where they gave self-reports of oral health behaviours, attitudes, knowledge and status of teeth. Social desirability and recall bias are known to be important sources of response biases and are likely threats to the validity of self-reported data. There is a risk that socially desired and undesired acts might be over-and underestimated in Paper 1 and 2 which may be the case with variables such as frequency of dental visits, use of toothbrush, consumption of sweets, poor school performance and oral health knowledge.

Study in Norway

Dental caries was examined with the help of bitewing radiographs in clinical settings following cleaning and drying of the teeth, thereby diminishing the possibility of misclassification and under-reporting of dental caries.

External validity

Study in India

The results from the study in Thiruvananthapuram are generalisable to all 12-year-olds in Kerala state, since the sample selected was representative of the population.

Study in Norway

The selected participants were not representative of the adolescents in Bergen, therefore the caries level of the study cannot be generalised to the Norwegian child population. The skewed caries distribution however is similar to the caries pattern in Norwegian adolescents. There is no reason to believe that the associations found in the studied population differ from associations present among other adolescents.

The non-response of 30% was considered acceptable in the follow-up study, since this percentage falls well between drop out rates of other studies [127, 167]. Drop outs had statistically significant higher caries prevalence at 12 years than the participants. The results are likely to underestimate the total caries experience in 18-year-olds. Similar results have been shown, where drop outs with high caries experience did not participate during the follow-up study [127]

5.4   Studies of dental caries in India and Norway

The information on dental caries in adolescents required for planning oral health services in India and Norway is different.

In India, as in many other developing countries, information about the caries situation in children is limited and most children have no access to dental services. Consequently, there is a need to describe the dental caries situation and how it influences the quality of life. The Indian study in this thesis describes the caries situation and identifies indicators influencing the level of caries and the oral health related quality of life.

In Norway, as in many other developed countries, the major portion of disease is found within a subgroup of the population. The challenge is to predict individuals at risk of developing caries so as to provide timely prevention. The Norwegian study in this thesis consequently identifies clinical predictors for early detection of these individuals.

5.5   Caries experience and planning oral health services in India

The results from India showed that the prevalence of dental caries and mean caries experience was low in Thiruvananthapuram compared to previous findings from other developing countries [43, 105]. Similar findings with low caries experience and prevalence have been reported from other states in India [66, 72]. Diehnelt and Kiyak [168] suggested that, low prevalence of caries might be a consequence of the type of diet consumed. In Kerala, the majority of the inhabitants have a traditional diet consisting mostly of rice, vegetable and pulses, while the consumption of processed food and sugary products is relatively low.

There were differences in dental caries experience among adolescents according to area; adolescents living in urban areas were 1.5 times more likely to have caries experience than those living in rural areas. It has been stated that in developing countries, individuals living in urban areas probably have greater access to sugary foods and drinks than those living in rural areas [25, 169, 170]. Though the level of dental caries is currently low in many developing countries, it is proposed that urbanisation may contribute to an increase in the caries prevalence [171].

Adolescents in Thiruvananthapuram who had visited a dentist were found to have more caries experience than those who had not visited a dentist. The visit to a dentist in this area is likely to be associated with a dental problem rather than a consequence of some form of treatment [102, 142]. This theory, that dental visits are made based on need, has been suggested previously by other researchers [96, 172, 173].

In the present study, adolescents using toothbrush had lower caries experience than those not using toothbrush. To our knowledge, there is no unequivocal evidence supporting the role of tooth brushing on dental caries [107]. Nonetheless, it is widely acknowledged that reduction of caries prevalence is largely due to the use of fluoridated toothpastes rather than the toothbrush itself [100, 107]. Although fluoridated toothpastes were introduced only a few years ago in the study area, majority of the adolescents (73%) reported its use. Further longitudinal studies are required to determine a cause-effect relationship between the use of fluoridated toothpaste and dental caries.

Higher caries experience was found in this study among adolescents who consumed sweets compared to those who did not. This result is in accordance with numerous other studies [98, 99, 102, 174, 175]. Adolescents are presumed to consume more sweets when they have

access to pocket money [176], a trend that will increase with growing disposable income among Indians, thus leading to increased risk of caries.

In the present study caries experience was found to be higher among adolescents who reported poor performance in school than among those who reported to perform well. Though other studies have described school performance as a risk indicator for dental caries, no precise reasoning has been given for the association [85, 108]. Nevertheless, it may be suggested that, adolescents who report poor performance in school also have low oral health knowledge, leading to unhealthy dental health behaviours. Crowley et al [109] have suggested that school performance is an useful indicator to identify individuals likely to be at risk of dental disease, as it is relatively easy to obtain information of this kind.

In this study, the majority (91%) of the teeth with caries experience were untreated. Similar findings were observed in other developing countries [55, 105], and this has been attributed to inaccessible and unaffordable oral health services [54, 177].

In India, as in other developing countries, dentists and oral health clinics are mainly situated in large cities and towns and are inaccessible to the majority of the individuals living in rural areas [178, 179].

