The development and application of a risk prediction model for dental caries in primary schoolchildren in Flanders

Jackie Vanobbergen

“Ik heb een steen verlegd
in een rivier op aarde.
Nu weet ik dat ik nooit zal zijn vergeten,
omdat door het verleggen van die ene steen,
de stroom nooit meer
dezelfde weg zal gaan."
Bram Vermeulen

To Carmen, Bruno, Lard, Erika,
Ulke, Nathalie, Anthony.

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General Introduction and objectives

General introduction and objectives

The concept of health and what it means to be healthy was initially concerned with striving after a condition of absence of disease. Currently, however, this concept has a much broader 'holistic' scope aiming a complete state of physical, mental and social well-being (WHO, 1964; WHO, 1981). As an implication of this concept, in stead of a merely body-approach, more attention needs to be paid to the totality of the person, his immediate and broader environment and to the community he is living in. In improving health both an individual and a societal responsibility needs to be emphasised and secured by collaborative actions at all levels of our society (Pine, 1997; Burt, 1999).

Health promotion has an important role to play in this concept. It will enable individuals and communities to increase control over the determinants of health and thereby improve their health, representing a mediating strategy between people and their environment, combining personal choice and social responsibility for health to create a healthier future (WHO 1984). It includes aspects of individual's lifestyle, structure of the society, and a multi-disciplined approach to health (Green and Kreuter, 1990).

Several WHO reports (1984-1989) outlined a set of principles and important key concepts for health promotion, applicable to oral health promotion, which can be summarised by five recommendations, requiring further elaboration:

1. *Focus on prevention*: a shift from curing disease to promoting health in a more preventive approach.

2. *Community participation*: involvement of the population, individuals and communities, in all decisions which affect their health. The empowerment of others, sharing responsibility for and control over health, is one of the most important tasks of health workers with respect to health promotion.

3. *Equity and equality*: identification of risk groups allows us to break down barriers to adequate health promotion and health care.

4. *A multi-sectorial approach*: involvement of teamwork-approach to improve both general and oral health. This includes also advocating and educating politicians,

community leaders and other influential individuals and an overarching co-ordination with other sectors than the health sector, such as social, economic, agriculture, food and education sectors in order to create supporting environments.

5. *An evidence based approach*, both in the management and the evaluation of the health promotion policy.

Tannahill (1985) described three elements essential to health promotion: health education, prevention and health protection. The elaboration of these three elements covers a high number of domains, resulting in a broad interrelationship between them. The *Tannahill model* supplies a useful framework in which to fit oral health promotion.

Reflecting all these considerations to the situation in Flanders Belgium, one has to consider the following shortcomings in the oral health care area: the non-existence of screening programs, preventive programs targeting high risk groups, water fluoridation, co-ordinated health education programs, integrated oral health promotion policy. The Flemish government should be convinced of establishing policies, founded on evidence based research, that underlies decision-making at the national, provincial, municipal and individual oral health unit level. This would allow plans for actions not only in the field of oral health promotion, but also in the field of the delivering of oral health care. Parallel with this management, the facilities should be created to evaluate both the quality and the quantity of plans of actions (Cohen, 1990).

Although oral health promotion must be viewed in a different perspective for the different age groups, it would be a mistake to suppose that oral health promotion for children is a reasonable end in itself. The number of older adults in our society is increasing and the proportion of them with natural teeth is also increasing. Oral health promotion and prevention is required for all age groups and for the whole period of a person’s life. Consequently an appropriate concept for different age groups becomes increasingly important.

To meet these shortcomings this thesis will focus specifically on the current situation in order to provide a scientific basis for future oral health care and oral health promotion strategies.

Evidently, the subject of the present study: ‘the development and application of a risk prediction model for dental caries in primary schoolchildren in Flanders’ is only a twig on the health promotion tree. Consequently, the author is conscious of the relativity of his work, but still remains convinced that this work will help in some small way to encourage a preventive mindset in health workers, politicians and community leaders, to benefit national and international co-operation and to procure a scientific basis for the establishment of a well-functioning and effective oral health promotion strategy in Flanders-Belgium.

Objectives of the present study

The present investigation is based on the Signal-Tandmobiel® data. This project aimed to estimate the oral health condition of Flemish primary schoolchildren. As a multi-centre project it is been co-ordinated by the Dental Departments (Paediatric and Preventive Dentistry) of the Catholic University of Leuven, the University of Ghent and the Free University of Brussels, the Youth Health Department of the Catholic University of Leuven, the Biostatistical Centre of the Catholic University of Leuven, the Working Group for Oral Health Care of the Flemish Dental Association and the Flemish Association for Youth Health Care.

The financial support for data collection is provided by an industrial partner: Lever-Elida (Unilever Belgium). Support for data analysis is provided by a scientific grant of the Ghent University and the Catholic University Leuven, and the Academic Research Collaboration Programme funded by the British Council and the Flemish Fund for Scientific Research.

The broad aim of the present study was to define and understand key aspects of the prevalence, incidence and causes of dental caries in primary schoolchildren in Flanders.

The specific objectives were:

- To describe the rates of dental caries in primary schoolchildren, aged 7 to 10, expressed in prevalence and incidence, and to improve common used descriptive information of oral health status.
- To define the impact of a set of behavioural and socio-demographic risk indicators on caries prevalence in a cross-sectional investigation.
- To understand the influence of social environment and social inequalities on oral health and oral health behaviour.
- To define the impact of a number of possible explanatory variables on the oral cleanliness in the mixed dentition and to assess the relation between plaque accumulation and caries experience.
- To elucidate, as part of the Academic Research Collaboration Programme, similarities and differences between child dental health in Flanders and Scotland and to investigate key explanatory variables.
- Finally to evaluate longitudinally the caries incidence predictive ability of these baseline risk indicators and predictors in order to confirm predominant risk factors and to establish a reliable screening method for the prediction of caries.

The content of this thesis

In the first part **"exploring the field"**, *chapter 1* compiles by a literature search epidemiological caries studies in children performed since 1980 in Belgium in order to assess the evolution and the actual dental health condition of primary schoolchildren in Belgium. As part of large-scale socio-demographic changes in the oral health landscape, questions are raised about the appropriateness and effectiveness of the oral health care delivering system. Hence, a critical approach of the actual oral health care delivering system in Belgium, mainly with respect to children and set in a European perspective, forms the content of *chapter 2*.

Dramatic improvements in oral health and an increasing knowledge of the dental caries process has changed our perspectives in risk and risk assessment. In *chapter 3,* recent ways to deal with these changes are described.

Quality standards and diagnostic criteria, reliability and reproducibility of measurements are essential for the quality of field trials, especially when more observers are used for the assessments. *Chapter 4* attempts to reduce confusion about the use of reliability measures and diagnostic criteria by illustrating and comparing different measures.

The second part describes "**the Signal-Tandmobiel® project".** In *chapter 5,* the baseline objectives and the material and methods are described, while in *chapter 6* the outline is given for the descriptive first year results and the evolution during the consecutive three years.

Part three **"the development and application of a caries risk assessment model"** forms the body of this dissertation.

Chapter 7 'assessing risk indicators for dental caries in the primary dentition' permits quantification of the degree of importance that particular putative risk indicators bring to the development of dental caries, both on a individual and a cumulative base. An important composite factor, dental plaque accumulation, as a result of several oral health behavioural and biological factors is described in *chapter 8,* related to the caries prevalence. As an important non causal factor that brings the subjects into contact with the causal chain, the importance of the socio-economic position in relation to the caries experience is studied in *chapter 9.* In an explanatory study the mechanisms that link material deprivation with the risk of caries, using the existing and assessed risk indicators of the previous analyses will be analysed. Finally this chapter assesses the major dental health related behavioural differences between the different socio-economic groups.

As part of the Academic Research Collaboration Programme between the British Council and the Flemish Funds for Scientific Research, *chapter 10* presents longitudinal comparative data on dental health, reported health behaviour and socio-demographic characteristics of Flemish and Scottish children.

While the chapters 7 to 9 are based on cross-sectional data, *chapter 11* seeks to confirm in a longitudinal prospective cohort study the previous potential risk factors in order to control their predictive power and to validate them against subsequent caries in the permanent dentition. The final goal will be to assess the ability of our cross-sectional risk model to recognise children who will develop caries (sensitivity) and to exclude those who will not (specificity).

Finally this dissertation is completed with a summarising general discussion and a final conclusion.

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I. Exploring the field

Chapter 1: Caries prevalence in Belgian children: a review.

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Abstract

A review of epidemiological surveys on dental caries prevalence, published between 1980 and 1999 in Belgian children, was compiled through a literature search. The number of studies performed in Belgium to date is limited. Methodological differences and confounding factors, especially socio-demographic influences, limit national comparisons of caries prevalence data.

Although exact comparisons are difficult, data suggest a decline in caries prevalence in 5, 7 and 12 year-old Belgian schoolchildren in the last 20 years. In the primary dentition mean dmft values have decreased from 2.66 (1981) to 1.38 (1994) in 5-year-olds and from 4.1 (1983) to 2.24 (1996) in 7-year-olds. In 12-year-olds DMFT values in the permanent dentition have decreased from 3.9 (1983) to 1.93 (1994). WHO goals for the year 2000 appear to have been already reached in Flanders, with a recent estimate of 1.93 for DMFT in 12-year-olds and 56% of children being recorded as caries free at the age of 5.

Continuing efforts are needed to screen the oral health of different age groups but standardised criteria and sampling procedures should be used if benefits are to be gained from national and international comparison. Data has often been limited to small selected areas and information representing the entire community of Flanders or Wallonia would be of particular value.

Introduction

During the past three decades many epidemiological studies and reports have demonstrated a dramatic decline in the prevalence of dental caries in children in countries of the Western world (Glass, 1982; Marthaler, 1990; Marthaler *et al.*, 1996; Petersson and Bratthall, 1996; Truin *et al.*, 1994; Elderton, 1994.) WHO goals set for the year 2000 of a maximum mean DMFT score of 3 for 12-year-olds and a target of 50% of children caries-free at the age of 5, have already been reached in many of these countries. The decline allows a focus on new challenges in dental public health, although disease prevention and health promotion will remain paramount. One of the challenges lies in the fact that, notwithstanding the lower mean caries levels, the disease has become increasingly polarised, with a large amount of disease in a small group of children. About 10 to 15% of the children now experience 50% of all caries lesions and 25 to 30% suffer 75% of lesions (Marthaler, 1990; Marthaler *et al.*, 1996; Petersson and Bratthall, 1996).

At the start of the third millennium, oral health promotion in children may have many major objectives. These include the further improvement of dental health through adequate fluoride-based programmes, dietary and oral hygiene counselling, the refinement of diagnosis, and early identification of groups at a particular risk of developing caries. For this reason epidemiological surveys remain of primary importance, since the monitoring of oral health allows compilation of information on oral health over time and the identification of high-risk groups at different ages. Epidemiology is also essential in the assessment of treatment need and in planning care, and in the further development of preventive and curative strategies, the determination of the cost-effectiveness of care and the evaluation and adjustment of treatment methodologies.

The aim of this report is to review studies of caries prevalence in Belgian children reported since 1980 in order to consider changes in disease prevalence and to compare the most recent estimates with established WHO goals for oral health in children by the year 2000.

Material and Methods

Epidemiological studies on caries prevalence in Belgian children, published since 1980, were compiled through a systematically approached search of published literature. The search and selection procedures were based on guidelines adopted from Cochrane. (*The Cochrane Collaboration*, 1994; Oxman *et al.*, 1994) and were carried out in a series of stages:

1. A www browse. This elicited web-based information provided by governmental authorities, academic centres and dental associations.
2. A literature search on MedHunt and Medline databases. The Medline database was searched using WinSpirs and PubMed. This search used a keyword filter including caries, children and Belgium. The period covered was 1980-2000.
3. Personal contact and hand-searching were used to identify unpublished reports, reports in local journals, non-English-language articles, PhD theses, and abstracts published in abstract books of National and International Conferences.

The following information was considered as essential for articles to be included in the review: information on sampling, study design, diagnostic criteria for measuring caries prevalence and calibration procedure. Next, the assessment of studies to be included was carried out using the guidelines of the British Association for Study of Community Dentistry (BASCD)(Pitts *et al.*, 1997; Pine *et al.*, 1997.). The different caries studies were evaluated with respect to methodologies used and the availability of dmft/DMFT data in specific age groups. In the case of intervention cohort studies, only base line data or, if available, data for control groups were used. Data for children with special needs were excluded. Finally, to determine trends in patterns in dental caries experience in Belgium and to allow comparisons with other countries, results were chronologically confined to three age groups, children of 5, 7 and 12-years of age.

Evaluation of the data

Studies selected on the initial inclusion criteria of this review are summarised in table 1.1. (Truin *et al.*, 1994; Staelens, 1982; De Vis, 1988; Kohl and Buttner, 1984; Kohl, 1984; Vanobbergen, 1989; Van Nieuwenhuysen, 1990; Van Nieuwenhuysen *et al.*, 1992; Declerck and Goffin, 1992; Declerck *et al.*, 1992; Marks *et al.*, 1996; Bolin *et al.*, 1996; Bolin, 1997; Vanobbergen *et al.*, 1997; Declerck *et al.*, 1998; Declerck *et al.*, 1999; Vanobbergen *et al.*, 2000; Carvalho *et al.*, 1998; Van Nieuwenhuysen *et al.*, 1999). Most were confined to particular age groups and were limited to local samples. One study was part of a Europe-based screening in which the national sample was not particularly representative, either in size or geographical spread (Marks *et al.*, 1996; Bolin *et al.*, 1996; Bolin, 1997) and one study was an overview (Truin *et al.*, 1994).

The report made by Staelens (1982) was the result of school examinations performed between 1969 and 1973, and was carried out without standardised criteria for caries diagnosis. A large number of dentist-examiners participated in this project without receiving any particular training programme, nor were any calibration procedures undertaken to reach agreement or an acceptable level of reliability. The sample was restricted to a single province (East-Flanders) and selection was made without recourse to existing well-defined criteria for stratification and sampling. The results were also difficult to interpret since caries prevalence, expressed in terms of percentage of children caries free or dmf averages, was reported irrespective of age group. Study results are therefore difficult to compare with those of other reports. In contrast, in the study reported by De Vis (1988) standardised and widely accepted criteria were used for diagnosing caries. Particular attention was paid to the intra-examiner reliability. However, although the level of agreement reached was high, the methodology differs from those used by other authors. The sample (n=504) was selected in only one city and is thus not representative of the whole country. As in the study of Staelens, there was no clear evidence of stratification and sampling and no information about caries prevalence or dmf average for specific age groups was reported.

Table 1.1.: Caries prevalence surveys in Belgian children
(publication period: 1980-1999)

Reference	***Year of investigation***	***Topic***	***Sample size / location***	***Age category (years)***
Staelens A. 1982	1969-1973	Caries	5600 / East-Flanders	6-12
De Vis H. 1988	1980	Caries, occlusal and functional conditions	504 / East-Flanders	3-6
Kohl J et al. 1984	1983	Caries, plaque	109 / Liège 113 / Liège	7 12
Kohl J	1983	Caries	- / Flémalle	5
Vanobbergen J. 1989	1981-1988	Caries, gingival condition	300 / Deinze	6-12
Van Nieuwenhuysen JP et al. 1992	1983-1989	Caries, fluorosis	3237 / Brussels-Moeskroen	5-21
Declerck D et al. 1992	1989-1991	Caries, gingival condition, oral health habits	3534 / Flanders 4162 / Flanders	5 12
Truin G J et al. 1994	1983-1991	Caries	-	5-7 11-13
Bolin AK et al. 1996	1994	Caries	200 / Ghent 200 / Ghent	5 12
Carvalho JC et al. 1998	1995	Oral hygiene, gingival condition, caries, dental anomalies, fluorosis, malocclusion, traumata,	750 / Leuven	3-5
Vanobbergen J et al. 1998	1996	Oral hygiene, gingival condition, caries, dental anomalies, fluorosis, traumata,	4351 / Flanders	7
Van Nieuwenhuysen et al. JP. 1999	1998	Caries	496 / Brussels	12

Reported sampling criteria	***Study design***	***Standardised methods***	***Reported calibration***	***Remarks***
None	Longitudinal	None	None	
At random stratified	Cross-sectional	Yes	Intra-examiner reliability tests	
None	Cross-sectional	Yes	None	
None	Cross-sectional	Yes	None	
Total municipal population	Prospective cohort	Yes	Inter-examiner reliability at baseline	Evaluation of a dental preventive primary school program
None	Cross-sectional	Yes	Intra-examiner reliability tests	
At random	Cross-sectional	Yes	Inter-examiner reliability tests	
Yes	Review	Yes	-	
At random	Cross-sectional	Yes	Intra-and inter-examiner reliability tests	Inter-European collaborative survey
None	Cross-sectional	Yes	Intra-examiner reliability tests	
Stratified cluster sampling	Prospective cohort	Yes	Intra-and inter-examiner reliability tests	Baseline results
None	Cross-sectional	Yes	Intra-and inter-examiner reliability tests	

The aim of the study by Vanobbergen et al. (1989) was to evaluate the effect of a 7-year preventive primary school programme, based on four strategies: motivation and oral health counselling, daily tooth brushing, weekly fluoride rinsing (0.2% NaF) on school premises and clinical examination three times a year. In this study standardised and widely accepted criteria were employed to determine caries prevalence although the sample (n=300) was limited and restricted to the rural city of Deinze. Ten dentist-examiners participated in this project. One weakness of the study was the lack of attention paid to training and calibration during the investigation. Inter- and intra reliability measures were determined only at baseline. However, baseline results and the findings for age-matched control groups may be used for comparison with other studies.

Kohl (1984) reported data on caries prevalence, registered using well-defined, standardised criteria. The sample was again limited, being confined to the cities of Liège and Flémalle. No criteria for stratification or sampling were reported and the report did not mention any specific training or calibration programme. Percentages of caries free children as well as dmf averages are reported for specific age groups.

In the study of Van Nieuwenhuysen *et al.* (1990, 1992) a large number of children was examined between October 1983 and May 1986. Sampling procedures were not according to defined criteria and the study was restricted to the areas of Brussels and Mouscron. Data were collected using standardised and widely accepted criteria, inter- and intra-reproducibility were recorded and high kappa values reported. This study has been continued with a smaller sample of 12-year-olds, located in Brussels, employing the same examination conditions (1999). Results could not be used for comparisons as the reported dmft/DMFT average included enamel lesions whereas other studies have more often been confined to caries involving dentine.

Declerck *et al*. (1992) included 3534 5-year-old and 4162 12-year-old children in their study, representing 5% of the target population. The sample was selected at random in the five Dutch-speaking provinces of Belgium. Data on caries prevalence and gingival condition were recorded using standardised and widely accepted criteria. A training and calibration programme preceded the study, but was not described in the final report and no data was made available on reproducibility of diagnosis and clinical examination.

Within the 'Children's dental health in Europe' (Marks *et al.*, 1996; Bolin *et al.*, 1996) surveys particular attention was paid to the training and calibration of the examiners who were spread over all the participating countries. Detailed data on calibration exercises and recalibration have been published (Bolin, 1997). All data was collected using standardised and/or well-studied criteria. Weak, but inherent to the design of this project, samples in the different countries were small and were not representative of the whole country.

The study of Carvalho *et al*. (1998) was confined to the municipality of Leuven. No sampling procedure was described in the report. Clinical examination using standardised criteria was carried out by one examiner and duplicate recordings were made on 10% of the sample. Non-cavitated early active lesions were included in the dmf scores in order to assess the need of non-interventional treatment procedures. Because of the differences in criteria, this study again could not be used for a comparison. A recent report included both cavitated and non-cavitated lesions (2001).

Shortcomings in previous studies and the need for more broadly based and standardised information provided one factor prompting the setting up of the longitudinal Signal Tandmobiel® project in 1996 (Vanobbergen *et al.*, 1997; Declerck *et al.*, 1998; Declerck *et al.*, 1999; Vanobbergen *et al.*, 2000). The most important objective of this project is to screen the oral health condition of primary schoolchildren in Flanders between ages of 7 and 12, both cross-sectionally and longitudinally. A stratified cluster sample of 5000 schoolchildren born in 1989 is to be followed for a period of 6 years (1996 – 2001). Examinations are carried out in a mobile dental clinic by a team of trained dentists and auxiliary personnel. Standardised criteria are used. The examiners are calibrated at baseline and at regular intervals during the project. The partners in this project are: the dental departments of the Catholic University of Leuven, University of Ghent and Free University of Brussels, the Youth Health Department of the Catholic University of Leuven, the Biostatistical Centre for Clinical Trials of the Catholic

University of Leuven, the Working Group for Oral Health Care of the Flemish Dental Association and the Flemish Association for Youth Health Care. The project is financed by an industrial partner: LeverElida (Unilever). Baseline results on 7-year-olds based on an effective sample size of 4351 children are currently available and have been included as relevant to the objectives of this paper.

Discussion

Table 1.2. summarises information from studies remaining after the final selection according to the criteria described above in the materials and methods.

It is apparent that the number of studies performed in Belgium in the last 20 years is limited and information is not representative of the country as a whole. Methodological difference and confounding factors, especially socio-demographic influences, limit national comparisons of caries prevalence data. In consequence, only an approximation can be made of trends between 1980 and 1999 in Belgium. The dmft/DMFT values among 5-year-olds, 7-year- and 12-years olds, obtained in relatively comparable data sets (table 1.2.), suggest a decrease in caries prevalence in these age groups during the period 1981-1996. As Belgium is a federal state with separate authorities for health promotion and disease prevention, epidemiological research is increasingly being conducted separately in the two communities (Flanders and Wallonia). In Flanders, the northern part of Belgium, the data set (Declerck and Goffin, 1992; Declerck *et al.*, 1992) suggest that WHO criteria for the year 2000 have been attained. According to these criteria children in Flanders belong to the moderate, or even low, caries experience category. 56% to 59% of 5-year-old Flemish children are caries-free and 12-year-old children have an average DMFT of 1.93. Preliminary results of the Signal-Tandmobiel® project confirm the skewed distribution and polarisation of caries prevalence in Belgian children as seen in other European studies. Recent estimates suggest that amongst 7-year-olds in Flanders 44% of children are caries-free and 50% of caries lesions are confined to 15.2 % of the children (Vanobbergen *et al.*, 1997; Declerck *et al.*, 1998; Declerck *et al.*, 1999; Vanobbergen *et al.*, 2000).

Table 1.2.: Final selection of comparable epidemiological caries surveys in Belgium published between 1980 and 2000.

Reference	*Municipality*	*Year (investig.)*	*Children (n)*	*dmft*	*% caries-free*	*DMFT*	*% caries-free*
5-year-old							
Vanobbergen	Deinze	1981	300	2.66	32%		
Kohl	Flémalle	1983	-		43%		
Declerck et al.	Flanders	1989-1991	3534	1.65	59%		
Bolin et al.	Ghent	1994	200	1.38	56%		
7-year-old							
Kohl & Buttner	Liège	1983	109	4.1	26		
Vanobbergen, Declerck et al.	Flanders	1996	4351	2.24	44%	0.16	89.7%
12-year-old							
Carvalho et al.	Brussels	1983	583			7.5	4%
Kohl & Buttner	Liège	1983	113			3.9	12%
Vanobbergen	Deinze	1986	300 (control)			3.24	17%
Declerck et al.	Flanders	1998-1991	4162			2.72	25%
Bolin et al.	Ghent	1994	200			1.93	37.5%
Carvalho et al.	Brussels	1998	496			1.6	50%

Conclusion

Despite a lack of sufficient available comparable data, the selected surveys reviewed in this report suggest a decline in caries prevalence in 5-, 7- and 12-year-old Belgian children. Results show that at least for Flanders the WHO goals for the year 2000 have now been reached. Results of the Signal-Tandmobiel® project confirm that there has been a polarisation of disease, with a significant amount of caries being confined to a small group of children. There remains a need for continuing efforts to screen the oral health status of different age groups and to identify high risk groups. If this is to be used to best effect, collection and presentation of data should be standardised and studies carried out according to well defined and recognised criteria.

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Chapter 2: The delivery of paediatric dental care in Belgium in a European perspective.

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Abstract

The delivery of oral health care has to be dynamic, responding the changes in population demographics and the patterns of oral diseases. In a European perspective, this report presents a qualitative approach of the oral health care system in Belgium, mainly with respect to children. According to the characteristics of an oral health care delivering system the following questions need to be dealt with: what are the objectives, who provide what service to whom, with what resources and with what effects?

There are no clearly nationally articulated oral health objectives in Belgium as oral health care objectives are considered as part of general health care objectives. Basically in Belgium health promotion, education and research is decentralised and the responsibility of the different federal regions. Health care is a national matter. The most frequently used structures for delivery of oral health care are independent dental practices and there is no oral health care provided at community level.

The population is targeted as a whole. This could result in a limited access to oral health care for those groups who are most in need.

In 1998 the number of active dentists in Belgium was 8095. Approximately 85% of these dentists were self-employed in private practices. The dentist-population ratio was 1:1266. Only a minority of dental practices employs dental assistants and dental hygienists do not exist at all.

Private fee-for-service payment is the traditional form for payment and reimbursement for dental services in Belgium. The National Health Insurance is responsible for the reimbursement of the patient. In 1998 the cost of dental care amounted to 0.18 % of the GNP. In a European context, the cost of oral health care in Belgium is rather low.

Although efforts to promote preventive care have already occurred to some extent, there is still a clear over-reliance in the Belgian oral health care system on treatment of oral disease rather than prevention of oral disease

Introduction:

Oral health care systems throughout different European countries have various historic roots, influenced by social, political or economic structures and societal norms (Andersen *et al.*, 1995). However, they all try to improve the quality of life of the population through research, education, provision of services and health promoting preventive strategies. In many countries oral health care is an integral part of the general health care system.

The delivery of oral health care has to be dynamic, responding to any changes in population demographics and the patterns of oral diseases. Many epidemiological studies and reports have demonstrated a dramatic decline in the prevalence of dental caries over the past three decades, especially in children and adolescents in the Western world (Glass, 1982; Marthaler, 1990; Axelsson *et al.*, 1993; Marthaler *et al.*, 1996; Petersson and Brathall, 1996; Truin *et al.*, 1994; Vanobbergen *et al.*, 2001). These changes in caries prevalence have influenced its distribution and induced a polarisation. It can no longer be assumed that the mean caries prevalence is representative for different groups within a population. An large amount of disease will be found in a small group of subjects, for example in primary schoolchildren about 10 to 15% bear 50% of all caries lesions (Marthaler, 1990; Marthaler *et al.*, 1996; Petersson and Brathall, 1996).

The actual reduction in caries prevalence in younger age groups will lead to an increase in the number of dentate adults in the coming decades. As teeth are retained longer, periodontal disease and root caries will become more important health problems and challenges for the future (Pilot and Miyazaki, 1991).

Besides ageing, deprivation and immigration become increasingly more important. They often act as a barrier to the maintenance of good oral health in both children and adults. Well-motivated regular dental attenders, who often make up the majority of a general dentist's patients, have different needs than those in the high disease tail, attending infrequently (Pine, 1997).

The objectives and organisation of oral health care systems should be adjusted to these changes and be reflected in her characteristics. Delivery of oral health care should be well-balanced between basic preventive strategies, high risk approaches and treatment provision, directed by identified needs and demands and based on the principle of equity.

This report presents a qualitative approach of the oral health care system in Belgium, in a European perspective, mainly with respect to children. According to the characteristics of an oral health care delivering system, the following questions will be dealt with: what are the objectives, who provide what service to whom, with what resources and with what effects?

Objectives

Objectives of oral health care systems range from prevention of future disease, to treatment of existing disease, to management and elimination of emergencies, pain and trauma, or a combination of any of these. They can be expressed by goals, purposes or expected outcomes of care, both oral health status outcomes and intermediate outcomes of oral health behaviours. In the UK, the Department of Health published in 1994 an oral health strategy, with specific targets such as: ‘by the year 2003 70% of 5-year-old children should have had no caries experience.” In the Nordic countries different Oral Health Acts resulted in a high and equal level of accessibility to dental care with regard to the age groups specified in the different acts (Pine, 1997).

In Belgium there are no clearly articulated oral health objectives. In Flanders (Northern Federal State) oral health goals are dispersed among the five general health promotion priorities, set by the Ministry of Welfare: a 10% lower rate of cigarette smoking, a decrease of fat consumption in favour of fibres, an accurate breast cancer screening for women over fifty years, an improvement of preventive measures related to infectious diseases, a reduction of the rate of fatal traffic accidents by 20% (Aelvoet *et al.*, 1998).

Systematic national screening programs to define the oral health situation in different age groups or population groups, and to evaluate preventive and restorative measures are clearly lacking. Therefore current policy is entirely based on reports from other European countries. Initiatives to implement self-determined objectives vary by the extent of responsibility taken by Dental Associations, Insurance Companies, Academic Centres, School Health Care Centres or other health care organisations.

Organisation

Any system of oral health care delivery results in a formal organisation, structured for the various components such as research, education and care provision.

In Belgium health promotion, education and research are decentralised and part of the responsibilities of the different federal communities (Departments of Education and Departments of Welfare), while health care delivery is national matter (Ministry of Health and Ministry of Social Affairs).

Research and education are the responsibilities of the universities (3 Flemish speaking - Gent, Leuven, Brussels - and 3 French speaking - Liège, Louvain, Bruxelles - universities).

Co-ordination of Oral Health promotion is provided by the Dental Associations and is, in Flanders, partially funded, but not integrated, by the Flemish Institute for Health Promotion. Some organisations such as The Red Cross, Child and Family, Insurance Companies, Industry, may also provide oral health promotion.

School Health Care Centres organise general health examinations in primary and secondary schools, including an oral examination. The examiners are general physicians and the examination is restricted to two oral health items: caries and orthodontic treatment need. Children are referred for treatment to their general dental practitioner.

Oral health care in Belgium, both preventive and restorative, is almost exclusively delivered in private dental practices, and only to a small extent (<5%) in public and private clinics. There is no oral health care delivery organised at community level.

Mainly, within the different countries in the European Union, dental care is provided in independent dental practices, hospitals and public or community dental services. There is a trend for general dentistry group practices and multi-speciality groups, employing a large number of staff with specific duties. Most of the West European countries have a Community Dental Service (table 2.1.) often originally conceived as a School Dental Service.

Table 2.1.: oral health care system: Dental Public Service, workforce, cost of dental care and oral health status for different West European countries (period 1996-1998)

	Community Dental Service *(% of dentists in CDS)*	***Dentist/population ratio***	***DMFT values for 12-year -olds*** *(% cariesfree)*	***GNP on dental care (%)***	***Dental hygienists***
Belgium	-	1:1266	1.9 (35%)	0.18%	-
The Netherlands	-	1:2240	0.6 (70%)	0.46%	+
France	+ (10%)	1:1504	1.9 (39%)	0.5%	-
Germany	± (1%)	1:1300	1.7 (42%)	0.9%	+
UK	+ (7%)	1:2260	1.4 (48%)	0.29%	+
Ireland	+ (30%)	1:2365	1.1 (51%)	0.25%	+
Sweden	+ (50%)	1:980	1.0 (62%)	0.4%	+
Denmark	+	1:1032	1.01 (55%)	0.56%	+
Norway	+ (30%)	1:1089	1.5 (46%)	0.35%	+
Switzerland	+	1:2083	1.1		+
Austria	+ (9%)	1:2084	1.7 (44%)	0.46%	-
Italy	+ (15%)	1:1282	2.1 (38%)	0.39%	+
Spain	+ (6%)	1:2667	1.75 (42%)		+
Greece	+ (10%)	1:877	2.7 (27%)	0.4%	-
Finland	+ (40%)	1:1070	1.1 (35%)	0.44%	+

They may have a health promotion role and a monitoring task, screening the oral health status and needs in different age groups. In some countries public dental services provide care to special needs groups such as disadvantaged, handicapped and institutionalised elderly people.

Usually they are involved in developing and evaluating plans and policies that support individual and community oral health efforts to address oral health needs (Pine, 1997; Van Tielen, 1999; Bolin, 1997; Cork, 2000).

University hospitals provide mainly secondary care as well as care for patients with special needs. Some primary care is provided within the context of undergraduate training.

Target population

The population of Belgian has now reached 10 211 000 (1998) and the annual rate of population increase during the 1990-2020 period is estimated around 0.2%.

Thus Belgium has one of the lowest growth rates in Europe. In the neighbouring countries estimated percentages are respectively 0.9% for Germany, 0.5% for The Netherlands, 0.4% for France and 0.2% for the United Kingdom. Life expectancy at birth increased in Flanders from 74.2 years in 1993 to 75.1 in 1996 for males and from 80.4 in 1993 to 81.3 in 1996 for females. Low birth rates combined with increasing life expectancy lead to the ageing of the Belgian population (Van Tielen, 1999). Within this potential of care-seekers one has to distinguish between expressed need (demand) and normative need. The organisation of services influences individual care-seeking behaviour. In open, unstructured systems, such as in Belgium, the population is targeted as a whole and individual motivation appears to be the predominant reason for dental utilisation. Within this system oral health care, initially, is the responsibility of the parents and later of the individual himself. As a consequence, populations or groups who are most in need of oral health care often have limited access to the system or do not avail themselves of the system. Unmet needs appear to be greater, especially among children (Andersen *et al.*, 1995).

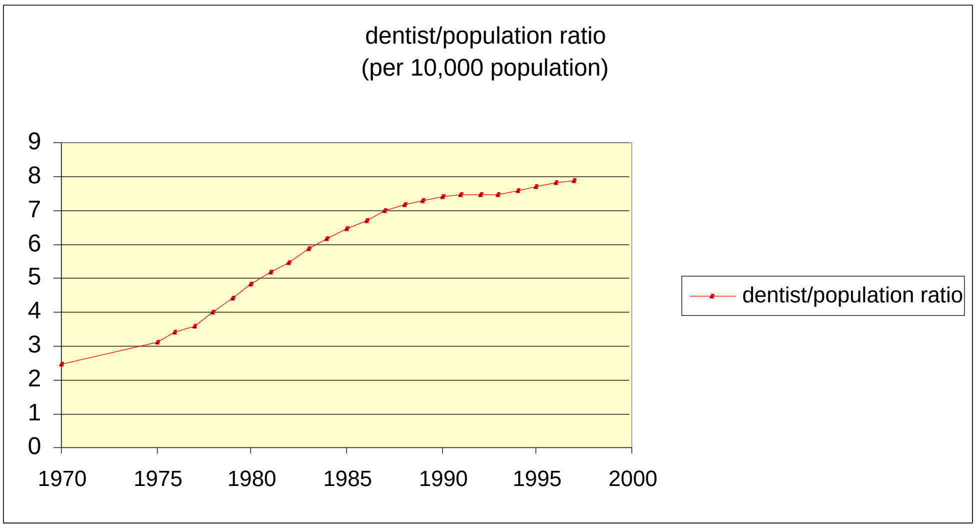
Oral health care personnel

In the different West European countries the dentist is the individual responsible for oral health care delivery, directly or indirectly overseeing or co-ordinating contributions from related personnel. This related personnel includes oral hygienists, dental assistants or dental nurses and dental technicians. The distribution of personnel within an oral health care system reflects the emphasis of the system (Andersen *et al.*, 1995). For example a high proportion of dental hygienists may demonstrate a preventive philosophy or policy at the system level. Furthermore, the distribution of personnel, measured by oral health providers to population ratio, may demonstrate the various levels of availability and access to care, however this supposes an equal distribution between rural and urban areas. Table 2.1. reports the dentist/population ratio for different West European countries and the availability of dental hygienists (Pine, 1997; Van Tielen, 1999; Bolin, 1997; Cork, 2000).

In Belgium the dentist is the only professional trained and educated in the chair-side provision of oral health care. A vocational and technical education exists in the field of prosthetic dentistry and leads to the profession of dental technician.

In 1998 the number of active dentists in Belgium was 8095 of whom approximately 85% were self-employed in private practices. The remaining 15% were employed in private practices or in dental clinics. As there is no public dental service in Belgium no dentists work at community level. The dentist-population ratio in 1998 was 1:1266, which compares with the neighbouring countries of France (1:1504) and Germany (1:1300). The Netherlands (1:2240), The United Kingdom (1:2260) and Ireland (1:2365) and the Central European countries (Switzerland and Austria) have remarkably higher ratio’s. By contrast, the Nordic countries, such as Sweden (1:980), Denmark (1:1032) and Norway (1:1089) have the lowest ratios. Figure 2.1. shows the evolution of the dentist-population ratio from 1970 to 1997, expressed as the number of dentists per 10.000 population (Van Tielen, 1999) showing a remarkable increase during the period 1975-1985. However, since 1985 only a modest increase, even a stabilisation, has occurred.

Figure 2.1.: number of dentists per 10 000 population in Belgium (1970-1997)



Only a minority of dental practices in Belgium employs chair-side dental nurses. There are no organised programs for training of dental assistants (nurses or hygienists). Auxiliaries are trained on the job by their dentist employers. Dental hygienists are not existing at all nor are there any dental therapists with limited training to care for children as in New-Zealand.

Dental technicians provide denture service, including removable and fixed dentures and orthodontic appliances. They provide their services to dentists in independent commercial laboratories. Service provided directly to the patients is illegal. In Europe nowhere technicians are licensed to provide dentures directly to patients (Pine, 1997).

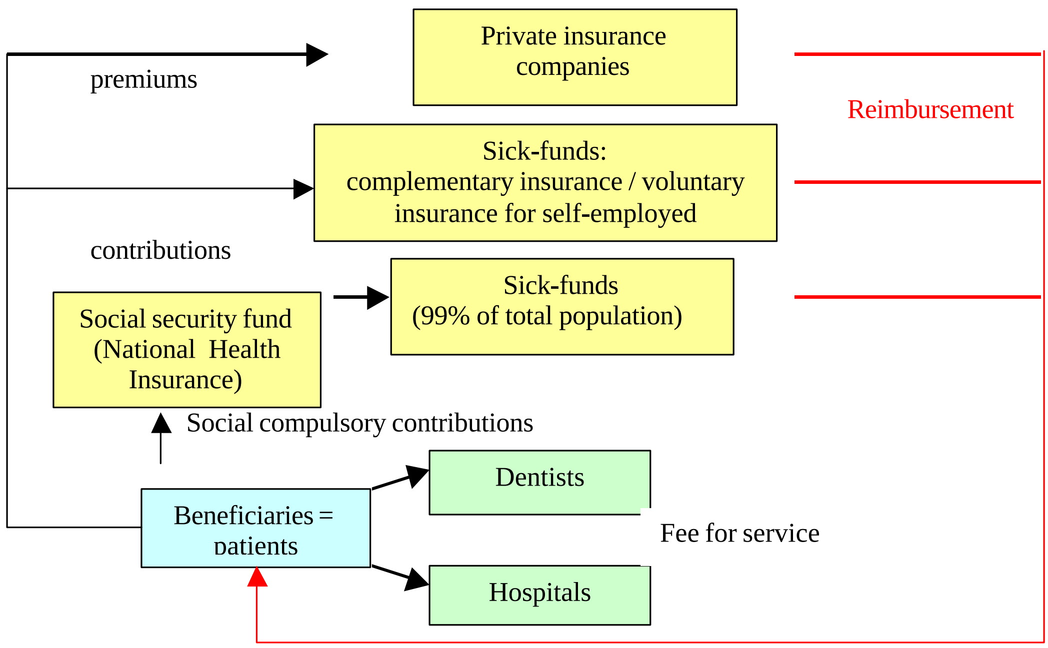
Financing and reimbursement

Financing reflects how the money gets into the system. The most common approaches being general government revenues or specific taxation, insurance or prepayment premiums paid by individuals and/or employers, and out-of-pocket direct payment by individuals. Reimbursement is the mechanism for payment for services. The most common are fee-for-service, capitation, budget, third-party payment or salary

(Andersen *et al.*, 1995). In most West European countries oral health care systems are financed by a social security system based on solidarity. The reimbursement mechanism varies a lot according to the different countries. In private practice services fee-for-service and capitation are currently most in use. The fee-for-service payment has been the dominating system. Dentists in public health services are mostly reimbursed by salaries.

In Belgium fee-for-service payment is the traditional form for payment of dental care. The patient decides when to visit a dentist, in private or in a hospital, at a primary or secondary health care level, the dentist formulates a treatment proposal and informs the patient of the fee. If the patient chooses to follow the recommendations and receives the services, the patient is then responsible for paying the fee. The National Health Insurance, represented by different 'Sick-funds', supplies a partial reimbursement of the patient Adults in work, both self-employed, employer and employed, have compulsory deductions from their wages or income to contribute to the health and social services provision in the National Health Insurance. This is illustrated in a structured scheme in figure 2.2. (National Health Insurance, 1995).

Figure 2.2.: the Belgian Oral Health Care System (part of General Health Care System)

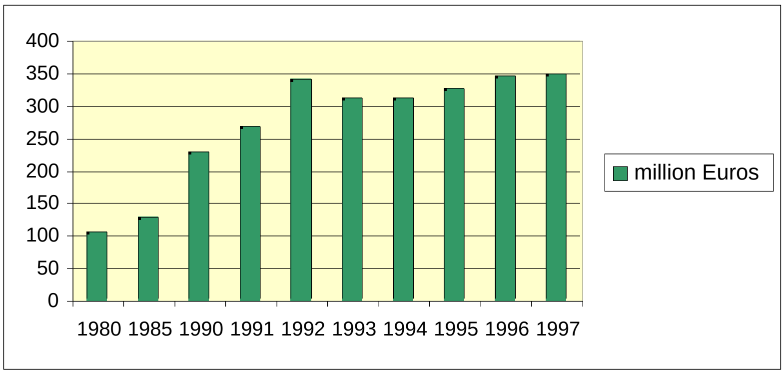


A convention between National Health Insurance and dental practitioners regulates treatment types and fees.

By means of the National Health Insurance today restorative care, removable dentures, minor oral surgery and limited preventive care are reimbursed at 75%. Restorations for children, aged 0-12, are reimbursed at 95%. To be reimbursed for preventive care, the patient has to prove that he/she visited the dentist within the last 12 months. Calculus removal before the age of 18 is not covered by the insurance system, except for handicapped children. Periodontal treatment, crown and bridgework and oral implants are not covered. There is only a low coverage for orthodontic treatment.

The total expenditure for oral care by Belgians grew very fast between 1980 and 1992, stabilised at the beginning of the nineties and had again a slow growth since 1995 (figure 2.3.). In 1998 the cost of dental care amounted to 0.18 % of the GNP. In a European context, the budget of oral health care in Belgium is rather low (Van Tielen, 1999). Table 2.1. provides an international comparison of these percentages for the period 1996-1998. The proportional cost of dental care was the lowest in Belgium.

Figure 2.3.: total expenditures for oral care in Belgium: 1980-1997 (million Euros)



The outcome

One possible outcome measure is the oral health status of the population. Reporting the oral health status of 12-year-old children in different West European countries (table 2.1.) is only an indication for the oral health status of the corresponding countries.

Besides, one has to acknowledge and emphasise that the oral health status is the result of complex interactions of oral health care delivery systems with social systems, environmental factors, such as fluoridation, income levels of the population, ethnic mix within populations, etc.. According to the 1996-1998 data, Belgium has the second highest mean DMFT for 12-year-old children and the second lowest percentage of caries free children within Western Europe (Vanobbergen *et al.*, 2001; Pine, 1997; Bolin, 1997; Joint BASCD-EADPH conference, 2000).

Remark

Due to many socio-political changes during the last decade in eastern Europe, East European countries were not included in this report. Most of them are in a transitional period: the former centralised, non-market-based oral health care system has been transformed to a more liberalised, decentralised and privatised system. It will be interesting in the near future to evaluate the impact of these two very different oral health care systems.

Discussion and recommendations

In West European countries, oral health care systems have evolved from a focus on removing and replacing teeth to restoring teeth, to preventing oral diseases and conditions, and now, envisioning oral health as part of general health (Andersen *et al.*, 1995). These changes have not yet been fully recognised in Belgium with respect to oral health care. The delivery of care still has predominantly technical and curative approaches, basically characterised as a fee-for-service private practice system, focussed on restorative treatment. Community based programmes, monitoring and targeting specific age- or risk groups do not exist and there is no evaluation of the outcome. There are only limited facilities in, loco-regional health councils, for oral health care workers to integrate with general health care and health promotion in a multidisciplinary approach, involving health and social workers from diverse backgrounds as well as the community at different levels. Besides, the divided governmental responsibilities, national and regional, concerning preventive and curative care, concerning health promotion and health care provision, do not stimulate or advance oral health workers towards a more preventive and integrated attitude, neither in private or community based devices.

On the other hand the nature of organising and financing a system and the mechanisms of reimbursement will interact with individual socio-economic status and influence equity and efficiency of the system. People who have the most of the oral disease seem to be the ones not receiving services from the current oral health care delivery system. This assumption leads us to the question: “How can we reach out to where the people are, rather than wait for them to come into the current system (Inglehart, 1993)?”. Despite the fact that dental care for children is free of charge or reimbursed at 95% in most European countries, only the Swedish system offers both preventive and restorative treatment irrespective of initiatives from the parents. In the other countries the initiative still relies to a great extent on the parents (Bolin, 1997). Cost-effective preventive programs, based on caries risk assessment, were introduced in pre-school and schoolchildren, especially in those areas with the highest caries prevalence (Axelsson *et al.*, 1993; Holst *et al.*, 1997). This explains why only in the Nordic countries, with a extensive public dental service system, equity of treatment access was reached for children.

In order to fulfil the requirements of a real up-to-date 21st-century oral health care system in Belgium, in accordance with other developed countries (Shalala, 1999), following measures could be beneficial:

- A clear and continuing population-based public dental service integrated in a general public health system, responsible for
  - →screening and independent data gathering,
  - →defining normative needs of oral health care and priorities,
  - → measuring the effects of oral health care,
  - →targeting high risk groups,

→co-ordinating oral health promotion and general preventive and curative measures in oral health.

- A revaluation of preventive treatment delivered in private dental practice and hospitals, and a well co-ordinated balance between primary health care and secondary health care.
- Special attention for dental care in growing minority groups, such as children in low socio-economic groups, handicapped children, medically compromised children, immigrants…
- Training in the special needs of the older patient.
- A well-balanced dental educational system, educating dental professionals and auxiliary oral health care personnel, with close attention for preventive care and research.
- Changes in financing systems with a properly balance between fee-for-service, capitation and budgeting, based on a growing awareness of the need for improved and equal accessibility of dental care.
- More integrated approach, also at political level (e.g. advertising for sweets, soft drinks, vending machines with soft drinks at school…).

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Chapter 3: Assessing caries risk in children: a review of the literature.

Introduction

In most of the developed countries in the world there has been a dramatic decline of dental caries in the last 30 years. This reduction has been attributed to the use of fluoridated drinking water and the use of fluoridated toothpaste, and in a minor degree to educational programmes and an awareness of the need for a healthy lifestyle (Petersson & Bratthall, 1996).

With these improvements in oral health, especially in children, the option of, and the need for targeted prevention of dental caries has become apparent. Several epidemiological data demonstrate that caries in a given population of children has been concentrated in a small minority (Stamm *et al.*, 1991; Bohannan *et al.*, 1985; Krasse, 1985; Vanobbergen *et al.*, 2000; Bolin *et al.*, 1997). This means that it should be possible to identify those individuals or groups of individuals who are at increased risk of developing caries.

Caries risk assessment is the actual instrument pre-eminently to identify individuals or groups at high risk for future caries development (Stamm *et al.*, 1988; Disney *et al.*, 1992). Many variables have been investigated for their association with the caries process. They are involved in the development of simple univariate and multiple risk assessment models in order to be applied to groups or individuals in the identification of their risk profiles. However, to date these models have not consequently enjoyed wide use in either public health or dental care centres, and, when used in targeting and appropriate application of preventive measures matched on the risk profiles of specific groups or individuals, they have not been as accurate as had been hoped (Moss and Zero, 1995).

Based on a literature search, this chapter will update current status of risk terminology and review the current risk assessment models, with reference to children, and their accuracy of prediction.

Material and methods

An initial literature search was carried out using the Medline database. The time period covered was 1980 – 06/2000, only English papers were included and the key words used were: caries risk assessment, health models, caries prediction and children.

In addition, reference lists from each article were reviewed to ensure a more complete bibliography.

The final strategy to include studies was focussed on retrieval of reviews, overviews, collaborative analyses and meta-analyses. Caries incidence as well as prevalence were considered and multifactorial models were preferred. Case studies and local small area based studies were excluded.

Analysis was been performed according to the main objectives of this review and focussed on risk assessment terminology, study designs, explanatory factors in caries risk, outcome measures and accuracy of the prediction models.

Analysis

Risk assessment terminology

Defining risk assessment, assessment models can be considered from two perspectives: firstly the risk assessment methods involving simply looking at a patient’s clinical appearance, frequently used by clinicians in examining patients and in making decisions in treatment planning. Secondly the assessment methods studied in epidemiological studies looking further into patient and environmental factors that may affect the caries process. Applying statistical analysis, these factors are investigated for their potential to predict caries activity.

Our focus in this study is on the epidemiological approach of caries risk assessment that results in the identification of individuals or groups of individuals at high risk for future caries development. This approach allows the use of individual-based preventive activities as a useful complement to the broader population-based strategy. At the level of the clinician, preventive therapies can be applied selectively dependent on the risk level. (Moss and Zero, 1995; Messer, 2000)

Consequently two alternative perspectives remain important: *the population perspective*, developed almost entirely within the field of epidemiology and public health and *the individual perspective*, based on epidemiological findings, but owing its origins to clinical preventive dentistry and the science of clinical decision theory.

The subject of risk assessment and disease prediction is complicated enough when everyone is using the same language, implying the need for some clear and unambiguous definitions of the terms we use. Dr James Beck from the University of North Carolina has prompted the continuing efforts on this topic. This resulted in a consolidation and updating of the current status of risk assessments terminology, as summarised below: (Beck, 1998; Alanen, 1999; Burt and Eklund, 1999)

Risk factor: an environmental, behavioural, or biologic factor confirmed by temporal sequence, usually in longitudinal studies, which if present, increases the probability of a disease occurring, and if absent or removed, reduces the probability. Risk factors are part of the causal chain, or expose the host to the causal chain.

Risk indicator: a probable or putative risk factor, shown to be associated with a disease in cross-sectional studies, that has not yet been confirmed by longitudinal studies, but on theoretical grounds, assumed to play some causal role.

Demographic risk factor: meets the definition of a risk factor, but currently is immutable to change. Perhaps more likely to expose the host to the causal chain than be part of it.

Risk predictor – risk marker: an attribute or exposure associated with the increased probability of disease, although not necessarily considered part of the causal chain (e.g. past caries experience).

Even today the terms risk predictor, risk indicator and risk marker are frequently confused.

Risk model: a multiple model developed to identify one or more risk factors for the disease so that likely points for intervention can be planned. Risk models should exclude risk predictors and demographic risk factors as they may mask potential risk factors.

Prediction model: a multiple model developed to identify who is at high risk. The main goal is to maximise sensitivity and specificity of the prediction, so that any good predictor or demographic risk factor may be included.

Study design

A variety of study designs can be used to assess the risk for dental caries. There are several levels of epidemiological study ranging from descriptive studies (cross-sectional studies), to studies of correlation at population level (ecological studies), to studies of individual based associations (case-control and cohort studies) and to studies which provide experimental confirmation of an empirical relationship (randomised controlled trials)

Cross-sectional studies describe individuals in the population at a particular point in time in terms of health condition and their history of exposure to putative and suspected causal agents. These studies are relatively simple to conduct and are relatively cheap. As it is not possible to assess whether the outcome followed the exposure they only provide risk indicators shown to be associated with the disease.

Ecological studies provide a relatively simple and inexpensive method of looking at disease occurrence, especially with regard to an environmental exposure. The average exposure of the population is plotted against the rate of the disease for that population to investigate any possible association between the two. These studies are considered to provide only weak evidence.

Case-control studies assess the association between an outcome, usually a disease, and an exposure. A population with the outcome of interest (cases) is selected and compared with another group in which the outcome is absent (controls). Differences in exposures between the groups are assumed to be responsible for the occurrence of the disease. This type of study design has the advantage that multiple exposures can be examined for one particular disease and is particular useful for investigation of relatively rare diseases.

In *cohort or follow-up studies* individuals are recruited classified according to whether they are (or have been) exposed or are (or have not been) not exposed to the factor of interest, which is thought to be associated with the outcome. The group which is unexposed must be drawn from a population that is similar to the exposed group in all aspects other than the exposure(s) under investigation. Cohort studies have the advantage that the exposure and confounding factors are measured before the outcome of interest has developed and that multiple outcomes can be examined for one exposure. This study design is of particular value when the exposure is rare.

Intervention studies and randomised control trials: these study designs are valuable to measure the efficacy and safety of particular types of preventive and therapeutic interventions, by randomly assigning people to one or two or more treatment groups and, where possible, blinding them and the investigators to the treatment that they are receiving.

Outcome and predictor variables

The essence is to study the association between exposure and disease or disease progression. Models based on prevalence or cross-sectional data are useful in the early identification of health related determinants, but the most appropriate risk models for predicting subjects likely to experience an increase in disease are those based on incidence or longitudinal data. (Powell, 1998).

No single variable has proven to be successful in predicting caries development. Caries is caused by a complexity of conditions or events which may be of genetic, environmental, biological, behavioural, social or psychological nature. Often they all can be related to the classic caries model: host, microflora and diet. One way to identify risk indicators may be to investigate variables according to their relationship to the disease process, which is etiologic or non-etiologic. In addition to identifying and categorising predictor variables, one has to investigate threshold levels for these variables. Many variables are dichotomised into positive and negative categories and the specific cut-off for each category needs to be established. Some assessment models are based on continuous or gradient variables or combinations.

Statistical methods in risk modelling

The choice of statistical methods is important because different methods can give different results (Stamm *et al.*, 1991). Earlier prediction models usually involved the association of one variable with caries development. More recently, multiple factors have been included in modelling.

Studies using a combination of variables generally have shown better results than single-factor studies (Tinanoff, 1995). This approach makes sense for ‘caries’ as it has multiple causes and consequently multiple risk factors.

Consequently the earliest modelling approaches in caries risk assessment relied on bivariate correlation techniques. A shortcoming was the limitation that they considered only one risk factor at a time and they were not well-suited for dealing with binary disease outcome measures (caries-no caries). For this reason investigators turned to linear discriminant analysis. A particular advantage of this analysis was that it produced the type of 2 x 2 classification table that permitted the calculation of sensitivity and specificity, appropriate measures to evaluate risk assessment models. A remaining difficulty was its limitation to handling only continuous, normally distributed predictor or risk factor variables.

The most commonly used statistical methods for caries risk assessment models today are multiple regression techniques and Classification and Regression Tree Analysis. Logistic regression uses binary or even multi-category outcome variables and does not require particular assumptions about the characteristics of the predictor variables. Interactions can be conveniently modelled and tested. Logistic regression will generate 2 x 2 classification tables and therefore provide sensitivity and specificity indices. A further advantage is its convenient approach to the generation of odds ratios for each risk factor. (Stamm *et al.*, 1991; Powell, 1998; Domingues-Rojas *et al.*, 1993; Helfenstein and Steiner, 1994; Stewart and Stamm, 1991). There is an agreement that the sensitivity or true positive rate should be 75% and the specificity or true negative rate should be 85% (Stamm *et al.*, 1988).

Conclusion

A caries risk assessment model should include multiple factors that are easy and inexpensive to measure and should report a sensitivity/specificity sum of at least 160 percent. Models using a dichotomous outcome and including both risk indicators and predictors appear to have high sensitivities and lower specificities than models using a gradient definition of the outcome. (Beck *et al.*, 1992)

Clinical variables appear to be stronger variables than non-clinical variables and ‘past caries experience’ was the most significant predictor. Other important variables are: age, socio-economic status, fluoride exposure, tooth morphology, and microbial agents.

Regression models appear to be the preferred analysis using multiple factors and longitudinal data.

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Chapter 4: Methods of measuring dental caries and observer variation in the assessment of dental caries.

Introduction

Epidemiological studies require that disease is measured quantitatively. The methods to do this are fundamental to the conduct of research. Thus, all epidemiological studies of dental caries depend for their credibility on the use of standardised diagnostic criteria and the diagnostic reproducibility of observers.

Measuring dental caries in a population requires a standardised and objective approach. This approach is clearly recognised (WHO, 1987; Pitts *et al.*, 1997). For each epidemiological survey specific diagnostic criteria will be written explicitly for use during the clinical examination and will replace the judgement of the practitioner. These criteria, meaning objective standards on which diagnostic judgement can be based, are applied to judge the condition of the teeth as they are at examination time, not how they might be in the future. The objective application of these criteria is the most important philosophical difference between an epidemiological examination and that carried out for treatment planning.