In Kerala, the government provides limited oral health services to the general population, thereby restricting access to free dental service. Utilising services from other available health sectors might aid in improving oral health to a certain extent [180-182]. A study in North Carolina, showed that medical and non-medical services were able to provide organized preventive oral health services [182]. A similar approach may be a basis for improving oral services in Kerala, as all adolescents in the state have access to free primary health care in the villages. Owing to a well developed health care system, adolescents in Kerala are more likely

to come in contact with a medical doctor and local health workers than with dentists at an early age. The present health care system could also incorporate strategies to educate women and children on oral health, for e.g. the need to use fluoridated toothpaste, and to provide simple preventive services such as fluoride application. In addition, private dentists and dental associations situated in local areas could be given incentives to participate in oral health education and treatment of children.

The national oral health policy in India recommends providing dental service at various levels of the health care system (primary health care, community health care and district level) [76]. This policy has yet to be implemented due to lack of financial resources, thereby making it difficult to recruit dentists into the current oral health system. Including dentists at the primary level is expensive [183, 184], and under similar situations in other parts of the world, dental nurses and dental therapists carry out simple restorative work for children [184, 185]. No difference in working skills were found when auxiliaries are given adequate training [184-186]. Auxiliaries are also known to show greater job stability than dentists [184], and this may assist in providing sustainable services to the community. Wang [187] suggested that the use of auxiliary personnel are cost-effective compared to dentists when providing preventive oral health care and performing simple clinical procedures.

Schools are a suitable arena to promote oral health in Kerala as above 95% per cent of the adolescents attend schools. Another reason for providing dental health education in schools is that oral health behaviours and attitudes are developed at a young age and are sustained in adult life [29]. The combined action of schoolteachers and parents can be used to promote the oral as well as general health in adolescents [181, 188, 189].

5.6 Information on self-reported state of teeth for planning services

Nearly one-fourth (23%) of the adolescents in Thiruvananthapuram reported having bad teeth (Paper 2). This is lower than the percentage seen in other countries using different single or multi-item measures [142, 146, 190, 191].

The correlates of self-reported bad state of teeth were poor school performance, self-reported oral problems like bad breath and food impaction, having visited a dentist, dissatisfaction with appearance of teeth and having caries experience.

The findings from Paper 2 revealed that an association existed between self-reported oral health and dental caries, which might provide evidence of criterion validity. Though this result accords well with some studies [137, 142, 144, 192, 193], it counteracts with others [136, 138, 148]. The association seen here might be attributed to the large number of un-restored teeth and the unmet need of dental care and also partly, to a high level of awareness and self-perception of dental disease on the part the children investigated. A similar assumption has been made by another researcher [194] and highlights the need for dental care among the children in Kerala. The finding in paper 2 is opposite to that revealed by Ostberg et al [136], where they mentioned that, with low scores of caries experience it was difficult to find an association between subjective and clinical indicators. Perhaps this might indicate that, a single-item subjective indicator like self-reported state of teeth is more sensitive at lower levels of caries experience than self-perceived oral health.

Forty per cent of the children visited dentists and 29% of them described that they were dissatisfied with the state of their teeth. Visiting a dentist in developing countries is mainly

attributed to a symptom-oriented dental condition rather than a response to previous dental treatment [144, 190, 195].

Children who reported having bad state of teeth were four times more likely to be dissatisfied with the appearance of teeth than those who reported having good state of teeth. Several studies have reported dissatisfaction with appearance of teeth mainly due to fractured teeth, dental pain or malocclusions [142, 146, 191]. Fractured teeth were found to be negatively associated with self-reported state of teeth and thus underscore its effect on the subjective measure. The reason for differences in perception among children in Kerala is not explicit, but is thought to be plausible due to socio-cultural variations.

There is a growing understanding today that information gathered by subjective indicators may be a cost-effective method for planning services [138, 196]. This implies that self-reported information can guide planners during the planning process, which comprises of assessing needs as well as, prioritising, monitoring and evaluating services [128].

5.7   Caries increment and planning of services in Norway

The primary aim of the public oral health services in Norway is to prevent oral disease. However, the national data on dental caries collected from the public dental clinics, is based on recording of dentinal lesions, missing teeth and restorations only. Initial caries lesions that are not in need of restorative treatment, but do require preventive or interceptive treatment are not recorded. This method of registering caries is not adequate when the primary aim of the services is prevention.

The mean caries experience of 12- and 18-year-olds in the present study was 1.9 ($D_{3-5}MFT$) and 6.1 ($D_{3-5}MFT$) respectively. The corresponding figures of the national caries data in

1993 and 1999 were 2.1 ($D_{3-5}MFT$) and 5.3 ($D_{3-5}MFT$) respectively [197, 198]. This suggests that a similar pattern in caries experience exists between the study sample and the general population from 12 to 18 years of age in Norway. The study revealed that when initial lesions were included, the mean caries experience increased by almost three times at 12-years of age ($D_{1-5}MFT = 5.3$). This shows that when initial lesions are not included, we are in fact excluding the majority of caries which later on progresses into lesions that require restorative treatment. This is in agreement with previous studies who have found that initial lesions make up more than half of the caries experience [38, 199].