The variability between and within examiners, measuring the disease, has important effects on the precision and power of the results of epidemiological studies. Thus, the diagnostic criteria must be applied the same way at different times by the same examiner or by different examiners. If they are not the results have little value.

Both the determination of a particular standardised measure in caries research and how to handle it reliably will be discussed in this chapter.

Measuring dental caries experience

The DMF index, an irreversible index, is applied to measure dental caries. The first description is attributed to Klein and Palmer (1938). It is a record of the number of decayed (D), missing due to caries (M), or filled (F) teeth. The DMF index can be applied to teeth (designated as DMFT) or to surfaces (DMFS). DMF for permanent teeth is always signified by uppercase letters. Small letters are used for the primary dentition. The DMFT/dmft score for any individual can range form 0 to 32 (permanent dentition) or 0 to 20 (primary dentition), in whole numbers, the DMFS/dmfs respectively from 0 to 148 and 0 to 88. A mean DMF/dmf score for a group, being the total score divided by the number of subjects examined, can have fractional values.

The major advantage of the DMF index is that, because of its widespread use over the past 60 years, it provides a reasonably accurate historical account of changes in the prevalence of dental caries, as well as in incidence. The limitations, however, of this index have been widely recognised. The principal ones are summarised below:

- DMF values are not related to the number of teeth at risk in different subjects.
- The DMF index gives equal weight to missing, untreated decayed, or well-restored teeth.
- The D-component is unable to quantify the severity and activity of the caries lesion.
- The DMF index is invalid when teeth have been lost for reasons other than caries.
- Teeth, and certainly surfaces, included in the F component have been treated by dental practitioners who vary enormously in their decision on when and how much to intervene in the caries process. This will be more pronounced with the actual preventive and restorative technologies.
- DMF data are of little use for estimating treatment needs.
- DMF cannot account for or interpret sealed teeth.

In the present study the status of the teeth present is coded at surface level, using the guidelines proposed by the British Association for the Study of Community Dentistry BASCD (Pitts *et al.*, 1997).

Code 0: *present and sound.*

A surface is recorded as sound if it shows no evidence of treatment or untreated clinical caries at cavitation level. White spots or early stages of caries and arrested caries are excluded.

Code 2: decayed, without pulpal involvement.

Score 2 is recorded if the examiner judges, after visual inspection, a carious lesion extending into dentine. In case of doubt the tooth surface is examined by a CPITN probe. Only if cavitation is detected without pressure the surface is coded 2.

Code 3: caries with pulpal involvement, necessitating extraction or pulp treatment.

When there is a carious lesion that, in the opinion of the examiner, involves the pulp, it is classified as code 3, even if there is a filling on the same surface.

Code 4: filled and decayed.

A surface that has a filling and a carious lesion is coded 4. If the lesion involves the pulp it is coded 3.

Code 5: filled with no decay.

Surfaces containing a restoration are coded 5. Provisional fillings or broken or lost fillings without secondary caries are also coded 5.

Code 6: extracted due to caries.

Missing deciduous canines and deciduous molars are included in this category for the 7-year-old sample. Missing deciduous incisors are not included, but registered as permanent teeth unerupted (code 8).

Code 7: extracted for orthodontic reasons.

Unless there is overwhelming evidence to the contrary, missing first permanent molars are scored as extracted due to caries (code 6). Code 7 judgement is based on clinical evidence and the child's history.

Code 8: unerupted.

A permanent tooth is scored 8 when unerupted, congenitally absent or missing for reasons unknown and no deciduous tooth is present.

Eruption stage.

Not fully erupted teeth are staged using the following scores

P1: occlusal surface or incisal edge only partially erupted (one cuspid).

P2: occlusal surface or incisal edge fully erupted, but less than half of the buccal surface erupted.

P3: more than half of the buccal surface erupted, no antagonistic contact.

P4: fully erupted and full occlusion.

Code 9: excluded.

When the examiner is unable to evaluate the condition of a surface, code 9 is used (e.g. teeth with orthodontic band).

Code C: crown.

When a tooth is fully covered by a crown code C is used. When surfaces are crowned due to trauma, code T is used.

Code $: sealant.

Sealants are scored where no evidence of a defined cavity margin can be seen. When doubt, sealant is preferred.

Code T: Trauma

Surfaces affected by trauma are coded T, whether or not the damage has been repaired with a restoration. Only permanent anterior teeth are scored. Additional data are registered concerning the type of traumatic injury:

- *T1:* grey or brown discoloration due to necrosis of the pulp.
- *T2:* untreated fracture of enamel.
- *T3:* untreated fracture involving enamel and dentine.
- *T4:* restored fracture (trauma - enamel and/or dentine).
- *T5:* avulsion of tooth due to trauma.

The DMF/dmf index is used to summarise *past and present caries experience of the permanent and primary dentition.*

Examiner reliability

Diagnostic criteria must be applied the same way at different times and by different observers. If they are not, the results of analyses, using the registered data, have little value. This is the issue of reliability of diagnosis.

The ability of one examiner to record the same conditions the same way over time is called *intra-examiner reliability.* Reaching agreement between 2 or more examiners is called *inter-examiner reliability.*

In order to ensure consistency in registrations, calibration before the onset and during the course of the survey have to be the rule today. Depending on the study design and purpose, this may be confined to inter-examiner or intra-examiner, or both. Pioneering work in this field is been done by the British Association for the Study of Community

Dentistry (BASCD) (Pine *et al.*, 1997). Their guidelines on training and calibration can be summarised as follows:

- Discuss extensively and in detail the standardised diagnostic procedures and criteria.
- Use a 'gold standard' to compare the results of the different examiners.
- For calibration examine at least 10 children with caries experience, including untreated caries, and some children who are caries free.
- Compare dmft/DMFT and dt/DT. In older children comparisons on FT are also advised.
- Re-calibrate or exclude outliers who are outside the 95% confidence interval of the group mean, or did not reach the necessary validation criteria.

There remains the problem of the appropriate methods to use to measure examiner consistency. A literature search provides a lot of reliability measures, all have advantages and disadvantages.

Many studies in the past have assessed examiner reliability by calculating the percentage agreement in scores from repeated examinations or examinations from different examiners. They are easily calculated as a simple ratio, using the proportion of the number of teeth or sites consistently diagnosed. Originally agreements on caries free (sound) teeth or surfaces were not included (*percentage reproducibility*). In many instances, however, the examiner's decision to diagnose a tooth or surface as caries free is just as critical as a diagnosis of caries. With the number of teeth consistently diagnosed as sound taken into account, Shaw & Murray (1975) proposed a modified reproducibility ratio: the *modified percentage reproducibility.* Off less importance was the introduction of a modification of the Shaw & Murray method by du Plessis et al.(1989), including inaccurate diagnoses due to misclassification of primary and permanent teeth.

The percent agreement methods, however, are potentially misleading. If the prevalence of the disease is low, which is the case in caries studies, much of the observed agreement is due to chance. Because these methods do not adjust for agreement expected by chance, they do not give an accurate measure of reproducibility.

It is worth mentioning to compare the data in its simplest form first. A lot of problems can be identified by calculating the mean DMF indices by examiner and the size and direction of the deviation from the gold standard. From the group mean DMF and the standard deviation, the 95 per cent confidence limits can be calculated. Any examiner outside the range of the confidence limits could be classified as an outlier and significant differences in mean caries scores can be checked by using a *paired t-test* (Pine *et al.*, 1997). A better measure of the difference in DMF scores is to compute a correlation between these scores, called the *intraclass correlation coefficient (r)*. The exact form of the intraclass correlation coefficient assesses the relative importance of the variation between examiners as a function of the variation among subjects (Kingman, 1998). This correlation coefficient is different from the usual *Pearson correlation coefficient* (r_p). The Pearson correlation coefficient is not appropriate to use for reliability purposes because he measures only the associations between sets of registrations and does not take into account any systematic biases in one or another set (Hunt, 1986). Furthermore, in dealing with a skewed distributed variable (dmf) this technique has to be discouraged.

If additional information is required to supplement clinical judgement and to provide a transparent independent judgement in depth, it is recommended that *sensitivity and specificity* calculations are undertaken for the different examiners, using the benchmark examiner as ‘gold’ standard. Sensitivity in this case would be defined as the probability of an examiner scoring a tooth (or surface) as decayed or filled when the benchmark examiner scores the same tooth (or surface) as decayed or filled. Specificity would be defined as the probability of an examiner scoring a tooth (or surface) as sound when the benchmark examiner scores the same tooth (or surface) as sound.

In addition, for categorical outcomes, the Kappa (κ) (Cohen, 1960; Landis and Koch, 1977) coefficient can be calculated between any pair of examiners to evaluate examiner reliability, in which correction for chance-expected agreement is included. Kappa is calculated as:

$$\kappa = \frac{(p_o - p_e)}{(1 - p_e)}$$

where p_o represents the proportion of observed agreement, and p_e represents the proportion of expected agreement. Kappa can range from values less than zero for poorer than chance agreement, to zero for just chance agreement and to a maximum of +1 for perfect agreement.

A scheme of agreement levels has been published by Landis & Koch (1977):

0	no agreement
0.1 - 0.4	slight - poor agreement
0.41 - 0.59	moderate agreement
0.60 - 0.79	substantial agreement
0.80 - 1.00	excellent agreement

In conclusion it is worth remembering to compare the data in its simplest form first and come to a preliminary decision before undertaking statistical tests, as these cannot provide a simple substitute for clinical judgement.

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II. The ‘Signal-Tandmobiel®’ project

Chapter 5: Objectives, Material and Methods.

This chapter has been published as part of:
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Abstract

The Signal Tandmobiel® is a collaborative project between academic centres, school health care services and the Dental Association in Flanders (Belgium). The aim of this project is to estimate the oral health condition of Flemish primary schoolchildren, to give the majority oral health education, and to determine the benefit of the intervention within a longitudinal survey (1996-2001).

A representative sample, obtained by a technique of stratified cluster sampling, comprised over 6000 children, i.e. 7% of all Flemish schoolchildren born in 1989.

4468 children were included in the study group and examined annually. Average age at baseline was 7.1 (± 0.4) years and the study is planned for 6 years. Data are collected on oral hygiene, gingival condition, dental trauma, prevalence and extent of enamel developmental defects, fluorosis, tooth decay, presence of restorations, missing teeth, stage of tooth eruption and orthodontic treatment need, all using established criteria. The dental examiners used are general dental practitioners (there is no public dental service in Belgium), trained and calibrated prior at baseline and are re-calibrated at regular intervals. In addition to clinical measures, data are collected on reported oral hygiene and dietary habits, use of fluorides, dental attendance, medical history and socio-demographic background of the children. These additional data were obtained by questionnaires completed by parents and school medical centres.

Introduction

During the past three decades many epidemiological studies have reported a dramatic decline in dental caries in children and adolescents in western countries (Glass, 1982; Marthaler *et al.*, 1996; Petersson and Bratthall, 1996). Most of these countries have already attained the WHO goals for the year 2000 of a maximum mean DMFT of 3 for 12-year-olds and 50% caries-free children at the age of 5. Caries prevalence has declined, but the decline has not been uniform, leading to a polarisation and a very skewed distribution, with caries experience concentrated among a small group of children (Holbrook *et al.*, 1993; Bolin *et al.*, 1997; Spencer, 1997; Truin *et al.*, 1998).

Preventive strategies and therapeutic oral health care in children and young adults should have two principal objectives: securing further improvement in oral health and early identification of disease in a multidisciplinary approach of groups at high risk to developing caries. The methods to achieve these objectives should include adequate fluoride programmes, dietary and oral hygiene counselling, and the refinement of diagnostic methods.

Monitoring oral health supports the identification of any high-risk groups at different ages, assessment of treatment need and treatment time, evaluation of preventive and curative strategies including the determination of their cost-effectiveness. This is best achieved if nationally co-ordinated longitudinal surveys are set up in well-defined age groups. In Flanders (the northern part of Belgium), oral health policy has been developed and introduced with no considerations for the change in prevalence of dental caries. There has been no analysis to identify low and high risk children or to discover how often children with low caries experience should be examined and what treatment measures should be delivered to high risk children. Any links between oral health, socio-economic levels and water fluoridation have not been investigated within Belgium.

Since 1980 a number of caries surveys have been undertaken in Belgium. In most cases, however, these were cross-sectional, of limited duration, confined to a particular age group or target group (e.g. the disabled), with limited parameters, or part of a European oriented screening in which the national sample was not representative. Due to different and/or inappropriate methodologies no comparison can be made between the reported studies. Therefore an accurate picture of any changes of caries prevalence between 1973 and 1998 cannot be given. Recently, however, some cross-sectional studies were undertaken, covering the whole Flanders and using standardised criteria (Declerck and Goffin, 1992; Declerck *et al.*, 1992) and these created a basis for the initiation of the present longitudinal Signal Tandmobiel® project. Accordingly, the aim of this paper is to describe the setting up of a longitudinal survey in Flanders.

Partners in the project

The partners in this collaborative project are: the Dental Departments (Paediatric and Preventive Dentistry) of the Catholic University of Leuven, the University of Ghent and the Free University of Brussels; the Youth Health Department of the Catholic University of Leuven; the Biostatistical Centre of the Catholic University of Leuven; the Working Group for Oral Health Care of the Flemish Dental Association and the Flemish Association for Youth Health Care.

A scientific team, representing each of these partners, has conducted the project. Within this team, a project co-ordinator (J.V.) is the immediate contact person for the examiners and their assistant. He supervises school visits and is responsible for the collection of the data. He jointly organised calibration exercises. The scientific co-ordinator (D.D.) prepared the protocol, has organised the regular calibration exercises and supervises the scientific outcome of the project.

Objectives

The first objective of the project is to determine the oral health condition of primary schoolchildren between the ages of 7 and 12, both cross-sectionally and longitudinally. The second objective is to provide oral health promotion and education in those children’s schools. The third objective is to determine the benefit of the education intervention on the dental health of those children in receipt of the advice compared to a control group of same aged children not participating in the programme over a period of time.

Material and Methods

Sampling

Following approval of the local ethics committee (Catholic University of Leuven) and the Education Department in Flanders, a representative cohort of schoolchildren born in 1989 was selected from school data. The sample was obtained using stratified cluster sampling without replacement. The target population was divided into 15 different strata, obtained by combining the 3 different types of educational system (public, municipal or private schools) in Flanders with areas of geographical distribution (the 5 Flemish provinces). Each child in Flanders had therefore an equal probability of being selected.

This cohort of children is being followed for a period of 6 years. At the start of the project the children were 7 years old. Over 6000 children (including control groups) have been recruited. They represent approximately 7 % of the total target population in Flanders.

Three groups were constructed from the overall sample (table 5.1).

Group A, the experimental group (n = 4468): these children are followed longitudinally over 6 consecutive years. In collaboration with their school health care centre they are examined annually in a mobile dental clinic by calibrated examiners and subjected to a programme of oral health education. Each year, they receive a questionnaire on oral health behaviour to be completed by the parents.

Group B is a longitudinal control group (n = 520) of children age-matched to group A and examined in the first year and the sixth year. They do not receive the health education programme. They receive the same questionnaire to be completed by their parents. This control group provides the comparative group to measure the effect of the educational programme on the oral health and oral health-related behaviour of the test group children.

Table 5.1. Study groups and examination periods for children participating in the Signal-Tandmobiel® project.

YEAR	1996	1997	1998	1999	2000	2001
GROUP A Experimental group (longitudinal)	☑	☑	☑	☑	☑	☑
GROUP B Control group (longitudinal)	☑					☑
GROUP C Control group (cross-sectional – by age, changing every year)		☑	☑	☑	☑	☑

☑ = clinical examination

Group C comprises different cross-sectional control groups selected each year (n = approximately 500/year). These groups change annually and they are used for cross-sectional comparison with the longitudinal A group. In the first year of the project group B also functions as the first C group.

Data collection

Questionnaires

Information on reported oral health habits and socio-economic background of the children was obtained respectively from the parents of the child and from the school health care centres using structured questionnaires. The questionnaire was developed based on literature (Rise *et al.*, 1990 a + b; Goldbohm *et al.*, 1993, Osler M and

Heitmann BL, 1996) and the experience obtained during the collaborative 'Children's Dental Health in Europe' study (Bolin *et al.*, 1997).

In order to check the ability of questions to collect the desired information, the relevance of the questions was studied during the pilot period (September 1996 – January 1997). After the pre-test of the questionnaire some questions were deleted (e.g. the specific use of sweets at home) and others were changed (e.g. the quantity of toothpaste was visualised by drawings instead of a textual description).

Further opportunities for validation were provided by using the questionnaire during the Academic Research Collaboration Programme between the University of Dundee and the Flemish universities.

The effect of potential bias, such as recall bias, will be limited. Particular exposures or adverse health outcomes are not likely to be remembered differently for the different groups in the sample who are not similarly affected. Some questions tend to be answered in a social desirable way, but this is not expected be different between the individuals or groups in the sample. Possible noise will lead to an equal shift of the results and will be minimised by the fact that in the analyses regression models are used with a dichotomised outcome and explanatory variables. If necessary this was further discussed in the different chapters. The more complex problem of missing data was corrected, if possible, by imputation of data. In order to check the possible influence of the missing data, the distribution of children with and without a complete questionnaire was compared regarding the stratification variables and the clinical variables.

Questionnaire to parents

The introductory paragraph of the questionnaire was used to inform the parents about the project and to obtain parental consent for data collection. Questions on a range of oral health related topics were included.

- Oral hygiene habits: the initial age of tooth brushing; the age at which toothpaste was first used; the amount of toothpaste used,; brushing frequency; and assistance with brushing.

- Use of fluoride supplements, topical and/or systemic.
- Dental attendance.
- Dietary habits, questioning the quality of breakfast, the number and kind of in-between-meal snacks and drinks, and the practice to take snacks to school.
- History of traumatic injuries to the teeth.

Questionnaire to school health care centre

The following variables on medical and socio-economic background of each child were registered using a questionnaire to the respective school health care centres:

- ethnic origin.
- socio-economic background, occupational level of the parents.
- urbanisation level of the school.
- medical background of each child.

Both questionnaires were returned, after completion, to the school and were available at school on the day of each child's dental examination.

Clinical examination

The children received a clinical examination by trained and calibrated dentists (n = 16), using standardised and widely accepted criteria, as recommended by the WHO report (1987) and based on the diagnostic criteria for caries prevalence surveys published by the British Association for the Study of Community Dentistry (BASCD) (Pitts *et al.*, 1997). The clinical examinations took place in a mobile dental clinic, with a standard dental chair and dental artificial light.

Diagnosis was performed visually, by using a disposable mouth mirror and a WHO/CPITN type E probe. No radiographs were taken. Decay was recorded at the level of cavitation. All necessary steps were taken to avoid cross-infection, always using a fresh set of sterilised instruments. During the examination the examiners work in optimal hygienic conditions, wearing mouth masks and gloves.

Prior to the clinical examination the children were asked whether they were left- or right-handed and were questioned on the brushing habits of their parents, both father and mother. They were asked whether their parents brushed their teeth every day, occasionally or never. This variable is to be used to assess the impact of a possible modelling process in the development of the child's oral health behaviour.

In order to register the level of *oral hygiene* the presence of plaque was determined. Buccal surfaces of the Ramfjord teeth (primary alternatives) 16(55), 21(61), 24(64), 36(75), 44(84), 41(81) were scored according to the index described by Silness and Löe (1964). Where present, permanent teeth were examined. Plaque on occlusal surfaces of first permanent molars was assessed using a simplified version of the index described by Carvalho et al (1989).

0 = no visible plaque (Carvalho 0)

1 = detectable plaque restricted to fossae and grooves (Carvalho 1 & 2)

2 = surface partially or totally covered with heavy plaque accumulation (Carvalho 3)

The gingival condition was measured using the Sulcus Bleeding Index method described by Mühlemann and Son (1971). The same index teeth were used as for registering oral hygiene on smooth surfaces.

Hard tooth tissues were examined in a standard order, beginning at the left side of the upper jaw. Debris and plaque were removed with cotton gauze or with the probe and compressed air was used to assure good visibility.

The status of the teeth present was coded at surface level, using the guidelines proposed by the BASCD (Pitts *et al.*, 1997).

Developmental defects and discoloration were registered using the Modified Developmental Defects of Enamel Index (Clarkson and O'Mullane, 1989; FDI-report, 1992). Teeth were examined wet. Defects less than 1 mm in diameter were not recorded. The buccal surfaces of fully erupted index teeth (14,13,12,11,21,22,23,24 and 36,46) were scored.

Mottling (fluorosis) was registered using the Index of Thylstrup & Fejerskov (1978). This examination was completed after drying the teeth, enhancing contrast between normal and abnormal enamel and allowing a more detailed examination. Only buccal surfaces of fully erupted index teeth were assessed.

A portable computer was used for data entry. Clinical data and data from questionnaires have been entered using Dental Survey Plus version 5.40 and Dental Survey Plus2. The assistant encoded all information on the day of the examination.
Finally a condensed oral health report has been made on behalf of the school health care centres and the parents by means of a referral letter.

Oral health education programme

Within the experimental group A, oral health education, undertaken by the dentist-examiner, has included instructions on oral hygiene, use of fluorides, nutritional habits and dental attendance. Attention is paid to the use of a correct age-matched brushing technique, stressing the importance of systematic, regular, time and duration of brushing. The importance of topical fluoride as a protective agent is emphasised, advising toothpaste as the preferred carrier three times a day. Diet counselling focuses on the danger of frequent intake between meals of sugar-rich food and beverages. For health educational and counselling purposes slides, audiocassettes, brochures, posters and games on caries preventive topics, such as cross-words, rebuses, etc, were designed. Particular attention has been and will be given to the preventive message to assure continuity and the material is reviewed annually to ensure it is appropriate to the specific age group.

Selection, training and calibration of the examiners and the auxiliary personnel.

Great importance and attention was paid to the selection and training of the dental examiners for the project. Training and calibration exercises were carried out using standardised, internationally accepted procedures and agreed criteria. The main lines of these exercises are based on the guidelines as recommended by the BASCD (Pine *et al.*, 1997). The selection of the examiners, who are general practitioners, graduated from various Flemish dental schools, with at least 5 years of clinical experience, was based on the results of an intensive *three days training programme*, including theoretical sessions, slide demonstrations and practical exercises.

In order to maintain a high level of intra- and inter-examiner reliability, a *calibration exercise* was carried out annually for all examiners involved. A minimum of 12 children was included in this exercise. When selecting children for this exercise, pre-screening was undertaken to ensure that a variety of pathology was present, including untreated caries, recurrent caries and fillings, and that some caries free children were also included. The results of the calibration exercises were initially evaluated by comparing the DMFT/dmft means for the different examiners. In a second step inter- and intra-examiner Cohen's kappa (Cohen, 1960) coefficient was calculated between the benchmark examiner and any examiner. Kappas were calculated on surface level for decayed, filled and sealed surfaces in the primary and permanent dentition (table 5.2). An acceptable level of agreement (0.60) (Landis and Koch, 1977) for each code has to be attained by every examiner on each calibration exercise, otherwise the examiner is individually re-calibrated or rejected.

Table 5.2. κ-values –mean and range- for inter-examiner agreement, using the benchmark examiner as 'golden standard'. Calibration exercise 16 examiners 1997. (DS and ds after recalibration of one examiner.

	DS	***ds***	***FS***	***fs***	***Sealants***
Mean score	0.79	0.77	0.97	0.90	0.96
Range	0.66-1.00	0.66-1.00	0.66-1.00	0.65-1.00	0.78-1.00

Statistical analysis

The Signal-Tandmobiel® database consists of dental, socio-demographic and questionnaire data. The oral variables will be the subject of analyses, included as response variables with the demographic and questionnaire data as explanatory variables.

Classical as well as less classical statistical techniques will be used. Analyses will be conducted using standard software such as SPSS, SAS (version 8, proc NLMIXED) and S-Plus, the choice depending on the scientific question as well as the methodological approach.

Discussion

This large scale, longitudinal comparative study has been successfully established in Flanders. It is unique for Belgium in its size and the use of a broad scale of parameters. The results will provide the first analyses in Flanders of the risk factors significant for the dental health of primary schoolchildren. In the absence of a public dental service and with a lack of a dental epidemiological tradition in Belgium, considerable efforts were needed to train and calibrate the team of dental examiners. It was essential to employ standard methods for the clinical examinations and the reports of the FDI (FDI-report 1982), WHO (WHO, 1987) and the BASCD (Pitts *et al.*, 1997; Pine *et al.*, 1997) provided a strong evidence-based framework.

Assessment of reported health behaviours remains challenging and it is essential to consider potential biases in the data. The present study highlights the need for validation of data. The validity and reliability of questionnaires in dental epidemiological investigations have rarely been tested. A few 20-year-old studies have been published by Helöe *et al*. (1972) and Norheim and Helöe (1977), supplemented by a more recent study by Palmqvist *et al* (1991).

Although all methods for collecting data on oral health behaviour have limitations, studies with standardised and calibrated methods are needed to enable comparison of oral health habits in different countries. For this purpose, a WHO Cross-National Survey was developed, promoting cross-disciplinary research and supporting international networking (Aaro and Wold, 1985).

The longitudinal character of the present study will enable us to contribute to the further development of standardised and calibrated questionnaires. This is being supported by an exchange of experiences in a British-Flemish *Academic Research Collaboration programme* between the Dental School of the University of Dundee and the Universities of Leuven and Gent, supported by the British Council and the Fund for Scientific Research Flanders (FWO). The Signal Tandmobiel® project will provide an example in the exchange of knowledge and experience in dental epidemiology. The unique collaboration within Flanders of dental schools, the dental association and the school medical service in undertaking a large intervention study will facilitate the implementation of the research findings into schools and clinical practice in the future.

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Chapter 6: Descriptive baseline results, evolution and trends.

First year results have been published as part of:
J Vanobbergen, L Martens, E Lesaffre, D Declerck. The Signal-Tandmobiel® project – a longitudinal intervention health promotion study in Flanders (Belgium): baseline and first year results.
European Journal of Paediatric Dentistry. 2000;2:87-96

Introduction

The present study is based on the cross-sectional data from the first year (1996) and the longitudinal data from the first four years (1996-1999) of the Signal Tandmobiel® project. This report uses data only from children in group A (experimental group).

In the first year (1996) of the project a total number of 4468 children was examined. The mean age of the children was 7.1 (+/- 0.4) years. In the second year (1997, mean age of 8.1 (+/- 0.4) years) 4381 children and in the third year (at a mean age of 9.0 (+/- 0.4) years) 4238 children were examined. In the 1999 Survey 5071 children were examined (mean age 9.8 (+/- 0.4) years). This chapter presents the descriptive results involving the children with complete data sets (4351, 4204, 4091 and 4141 children respectively).

The results from the clinical examinations and the questionnaires, used as variables in the inferential analysis of this thesis, are summarised: the oral health status, the oral cleanliness and the reported oral health behaviour.

Oral health habits

Oral hygiene habits

Flemish children *start brushing* their teeth at a mean age of 2.6 years (± 1.1; SEM: 0.018). Only 13.8% of the children started brushing before the age of 2. A large group of children (17.8%) started brushing only at the age of 4 or later.

It is generally accepted that children should receive *help with brushing* until the age of 8-10 years. In order to evaluate whether parents help their children with brushing and if so, until what age, these questions were included in the questionnaire. Regular help with brushing was provided by the parents of 8.7% of the children when examined at the age of 7 years, at 8 years this was the case in only 4.7% of the children and at the age of 9 years in 2.9% of the children. Only 1.7% of the children received help with brushing at the age of 10 years. Most parents abandoned helping by the age of 4 or 5 years (30.0% and 35.5%). More than 11% of the children never received any help with brushing.

The *frequency of tooth brushing* is presented in Table 6.1. and Figure 6.1. Most parents reported that their children brushed their teeth only once a day, in most cases in the evening. The advice to introduce at least two brushing moments a day, as is generally recommended, was followed by 1 out of 3 Flemish children.

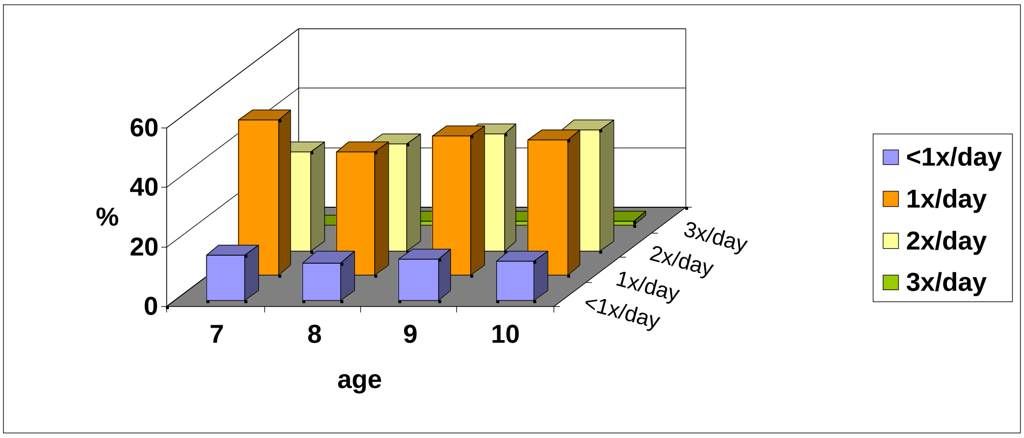
For a considerable number of children brushing was not a daily activity.

In 85.7% of the children parents taught their children how to brush their teeth. The dentist was mentioned by only 5.2% of the parents.

Table 6.1. Tooth brushing frequency (reported by parents)

	at the age of 7 years	***at the age of 8 years***	***At the age of 9 years***	***At the age of 10 years***
Never	0.3%	0.1%	0.2%	0.1%
Not every day	14.7%	12.6%	13.2%	13.0%
1x/day	51.6%	40.8%	46.2%	45.3%
morning	13.2%	14.1%	14.2%	15.3%
evening	30.4%	29.3%	25.0%	22.7%
alternating	8.0%	7.4%	7.0%	7.3%
2x/day	32.9%	35.4%	38.9%	40.2%
3x/day or more	0.4%	1.2%	1.5%	1.5%

Figure 6.1. Tooth brushing frequency at different age levels



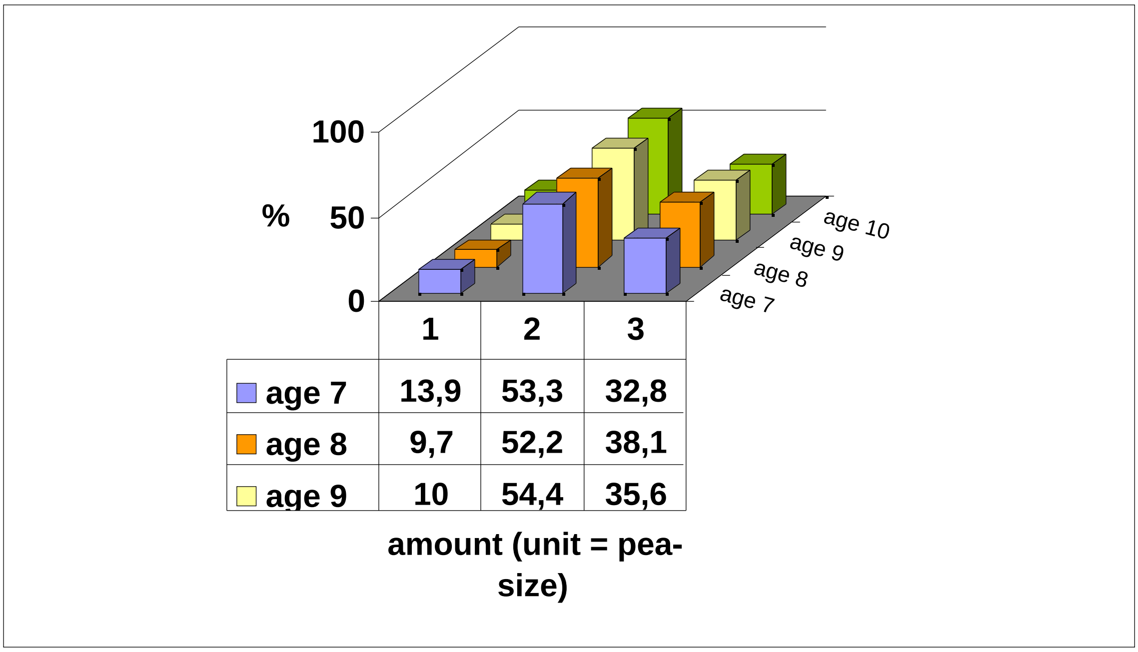
Use of fluorides

About 2/3 of the children (66.1%) received some form of *systemic fluoride* supplementation. In most cases fluoride tablets were used (53.5%). The administration of this supplement was reported to be regular by 70.3% of the parents. The use was discontinued before the age of 4 years in 68.3% of the children.

A fluoride containing *toothpaste* was used by more than 90% of the children, in all age groups (90.3%, 93.6%, 90.3% and 92.7% respectively). This was a children's toothpaste in 65.9% of the cases at the age of 7 years, 60.4% at the age of 8 years, 51.4% at the age of 9 years and 42.3% at the age of 10 years.

The amount of toothpaste used varied largely between children. the amount was described as one pea-size (1), half a brush (2) and head of toothbrush completely covered (3). Figure 6.2. shows the distribution of the amount of toothpaste used per brushing episode.

Figure 6.2. Amount of toothpaste used per brushing episode



Systemic fluoride supplementation was quite common in Flemish children but was usually discontinued at an early stage. A fluoride-containing toothpaste was used by most children and in most cases in large amounts. The amount of toothpaste used changed little over the years. The use of toothpaste especially designed for children was widespread. It is important to underline that children's toothpaste contains highly variable amounts of fluoride in Belgium (between 250 and 1500 ppm F, according to type and brand).

Dietary habits

Dietary habits are important in the development of caries. Therefore several questions regarding this topic were included in the questionnaire to the parents.
Breakfast habits were summarised in table 6.2.

Table 6.2. Breakfast habits of the children as reported by their parents

	at age 7 years	***at age 8 years***	***at age 9 years***	***at age 10 years***
Never	1.3 %	1.3 %	1.0 %	1.3 %
Seldom	8.1 %	6.8 %	7.4 %	7.7 %
Usually	14.5 %	15.6 %	15.1 %	15.7 %
Every day	76.1 %	76.3 %	76.5 %	75.2 %

Parents were also asked whether their child was allowed to take *sweets* or dry *biscuits* to school (table 6.3.). Sweets were usually taken to school at special occasions (e.g. birthdays). Biscuits were taken to school on a daily basis by more than half of the children.

Table 6.3.: Sweets and biscuits at school (daily and/or regularly)

	at age 7	***at age 8***	***at age 9***	***at age 10***
Sweets	12.6%	12.4%	13.1%	13.7%
Biscuits	90.4%	88.0%	87.1%	85.5%

Additional eating moments outside of main meals were common in Flemish children. A considerable number of children took sweets or biscuits to school on a regular basis.

Parents reported that their children took a number of *between-meal snacks* per day (table 6.4), ranging from 0 up to 5 or more. Most children had 2 or 3 eating or drinking moments (except water) between main meals.

Table 6.4.: Number of between-meal snacks per day

Snacks	***at age 7***	***at age 8***	***at age 9***	***at age 10***
0	5.9%	3.6%	1.2%	1.8%
1	22.4%	24.0%	25.9%	27.0%
2	40.4%	40.5%	40.9%	41.0%
3	21.5%	22.0%	20.4%	19.8%
4	6.0%	5.8%	6.6%	6.0%
5	2.5%	2.4%	2.8%	2.5%
6	0.8%	0.6%	0.9%	1.1%
7	0.1%	0.2%	0.2%	0.1%
8	0.1%	0.0%	0.3%	0.2%
9	0.0%	0.1%	0.2%	0.1%
10 or more	0.4%	0.7%	0.6%	0.4%

Dental attendance

Table 6.5. presents data on reported dental attendance of the children. More than 14% of the children did not yet *visit a dentist* at the age of 7 years. This number quickly drops in the following age groups.

Table 6.5.: Dental attendance pattern

	at age 7	***at age 8***	***at age 9***	***at age 10***
not yet	14.3%	0.9%	0.1%	0.1%
at school	6.1%	12.7%	11.1%	8.6%
> 12 months ago	9.0%	7.4%	6.4%	6.4%
6-12 months ago	22.7%	24.5%	24.5%	25.1%
< 6 months ago	47.9%	54.5%	58.0%	59.8%

Oral cleanliness and gingival condition

The *presence of plaque* on the buccal surfaces of reference teeth was measured using the Index of Silness and Löe (see chapter 5). The presence of plaque on the occlusal surface of the first permanent molars was measured using the index described by Carvalho et al (see chapter 5). Table 6.6. and figure 6.3. present the results of the measurements at different ages. Due to the skewed distribution the mean and standard deviation are less informative. The Standard Error of the Mean is reported.

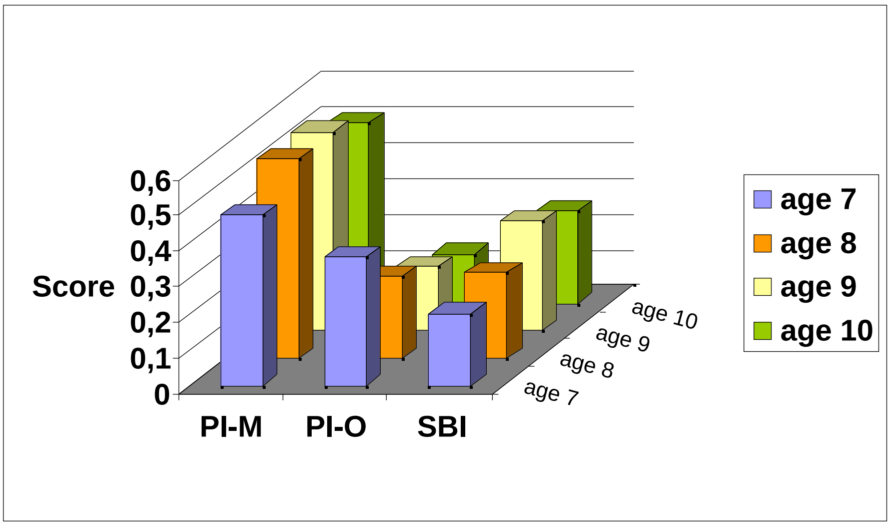
Plaque accumulation on buccal surfaces showed only little variation with age. This was not the case for plaque found on the occlusal surface of the first permanent molars. Plaque-accumulation on this tooth surface decreased when the child became older.

The Sulcus Bleeding Index described by Mühlemann and Son (see chapter 5) was used to assess *the level of gingivitis*. Results can be found in table 6.6. and figure 6.3.. The level of gingival inflammation tended to increase with age.

Table 6.6.: Oral cleanliness and gingival condition (mean (SD) and SEM, median)

	1996 Survey (7-year-olds)	***1997 Survey (8-year-olds)***	***1998 Survey (9-year-olds)***	***1999 Survey (10-year-olds)***
Plaque on Buccal surfaces (PlIM)	0.48 (0.49) SEM: 0.0074 Median: 0	0.56 (0.55) SEM: 0.0085 Median: 0.4	0.56 (0.55) SEM: 0.0086 Median: 0.4	0.51 (0.52) SEM: 0.0080 Median: 0.33
Plaque on Occlusal surfaces (PlIO)	0.36 (0.47) SEM: 0.0075 Median: 0	0.23 (0.39) SEM: 0.0060 Median: 0	0.18 (0.34) SEM: 0.0053 Median: 0	0.14 (0.30) SEM: 0.0046 Median: 0
Gingival condition (SBI)	0.20 (0.40) SEM: 0.0061 median: 0	0.24 (0.47) SEM: 0.0073 median: 0	0.31 (0.53) SEM: 0.0083 median: 0	0.26 (0.47) SEM: 0.0073 median: 0

Figure 6.3. Oral cleanliness (mean PlI-M and PlI-O) and gingival condition (mean SBI) at different age levels



Caries experience

Deciduous dentition

Table 6.7. summarises the caries experience scores of the children examined in each age category. Caries experience, expressed by means of the dmft-index, is usually presented using mean value and standard deviation (SD). However, as depicted in Figure 6.4., the distribution of the scores is non-normal and strongly skewed towards the right. For this reason, to quantify the spread, the mean value and standard deviation are no good measures to describe this variable. Median and Inter Quartile Ranges are more accurate. In addition the Standard Error of the Mean (SEM) provides information on the precision of the estimation of the true value of the mean for the studied population from which the sample is drawn. Since mean values and standard deviations are still widely used in the dental literature, and useful in comparing different groups, they were included in the table together with the Standard Error of the Mean.

Figure 6.5. presents caries experience scores in the different age categories graphically.

Table 6.7.: Caries experience in the deciduous dentition at different age levels

	1996 Survey	*1997 Survey*	*1998 Survey*	*1999 Survey*
Age category	age 7	age 8	age 9	Age 10
n children examined	4351	4204	4091	4141
mean deciduous teeth present (SD)	15.01 (2.83)	12.41 (2.32)	10.72 (2.57)	8.83 (3.53)
% caries free	44.0%	37.5%	33.1%	34.7%
dt (mean + SD) SEM	1.19 (2.02) 0.031	1.12 (1.82) 0.028	1.09 (1.71) 0.026	0.87 (1.43) 0.022
mt (mean + SD) SEM	0.16 (0.61) 0.0092	0.26 (0.76) 0.012	0.25 (0.77) 0.012	0.21 (+/- 0.74) 0.011
ft (mean + SD) SEM	0.89 (1.67) 0.025	1.20 (1.86) 0.029	1.34 (1.92) 0.030	1.22 (1.79) 0.028
dmft (mean + SD) SEM	2.24 (2.82) 0.043	2.58 (2.82) 0.043	2.68 (2.73) 0.043	2.29 (2.43) 0.038
Median	1	2	2	2
Mode	0	0	0	0
Range	0-18	0-16	0-14	0-12
Interquartile range	4	5	5	4
ds (mean + SD) SEM	2.38 (5.00) 0.075	2.23 (4.59) 0.070	2.01 (3.89) 0.061	1.63 (3.24) 0.050
fs (mean + SD) SEM	1.70 (3.38) 0.051	2.31 (3.78) 0.050	2.67 (4.01) 0.063	2.45 (3.74) 0.058
Dmfs (mean SD) SEM	5.02 (7.69) 0.12	6.05 (8/13) 0.12	6.17 (7.71) 0.12	5.30 (6.86) 0.11
Restorative Index (ft/dft)	43%	52%	57%	58%

Figure 6.4.: Distribution of the dmft-score at the age of **7**

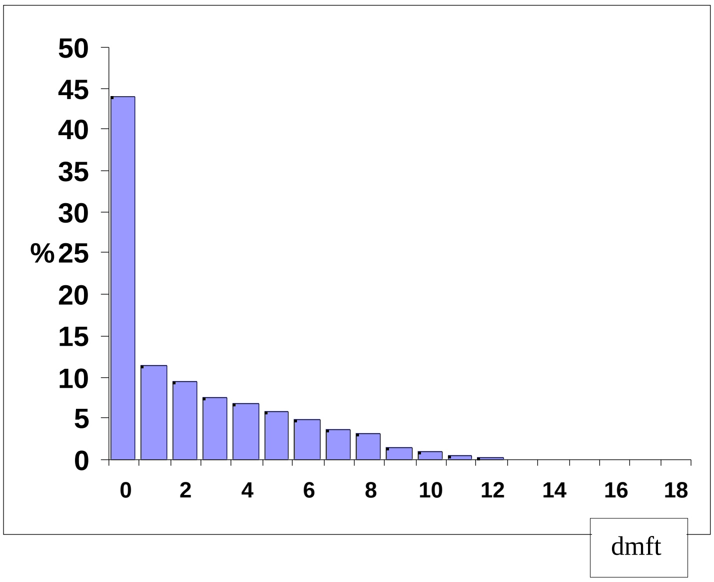
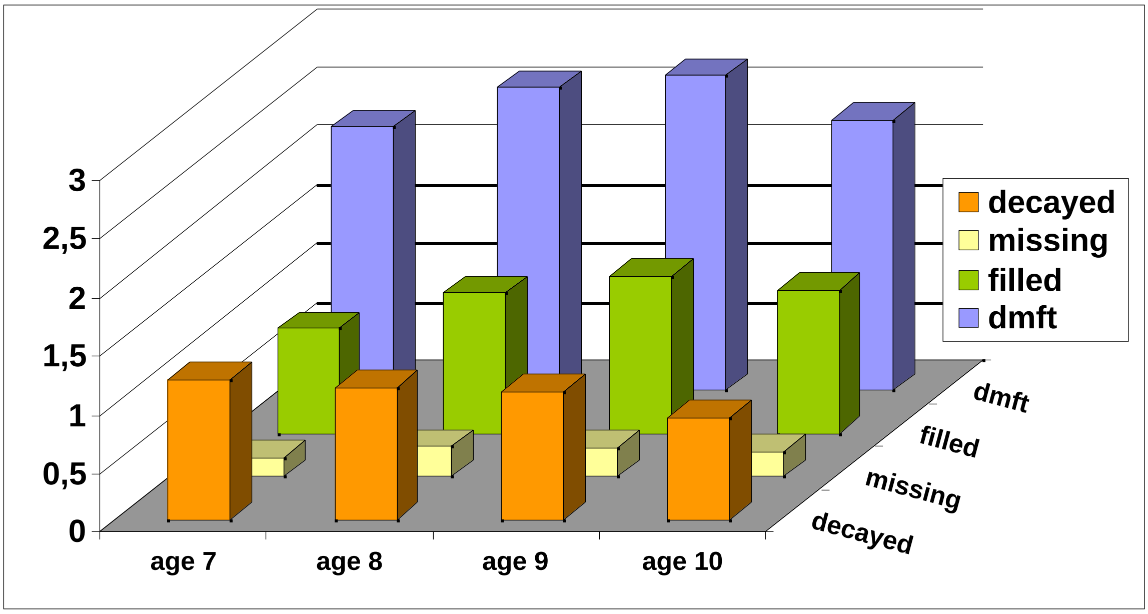


Figure 6.5.: Caries experience scores in the deciduous dentition (mean dmft, dt, mt and ft) at different age levels.



The data shows moderate caries experience levels in the deciduous dentition of Flemish children. Total caries experience showed only minor fluctuations between the age of 7 and 10 years, but there is a shift from untreated towards treated disease. This is confirmed by the rise in restorative index.

Most of the disease is found in a limited proportion of the children, stressing the necessity of early caries detection, risk assessment and introduction of risk management strategies. The restorative level of deciduous teeth is low, indicating the importance of informing parents (and dentists) about the necessity and possibilities of treatment of primary teeth.

Table 6.8. shows the percentage of the individual deciduous teeth affected by caries in the 7-year-olds. Actually this includes teeth that are decayed, filled or extracted due to caries. The second entry for each location is the percentage of teeth that are in the transitional stage.

Table 6.9. shows the caries prevalence according to different caries patterns.

Table 6.8.: Prevalence of caries (%C) in deciduous dentition of 7-year-olds according to position of tooth in the mouth. The percentage of teeth that are in the transition stage from deciduous to permanent teeth are also given (%P).

	55	54	53	52	51	61	62	63	64	65
% C	23.8	18.0	2.3	2.6	3.5	3.3	2.4	2.2	18.6	23.7
% P	0.37	0.64	0.76	30.0	63.3	63.8	29.6	0.46	0.97	0.74
	85	**84**	**83**	**82**	**81**	**71**	**72**	**73**	**74**	**75**
% C	25.4	27.0	2.3	0.16	0.07	0.07	0.14	2.1	27.0	24.7
% P	0.30	0.57	1.0	50.9	90.0	89.4	51.2	1.0	0.55	0.64

Table 6.9.: Prevalence of caries (%) according to studied caries pattern and according to position of tooth in the mouth in 7-year-olds.

	55	54	53	63	64	65
Fissure pattern	9.4	7.8			7.5	10.0
Posterior proximal pattern	7.8	11.3	1.5	1.4	11.8	7.9
Posterior smooth surface pattern	2.2	2.8			3.1	2.5
	85	**84**	**83**	**73**	**74**	**75**
Fissure pattern	11.4	13.2			12.6	11.7
Posterior proximal pattern	8.1	17.5	2.0	1.7	17.2	8.2
Posterior smooth surface pattern	5.0	7.4			6.0	5.7

From the descriptive part of this spatial correlation analysis it became obvious that the prevalence of caries followed a left-right symmetric pattern in the mouth. On the whole the left-right symmetric associations were higher than the top-down associations of corresponding teeth in caries prevalence and caries patterns. The symmetry was most observed in the posterior proximal pattern.

Permanent dentition

Table 6.10. summarises the caries experience scores of the children examined in each age category. For the descriptive, the same remark as for the deciduous dentition applies to permanent dentition. Figure 6.6. presents the frequency distribution of the DMFT-score at the age of 10 years. Caries experience scores in the different age categories are depicted in Figure 6.7. These data demonstrate that 1 out of 10 Flemish children developed caries shortly after eruption of the permanent teeth (examination at age 7 years). By the age of 10 years this is the case in 1 out of 3 children. Most of the lesions were localised on first permanent molars. When the one third of the population with the highest caries score is selected in the 10-year-olds, the mean DMFT for this subgroup is 2.20, which is clearly above the general mean of 0.75.

Table 6.10.: Caries experience in the permanent dentition at different age levels

	1996 Survey	***1997 Survey***	***1998 Survey***	***1999 Survey***
Age category	Age 7	age 8	age 9	Age 10
n children examined	4351	4204	4091	4141
Mean permanent teeth present (SD)	7.46 (3.22)	10.62 (2.27)	12.49 (2.43)	14.56 (3.66)
% caries free	89.7%	79.5%	71.2%	65.0%
DT (mean + SD) SEM	0.10 (0.43) 0.0064	0.15 (0.51) 0.0079	0.21 (0.71) 0.011	0.21 (0.71) 0.011
MT (mean + SD) SEM	0.01 (0.06) 0.00086	0.01 (0.09) 0.0014	0.01 (0.15) 0.0024	0.02 (0.26) 0.0041
FT (mean + SD) SEM	0.06 (0.37) 0.0055	0.20 (0.64) 0.010	0.36 (0.86) 0.013	0.51 (1.03) 0.016
DMFT (mean + SD)	0.17 (0.58) 0.0087	0.36 (0.84) 0.013	0.58 (1.15) 0.018	0.75 (1.33) 0.021
Median	0	0	0	0
Mode	0	0	0	0
Range	0-6	0-6	0-20	0-21
Interquartile range	0	0	1	1
DS (mean + SD) SEM	0.12 (0.62) 0.0094	0.19 (0.76) 0.012	0.26 (1.10) 0.017	0.27 (1.11) 0.017
FS (mean + SD) SEM	0.08 (0.51) 0.0076	0.27 (0.94) 0.014	0.50 (1.34) 0.021	0.74 (1.75) 0.027
DMFS (mean + SD) SEM	0.22 (0.91) 0.014	0.49 (1.36) 0.021	0.82 (2.12) 0.033	1.11 (2.66) 0.041
Restorative Index (FT/DFT)	37%	55%	63%	69%

In almost 2/3 of the children with evidence of caries activity untreated disease was present at the age of 7 years. The restorative level reached 69 % by the age of 10 years.

Figure 6.6.: Distribution of the DMFT-score at the age of 10 years

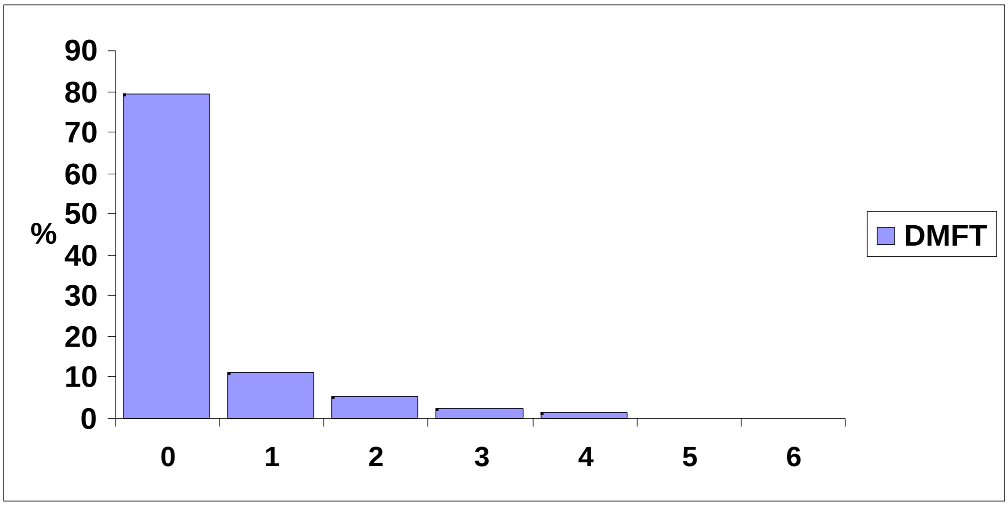
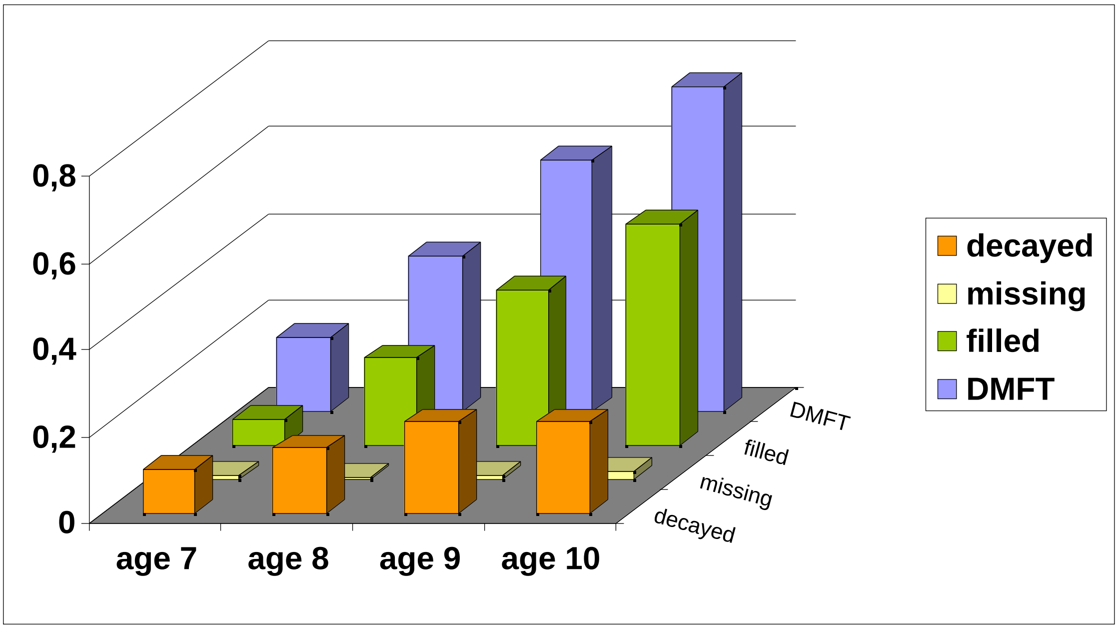


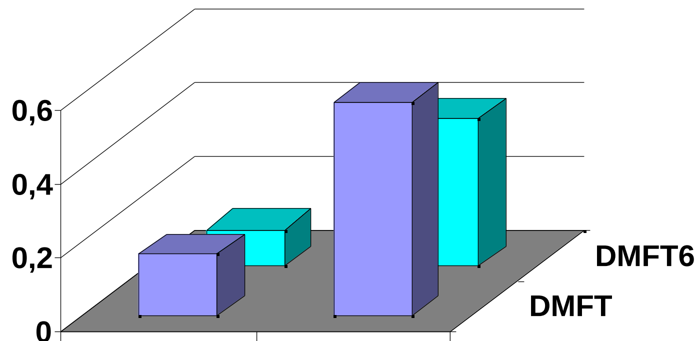
Figure 6.7.: Caries experience scores in the permanent dentition (mean DMFT, DT, MT and FT) at different age levels.



Caries experience – first permanent molar

As mentioned above, the largest part of the DMFT-score was made up by disease situated on the first permanent molar teeth. Figure 6.8. shows the proportion of the total caries experience that was found on the first permanent molars ($DMFT_6$).

Figure 6.8.: Proportion of total caries experience made up by disease on first permanent molars in 7 and in 9-year-olds



	age 7	age 9
DMFT	0,17	0,58
DMFT6	0,1	0,4

Remark

The descriptive results reported in this chapter refer to the study group. Since this is the intervention group only baseline results (7-year-olds) are representative for Flemish 7-year-olds. Considering the first comparative results with the control group (continuing research) the intervention has had a minimal effect on the oral health. However, the data for the 8- to 10-year-olds have to be evaluated with this reserve and against the background of the intervention.