Even if the number of studies is limited, there is reasonable evidence that initial lesions may be arrested or that the progression may be postponed by the application of fluorides, glass-ionomers, fissure sealants and other substances [200]. Raadal [39] has termed the management of initial lesions in the individual patient as "interceptive caries treatment", including both general (oral health promotion) and local (plaque removal and application of substances to the lesion) interventions. This intends to reduce the need of restorations. Recording and treatment of initial lesions will not only aid in preventing dentinal caries and restorations, but also assist in planning and estimating required treatment costs [40].

Some researchers have maintained that the inclusion of initial lesions in epidemiological studies increases the examiner variability [35], thus making the data unreliable. However, many studies including the present have shown that a good examiner reproducibility can be attained by the use of strict criteria and calibration of examiners [34, 36, 38, 201]. The inclusion of initial lesions in the diagnostic criteria need not always be worthwhile due to the high costs involved, but it might be valuable when monitoring the progression and management of caries [42].

One obvious prerequisite for recording initial lesions in a survey is that the findings are useful for planning dental services for the population. If the goal of the service is solely to treat dentin lesions by the use of restorative care, it will be of less importance. In a well organised and resourceful public dental service, as that of the Norwegian dental services where all children and adolescents are regularly recalled to a clinic for check-up, it seems reasonable that the prevention and treatment philosophy aims at preventing the initial caries lesions from progressing into lesions that need restorative care. Based on the present findings it should be concluded that, recording of initial lesions by calibrated examiners, must be included in surveys.

The highest number of caries increment during the age period from 12 to 18 years was on the occlusal surfaces of first and second molars. Although a proportion of this increment must be attributed to class-II fillings, where approximal caries lesions were the reason for the fillings, the finding indicates a potential for preventing caries initiation and progression by the use of fissure sealants during this age period.

5.8   Approximal caries as a basis for planning services in Norway

The study showed that almost half of the adolescents developed at least one manifest (dentin) approximal lesion from 12 to 18 years, and 40% of these lesions were in premolars. It is well known that these teeth are vulnerable to cusp infractions and fractures, when class-II restorations are done, due to loss of considerable tooth substance on both the occlusal and approximal surfaces. Our findings therefore indicate a specific need for prevention as well as early diagnosis and treatment of such lesions before restorative care is needed.

Even if the evidence regarding the efficiency of managing such lesions is weak [200], some studies have shown good results, among which the follow-up study by Axelsson et al in 1987 [202], is the most successful. There seems, however, to be an urgent need for developing more effective techniques for the management of early caries on the approximal surface during this age span.

Most lesions on the approximal surfaces tend to progress slowly [127], but the variation is large. It is therefore important to find risk indicators for those who develop such lesions early in life in order to be able to provide preventive and interceptive treatment. Our prediction analyses showed that approximal caries on the premolars and second molars at 12 years of age were the best predictors of development of manifest lesions in the age period up to 18 years. This is reasonable since it is during this period that posterior teeth establish contacts [126], and the risk for development of caries soon after eruption is known [127]. Caries is a chronic disease that develops over time in the mouth throughout the age period, and the predictors at 12 years of age were therefore to a great extent early signs of the same disease as recorded later.

However, in clinical dentistry it is important to have indicators that are reasonably, sensitive and specific enough to be used in practice, and we suggest that Table 7 in Paper 3 may be useful for that purpose. By using the prevalence of approximal lesions on premolars and second molars in 12-year-old children as predictors, it seems to be possible to predict those who develop many manifest approximal lesions in the period up to 18 years, particularly those that develop more than four lesions. This predictor may be of value in clinical dentistry. The study showed that 12% of adolescents had 62% of the total approximal manifest caries increment during the period from 12 to 18 years of age.

It is our recommendation that children at 12 years of age with approximal caries (enamel or dentin lesions) on newly erupted premolars and second molars are given extra preventive care and interceptive caries treatment during the follow-up period.

6. Conclusions

This thesis provides information on dental caries among adolescents in India and Norway, which is useful for the planning and designing of preventive oral health services in the two countries. Different methods have to be used in order to identify adolescents at risk of dental caries in a developing and developed country. In the Indian study, risk indicators and self-reported data were used, whereas, in Norway possible predictors were utilized. Strategies involved in reducing caries prevalence will differ between the two countries due to dissimilarities in terms of available resources.

The conclusions to be drawn from the studies are:

- The caries prevalence was low in Kerala. The majority of the decayed teeth were not restored.

- The probability of having caries in schoolchildren was related to living in urban areas, having visited a dentist, not using a toothbrush, consuming sweets and performing poorly in school.

- One forth of schoolchildren in Kerala reported to have bad teeth. Risk indicators related to reporting to have bad teeth were performing poorly in schools, having bad breath, having food impaction, having visited a dentist, being dissatisfied with the appearance of teeth and having caries experience.

- In order to predict adolescents in Norway at risk of developing many approximal manifest caries lesions from 12 to 18 years of age, monitoring approximal lesions at age 12 is prudent. Predictors for increment of manifest lesions on approximal surfaces from 12 to 18 years were approximal lesions in premolars and second molars at the age of 12 years.

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