III. Development and application of a caries risk assessment model.

Chapter 7: Assessing risk indicators for dental caries in the primary dentition.

This chapter has been published as:
J Vanobbergen, L Martens, E Lesaffre, K Bogaerts, D Declerck: Assessing risk indicators for dental caries in the primary dentition.
Community Dentistry Oral Epidemiology 2001;29:in press.

Abstract

The aim of the present study was to assess indicators, shown to be associated with the prevalence of caries in the primary dentition of 7-year-old Flemish schoolchildren. Cross-sectional first year data of the longitudinal Signal-Tandmobiel® survey were analysed (n = 4468). Gender, age, oral hygiene habits, use of fluorides, dietary habits, geographical factors and parental modelling were the considered predictors.

From the multiple logistic regression analysis, including schools as a random effect, and after adjusting for the confounding variables: educational system and province (stratification variables), gender and age, it became clear that the following risk indicators remained significant (at 5% level) for the presence of caries: frequency of tooth brushing ($P = 0.05$) with an odds ratio = 1.24 for brushing less than once a day, age at start of brushing ($P < 0.001$) with an odds ratio = 1.22 for a delay of one year, regular use of fluoride supplements ($P < 0.001$) with an odds ratio = 1.54 for no use, daily use of sugar containing drinks between meals ($P < 0.001$) with an odds ratio = 1.38, and number of between-meals snacks ($P = 0.012$) with an odds ratio = 1.22 for using more than 2 between-meal snacks. There was a significant difference ($P < 0.05$) in caries experience determined by the geographical spread, with an explicit trend of caries declining from the east to the west. In a model with an ordinal response outcome the daily use of sugar containing drinks between meals had a more pronounced effect when caries levels were high.

From this study it became obvious that, in Flemish children, an early start of brushing and a brushing frequency of at least once a day need to be encouraged, while the use of sugar containing drinks and snacks between meals needs to be restricted to a maximum of 2 per day. Geographical differences need to be investigated in more detail.

Introduction

Looking at the skewed distribution of dental caries experience (Spencer, 1997), due to the increase of caries free children over the last decades, polarisation seems to become more prominent. About 10 to 15% of the children bear 50% of caries lesions and 25 to 30% bear 75% of the lesions (Stewart and Stamm, 1991; Holbrook *et al.*, 1993; Bolin *et al.*, 1997; Powell, 1998). In order to influence this polarisation in a positive sense it is important that children at high risk of developing caries are identified and targeted for specific individual or group preventive measures. For that reason it is important to recognise and to quantify probable and putative risk factors in a cross-sectional way, defined as risk indicators. This could result in the construction of a risk model, that, in a longitudinal assessment, can confirm the risk indicators as true risk factors (Holbrook *et al.*, 1993; Helfenstein and Steiner, 1994; Abernathy *et al.*, 1987; Hausen, 1997; Bader *et al.*, 1986; Beck, 1998).

As mentioned by many authors (Stewart and Stamm, 1991; Dominguez-Rojas *et al.*, 1993; Leverett *et al.*, 1993; Beck *et al.*, 1992; Bolin *et al.*, 1997; Al Ghanim *et al.*, 1998; Freeman *et al.*, 1989; Grindefjord *et al.*, 1993; Verrips *et al.*, 1993; Eriksen and Bjertness, 1991; Grindefjord *et al.*, 1995; Stecksén-Blicks and Gustafsson, 1986) there is a strong correlation between *oral hygiene habits* and the prevalence of caries**.** The more frequent the brushing is performed, the less caries children experience. Additionally Freeman et al. (1989) stressed that participation and help by parents are essential components in a pre-school child's oral hygiene. In the development of a caries risk (assessment) model the importance of *the fluoride component* has been emphasised by many authors (Stewart and Stamm, 1991; Holbrook *et al.*, 1993; Abernathy *et al.*, 1987; Domingues-Rojas *et al.*, 1993; Leverett *et al.*, 1993; Beck *et al.*, 1992; Grindefjord *et al.*, 1993; Grindefjord *et al.*, 1995; Stecksén-Blicks and Gustafsson, 1986; Disney *et al.*, 1992). For most of them the use of fluoride behaves as a strong protective factor. Recently, several investigators have stressed the importance of the topical effect of fluorides in sustained low concentrated quantities (Fejerskov *et al.*, 1981; Featherstone *et al.*, 1990; Ten Cate, 1990). Different opinions exist about the relationship between caries development and *nutrition-related variables* (Holbrook *et al.*, 1993; Powell, 1998; Domingues-Rojas *et al.*, 1993; Al Ghanim *et al.*, 1998; Freeman *et al.*, 1989; Grindefjord *et al.*, 1993; Verrrips *et al.*, 1993; Eriksen and Bjertness, 1991; Grindefjord *et al.*, 1995; Holbrook 1993). Sugar misuse, in particular a high frequency of consumption of sugared beverages, has been reported as a risk indicator and a confirmed risk factor in many caries risk assessment models, mainly in very young children (Al Ghanim *et al.*, 1998; Grindefjord *et al.*, 1993; Verrips *et al.*, 1993; Grindefjord *et al.*, 1995; Leverett *et al.*, 1993; Grindefjord *et al.*, 1996). Several authors have stressed the importance of *psycho-social caries determinants* (Stewart and Stamm, 1991; Bolin *et al.*,1997; Abernathy *et al.*, 1987; Beck *et al.*, 1992; Freeman *et al.*, 1989; Verrips *et al.*, 1993; Disney *et al.*, 1992; Gratix *et al.*, 1990). Parental modelling has been shown to correlate with caries experience (Bolin *et al.*, 1997; Gratix *et al.*, 1990).

Grindefjord *et al*. (1993) found a significant higher caries prevalence in 2.5-year-old children with an *immigrant back-ground*, but this finding was mainly due to a significant higher sugar consumption, no use of fluoridated toothpaste and significantly lower frequency of toothbrushing. Verrips *et al*. (1993) considered ethnicity as an 'interesting' risk indicator correlated to maternal education level, especially in the permanent dentition and probably confounded by dental behaviour. Freeman *et al*. (1989) suggested a possible influence in pre-school children, probably due to both nutrition and oral hygiene. However, the variable '*ethnic origin*' did not influence caries prevalence in many other publications (Stewart and Stamm, 1991; Abernathy *et al.*, 1987; Disney *et al.*, 1992)

Many authors have emphasised the complex and multifactorial nature of caries development, combining biological, environmental and behavioural factors. It has been recognised that possible risk factors should be evaluated in multiple models both in a cross-sectional and in a longitudinal way. For this purpose the Signal-Tandmobiel® project was started in Flanders in 1996 (Vanobbergen *et al.*, 2000). The aim of this 6-years longitudinal project is to determine the oral health condition of primary schoolchildren between the ages of 7 and 12, both cross-sectionally and longitudinally. In addition oral health education has been provided, and the benefit of this intervention will be evaluated in a longitudinal survey.

The aim of the present cross-sectional study was to define the impact of a set of risk indicators on caries prevalence in the primary dentition of 7-year-old children in Flanders. Gender, oral hygiene habits, use of fluorides, dietary habits, geographic factors and parental modelling were evaluated in a multiple model, using the first year results of the Signal-Tandmobiel® project.

Material and methods

Sample

This study involved a representative sample of 4468 Flemish primary schoolchildren, born in 1989 and examined in 1996. The mean age of the children on the day of examination was 7.07 years (SD = 0.41).

A technique of stratified cluster sampling, using 15 different strata, was employed to obtain the sample (7% of the target population). Strata were obtained by combining the 3 types of educational system (public, municipal and private schools) with the 5 Flemish provinces, caring for an equal spread on rural and urban regions. Whenever a school was selected, all children in the first class of the selected school were included. Selecting individual children instead of schools would not have been feasible for practical and economical reasons and it would be unfair to allow only some children to participate. The schools were selected with a probability proportional to their size, i.e. the number of children in the first year. This approximates selecting children with equal probability. Since this sample can be considered representative, the paper was based on unweighted analyses.

The boys/girls ratio in the sample was 51.8 % to 48.2 %.

Clinical examination

The children were examined on school premises in a mobile dental clinic . The dental examinations were conducted following standardised and widely accepted criteria, as recommended by the WHO report on oral health surveys (1987) and based on the diagnostic criteria for caries prevalence surveys published by the British Association for the Study of Community Dentistry (BASCD) (Pitts *et al.*, 1997). No radiographs were taken and decay was recorded at the level of cavitation, using a WHO/CPITN type E probe. Dentist-examiners were specifically trained at baseline and participated in calibration exercises according to the guidelines on training and calibration published by the BASCD (Pine *et al.*, 1997). The examiners were calibrated by examining the same group of 12 children (all tooth surfaces) and comparing with the examination results of the benchmark examiner. Calibration exercises were conducted in age matched children with a variety of pathology present, including untreated caries, recurrent caries and fillings, nevertheless making sure that some caries free children were included also. To evaluate the levels of reliability master sheets were used and scores compared using paired t-tests. To obtain more detailed information the Cohen's kappa coefficient was calculated, since this score corrects by chance-expected agreement. The kappa coefficient was calculated at surface level for decayed and filled surfaces in the primary dentition, together with an overall kappa value for the dmfs-score. An acceptable level of inter- and intra-examiner agreement (kappa > 0.60) (Landis and Koch, 1977) was obtained for all 16 dentists involved. The overall inter-examiner agreement ranged between 0.70 and 0.98. Details on the set-up of the Signal-Tandmobiel ® project were published elsewhere (Vanobbergen *et al.*, 2000).

Questionnaires

Clinical findings were completed with data on oral hygiene habits, dietary habits, exposure to fluorides, dental attendance pattern and medical and social history of the children. These additional data were gained from written questionnaires, completed by the parents of the child and by school health care centres.

Data management

Clinical data and data from questionnaires were entered directly into a database, using a lap-top computer and the Dental Survey Plus Programme, version 5.40. Error reporting beeps are incorporated in the programme to alert examiner and recorder if an illogical code has been entered. Data files were converted into SAS-files for subsequent statistical analysis.

Definition of variables and annotation

Response variable

In the present analyses the dmf-t index was used as response variable, both dichotomised (dmft = 0 versus dmft ≠ 0) and subdivided in three subgroups: group A consisting of children with dmf-t = 0 (no caries experience), group B children with 1 ≤ dmf-t < 5 (low caries experience), and group C children with dmf-t ≥ 5 (high caries experience). The cut-off point at a dmf-t of 5, corresponding with 21% of high caries experience children, was defined taking into consideration that the group of high risk children selected in this way should not exceed 25% of the target population. Larger groups do not allow efficient targeted prevention (Hausen, 1997).

Explanatory variables

A large number of risk indicators, considered to be part of the causal chain or to expose the child to the causal chain, were included in this analysis and acted as explanatory variables. Socio-economic variables are also suggested to be of possible importance. Due to their complexity, the effect of other co-variates might be hidden when including these variables in our model. Therefore these variables will be reported in a separate paper. The variable 'amount of plaque' was also taken into consideration. Since this variable was considered to indicate the efficiency and frequency of brushing, and possibly of dietary habits, 'amount of plaque' was not included in the present model, since it can also be looked at as a response variable. The first column of table 7.1. shows the annotation of the explanatory variables and their different levels.

Table 7.1.: Annotation and distribution of explanatory variables in the study population.

Study population: 4468 (mean age 7.07 years)
Effective sample size with full clinical data: 4351

	n (effective sample size)	Ratio*
Educational system	(4351)	0.56
Municipal	555	0.59
Public	903	0.58
Private	2893	0.55
Province	(4351)	0.56
Limburg	779	0.64
Antwerp	1230	0.55
Fl. Brabant	630	0.54
East-Flanders	995	0.56
West-Flanders	717	0.50
Ethnic origin	(4219)	
Belgian	4065	0.55
Non Belgian	154	0.60
Gender	(4351)	
Girl	2094	0.55
Boy	2257	0.56
Age at start of brushing (first brushing)	(3774)	
Continuous variable	range from 0 to 7 years	
Brushing help	(3855)	
No	1746	0.54
Yes	2109	0.56
Frequency of brushing	(3934)	
< once a day	590	0.63
once a day	2034	0.56
> once a day	1310	0.52
Quantity of toothpaste	(3931)	
One pea size	546	0.51
Two pea sizes	2098	0.54
Full brush	1287	0.61
Regular use of fluoride supplements	(3899)	
No	2135	0.62
Yes	1764	0.49
Regular use of fluoridated toothpaste	(3827)	
No	1327	0.61
Yes	2455	0.53
Taking dry biscuits at school	(3897)	
No	370	0.50
Yes	3527	0.56
Taking sweets at school	(3907)	
No	3419	0.54
Yes	488	0.62
Daily use of sugar containing drinks	(4351)	
No	1968	0.52
Yes	2383	0.59
Number of in between-meal snacks	(3483)	
>2 per day	1088	0.60
≤2 per day	2395	0.53

Reported brushing habits of mother	(3739)	
Regular	3647	0.55
Never/don't know	92	0.67
Reported brushing habits of father	(3739)	
Regular	3385	0.51
Never/don't know	181	0.68

* Ratio = the proportion of children with caries experience versus the total sample size

The stratification variables 'educational system' and 'province' were included as non-individual factors. The latter geographical variable included the five Flemish provinces. The variable 'age at start of brushing' reflects the moment of first brushing. The variable 'brushing help', expressing the participation and help by parents in the child's oral hygiene, was categorised with two levels: 'Yes' if help was provided mostly or always, at least till the age of 4; 'no' otherwise. The 'regular use of fluoride supplements' means that tablets or drops were regularly used and the 'regular use of fluoride toothpaste' indicates that it has been used since the age of 3 years and at least once a day. The quantity of toothpaste was based on the amount most often used and was illustrated in the questionnaire by drawings (one pea size, half a brush, brush completely covered). Taking 'dry biscuits' and 'sweets' to school was dichotomised with: 'never, rarely or only for special occasions' (e.g. birthday) = 'No' versus 'regularly or every day' = 'Yes'. Daily consumption of 'sugar containing drinks between meals' was compared with the use of water, milk, etc..

Statistical methods

Due to the positively skewed distribution of caries experience, from a statistical point of view, the median, as a more central value, together with 25% and 75% quartiles, are the preferred summary statistics. For that reason the 'mean' and the 'median' are both reported in the descriptive analysis together with the 25% and 75% quartiles.

The univariate analyses comprised chi-square tests to evaluate the relationship of categorical risk factors separately with the response variable. A t-test or an ANOVA test was used for continuous variables, depending on the way caries experience was taken into account. The variable age at start of brushing was not normally distributed, but the central limit theorem ensures that sample means will be normally distributed for large enough samples. So a t-test was applied, in view of the high number of observations. Due to the large number of significance tests involved, the reported P-values have only an exploratory nature. No correction for multiple testing was attempted.

Multiple logistic regression analyses enabled a quantitative comparison of the separate effects of putative risk factors with their joint effect on the caries experience response. The presence of interactions was explored.

Odds ratios were calculated together with their 95% confidence interval (CI). As nominal level of significance, 0.05 was chosen. A random effect, corresponding to the school (actually class) the child attended, was included.

In both models, univariate and multiple, two series of inferential analyses were performed. First, risk indicators for caries were investigated irrespective of the extent of caries experience (dichotomised dmf-t: = 0 or ≠ 0). Second, the extent of caries experience was taken into consideration (ordinal response). Finally it was verified in the ordinal logistic regression model whether the effect of a risk factor changed for the transition from no caries to caries, versus no or mild caries to severe caries.

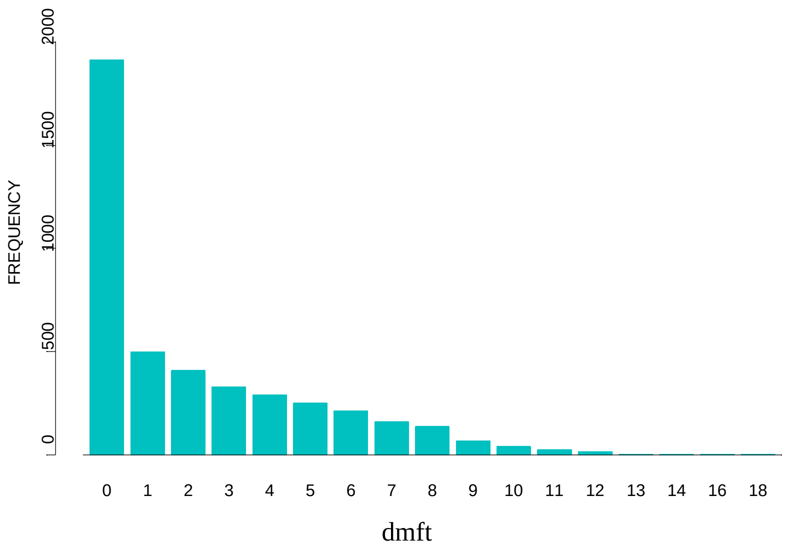
The final logistic regression analyses with random school effect were performed with the SAS procedure Proc NLMIXED. The intra-class correlation, indicating the correlation of caries experience between children attending the same class (school), was checked. Children having the same characteristics, but belonging to a different school could not have the same probability of having caries. All analyses performed were unweighted analyses.

Results

Descriptive analysis

The distribution of the dmf-t score is shown in figure 7.1. (n = 4351). As in most of our industrialised populations, especially among children, the recent decline in caries occurrence resulted in a skewed distribution of caries prevalence (Spencer, 1997). In our sample 15.2 % of the children bear 50% of caries and 27% of the children bear 75% of caries.

Figure 7.1.: distribution of dmft score in 7-year-olds in Flanders



The mean dmf-t score was 2.24 (SD = 2.81, SEM = 0.043)), ranging from 0 to 18. The median was 1, indicating that half of the children (50%) had none or one tooth affected by caries, and the inter-quartile range equalled 4 (Q3 – Q1), expressing that the middle 50% of the 7-year-olds had a dmft between 0 and 4. The mean number of decayed teeth was 1.19, filled teeth 0.89 and missing teeth 0.16.

Exactly 44% of the children examined were classified as caries free (i.e. without any clinical manifest lesions) in the primary dentition and 21% were classified as children with high caries experience (dmf-t ≥ 5).

The distribution of the different explanatory variables in the study population and the proportion of children with and without caries experience are shown in table 7.1.. A caries ratio was calculated, expressing the proportion of children with caries experience versus the total sample size (total sample caries ratio = 0.56). According to this descriptive distribution educational system, gender, ethnic origin and help with brushing did not seem to influence caries experience, whereas geographical spread, frequency of brushing, regular use of fluoride supplements and fluoridated toothpaste, use of sweets, daily use of sugar containing drinks between meals and between-meal snacks and brushing habits of the parents seemed to play a more important role in caries experience outcome.

In the caries-free group the mean age at start of brushing was 2.4 years (SD = 1.09, median = 2), while children with caries experience started brushing their teeth on average at the age of 2.7 years (SD = 1.13, median = 3).

Inferential analysis

Table 7.2. shows the different statistical values obtained by *simple analysis in the logistic regression model with random school effect.* With the exception of educational system, ethnic origin, gender and brushing help, most of the variables analysed were significant ($P < 0.05$). Although the *P*-value for 'taking sweets at school' was significant in the logistic regression without random effects, significance disappeared when including random school effect. Geographical distribution was highly significant ($P < 0.01$), suggesting that living in the western part of Flanders decreases the risk of development caries. The age at start of brushing was highly significant ($P < 0.0001$) and brushing with a small amount of toothpaste ($P < 0.001$) and the regular use of fluoride supplements ($P < 0.0001$) and fluoridated toothpaste ($P < 0.0001$) were protective factors as well, while brushing less than once a day ($P < 0.001$), an increasing number of between-meals snacks ($P < 0.001$), daily use of sugar containing drinks between meals ($P < 0.0001$) and -to a minor degree - biscuits ($P < 0.05$) increased the risk of having caries. The modelling behaviour of the parents (especially of the father) is associated with children's oral health.

Table 7.2.: Statistical values for simple logistic regression analysis with random school effect and dmft (caries versus no caries) as dependent variable (n = 3274).

Variable	***Odds ratio***	***95% CI***	***P-value***
Educational system			
Private (ref)	1		
Municipal	1.12	0.85-1.46	0.42
Public	1.10	0.89-1.37	0.38
Province			< 0.01
Antwerp (ref.)	1.		
Limburg	1.45	1.14-1.84	< 0.01
Fl.Brabant	0.95	0.74-1.21	0.69
East-Flanders	1.04	0.84-1.28	0.74
West-Flanders	0.74	0.59-0.93	<0.01
Ethnic origin (non Belgian)	0.83	0.60-1.15	0.26
Gender (boy)	0.96	0.84-1.09	0.53
Age at start of brushing	1.24	1.17-1.32	< 0.0001
Brushing help (no help)	1.13	0.99-1.30	0.055
Frequency of brushing			
Once a day or more	1		
Less than once a day	1.39	1.20-1.60	< 0.001
Quantity of toothpaste			
Large amount (level 3)	1		
Small amount (level 1 + 2)	0.77	0.67-0.89	< 0.001
No regular use of fluoride supplements	1.67	1.46-1.90	< 0.001
No regular use of fluoridated toothpaste	1.39	1.20-1.60	< 0.001
Taking dry biscuits at school	1.26	1.01-1.56	0.04
Taking sweets at school	1.00	0.09-1.14	0.96
Daily use of sugar containing drinks	1.33	1.16-1.50	< 0.0001
In between-meal snacks (more than 2 per day)	1.30	1.12-1.51	< 0.001
Reported brushing habits mother (mother brushes)	0.59	0.37-0.91	0.020
Reported brushing habits father (father brushes)	0.58	0.42-0.81	< 0.01

Table 7.3.: Statistical values for multiple logistic regression analysis with random school effect and dmft (caries versus no caries) as dependent variable. (n = 3274)

Variable	***Estimate***	***SE***	***Z-score***	***p-value***	***Odds ratio***	***95% CI***
Intercept	-3.127	0.705	-4.43	<0.001	0.04	0.01-0.17
Province						
Antwerp					1	
Limburg (easternmost province)	+0.274	0.138	1.99	0.048	1.32	1.00-1.72
W-Flanders (westernmost province)	-0.329	0.129	-2.54	0.010	0.72	0.56-0.92
Age (years)	+0.329	0.095	3.44	<0.001	1.39	1.15-1.68
Frequency of brushing						
≥once a day					1	
< once a day	+0.2129	0.1096	1.94	< 0.05	1.24	1.01-1.53
Age at start of brush. (years)	+0.196	0.035	5.55	<0.0001	1.22	1.14-1.30
Regular use of fluor.suppl.						
Yes					1	
No	+0.433	0.074	5.86	<0.0001	1.54	1.33-1.78
Daily use of sugar Containing drinks						
No					1	
Yes	+0.316	0.075	4.19	<0.0001	1.38	1.18-1.59
In betw. –meal snacks						
≤ 2	1				1	
> 2	+0.202	0.079	2.53	0.012	1.22	1.05-1.43

Intracluster (= class) correlation: 0.0001 (p > 0.01)

This model included gender, educational system and province (stratification variables)

The results obtained after *multiple logistic regression* with random school effect are shown in table 7.3.. Variables significant (*P*-level < 0.05) in the simple analysis were checked one by one by stepwise selection and were controlled for possible confounding. The stratification variables were kept fixed in the model, irrespective of their significance. The intraclass correlation, based on the multiple logistic regression model, was 0,0001, indicating that the effect of class/school was very small. The estimates and standard errors of only a few variables changed slightly when including a school random effect, namely for the variables ‘frequency of brushing’, ‘age’ and ‘geographical distribution’. *P*-values of the model without the random effect were somewhat less extreme in these variables.

The odds ratio of ‘child’s age at start of brushing’ represents the increase in risk for having caries when this variable increases by one year. This variable was highly significant in the multiple logistic regression model (or = 1.22, CI = 1.14-1.30). Living in the western part of Flanders remained an important protective factor (or = 0.72, CI = 0.56-0.92). Daily use of sugar containing drinks between meals (or = 1.38, CI = 1.18-1.69), consumption of more than 2 between-meals snacks per day (or = 1.22, CI = 1.05-1.43) continued to be important risk factors. Regular use of fluoride supplements (or = 1.54, CI = 1.33-1.78 for no use) and brushing more than once a day (or = 1.24, CI = 1.01–1.53 for brushing less than once a day) remained protective factors. The following variables, significant in the univariate model, did not influence caries experience in the multiple logistic regression model: quantity of toothpaste used, use of fluoridated toothpaste and modelling behaviour of the father. Comparable results were obtained for analyses with an ordinal response.

The multiple logistic regression model was checked for possible interactions (at 0.05 level), but none were significant. Further, it was shown that the combined effect of daily consumption of sugar containing drinks between meals and more than 2 between-meals snacks was neutralised by the use of systemic fluorides and daily brushing with a fluoridated toothpaste.

The ordinal analysis assumes that the effect of a covariate on a logistic scale is equal for the transition from caries free to low caries experience and for the transition from low caries experience to high caries experience. This assumption was verified for all variables. Only the variable “daily use of sugar containing drinks between meals” showed an unequal effect. The odds ratio in the model ‘no caries experience versus caries' was 1.38 while the odds ratio in the model 'no caries and low level versus high level of caries experience' was 1.82. This variable gains importance as a risk indicator in the transition to higher levels of caries experience.

Discussion

The impact of different determinants on caries prevalence has already been investigated in several studies. However, a large number of studies relate to individual determinants, studied by univariate analyses in small samples or to a mixture of indicators and predictors, immediately assessed in longitudinal caries incidence studies. The strength of the present study is the large number of detailed probable and putative risk factors, assessed as risk indicators for caries prevalence *at base line* in a multiple logistic regression model, using a well defined age group and a large sample.

The loss of children due to missing data was fairly high. From the initial selection (4468 children) 4351 were left with a complete clinical data set (97%) and 3274 with a complete clinical and questionnaire data set (73%). This was mainly due to missing or incomplete questionnaires and, to a minor degree, to refusals, absence because of illness or moving. To check the influence of this loss of children the distribution of the children with (3274) and without a complete questionnaire data set (1077) was compared with regard to the variables age, province, educational system, gender and dmft. The degree of missing depended on province ($P < 0.0001$), educational system ($P < 0.0001$) and dmft ($P = 0.03$). As we expected, the mean caries prevalence for those who were lost was somewhat higher than average (2.5 versus 2.2). More children had missing data in municipal and public schools than in free schools and more in the eastern provinces than in the western province. Although the non-response problem is of some magnitude, the sampling procedure in the study, sampling proportional to school size, would indicate that for reasonable complete data the unweighted approach is fine.

The distribution of the explanatory variables within the population, evaluated through a univariate and a multiple analysis, taking into account possible interactions and compensations, indicates that educational system, gender, ethnicity and brushing help did not influence caries experience in the primary dentition in 7-year-olds in Flanders. This is consistent with findings from other investigators (Stewart and Stamm, 1991; Bolin *et al.*, 1997; Abernathy *et al.*, 1987; Domingues-Rojas *et al.*, 1993; Disney *et al.*, 1992).

Studies reporting the influence of ethnicity on caries prevalence (Freeman *et al.*, 1989; Grindefjord *et al.*, 1993; Verrips *et al.*, 1993) are difficult to compare due to the variety of definitions used to assess ethnicity, ranging from nationality to origin or roots, and due to the variation of confounding factors involved, such as dietary and oral hygiene habits. This particular sample contained a very small proportion of non-Belgian children, since nationality was recorded. Being second or third generation, most immigrant children have Belgian nationality.

The findings reported by Freeman et al. (1989) concerning 'brushing help' were not confirmed in the present study.

Variables playing an important role as determinants of caries experience in the primary dentition in Flanders in this age group are: geographic area (province), oral hygiene habits (age at start of brushing, frequency of brushing, quantity of toothpaste used), the use of fluoride supplements and fluoridated toothpaste, dietary habits (dry biscuits or sweets to school, daily use of sugar containing drinks between meals, in-between-meal snacks) and parental modelling (reported brushing habits of father-mother by child).

The *geographic variable* (province) showed that living in the western part of the country, in the province of West-Flanders, seems to be a protective factor. The probability of remaining caries free was 14% higher for children living in the western compared with the eastern part of Flanders. Up to now very few geographical variations were reported in the literature (Burt, 1994; Kunzel, 1991; Oulis *et al.*, 1998, Watt and Sheiham, 1998), and they are primarily correlated with fluoride levels in the drinking water and deprivation levels. Further investigations are needed to explore this finding. In the present report the results of the calibration exercise do not allow us to presume confounding due to differences between the examiners. Each region was covered by at least three examiners. Only one examiner [examiner 11], covering the western province, needed to be recalibrated because of over-scoring the number of decayed and filled surfaces. This could have reduced geographical differences instead of accentuated them.

To check the influence of the examiner a multiple regression analysis was performed including the examiner as a fixed variable. In this model the large regional differences disappeared and differences between some examiners became significant. This, however, is not surprising. Examiners examining children in low caries prevalence regions have different profiles than examiners examining children in high caries prevalence regions. Based on the results of the calibration exercise, we assume that regional differences really do exist in Flanders. Of course, the investigators need to control the regional differences for their consistency during the longitudinal analyses. This would indicate that the observed differences might be under-expressed relative to the actual and would also clarify the effect of the examiner.

In the present analyses the most significant variable, with respect to *oral hygiene*, was “age at start of brushing”. The probability of remaining caries free for children who started brushing before the age of 3 was 46%, versus 36% for children starting after the age of 3. Ghanim (1998) reported the same findings in Saudi Arabian pre-school children. Regarding the “frequency of brushing” the most important cut-off level was ‘once a day’. Brushing at least once a day was an important protective factor, but it did lose some importance in the multiple logistic regression model. Only in the univariate model was a significant relationship found for the variable ‘amount of toothpaste used’. Using a small amount of toothpaste (one pea size amount) seems to be more protective. This unexpected finding could be explained by a probable correlation between the amount of toothpaste and the frequency of brushing, which is suggested by the multiple logistic regression analysis.

It remains difficult, in epidemiological surveys, to quantify the effect of topical and systemic *fluorides* separately. The global amount of fluorides to which children were exposed, such as dietary fluoride supplements, environmental supplements and fluoridated toothpaste, is difficult to assess. Fluoride is so commonly used that it is very hard to distinguish between topical and systemic use.

In the present study a highly significant effect of both systemic and topical fluorides was seen in the univariate model. Only fluoride supplements remained significant in the multiple logistic regression models. The influence of the use of fluoridated toothpaste was probably linked and partially masked by the age at start of brushing and the frequency of brushing.

From the multiple logistic regression analysis, it became clear that frequent use of sugar containing drinks and in between-meal snacks increased significantly the risk of having caries. The probability of having caries was 53% for children who took 2 or less between- meals snacks a day and 60% for children who took more than 2 between-meals snacks a day. The probability of having a high level of caries experience was strongly affected by the consumption of sugared beverages. This is in agreement with the statements found in the literature concerning *nutrition related habits* (Al Ghanim *et al.*, 1998. Grindfjord *et al.*, 1993; Verrips *et al.*, 1993; Grindefjord *et al.*, 1995; Leverett *et al.*, 1993). The variable ‘sweets at school’ was significantly related to caries in a simple logistic regression analysis without a random class effect, but was no longer significant when the random effect was included. It is conceivable that the class/school could have an important influence in discouraging the use of snacks and sweets at school.

Finally in contradistinction to Gratrix (1990) and Verrips (1993) fathers’ dental behaviour patterns as reported by their children were found to be more closely associated with their children’s caries experience than mothers’ oral hygiene behaviour.

Certainly the relativity of the reported odds ratio’s should be borne in mind by all those interpreting risk assessment. Even when only one factor describing oral health behaviour has an independent impact on dental caries (regular use of fluoride supplements), corresponding to an increased risk of 1.5, which is usually, but arbitrarily, considered the lower limit for preventive measures, this finding stresses even more the importance of the multifactorial character of the disease. If only one or two variables would be strongly associated with caries experience, it would be much more easier to establish an efficient and simple preventive care system. The present report emphasises the importance of multiple factors found to be significant in the different models. In particular, the combined and cumulative effect of all these risk indicators will be important when assessing children's risk for dental caries.

Conclusion

The purpose of this study was to look for statistically relevant differences with respect to a broad number of environmental and host-related variables, acting as risk indicators, for caries experience in 7-year-old children in Flanders, in order to quantify these variables in a risk assessment model.

The results of this cross-sectional risk assessment study confirmed the importance of oral hygiene and dietary habits in caries development. An early start of brushing and a brushing frequency of at least once a day needs to be encouraged, while the use of sugar containing drinks and snacks between meals needs to be restricted to a maximum of 2 per day. Geographical variations in caries experience need to be analysed more in detail.

Protective factors, significant in the present assessment model (use of fluorides), are able to neutralise some risk of caries development.

Taking into account the multifactorial nature of caries development, other variables, not considered in the present study, may have an important role. For the success of a longitudinal caries risk assessment model, which will subsequently be developed, based on this cross-sectional study, the multifactorial and cumulative aspects found in the present investigation, complemented with socio-economic and socio-demographic variables, need to be considered.

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Chapter 8: Determinants of dental plaque related to the caries prevalence in the primary dentition.

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Abstract

The present investigation aimed to define the impact of a number of possible explanatory variables on the variation in the amount of dental plaque present in the mixed dentition of 7-year-old Flemish children and to investigate the potential correlation between caries experience and the amount of dental plaque. Analyses were performed with ordinal plaque index as outcome measure, considering the children's school (i.e. class) as a random effect. This random effect turned out to be of great importance when dealing with large clustered samples. From the multiple logistic regression analysis, it was concluded that the older the subjects the more dental plaque was observed (or = 1.35; CI: 1.08 – 1.68; *P* = 0.0081). Four exploratory variables could be identified as important risk indicators for dental plaque accumulation in the mixed dentition: 'start of brushing after the age of 2 years' (or = 1.161; CI: 1.09 – 1.23; *P* < 0.0001), 'brushing frequency of < 1x/day (or = 1.37; CI: 1.12 - 1.66; *P* = 0.0019), more than two in between meal snacks (or = 1.18; CI: 1.03 - 1.36; *P* = 0.02) and daily intake of sugar containing drinks (or = 1.24; CI: 1.08 – 1.42; *P* = 0.002). Further, being male was linked to a higher amount of plaque (or = 1.16; CI: 1.00 – 1.34; *P* = 0.0506). Finally a weak but significant correlation (spearman's rho: r = 0.23; *P* < 0.0001) between caries experience and the amount of cervical plaque was shown.

Introduction

Dental plaque is considered an etiologic agent for dental caries (von der Fehr *et al*., 1970; Löe *et al*., 1972) and periodontal diseases (Löe *et al*., 1965; Lang *et al*., 1973; Page and Schröder, 1976; Bosman and Powell, 1977). Longitudinal studies in humans have shown that plaque control is a key factor in the prevention of both dental caries (Axelsson and Lindhe, 1977; Wendt *et al*., 1994; Øgaard et al., 1994; Nyvad and Fejerskov, 1986; Kuzmina, 1997; Thylstrup *et al*., 1997) and gingivitis and periodontitis (Lövdal *et al*., 1961; Axelsson and Lindhe, 1977; Axelsson and Lindhe, 1981). However, the relation between the level of oral hygiene, reported oral health habits and caries development remains confusing (Warnakulasuriya,1988). Plaque removal, although of primary importance in preventing gingivitis, appears secondary in the scope of caries prevention. Plaque harbours cariogenic bacteria, but is also the main intra-oral reservoir of fluoride and other beneficial substances. Further, plaque accumulation has to be considered as a complex and multicausal process. Results of previous studies suggest that, besides oral health behavioural habits, other variables such as gender and family economy may influence the clinical situation (Kuusala *et al*. 1997). There is no consensus on the impact on plaque accumulation of intake of sweets, consumption of sugared drinks and snacking.

The aim of the present cross-sectional study was to define the impact of a number of possible explanatory variables on the variation in the amount of dental plaque present in the mixed dentition of 7-year-old children in Flanders and to investigate the potential correlation between caries experience and the amount of dental plaque. Reported oral health habits (oral hygiene, dietary habits, use of fluorides) as well as socio-demographic factors (gender, province and parental modelling) were evaluated.

Material and methods

Sampling and data collection

For this study, data from the *Signal –Tandmobiel® project,* a longitudinal oral health promotion study in Flanders (Belgium) were used (Vanobbergen *et al*., 2000). By means of a stratified cluster sampling technique, a sample of 4468 children was obtained, representative for Flemish seven-year-olds (born in 1989). The mean age of the children was 7.07 years (SD = 0.41) and the boys/girls proportion in the sample was 51.8% versus 48.2%. The children were examined on school premises by trained dentists in a mobile dental clinic. Clinical examinations were carried out using standardised criteria, after calibration of the examination methodology. Caries experience, expressed using dmf-t index, was scored as recommended by the WHO report on oral health surveys (1987) and based on the diagnostic criteria for caries prevalence surveys published by the British Association for the Study of Community Dentistry (BASCD) (Pitts *et al*., 1997). Oral hygiene level was assessed using the plaque index (PlI) described by Silness and Löe (1964) and was scored on the buccal surfaces of Ramfjord teeth (primary alternatives) 1.6 (5.5), 21 (6.1), 2.4 (6.4), 3.6 (7.5), 4.4 (8.4) and 4.1 (8.1), using a mirror and a WHO CPITN type E probe. If present, permanent teeth were preferred. The PlI index was calculated as the mean score for the examined sites and was used as a measure for the average level of plaque accumulation. Data on oral health habits and socio-demographic situation were collected using questionnaires, completed by the parents of the children and by the school health care centre. Data were entered at the moment of examination into a database, using a laptop computer with the Dental Survey Plus Programme, version 4.50. Error reporting beeps were incorporated in the programme to alert examiner and recorder if an illogical code had been entered. Data files were then converted into SAS files, for subsequent statistical analysis. An ‘in extenso’ description of the complete set-up of this project including details on calibration, descriptive results and assessment of caries risk have been reported earlier (Vanobbergen *et al*., 2000; Vanobbergen *et al*., 2001a).

Variables included

Within the present study the plaque index with ordinal outcome was used as response variable. The considered explanatory variables can be deduced from table 8.1. (first column). The stratification variables ‘province’ and ‘ educational system’ were included as non-individual factors. The continuous variable 'Age at start of brushing' reflects the first brushing while the variable 'help with brushing' expresses the participation and help provided by parents in their child's oral hygiene and was dichotomised as 'Yes' if help was provided mostly or always, at least till the age of four; otherwise 'No'. The topical use of fluorides expresses the use of a fluoridated toothpaste at least since the age of three on a regular base. The systemic use of fluorides means that tablets or drops were regularly used as fluoride supplements. The 'quantity of toothpaste' refers to the amount of toothpaste that was most often used and was illustrated in the questionnaire by drawings: one pea size amount, half of the brush covered or a brush completely covered (full brush). These data were dichotomised in 'one pea size or half brush' versus 'full brush'. The intake at school of both ' dry biscuits' and 'sweets' was dichotomised with 'regularly or every day' being 'Yes' and 'never, rarely or only for special occasions ' being 'No'. Daily consumption of sugar containing drinks was compared to the use of water, milk etc. Intake of 'in between meals' was dichotomised in ≤ 2 versus > 2. The brushing habits of the parents, reported by the child, were dichotomised with 'every day' or 'now and then' being 'Yes' and 'never' or 'don't know' being 'No'.

Statistical analysis

Odds ratios (or) and their 95% confidence intervals (CI) were determined for all variables using a simple ordinal logistic random effect model, where the random effect was represented by "school" (i.e. class). The two-sided significance level was set at 5%. In a second step, a multiple ordinal logistic random effect model was performed, involving the significant variables from the simple analysis. Both random effect models were estimated with the SAS procedure Proc NLMIXED. Spearman rank correlation was used to study the relation of the amount of plaque with caries experience in the mixed dentition.

Results

Descriptive analysis

The mean dmf-t was 2.24 (SEM = 0.043), the median was 1 and the IQ-range was 4. Small amount of dental plaque accumulation (PlI 1 or 2) was found on 36.6 % of the examined surfaces while a lot of plaque (according to PlI 3) was recorded on only 0.85 % of all surfaces. The mean buccal PlI (n = 4351) was 0.48 (SD = 0.49, SEM = 0.007). The median buccal plaque index was 0.33 and the interquartile range (Q3-Q1) equalled 0.8. From the questionnaires, it could be concluded that 52.9 % of the children commenced brushing before the age of three while 18% of the parents reported their child having started at four or later. Help with brushing was provided in only 9% of the children and mostly only until the age of five years (35%). It was reported by 85% of the parents that their child brushed at least once a day. The quantity of toothpaste indicated was: a pea size amount (13.9%), half of brush covered (53.3%) or a full brush (32.8%). Further 45.2 % of the parents reported that their child received fluoride supplements on a regular base. With respect to dietary habits, 68.6% of the parents reported that their child had ≤ 2 snacks/ a day. At school 90.5% took biscuits regularly, while 87% stated that sweets were never consumed at school. The daily use of sugar containing drinks was reported by 54.8 % of the children. Finally most of the children reported seeing their parents brush their teeth.

Inferential Analysis

From a simple analysis with ordinal plaque outcome, it was evident that having experienced caries in the primary dentition was an important risk indicator for having visible buccal plaque at the age of 7 (or = 2.0; $P < 0.001$).

Table 8.1. shows the different statistical values obtained by *simple univariate analysis* in the logistic regression model with ordinal plaque score as outcome measure, considering a random school-effect.

Table 8.1.: Statistical values by simple logistic regression analysis with ordinal plaque index outcome including random school effect. (n = 3271)

Explanatory Variable	***Estimate***	***S.E.***	***P-Value***	***Odds ratio***	***95% C.I.***
Province					
Antwerp (ref.)	1				
Brabant	0.1618	0.2217	0.4628	1.18	0.76 - 1.82
Limburg	-0.5082	0.1556	0.0013	0.6	0.44 - 0.81
E-Flanders	0.2532	0.1391	0.0705	1.29	0.98 - 1.69
W-Flanders	-0.1894	0.1512	0.212	0.83	0.61 - 1.11
Educational system					
Private (ref.)	1				
Municipal	0.1978	0.1981	0.3196	1.22	0.82 - 1.79
Public	0.0335	0.3987	0.9324	1.03	0.47 - 2.26
Age	0.1683	0.0658	0.0141	1.18	1.04 - 1.35
Gender (Boy)	0.2217	0.062	0.0005	1.24	1.10 - 1.41
Frequency of brushing (Once a day or more versus less than once a day)	-0.4379	0.0872	<0.0001	0.64	0.54 - 0.76
No help with brushing	0.027	0.0617	0.6631	0.97	0.86 - 1.10
Age at start of brushing	0.1682	0.0286	< 0.0001	1.18	1.12 - 1.25
Regular use of systemic fluoride	-0.1532	0.0612	0.0133	0.86	0.76 - 0.96
Regular use of topical fluoride	-0.3525	0.0657	< 0.0001	0.7	0.62 - 0.81
Quantity of toothpaste (peasize or half brush versus full brush)	-0.2056	0.0648	0.0018	0.89	0.87 - 0.90
Taking dry biscuits to school	0.0781	0.1049	0.4576	1.08	0.88 - 1.33
Taking sweets to school	-0.0716	0.0589	0.2262	0.93	0.83 - 1.04
Daily use of sugared drinks	0.169	0.0592	0.0048	1.18	1.05 - 1.33
In between meal snacks (>2/day)	0.1791	0.0697	0.0111	1.2	1.04 - 1.37
Brushing habits mother (mother does not brush)	0.7285	0.2011	0.0004	2.07	1.40 - 3.07
Brushing habits father (father does not brush)	0.4787	0.1472	0.0014	1.61	1.21 - 2.15

With the exception of ‘educational system’, ‘help with brushing’ and ‘ taking dry biscuits’ and ‘taking sweets to school', all variables were significantly associated with the amount of plaque present ($P < 0.05$). It can be observed that ‘brushing frequency’ ($P < 0.0001$), 'the regular use of topical fluoride' ($P < 0.0001$) and ‘age at start of brushing’ ($P < 0.0001$) are highly significant. The increase in risk for having higher amount of plaque accumulation when the age at start of brushing increases by one year is represented by an or = 1.18. Brushing once a day or more (or = 0.64) and the regular use of topical fluoride (i.e. toothpaste; or = 0.86) are indicative of lower plaque levels. Boys had more plaque than girls (or = 1.24; $P = 0.0005$) and daily use of sugared drinks (or = 1.18; $P = 0.0048$) and having more than 2 in between meals a day (or = 1.20; $P = 0.0004$) seem to be linked to higher amounts of plaque. Further it became clear that the regular brushing habits of the parents reported by their children appeared to be highly linked to a lower amount of plaque (mother: or = 2.07; $P = 0.0004$; father: or = 1.61; $P = 0.0014$).

Table 8.2.: Statistical values by multiple logistic regression analysis with ordinal plaque index as dependent variable including random school effect. (n = 3271)

Explanatory Variable	***Estimate***	***S.E.***	***P-Value***	***Odds ratio***	***95% C.I.***
Age	0.2999	0.1119	0.0081	1.35	1.08 - 1.68
Gender (Boy)	1.4640	0.0744	0.0506	1.16	1.00- 1.34
Frequency of brushing (Once a day or more versus less than once a day)	-0.3100	0.0985	0.0019	0.73	0.60 - 0.89
Age at start of brushing	0.1491	0.0313	< 0.0001	1.16	1.09 - 1.23
Quantity of toothpaste (peasize or half brush)	-0.1851	0.0714	0.0103	0.83	0.72 - 0.96
Daily use of sugared drinks	0.2154	0.0696	0.0023	1.24	1.08 - 1.42
In between meal snacks (>2/day)	0.1657	0.0722	0.0223	1.18	1.025 - 1.36

From the *multiple analysis* (table 8.2.), it was found that children who started brushing early (or = 1.16 for an increase of one year; $P < 0.0001$) and brushed at least once a day (or = 0.73; $P = 0.0019$) with a small amount of toothpaste (or = 0.83; $P = 0.01$) were most likely to have lower plaque levels. The daily use of sugared drinks (or = 1.24; $P = 0.0023$) and having more than 2 in between meals a day (or = 1.18; $P = 0.02$) turned out to be factors linked to heavy plaque accumulation. Boys were more likely to have larger plaque amounts than girls, but gender was in the multiple analysis borderline significant (or = 1.16; $P = 0.05$).

Discussion

Literature on dental epidemiology is mostly dealing with risk assessment for dental caries and periodontal diseases. Considering 'plaque' as the response variable in multiple analyses is rare. The large number of detailed potential risk indicators for plaque development to be included in a multiple logistic regression model is the strength of the database used in this study. Having started with an initial selection of 4468 children, a complete clinical data set was gathered from 4351 children (i.e. 97%) and a complete clinical and questionnaire data set from 3271 children (i.e. 73%). The non-response was mainly due to missing or incomplete questionnaires and to a lesser degree to refusals and/or, absence for illness. In order to check the possible influence of the missing data, the distribution of the children with (n = 3299, i.e. 76.4%) and without (n = 1022, i.e. 23.7%) a complete questionnaire was compared regarding the variables province, educational system, gender, age and PlI. Significant differences were found for age ($P = 0.0001$), province ($P = 0.0001$) and educational system ($P = 0.0001$). More children had missing data in municipal and public schools than in free schools and more in eastern provinces than in the western province. No significant difference was found for gender ($P = 0.29$) nor for plaque index ($P = 0.8$). The latter seemed surprising as we expected that children with missing data would have been less dental minded and consequently would have displayed worse oral hygiene. Although the non-response problem was of some magnitude, the sampling procedure in this study indicated that for reasonable complete data the unweighted approach was fine.

Arguing that health related behaviour needs to be placed within a larger perspective and connected with the broader social environment (Duncan *et al*., 1996) a random school (i.e. class) effect was taken into consideration. Incorporation of this effect implies that a common (unknown) factor is assumed to exist in children from the same school. Thus, children having the same known characteristics, but belonging to a different school could not have the same probability of having plaque. The intra class correlation equalled 0.22 and was strongly significant ($P < 0.001$) which supports the choice for a statistical model with this random effect included.

The procedure used to evaluate oral hygiene, using a probe and scored by visual plaque index, does not allow any registration of reproducibility. As plaque was removed by the first examiner, the second one was unable to evaluate the amount of plaque and thus oral hygiene. Eaton *et al*. (1997), however, reported it would be possible to train a small number of examiners to achieve high levels of inter-examiner consistency in the use of plaque indices and gingival indices and to maintain them. In the present study this inter-examiner agreement was registered only in the first calibration exercise, which may result in less reliable information.

From the present analysis it became clear that the amount of dental plaque increases with increasing age. This confirms the findings by others (Frencken *et al.*,1991). Most significant variables, with respect to oral hygiene level seemed to be the age at start of brushing (or = 1.16; $P < 0.0001$,) and the reported brushing frequency (or = 0.73; $P = 0.0019$). The latter was clearly confirmed by Addy *et al*. (1987) who showed that toothbrushing frequency had a very low but significant correlation with the distribution of plaque and gingivitis. The latter authors, however, concluded that toothbrushing frequency accounted for only a small percentage of the variance in plaque and gingivitis for 11-12-year-old children and that the influence of frequency of brushing on the size of differences between children turned out to be small and of questionable clinical significance. These findings were consistent with the results of Cumming and Löe

(1973) who claimed that frequency of brushing does not necessarily reflect thoroughness. From a consecutive study (Addy *et al*., 1990) it was concluded that social class and sex (being male) were more important than brushing frequency. In the present study gender was highly significant in the univariate analysis and borderline significant in the multivariate analysis (P= 0.05); girls seemed to have a lower amount of dental plaque on the buccal surfaces of the examined teeth, which is in agreement with previous studies (Addy *et al.*, 1990; Frencken *et al.*, 1991). From a European survey (Kuusela *et al*., 1997) it became obvious that the better tooth brushing behaviour of girls was universal, with the exception of France. According to these investigators boys require more targeted health education programs. Girls are in general more concerned about their personal hygiene.

Because oral health promotion focuses on the improvement of oral health behaviours, description of current habits is crucial. The most important oral health habit is regular tooth brushing; in the scope of caries prevention it is recommended to brush twice a day. The effectiveness, however, depends on motivation, knowledge, oral hygiene instruction, oral hygiene aids and manual dexterity. The main purpose of regular tooth brushing, in terms of caries prevention, is to introduce fluoride into the mouth regularly via toothpaste.

In earlier reports a clear correlation was shown between the degree of oral cleanliness and caries experience (Ratka-Kruger and Koroluk, 1994; Mascarenhas, 1998). In a younger age group the presence of visible plaque was even considered the best indicator for future caries risk development (Alalusuua, 1994). In the present study at school level, a relatively low but significant correlation was found between the mean PlI and the mean dmf-t (r = 0.18, P = 0.019) (figure 8.1.). On an individual level, plaque was significantly associated with caries experience in the primary dentition as measured by the Spearman correlation (P < 0.0001). However the actual correlation is fairly low (r = 0.23) which implies high variability in caries among children with the same plaque score (figure 8.2.). From a review on oral hygiene level and dental caries experience it was concluded that individual oral hygiene is traditionally seen as poorly related to

Figure 8.1.: Comparison of the mean dmf-t and mean PlI. On school level.

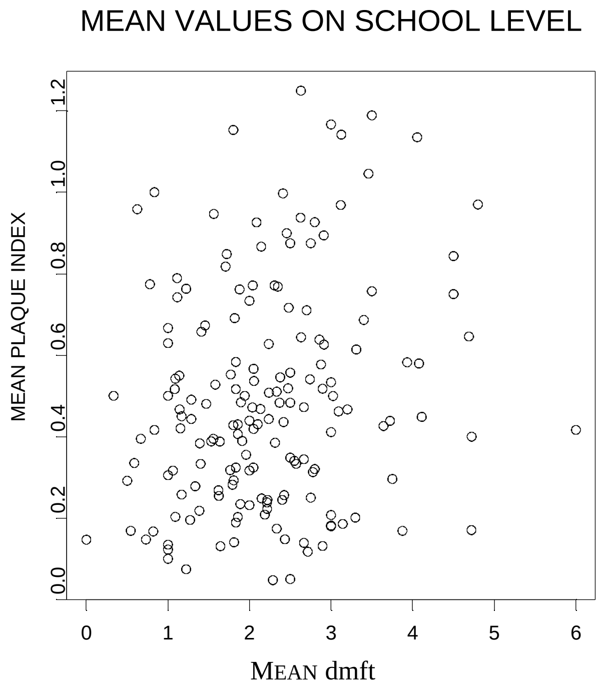
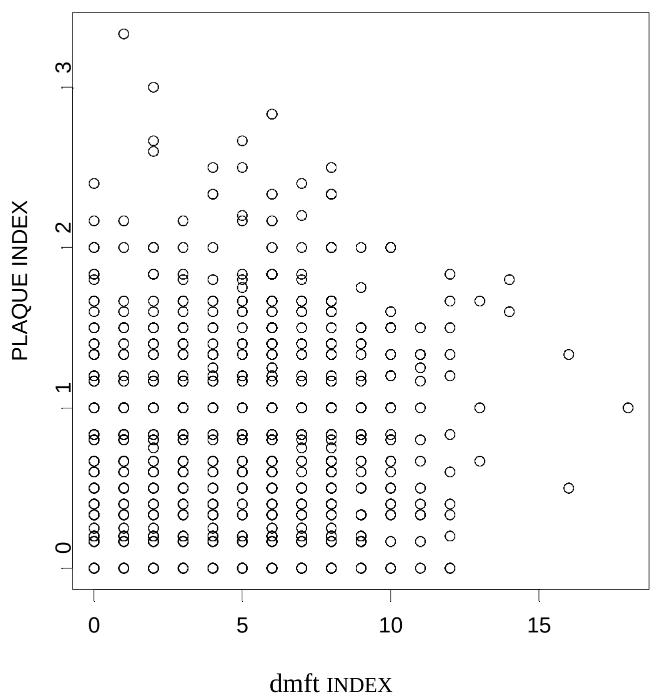


Figure 8.2.: Comparison of the mean dmf-t and mean PlI. On individual level.



caries experience (Andlaw, 1978; Bellini *et al*., 1981). It is important to note that a plaque represents a picture of the oral hygiene level at a given moment only, whereas the dmft-score represents the result of oral hygiene, dietary habits, exposure to fluorides, … over a longer period of time.

In contrast with ‘brushing frequency’, ‘help with brushing’ was not found to be important for the amount of plaque (*P* = 0.66) in the multiple analysis. Within the studied population the investigators found no benefit for the child when being helped during toothbrushing. Parental modelling (i.e. children seeing their parents brushing) seemed only in the simple analysis of some importance. This is however probably influenced by the distribution of the data. For this analysis, data were dichotomised in ‘Yes’ for ‘daily’ and ‘now and then ‘ and ’No’ for ‘never’. This resulted in 84.6 % seeing their mother brushing (daily or now and then) versus 76.6 % for father.

As far as dietary habits are concerned, we observed that having more than 2 in between meal snacks (or = 1.18; *P* = 0.02) was risky. More surprisingly, the consumption of sugar containing drinks (or = 1.24; *P* = 0.002) appeared to be more linked to high levels of plaque compared to the consumption of candies, sweets or biscuits at school. Measurement of voluntary food intake is extremely difficult (Garrow, 1974). It is uncertain whether the intake of smaller items of the diet, and therefore the frequency of intake, was accurately recorded. In addition, the fact that dietary information was obtained in connection with a dental examination might have biased the validity of the answers to the questionnaires, as the connection between dental caries and sugar consumption is common knowledge. While the assessment of the magnitude of the bias is not possible, its direction is certainly towards less frequent and smaller intakes (Bjarnason *et al*., 1989).

Conclusion

It was the purpose of the present study to define the impact of a number of possible explanatory variables on the variation in the amount of dental plaque present in the mixed dentition of 7-year-old children in Flanders and to investigate the potential correlation between caries experience and the amount of dental plaque. From this investigation, a marked correlation between caries experience and the amount of dental plaque was observed. Four parameters were of paramount importance for low amounts of plaque in the mixed dentition: start of brushing before the age of 2, brushing at least once a day, restricting in between meal snacks to '2' and no daily consumption of sugar containing drinks. Girls seemed to have significantly less dental plaque while 'help with brushing' and 'parental modelling' in the multiple model did not seem to influence children's oral hygiene level. The high variability in caries experience found among children with the same amount of plaque, clearly confirmed the multicausal origin of caries.

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Chapter 9: Parental occupational status related to dental caries in the primary dentition.

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Abstract

The present study aims to investigate differences in oral health condition in 7-year-old Flemish children by the parents' occupational class and to explore behavioural and demographic factors linked to social inequalities in oral health.

A stratified cluster sample of 1500 primary school children in Flanders, born in 1989.

The clinical oral examination was performed in the first year of a longitudinal oral health project in Flanders (1996-2001) by 16 calibrated examiners. Information on occupational level of the parents and on oral health related behaviour was gained respectively by the school health care centres and the parents of the children using a structured questionnaire.

The mean dmf values between the several SES-groups, assessed by occupational status of the parents (POS), were significantly different ($P < 0.001$). The mean dmft and dmfs values were the lowest for the most advantaged children (1.3/2.7) and finished threefold higher in the least advantaged children (3.9/8.9). The prevalence of caries-free children was 2.5 times higher among the highest POS families compared with the lowest POS families. In a logistic regression model adjusted for the stratification factors, the excess risk for caries in children increases with decreasing occupational level of the parents. There was a cumulative effect of decreasing occupational level and oral health habits on the caries prevalence.

The results of the present study allow us to suppose that social inequalities in oral health among children really exist in Flanders. Environmental factors and individual behavioural factors partially explain why social class might influence oral health.

Introduction

Inequalities in oral health have been demonstrated consistently to be linked to differences in socio-economic back-grounds. This has been observed and reported in different West-European surveys (Petersen, 1990; Bolin *et al.*, 1997; Truin *et al.***,** 1998; Sweeney *et al.*, 1999; Faggiano *et al.*, 1999; Flinck *et al.*, 1999). Lower socio-economic class children have been reported to have higher caries experience both in the deciduous and permanent dentition, resulting in lower percentages of caries free children and lower levels of care indices, compared with children from high socio-economic backgrounds. The improvement in oral health condition, observed during the last decades in most industrialised countries, has not been experienced equally across the population of examined children. As a consequence a polarisation in the health condition became more prominent, resulting in a concentration of caries in a minority of the children, often children of lower social classes (Petersen, 1990; Bolin *et al.*, 1997; Powell, 1998; Sweeney *et al.*, 1999). These inequalities in oral health condition are particularly unethical and inequitable, hitting mainly the most vulnerable group of children in our society. More information is needed on mechanisms by which social class might influence (oral) health in a positive or negative way (Locker, 2000).

Several different indices for the assessment of deprivation and socio-economic background have been used, some of them referring to income, occupational status or educational level of the head of the family or both father and mother (Petersen, 1990; Bolin *et al.*, 1997; Flinck *et al.*, 1999), others referring to composite measures combining unemployment rates, overcrowding, the possible access to material resources (e.g. car, TV, …) (Provart & Carmichael, 1995; Sweeney *et al.*, 1999; Jones *et al.*, 1999; Jones & Worthington, 1999). Beside, some times socio-economic groups can be categorised according to small area typologies (e.g. postcode references) (Provart & Carmichael, 1995; Truin *et al.***,** 1998; Sweeney *et al.*, 1999; Jones *et al.*, 1999; Jones & Worthington, 1999) or to individual measurements (Petersen, 1990; Bolin *et al.*, 1997; Flinck *et al.*, 1999; Faggiano *et al.*, 1999). This lack of standardisation in methodology encompasses comparisons between reported surveys.

In Flanders a remarkable association between geographic distribution and dental caries experience has been observed during previous investigations (Declerck & Goffin, 1992; Vanobbergen *et al.,* 2000), reporting a caries prevalence for 7-year-old children of 50 per cent in the Western and 64 per cent in the Eastern part of Flanders. The mean dmft was 1.7 in the West and 2.9 in the East.

Findings with respect to the polarisation of caries prevalence, reported in other West European studies, seem to be upheld by the Flemish results: 15.2 per cent of 7-year-old Flemish children bear 50 per cent of the caries (Vanobbergen *et al.,* 2001).

The objective of the present paper was to study the relationship between socio-economic status, assessed by the occupational status of the parents, and the dental caries experience of 7-year-old children in Flanders and to explore behavioural and demographic factors linked to social inequalities in oral health.

This study is part of the Signal-Tandmobiel® project, a 6-years longitudinal survey started in 1996, studying the oral health condition of primary schoolchildren in Flanders – Belgium (Vanobbergen *et al.*, 2000).

Material and methods

This paper was based on a sample of 1453 children, who were part of the longitudinal Signal-Tandmobiel® project. The methods presented briefly in this paper have been reported in more detail elsewhere (Vanobbergen *et al.*, 2000). A technique of stratified cluster sampling was used to obtain the sample. Strata were obtained by combining 3 types of educational system (public, municipal and private schools) within the 5 Flemish provinces. All children were born in 1989 and examined during the 1996-97 school year, the first year of the Signal-Tandmobiel® project. Children were examined by trained dentists in a mobile dental clinic on school premises (Vanobbergen *et al.*, 2000). Standardised and widely accepted criteria were used, as recommended by the World Health Organisation report on oral health surveys (WHO, 1997) and based on the diagnostic criteria for caries prevalence surveys published by the British Association for the Study of Community Dentistry (Pitts *et al.*, 1997). Training and calibration exercises were carried out based on the guidelines as recommended by the BASCD (Pine *et al.*, 1997). Teeth were scored using a WHO/CPITN type E probe. Decay was recorded at the level of cavitation and caries experience was expressed by means of dmf-scores (Klein and Palmer, 1938). Radiographic examination was not included.

Clinical findings were complemented with data on occupational level of the parents and on present and past oral health related behaviour. These additional data were gained from the school health care centres and the parents of the children respectively using a structured questionnaire. The first paragraph of the questionnaire was used to obtain consent from the parents to participate in the study.

The response in the present analyses was the dmft/s score along with derivations: dt/s, mt/s and ft/s, the restoration index (f/df x 100) and the care index (mf/dmf x 100) in children with disease experience and finally the percentages of caries free children (without any clinical manifest treated or untreated caries lesions – dmf = 0). Attention has to be paid to the slight difference between the definition of care index as used in this paper (mf/dmf%) and that used by the BASCD (f/dmf%).

The explanatory variable was the socio-economic status (SES) indicator of the child, classified according to the parents occupational status, both the father and the mother. Three individual indicators are likely to identify the socio-economic background of the children: income, education and occupation. The use of parental occupational status (POS) was justified by the fact that income was the most delicate and difficult variable to assess and occupation the most reliable variable available at the school health care centres. The classification was based on the Standard Occupational Classification, published by the Office of Population Censuses and Surveys in London (1990).

Table 9.1. shows the allocation of the different Occupational Unit Groups to the different SES levels, the highest number refers to the lowest social class occupation. Self-employed subjects were allocated in different categories whether they have employees (class 2) or not (class 4). Members of the armed forces without specification were allocated in class 7. If there was some more information they were allocated in

more specific classes (officers: class 2, non-commissioned officer: class 3). Included in class 8 were students, housewives/house-men, retired people and unemployed people.

Table 9.1.: Social class classification based on the Standard Occupational Classification, published by the Office of Population Censuses and Surveys in London (1990).

Class	***Specification***	***Example***
High 1	Professional	Medical and dental practitioners, pharmacists, veterinarians, lawyers, civil engineers, chartered accountants, psychologists, management consultants, biochemists, economists, architects, actuaries, surveyors, university teaching professionals, …
High 2	Managerial	Teachers, managers, nurses, midwives, social workers, physiotherapists, speech therapists, insurance brokers, management accountants, engineering technicians, computer analysts, programmers, officers, authors, musicians, graphic designers, journalists, …
Middle 3	Skilled non-manual	Secretaries, clerks, employees, receptionists, draughtsmen, librarians, photographers, professional athletes, sportsmen, medical secretaries, policemen/women, sales representatives, …
Middle 4	Skilled manual	Masons, painters, electricians, plumbers, motor mechanics, shoe repairers, tailors, bakers, butchers, store-keepers, hairdressers, nursery nurses, elderly carers, farmers, drivers, self-employed professions, …
Low 5	Semi-skilled	Waiters, postmen, metal workers, shop-girls, assemblers, …
Low 6	Unskilled	Labourers,
Low 7	Armed forces	
Low 8	Not working	Unemployed, single housewives/house-men, retired, students, …
Low 9	Unclassified	

A family POS indicator was calculated combining both the occupational status of the father and the occupational status of the mother. In this case three subgroups of occupational status of the father and the mother were used: high social class (category 1-2) representing upper-level self employed professionals, employees and businessmen, middle social class (category 3-4) representing middle-class skilled manual workers and employees and finally low social class (category 5-8) representing unskilled and semi-skilled workers and employees and unemployed and retired people.

In this way a family POS was modelled with 9 combinations. Only if both fathers and mothers occupational status was known, even when they were divorced, data were used to compute the family POS.

Data were recorded using the Dental Survey Plus version 5.4 programme. Statistical analyses were performed with the SPSS 9.0 soft-ware package. Due to the skewed distribution of the response and the small number of cases in some subgroups, non-parametric tests were preferred. After linear chi-square analysis, non-parametric correlation analyses (Spearmans' correlation coefficients) were used to calculate the correlation between the occupational status of the father and the mother of the child and the dmft/s index of the child. Non-parametric Kruskal-Wallis tests were used to compare differences in distribution of dmft/s between groups of POS and province. Mutual differences between groups were tested with the Mann-Whithney U test and adjusted for the fact that multiple comparisons were made (Bonferroni correction). Differences were considered significant at $P < 0.05$. Odds ratios together with a 95% confidence interval, measuring the surplus in caries risk for the different occupational levels compared with the highest occupational level were computed by means of logistic regression (dmft = 0 versus dmft ≠ 0) by controlling for the stratification variables as possible confounders. In order to measure the influence of oral health related behaviour a regression model was fitted to the dependent variable (caries or not) with occupational level factors combined with different oral health related behaviours as independent variables.

Results

Of the total sample of 1453 children, 1325 had a complete data set, containing data on occupational level of the father, occupational level of the mother, oral health behaviour, postcode, date of birth, the number of decayed, missing and filled teeth and surfaces. A total of 1420 included information about the father's occupational level and 1343 included information about the mother's occupational status.

The mean dmft/dmfs in the study group was 2.10 (SEM 0.072) / 4.70 (SEM 0.19). The median was 1 for dmft and for dmfs, the interquartile range was 4 for dmft and 7 for dmfs. The proportion of caries free children was 46 per cent. The caries prevalence in the study sample was similar but somewhat more favourable than the national results for the same age group (dmft 2.24 (SEM 0.042) dmfs 5.02 (SEM 0.12) / median 1 / interquartile range 4 and 7 / 44 per cent caries free , Vanobbergen *et al.*, 2000).

A significant correlation was found between socio-economic status, as measured by the occupational status both of the father and the mother, and the dmft/dmfs index for 7-year-old children in Flanders (Spearman's ρ ranking between 0.212 and 0.235; $P < 0.001$).

A highly significant association was found (linear chi-square analysis: $P < 0.001$) between decreasing social level and decreasing proportion of caries free children (table 9.2^a and 9.2^b). Maybe due to the small number of parents belonging to category 7 (armed forces), their results are not significant ($P = 0.4$).

Mean values for dt, mt, ft and dmft were analysed by each of the seven significant POS categories for father and mother, based on the occupational levels, and presented in tables 9.2^a and 9.2^b and figures 9.1^a and 9.1^b.

The highest caries experience level was found in the most disadvantaged children (unskilled fathers – unemployed mothers) with dmft values of 3.66 and 3.50 (dmfs values of 8.48 and 8.51). The difference in distribution of dmft/s values between the POS categories, both based on the occupational levels of the mother or the father, was highly significant (Kruskal-Wallis test: $P < 0.001$). Mutual differences between groups, with occupational level 1 as reference, were tested and adjusted for multiple comparisons. The most important cut point was located between occupational level 3 and 4. Whereas in the most advantaged categories (category 1 to 3) the decayed and filled components were approximately the same, in the most deprived categories (category 4 to 8) the decay component became the most important component.

Table 9.2[a] : The mean values of dt, mt, ft, dmft (+ Standard Error of the Mean) of 7 year old children in Flanders, care index and percentages of caries free children by occupational class of the father (n = 1420).

Occupational level father	***dt*** $P < 0.001$	***mt*** $P < 0.01$	***ft*** $P < 0.05$	***dmft*** $P < 0.001$	***Care index*** (mf/dmf%)	***% caries free children*** $P < 0.001$
1 (n = 143)	0.66 (0.14)	0.10 (0.03)	0.66 (0.12)	1.43 (0.21)	46%	62.2% (n = 89)
2 (n = 273)	0.63 (0.09)	0.09 (0.02)	0.71 (0.09)	1.43 (0.14)	50%	55.3% (n = 151)
3 (n = 367)	0.89* (0.09)	0.10 (0.02)	0.83 (0.08)	1.81* (0.13)	46%	49.0% (n = 180)
4 (n = 375)	1.37** (0.11)	0.19 (0.04)	0.91* (0.08)	2.47** (0.15)	37%	41.3% (n = 155)
5 (n = 88)	1.49** (0.22)	0.10 (0.04)	1.13* (0.19)	2.72** (0.31)	41%	36.4% (n = 32)
6 (n = 137)	2.16** (0.22)	0.28* (0.06)	1.22* (0.18)	3.66** (0.29)	33%	23.4% (n = 32)
7 (n = 13)	-	-	-	-	-	-
8 (n = 24)	1.29 (0.44)	0.46 (0.28)	0.50 (0.31)	2.25 (0.65)	22%	45.8% (n = 11)

* denotes a statistically significance increase in mean between occupational classes referring to occupational level 1: $P < 0.05$
** denotes a statistically significance increase in mean between occupational classes referring to occupational level 1: $P < 0.01$
P adjusted for multiple comparisons

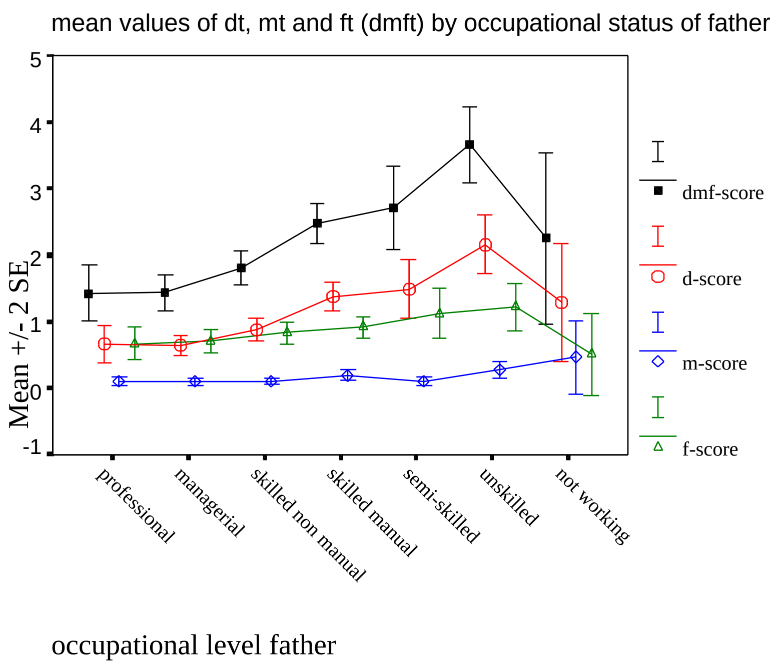
Table 9.2[b] : The mean values of dt, mt, ft, dmft (+ Standard Error of the Mean) of 7 year old children in Flanders, care index and percentages of caries free children by occupational class of the mother (n = 1343).

Occupational level mother	***dt*** $P < 0.001$	***mt*** $P < 0.01$	***ft*** $P < 0.001$	***dmft*** $P < 0.001$	***Care index*** (mf/dmf%)	***% caries free children*** $P < 0.001$
1 (n = 56)	0.66 (0.21)	0.05 (0.04)	0.43 (0.18)	1.14 (0.33)	38%	71.4% (n = 40)
2 (n = 357)	0.70 (0.07)	0.13 (0.03)	0.78* (0.08)	1.61* (0.13)	48%	52.7% (n = 188)
3 (n = 413)	0.76 (0.07)	0.10 (0.02)	0.86* (0.08)	1.72** (0.11)	50%	49.6% (n = 205)
4 (n = 157)	1.29* (0.17)	0.12 (0.04)	0.63 (0.10)	2.04** (0.22)	31%	48.4% (n = 76)
5 (n = 64)	1.25** (0.21)	0.25 (0.12)	1.11** (0.23)	2.61** (0.34)	42%	31.3% (n = 20)
6 (n = 88)	2.30** (0.27)	0.20 (0.07)	0.81* (0.16)	3.33** (0.33)	24%	30.7% (n = 27)
7 (n = 3)	-	-	-	-	-	-
8 (n = 205)	1.92** (0.17)	0.30* (0.06)	1.28** (0.14)	3.50** (0.23)	36%	29.3% (n = 60)

* denotes a statistically significance increase in mean between occupational classes referring to occupational level 1: $P < 0.05$
** denotes a statistically significance increase in mean between occupational classes referring to occupational level 1: $P < 0.01$
P adjusted for multiple comparisons

Figure 9.1: Mean values of dmft (deciduous dentition) by occupational status of father (a) and mother (b)

(a)



(b)

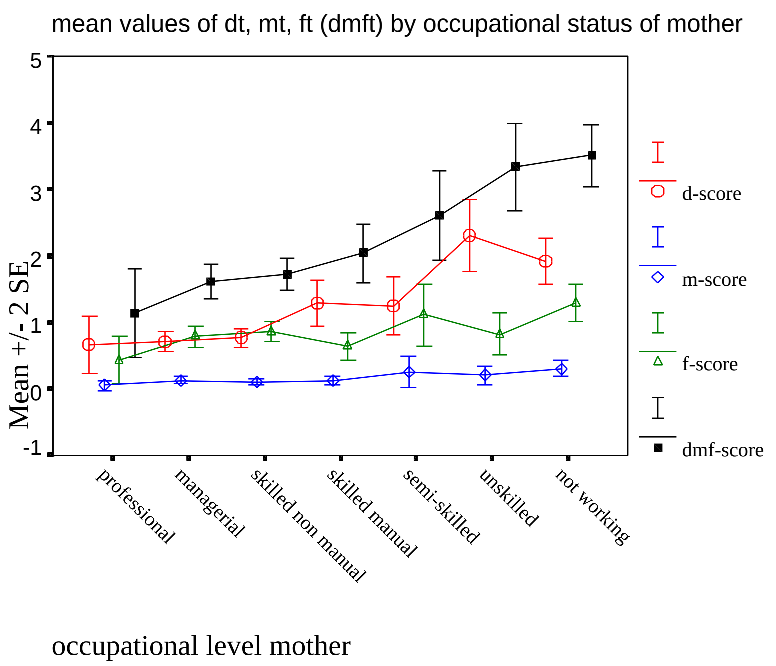


Table 9.3. : Mean values of dmft/s, percentage of caries free children and care and restorative indices in 7-year-old Flemish children with varying family occupational status. n= 1325

POS family	***dmft (SEM)*** $P < 0.001$	***dmfs (SEM)*** $P < 0.001$	***% caries free*** $P < 0.001$	***Care index*** (mf/dmf%) $P < 0.05$ (n = 717)	***Restorative index*** (f/df%) $P < 0.05$ (n = 705)
Father high + mother high (n = 246)	1.3 (0.14)	2.7 (0.33)	61%	53% (33%)*	48%
Father high + mother middle (n = 108)	1.8 (0.22)	3.7 (0.56)	52%	52% (31%)	50%
Father high + mother low (n = 34)	1.3 (0.36)	2.5 (0.43)	59%	35% (14%)	25%
Father middle + mother high (n = 139)	2.0 (0.22)	4.3 (0.58)	48%	53% (32%)	50%
Father middle + mother middle (n = 380)	1.7 (0.12)	3.8 (0.32)	49%	45% (29%)	43%
Father middle + mother low (n = 172)	3.2 (0.22)	8.1 (0.74)	29%	47% (21%)	44%
Father low + mother high (n = 25)	1.9 (0.42)	3.9 (0.90)	40%	39% (20%)	34%
Father low + mother middle (n = 74)	2.2 (0.30)	5.0 (0.74)	43%	54% (37%)	48%
Father low + mother low (n = 147)	3.9 (0.28)	8.9 (0.81)	24%	36% (15%)	31%

* percentage of children with 100% complete dental care (restorative and extractions)

Table 9.3. presents the family POS of families where father's and mother's occupational status were classified as high, middle or low and combined in 9 different categories, together with the dmft/s, the percentage of caries free children and the care and restorative index. Broadly speaking the dmft/s was lower and the percentage of caries free subjects was higher in children with parents, especially the father, belonging to a high social class. The mean values for the dmft/s between the several occupational groups were significantly different ($P < 0.001$). The mean dmft and dmfs were lowest for the most advantaged children (1.3 / 2.7) and finished threefold higher in the least advantaged children (3.9 / 8.9). The prevalence of caries-free children was 2.5 times higher among the highest POS families than among the lowest POS families.

The differences in care and restorative indices were significant at the 0.05 level. There was a trend towards a reducing index on moving from the most affluent to the most deprived categories. The number of children in which complete dental care (restorative and extractions) had been provided was more than twice as high in children with a high socio-economic background than in the most deprived category (33 per cent ↔ 15 per cent).

Table 9.4.: Odds ratio of caries prevalence in 7-year-old Flemish children (dmf dichotomised as dmf = 0 and dmf ≠ 0) and 95% confidence interval for the different POS groups derived from logistic regression analysis (occupational level 1 was used as reference group)

Social Class	***Based on fathers' occupational level*** (n = 1420)			***Based on mothers' occupational level*** (n = 1343)		
	odds ratio	95% CI	*P*-value	odds ratio	95% CI	*P*-value
Professional (1)	1			1		
Managerial (2)	1.3	0.9-2.0	= 0.16	2.3	1.3-4.4	<0.01
Skilled non manual (3)	1.7	1.2-2.6	<0.01	2.6	1.4-4.8	<0.01
Skilled manual (4)	2.4	1.6-3.6	<0.001	2.9	1.5-5.6	<0.01
Semi-skilled (5)	3.0	1.7-5.1	<0.001	5.8	2.6-12.7	<0.001
Unskilled (6)	5.5	3.2-9.3	<0.001	6.0	2.8 -12.5	<0.001
Armed Forces (7)	0.8	0.2-2.6	= 0.7	1.1	0.1-13.7	= 0.9
Unemployed –retired (8)	1.9	0.8-4.7	= 0.1	6.4	3.3-12.3	<0.001

Comparisons of group specific values in terms of relative excess risk for caries, expressed in odds ratios, were computed by means of logistic regression (caries versus non-caries) and presented in table 9.4. For these analyses the group with the highest occupational level was taken as reference category. In a model adjusted for the stratification factor province, the excess risk for caries in children increased with decreasing social level. The odds ratios were considerably increased for families with unskilled fathers (or = 5.5) and semi-skilled (or = 5.8), unskilled (or = 6.0) or unemployed (or = 6.4) mothers.

Table 9.5.: Odds ratio of caries prevalence in 7-year-old Flemish children (dmf dichotomised as dmf = 0 and dmf ≠ 0) and p values for the different POS groups with different oral health related behaviour derived from logistic regression analysis (the highest occupational level with the best oral health related behaviour was used as reference group)

SES mother	***Start brushing before the age of 2***	***Start brushing from the age of 2***	***Brushing more than once a day***	***Brushing once a day***	***Brushing less than once a day***	***Less than 2 between meal snacks***	***More than 2 between meal snacks***	***Regular use of fluoride supplements***	***No Regular use of fluoride supplements***
High	1	1.86*	1	1.43	2.29*	1	1.61*	1	1.92*
Middle	1.50	2.18**	1.46	1.76**	1.61	1.42*	1.52*	1.25	1.78*
Low	3.14**	4.82***	3.36***	3.67***	4.65***	2.39***	6.60***	2.42***	3.78***
SES father									
High	1	2.20*	1	1.46	1.26	1	1.23	1	2.21**
Middle	3.79**	3.16***	1.78*	2.12***	2.86***	1.64**	2.21***	1.82**	2.34***
Low	1.16	5.91***	3.17***	3.10***	4.59***	1.80*	4.64***	2.19**	5.44***

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

The most relevant behavioural factors associated with caries activity in 7-year-old Flemish children (Vanobbergen *et al,* 2000) were linked to the different socio-economic groups, assessed by occupational level of both parents (table 9.5). These factors were ‘age at start of brushing’, ‘frequency of brushing’, ‘number of between meal snacks’ and ‘regular use of fluoride supplements’.

Looking at the results two important observations can be made: (1) a cumulative negative effect of decreasing occupational level of both parents and reported unfavourable oral health related behaviour on caries risk in children and (2), surprisingly, a remaining negative effect of occupational level of both parents, even in cases with reported good oral health related behaviour.

Table 9.6. : Differences in mean dmft (SEM), percentage of caries free children, percentage of families with the lowest social classification and unemployment level according to province, ranged from east to west.

Province	***Mean dmft*** (n = 1325)	***% caries free*** (n = 1325)	***% lowest social class families*** (n = 1325)	***Unemployment level (national data)***
Limburg	2.91 (0.095)	41.1%	26.6%	2.54%
Fl. Brabant	2.19 (0.077)	44.1%	9.4%	1.42%
Antwerp	2.15 (0.072)	44.8%	8.8%	1.87%
East-Flanders	1.95 (0.070)	47.1%	9.9%	1.88%
West-Flanders	1.80 (0.068)	49.5%	6.3%	1.05%
P-value	< 0.05*	= 0.41	< 0.01	

* Kruskal-Wallis

The association between caries experience and the geographical distribution of 7-year-olds in Flanders observed in previous studies was confirmed in the present study, with a decrease of the caries prevalence from the east to the west of the country (59% - 50%). To find a correlation between the SES index and the geographical distribution, for the five different provinces the percentage of families with both father and mother belonging to the lowest social classification was calculated within families with full available data (n = 1325), combining occupational status of both parents (table 9.6). A significant difference between the provinces was observed ($P < 0.01$) with a decreasing percentage of low POS families from the east to the west. The latter was confirmed by the national data of unemployment, based on reported percentages of persons drawing unemployment benefits since at least one year.

Discussion

For lack of data on ward level in Flanders to assess socio-economic backgrounds of children, the present study was based on data recorded at an individual level, namely the occupational level of the parents. SES and social class however are complex concepts and are determined by occupation and many other factors. The use of other indicators could have produced slight different results. Some limitations inherent in this measure (POS) are changes over time, particularly in early adulthood (the age group of parents in this study) and a lack of differentiation among different types of "non-employed" who have different socio-economic realities. Consequently, special attention has to be paid to the effect of different occupational groups within one category. For instance one of the most favourable combinations, beside the group with both 'high occupational level' parents, seems to be 'father high + mother low'. Children in this category present the lowest dmft (1.3) and dmfs (2.5) and 59 per cent of them are caries free. This group combines fathers with a high occupational status (categories 1 and 2) and mothers belonging mainly to the occupational group of housewives within category 8. On the other hand, low categorised mothers in combination with middle and low categorised fathers mostly belong to the unskilled (category 6) and the unemployed occupational group within category 8. Their children presented the highest dmft (3.2 and 3.9) and dmfs (8.1 and 8.9) scores.

The results of the present study assume a relation between regional differences in caries prevalence and the socio-economic environment of children. One could suppose a confounding effect due to differences in fluoridation of drinking water as reported in different recent studies (Jones and Worthington, 1999; Locker, 2000). Although the highest concentration of fluorides in the drinking water was found in the most westerly province and the lowest fluoride levels in the most easterly province, fluoride levels in drinking water do not reach a therapeutic level in Flanders and do not differ significantly within and between the different regions (range 0.1 – 0.37 ppm).

In the Netherlands (The Hague) differences in oral hygiene between SES groups were supposed to be related to differences in caries experience (GJ Truin *et al.,* 1998). In Flanders differences in oral health related behaviour and socio-economic determinants have a clear cumulative effect on the caries risk in 7-year-olds, but oral health related behaviour cannot explain differences in oral health between the SES groups. These findings allow on one hand the emphasis on the weakness of individual oral health related knowledge and behaviour in determining oral health and on the other the need for community preventive measures, such as water fluoridation, to support oral health education, especially in regions with predominantly a low social class population.

Although there is only one type of oral health care delivering system in Belgium, covering the whole country, a report on 3237 Belgian schoolchildren, published in 1991 (W D'Hoore and JP Van Nieuwenhuysen, 1991) concluded that the system of dental care does not favour equity nor maintenance of dental health, due to the difference in access to oral care and differences in the quality and quantity of oral care between the different social classes.

Conclusion

The results of the present study allow a suppososition that social inequalities in oral health in Flanders really exist. Despite the methodological differences between studies conducted elsewhere in Europe our results agree on showing the inverse relationship between social status and dental caries. Regional differences in oral health are correlated with regional differences in social classes. Oral health related behaviour is linked to social inequalities and acts as a cumulative risk factor for dental caries.

One of the main objectives in the future should be to stop the huge discrimination against social deprived groups in the community, which is unacceptable and unethical. For this purpose reasons for the relation between social deprivation and dental health have to be understood. Different explanatory patterns will be applied and further analyses are planned to explore the interactions between personal and social factors and to analyse the causes of inequalities in oral health and their associated risk factors in a longitudinal perspective.

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Chapter 10: Dental health, reported behaviour and socio-demographic characteristics of Flemish and Scottish children.

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Abstract

The aim of this collaboration was to compare dental health in children from two provincial cities in Scotland and Belgium, and to investigate the contribution of health behaviour and socio-demographic characteristics as explanatory variables.

Representative samples of 152 children from Dundee, Scotland and 261 children from Gent, Belgium were examined at age 7 and again at age 10. Examinations for dental caries and oral cleanliness were undertaken to the same diagnostic criteria. Parents (or guardians) in both cities completed structured questionnaires with the same questions to obtain information on family background and oral health behaviour.

There was a significant difference in the proportion of children with no caries experience in deciduous teeth at age 7, with 46% in Gent, compared with 22% in Dundee. There was a marked difference in the numbers of extracted teeth, with those in Dundee having a mean of 1.82 extracted teeth compared to 0.08 in Gent. This trend continued in the permanent teeth at age 10. Children in Gent had significantly better oral cleanliness than their counterparts in Dundee despite Dundee children having better reported oral hygiene habits. In both communities, the most important explanatory factor for an increase in DMFT between 7 and 10 was deciduous caries at age 7.

In both communities, deciduous caries experience remains the most important explanatory variable of caries in permanent teeth, although enhanced cleanliness and use of fluoride either in toothpaste or as supplements, are key moderators of risk.

Introduction

In 1994, a cross-sectional study entitled “Children’s Dental Health in Europe” (CDHE) was established. In this study, eight countries participated and representative samples of around 200 children aged 5 and 12 years were included. As part of the preparative work, inter-country calibration of the dental examiners was undertaken (Bolin *et al.*, 1995). In Belgium the sample was drawn from the city of Gent and surrounding areas and in Scotland from the city of Dundee. Both Gent and Dundee are university cities, and North Sea ports. Gent has a population of around 227 000 inhabitants, and Dundee approximately 145 000. In both areas, levels of fluoride in the drinking water are below levels expected to generate a benefit to dental health (in Dundee at 0.01 ppmF^- and in Gent between 0.10 and 0.16 ppmF^-).

In Dundee, the sample of 5-year-old children has been followed longitudinally for 5 years providing further data on dental health and related information at 7 and 10 years. In Flanders, parallel to the CDHE study, the Signal Tandmobiel® project was established (Vanobbergen *et al.*, 2000). This six year longitudinal programme incorporating a health education component commenced in 1996 with children aged 7 years. The dental examinations have been conducted following the published criteria used in surveys co-ordinated by the British Association for the Study of Community Dentistry (BASCD). The same criteria have been used in the longitudinal study conducted with the Dundee children (Mitropoulos *et al.*, 1992; Pitts *et al.*, 1997). In addition, research interchange continued between Flanders and Scotland as part of the Academic Research Collaboration Programme funded by the British Council and the Flemish Fund for Scientific Research. The aim of this collaboration was to elucidate similarities and differences between child dental health in both countries and to investigate key explanatory variables. Therefore, this paper presents comparative data on dental health, reported health behaviour and socio-demographic characteristics of Flemish and Scottish children.

Materials and Methods

The populations and samples

In Dundee, the population comprised all 5 year olds attending state-funded schools and a representative sample was drawn using a 2-stage sampling method for the 1993 CDHE study (Bolin *et al.*, 1996). The children were born in 1988. A subsample was re-examined in 1995 at age 7 and in 1998 age 10 years (n=152).

In Flanders, a 7% sample of the population of children born in 1989 was drawn for the Signal Tandmobiel® project using a stratified cluster sampling technique. The children were drawn from all school types. All schools are state-funded in Belgium, but some have a different tradition and also have a small element of parental co-funding. From this sample, a sub-sample was drawn comprising all children living in the Gent area. This resulted in a sample of 261 children. The children were examined at age 7 and annually to age 10.

Dental Examinations

Dental caries

At both sites, the dental examinations have been conducted following the published criteria (Pitts *et al.*, 1997) used in surveys co-ordinated by the British Association for the Study of Community Dentistry (BASCD). In Gent, 7 examiners were involved. These examiners had been trained and calibrated in the method prior to each examination. In Dundee, the same single examiner (C.P.) conducted all the dental examinations.

Children were examined on school premises. In Dundee, portable dental equipment was taken into schools and in Flanders, a mobile dental unit was used. Examinations were conducted using an overhead operating light, a plane mouth mirror and a WHO CPITN type E probe. No radiographs were taken and caries was recorded at the dentinal level of involvement (D_3).

Plaque examinations

Similar plaque examinations were conducted in both centres when the children were aged 10 years. The plaque examinations were designed to reflect oral cleanliness and therefore a visual assessment was made of the presence or absence of plaque on buccal surfaces of index teeth comprising first permanent molars and central incisors.

Methods to capture data on socio-demographics and reported oral health behaviour

A structured questionnaire was designed in order to obtain information on family background and oral health behaviour. This questionnaire was given to the children to take home to be completed by their parents or guardians. The same questions were used in both countries and issued in the home language. The questionnaire sought information on parental occupation, child oral hygiene habits, use of fluoride (both topical and systemic), dietary habits and dental attendance.

Information on parental occupation was transformed into categories of social class using the Registrar General's Classification of Occupations (1990). This was undertaken for both mothers and fathers separately. In Dundee, parents provided information on the postal code of their home address. This was used in conjunction with a postcode look-up file to generate a small area classification of material deprivation commonly used in Scotland, DEPCAT (Carstairs and Morris, 1991). This divides areas into 7 broad groupings of similar areas using data from the decennial UK census. The DEPCAT index is composed of four variables, namely, the proportions of households within a postcode area in which households are overcrowded, without a car, and with head of households in unskilled occupations or unemployed. In Flanders, small area statistics such as this are not available.

Statistical Analysis

In Flanders, data was recorded at the chairside directly into a laptop computer using the Dental SurveyPlus programme. An SPSS output file of key variables was generated. In Dundee, data was recorded onto schematised charts and entered into a database using

SPSS data entry. The SPSS files were merged into a single data file. Examiner reliability in the detection of dental caries was tested using Kappa statistics. Descriptive statistics were generated and are shown in tables 10.1. to 10.4. The differences between the samples in caries experience and oral cleanliness were tested using Pearson's chi-squared test (0.05). Stepwise logistic regression was used to model the effects of various factors on caries in the permanent teeth developing between the examinations at ages 7 and 10. Separate models were generated for Gent and Dundee.

Results

Examiner reliability

In Gent, where 7 dentists were involved in the examinations, intra- and inter-examiner agreement was excellent ($\kappa>0.8$). In Dundee, where one dentist conducted all examinations, intra-examiner agreement was also excellent ($\kappa>0.8$)(Landis and Koch, 1977).

Sample characteristics and dental health of the Flemish and Scottish children

The same children were examined on two occasions 3 years apart in both cities, at age 7 and again at age 10. Analyses of the disease data by school type in Belgium showed that there were no significant differences and therefore the data was pooled for all subsequent analyses. In Dundee, 152 children in 14 schools were examined and in Gent 261 children in 9 schools. The mean ages and gender distribution are given in Table 10.1. In Dundee, the dmft at 7 was 4.07 (median = 4; range = 14; interquartile range = 6) but in Gent was only 2.00 (median = 1; range = 11; interquartile range = 3). At both 7 and 10 years, missing deciduous incisors are not included in the extracted component.

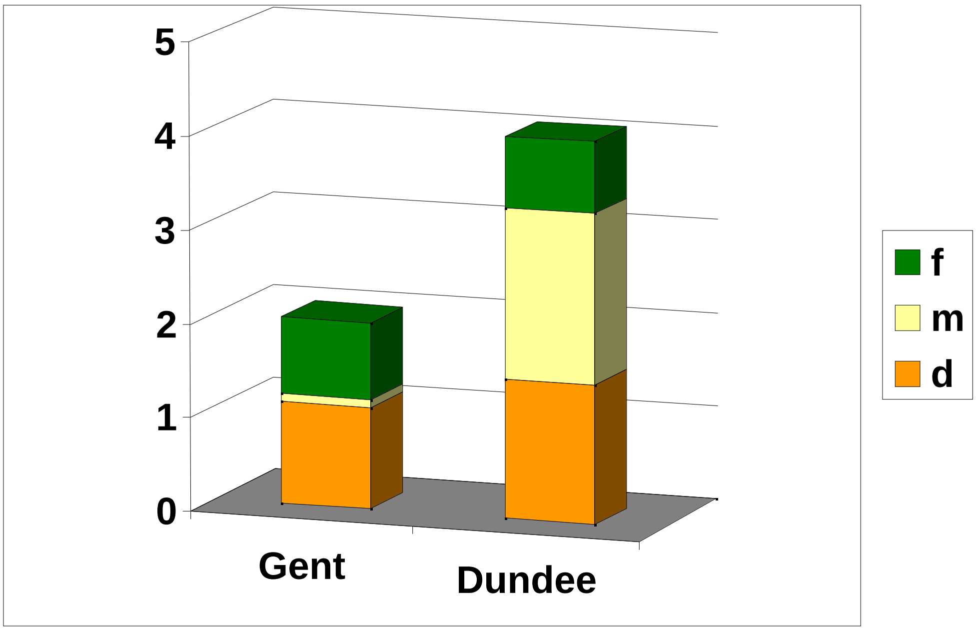
Table 10.1: Sample Characteristics of the Flemish and Scottish children : number of children, gender distribution, mean age, caries experience, presence of fissure sealants and levels of oral cleanliness.

	Dundee		***Gent***	
Number of children	152		261	
Gender (M/F%)	51/49		44/56	
	At age 7	**At age 10**	**At age 7**	**At age 10**
Mean age (s.d.)	7.3 (0.3)	10.2 (0.3)	7.3 (0.3)	9.9 (0.3)
Deciduous teeth				
dmft (SEM)	4.07 (0.28)	3.49 (0.23)	2.00 (0.16)	1.74 (0.14)
dt (SEM)	1.49 (0.14)	1.34 (0.13)	1.09 (0.12)	0.62 (0.08)
mt (SEM)	1.82 (0.22)	1.66 (0.20)	0.08 (0.02)	0.22 (0.04)
ft (SEM)	0.76 (0.11)	0.49 (0.08)	0.83 (0.10)	0.89 (0.10)
dft (SEM)	2.25 (0.19)	1.83 (0.15)	1.92 (0.16)	1.52 (0.13)
dmfs (SEM)	13.07 (1.13)		4.57 (0.43)	
dfs (SEM)		3.73 (0.36)		2.77 (0.27)
ds (SEM)	2.62 (0.29)	2.74 (0.31)	2.40 (0.31)	1.08 (0.16)
fs (SEM)	1.34 (0.21)	0.99 (0.17)	1.67 (0.22)	1.69 (0.21)
% of children without caries experience (at D_3)	22**		46**	
Permanent teeth				
DMFT (SEM)	0.15 (0.04)	0.94 (0.12)	0.17 (0.03)	0.57 (0.07)
DT (SEM)	0.06 (0.02)	0.50 (0.07)	0.11 (0.02)	0.18 (0.04)
MT (SEM)	0.01 (0.01)	0.15 (0.05)	0.00 (0.00)	0.03 (0.02)
FT (SEM)	0.08 (0.03)	0.29 (0.05)	0.05 (0.02)	0.36 (0.05)
DMFS (SEM)		1.82 (0.32)		0.82 (0.12)
DS (SEM)		0.65 (0.11)		0.19 (0.04)
MS (SEM)		0.76		0.13 (0.08)
FS (SEM)		0.41 (0.08)		0.49 (0.08)
% of children without caries experience (at D_3)	89	60*	88	71*
% with one or more fissure sealants	30**	57**	4**	14**
Oral cleanliness : % with no plaque on index teeth		13**		45**

* P =0.015
** P <0.001

The mean number of fillings in deciduous teeth was very similar at 0.76 for Dundee and 0.83 for Gent. Decayed teeth were marginally higher in Dundee (1.49 v. 1.09). However, there was a large difference in the number of extracted teeth (1.82 v. 0.08). This is displayed graphically in Figure 10.1.

Figure 10.1.: Caries experience on deciduous teeth at age 7 in Flemish and Scottish children (mean values)



These differences are reflected at the surface level and in the percentage of children without caries experience (at the D_3 level). More than twice as many children in Gent (46%) were without caries experience as in Dundee (22%). By age 10 years, the dmft reduces in both samples as teeth are shed. However, the same trend of extractions being the principal mode of treating deciduous caries in Scottish children continues. At age 7 in Dundee, the mean number of extracted teeth is more than twice the mean of filled teeth. By 10 years, the mean number of extracted teeth is more than three times the level of fillings in Dundee's children. In Dundee at 7 years, fillings were 19% of the dmft and only 14% at age 10. In contrast, in Gent, fillings were 42% of the dmft at 7 and 51% by age 10.

At 10 years, the mean DMFT was 0.94 in Dundee (median = 0; range = 8; interquartile range = 2) and 0.57 in Gent (median = 0; range = 4; interquartile range = 1). Although considerably lower disease levels are present in the permanent teeth at this age, the trend for a higher level of extractions in Dundee is still present, with 16% of the DMFT being accounted for by extractions in Dundee compared to less than 5% in Gent. At surface level, 36% of the DMFS are decayed surfaces in Dundee and 23% in Gent. The proportion of the caries experience on permanent teeth which is filled is 61% in Gent, nearly three times that of Dundee (23%). The percentage without caries experience is similar (88% and 89%) at 7 years when extractions make a negligible contribution. However, by 10 years a difference in the two communities is apparent with 60% unaffected in Dundee compared to 71% in Gent. The level of fissure sealants was significantly higher in Dundee children at both 7 and 10 years (Table 10.1.).

At 10 years of age, significantly more children in Gent had cleaner mouths with 45% having no plaque on index teeth compared to only 13% of Dundee children (P <0.001).

Dental health, parental occupation and material deprivation

Information on parental occupation from both communities was transformed into categories of social class using the UK Registrar General's Classification of Occupations (1990). Three categories were formed: high social levels (classes I and II); low social levels (classes III-V); and, a third group comprising children where classification was not possible because parents were unemployed or data was missing or unclear.

The dental health of the children according to the occupational status of the mother is presented in Table 10.2. In both Dundee and Gent children in lower social classes had more decayed and extracted teeth, and in Gent more filled teeth. Taking the whole index, mean dmft at 7 were at least twice as high in children with mothers from lower social classes from Gent and from Dundee. Similar results were found for mean DMFS at age of 10. In addition, a similar trend, although less pronounced, was seen for occupational status of the father (data not presented). The dental health of children with missing parental occupation data from families in both communities was similar to that of children from the lower social groups. However, because of the large numbers of missing data for these variables, they were not included in the multivariate analysis.

Table 10.2.: Dental health of the children according to the occupational status of the mother

	Dundee				***Gent***		
Mother's occupation	***Mean (SEM) of components of deciduous caries experience at age 7***			***Mother's occupation***	***Mean (SEM) of components of deciduous caries experience at age 7***		
	dt	**mt**	**ft**		**dt**	**mt**	**ft**
I, II (n=25)	1.12 (0.37)	0.44 (0.20)	0.92 (0.29)	I, II (n=55)	0.44 (0.14)	0.05 (0.04)	0.42 (0.18)
III – V (n=74)	1.47 (0.20)	2.14 (0.36)	0.84 (0.19)	III – V (n=72)	1.10 (0.22)	0.13 (0.05)	0.71 (0.16)
No classification (n=53)	1.68 (0.25)	2.04 (0.37)	0.58 (0.13)	No classification (missing=111 and unemployed=23)	1.35 (0.18)	0.07 (0.03)	1.07 (0.16)

In Dundee, children's dental health could also be compared on an area measure of material deprivation, i.e. according to DEPCAT. Dental health comparisons yielded a picture comparable to the information presented in Table 10.2. The mean dmft at 7 was 2.53 in children in DEPCATs 1 and 2, the most affluent areas, compared with 4.53 in children in DEPCATs 3 to 7, the more deprived areas. As with differences in disease experience expressed by maternal occupation, a key reason for the difference in caries experience was that children in DEPCATs 1 and 2 (n=34) had few extracted teeth, with a mean of 0.29 (SEM = 0.15) compared to those in the poorer areas of DEPCATs 3-6 (n=116) who had a mean of 2.27 (SEM = 0.09) extracted teeth. This trend continued in DMFS at 10.

In Flanders similar small area statistics on comparative material deprivation are not available.

Reported oral health behaviour

Missing data from the questionnaires in Gent was between 1 and 3%. In Dundee, this was more variable and missing data was found for a maximum of 14% of cases.

Information concerning the age of commencement of toothbrushing and age when fluoride toothpaste was first used was asked of Dundee parents when their children were aged 5 and again at 10 years. 70% of parents gave the same age on both occasions. Of the 30% giving different ages of commencement, most reported older commencement ages when asked at 10 years giving an over-estimation. In Flanders, this question was asked only at 7 years. This recall bias found in Dundee would tend to further increase the observed differences in age reported in Table 10.3.

More parents of the Dundee children reported tooth brushing at least twice daily (66%) compared to parents of the Gent children (38%). Most parents reported that their children used a fluoridated toothpaste in both countries. Table 10.4. presents a comparison of the caries experience by reported frequency of toothbrushing. Children who reportedly brushed less than once a day had the worst dental health in both communities. In general, those who brushed more than once a day had the best dental health.

There was little difference in the reported frequency of between meal snacks (Table 10.3.). However, there were important differences in reported behaviour in relation to regular consumption of breakfast and the type of snacks taken to school (Table 10.3.). In Dundee, only 51% of children ate breakfast daily compared to 73% in Gent. Many children in both Dundee and Gent took a sweet snack to school, however in Dundee this was likely to be in the form of sweets (28% v. 2%) and in Gent it was biscuits (48% v. 8%).

Recent dental attendance at 10 years was common in both countries with parents reporting that at least 80% of children attended in the previous year.

Table 10.3.: Reported oral health behaviour from questionnaires to parents (and guardians) of Scottish and Flemish children

	Dundee	*Gent*
Oral Hygiene habits		
Age commenced toothbrushing Mean (s.d.) (yrs)	1.6 (1.1)	2.6 (1.1)
Frequency of toothbrushing at 10 yrs < daily daily ≥ 2 daily	 9 25 66	 14 48 38
Use of fluoride		
Age commenced using fluoride toothpaste mean (s.d.) (yrs)	1.7 (1.1)	2.9 (1.1)
% using a fluoridated toothpaste at 10 yrs	97	91
% ever using a systemic fluoride supplement	19	68
Dietary Habits (at 10 yrs)		
Mean number of between meals snacks (s.d.)	2.41 (1.05)	2.19 (1.17)
% of children eating breakfast daily	51	73
% of children taking sweets to school daily	28	2
% of children taking biscuits to school daily	8	48
Dental attendance		
Last dental visit at age 10 (%) Check-up at school Check-up at the dentist > 1 year ago < 1 year ago < 6 mths ago	 5 1 13 68	 9 6 24 62

Table 10.4.: Caries experience according to the frequency of reported toothbrushing in children at age 7 and at age 10 years (mean and SEM)

	Gent			***Dundee***		
	n	***dmfs at 7***	***DMFS at 10***	***n***	***dmfs at 7***	***DMFS at 10***
Brush < once per day	37	7.54 (1.54)	1.03 (0.30)	12	17.08 (3.61)	2.83 (1.00)
Brush once per day	123	3.81 (0.50)	0.84 (0.14)	33	13.55 (2.32)	2.12 (0.94)
Brush > once per day	98	4.48 (0.75)	0.73 (0.25)	87	11.40 (1.48)	1.41 (0.35)

Caries development in the permanent dentition between 7 and 10 years

Table 10.5. summarises a comparison of dental health data and reported oral health behaviour between children whose DMFT increased and those whose DMFT remained the same between the examinations at age 7 and 10 years, both for Dundee and Gent children. Children in both samples with an increase in DMFT-score between the examinations at 7 and 10 years had a higher caries experience in the primary dentition, reported less favourable oral hygiene habits, and were less likely to have received a systemic form of fluoride supplementation. Dental visits tended to be less regular (Gent) or were more likely to take place at school (Dundee).

Multivariate Analysis

Stepwise logistic regression was used to model the effects of various factors on caries in the permanent teeth developing between the examinations at ages 7 and 10. Separate models were generated for Gent and Dundee. The variables used as possible predictors were gender, deciduous caries experience at age 7, presence of plaque on index teeth, age at start of brushing, age fluoride toothpaste was first used, frequency of brushing, use of systemic fluoride, number of between meals snacks, whether breakfast was eaten every day, whether biscuits or sweets were taken to school regularly, and in Dundee only, the examiner’s classification of each child’s oral cleanliness as good, fair, or poor.

Table 10.5.: A comparison between children whose DMFT increased and those whose DMFT remained the same between 7 and 10 years in Dundee and in Gent

	Dundee		Gent	
DMFT between 7 and 10	***No change***	***Increase***	***No change***	***Increase***
Number of children	92 (61%)	60 (39%)	195 (75%)	66 (25%)
Dental Health				
dmft at 7 years(SEM)	3.09 (0.34)	5.58 (0.41)	1.54 (0.17)	3.36 (0.36)
% children with Fissure Sealants at age 10	58.7	53.3	13.3	20.0
Oral cleanliness at age 10 - % with no plaque on index teeth.	15.2	10.0	49.2	33.3
Oral hygiene habits				
Age commenced toothbrushing mean (s.d.) (yrs)	1.41 (1.03)	1.98 (1.13)	2.54 (1.07)	2.99 (1.21)
Frequency of toothbrushing at 10 yrs				
< daily	5	16	11	20
daily	25	25	47	52
≥ 2 daily	70	59	42	28
Use of fluoride				
Age commenced using fluoride toothpaste mean (s.d.) (yrs)	1.53 (0.98)	2.01 (1.21)	2.89 (1.09)	3.18 (1.21)
% using a fluoridated toothpaste at 10 yrs	98	96	93	86
% ever using a systemic fluoride supplement	27	14	70	61
Dietary Habits (at 10 yrs)				
Mean number of between meals snacks	2.32 (0.93)	2.55 (1.23)	2.22 (1.24)	2.10 (0.95)
% of children eating breakfast daily	52	49	75	69
% of children taking sweets to school daily	27	31	3	0
% of children taking biscuits to school daily	9	6	50	41
Dental attendance				
Last dental visit at age 10 (%)				
Check-up at school	2	12	11	3
Check-up at the dentist				
> 1 year ago	1	0	4	11
< 1 year ago	12	20	24	25
< 6 mths ago	84	67	62	61

In both models, dmfs at 7 was a strong explanatory variable yielding an odds ratio of 1.05 for an increase of dmfs-score of one unit in Dundee, and 1.09 in Gent. The variables measuring the level of oral cleanliness and age at start of brushing also contributed to both models, underlining the importance of oral hygiene. Use of a systemic fluoride supplement was significant only in the Dundee sample. The Nagelkerke R-squared statistic, which is an estimate of the proportion of variation in the objective variable explained by the model, was 0.32 for the Dundee model, and 0.15 for the Gent model (Table 10.6.).

Table 10.6.: Multivariate Analyses to define the contribution of explanatory variables to the increase in DMFT between 7 and 10 years in Dundee and in Gent: Results of the Stepwise Logistic Regression

Dundee			***Gent***		
Step, Variable	***Nagelkerke R-squared***	***Odds Ratio (95%CI)***	***Step, Variable***	***Nagelkerke R-squared***	***Odds Ratio (95%CI)***
1, dmfs at 7	0.18	1.05 (1.02-1.09)	1, dmfs at 7	0.09	1.09 (1.03-1.55)
2, age at start of brushing	0.25	1.59 (1.03-2.45)	2, plaque present at age 10	0.12	2.04 (1.00-4.15)
3, oral cleanliness level at age 10	0.29	2.73* (1.15-6.45)	3, age at start of brushing	0.15	1.36 (1.00-1.87)
4, systemic fluoride	0.32	2.81** (0.90-8.77)			

* those with fair or poor oral cleanliness: 2.73 times more likely to have DMFT>0
** those who never used systemic fluorides: 2.81 times more likely to have DMFT>0

Discussion

This report presents similarities and differences between child dental health in two countries and investigates some possible explanatory variables. Longitudinal data were available from two comparable cities, Dundee (Scotland) and Gent (Flanders), where a representative sample of children was examined at the same ages (7 and 10 years). Comparisons were possible since the same examination method was used for the clinical part and the same questionnaire on oral health habits (completed by the parents) was used at age 10.

Caries experience was expressed using dmft/DMFT-scores. Traditionally, mean values and standard deviations are used in dental epidemiology to describe the distribution of caries experience scores in the sample of children examined. These measures are only appropriate when a normal distribution is present. Since nowadays caries distribution is strongly skewed, it is more descriptive to use median values (together with range). As in previous reports in this report both measures are presented. Means are presented with their Standard Error of the Mean, indicating the precision of the estimate.

Although many similarities exist between both cities, important differences in child dental health and reported oral health behaviour were found. Dundee children presented more often with caries experience and had higher dmft scores (both at 7 and at 10 years) than their Flemish counterparts. They also had more untreated disease and much higher extraction levels. In the permanent dentition a comparable picture was seen with more Dundee children being affected and the same trend of higher DMFT-scores and higher levels of extractions. As well as a higher disease level in Dundee, there is clearly also a different treatment approach reflected by the low number of fillings (restorative treatment) and high number of extracted teeth. Neither costs of dental treatment to patients nor fees paid to dentists are likely to be contributory factors in the selection of extractions rather than fillings. In Belgium, there is no refund for extracting teeth, and in Scotland, under the capitation system that was in place between 1990 and 1996, there was a single fee for the dental care of children that changed with age rather than treatment modality. In addition, all dental care is free for children under the National Health Service in Scotland. The preference for extraction of deciduous teeth in Dundee is more likely to reflect a cultural norm, particularly amongst disadvantaged families. Furthermore, because the majority of these teeth will have been extracted under general anaesthesia, a more radical extraction pattern is favoured. In this case, deciduous molars which are sound or with small carious lesions may also be extracted “to balance” extractions of other very carious molars in opposing quadrants. This practice may tend to an over-estimation of caries experience as measured by the dmft index. In fact, inspection of Figure 10.1. shows that the dt and ft components of children in Dundee and Gent are similar and it is the large difference in the number of extracted teeth that is at the heart of the difference in “disease experience”.

The number of fissure sealants provided was higher in Scotland compared to Gent.

This difference was already apparent at the age of 7 years. Historically, Scotland has had the highest rates of sealant provision in Great Britain. Some are paid for privately by parents, but most are provided at no additional cost by the Community Dental Service, or under general dental practice capitation. In both Dundee and Gent children more sealants were found in the most caries-active children. However, data presented in table 10.4. leads to the conclusion that the application of sealants seems to have only a minimal impact on further caries development in these children.

In this survey, information was obtained using structured questionnaires that were completed by the parents of the children. The use of questionnaires possibly results in a more positive picture than the actual situation since parents tend to answer in a social positive way. Marked differences were found in reported oral health behaviour. Dundee children, although presenting higher disease levels than Gent children, had more positive oral hygiene habits: they began toothbrushing at a younger age, brushed more regularly and more frequently and began using a fluoridated toothpaste at a younger age. Flemish children received more systemic fluoride supplements, ate breakfast more regularly and took less often sweets to school on a daily basis. In spite of more positive reported oral hygiene habits, Dundee children had considerably more plaque on their teeth. This could reflect differences in the quality of the brushing but could also be explained by differences in plaque formation rates (Simonsson *et al.*, 1987), possibly induced by dietary habits (more frequent consumption of carbohydrates) or differences in composition of plaque microflora (Reich *et al.*, 1999).

In both cities inequalities in oral health were present when results were analysed according to social class and deprivation level indicators. Although the dental health situation of the children differed considerably between both cities, the impact of socio-economic factors remained important. Deciduous caries experience remains the most important explanatory variable of caries in permanent teeth, although enhanced cleanliness and use of fluoride either in toothpaste or as supplements are key moderators of risk. In conclusion, differences in deciduous caries experience between Dundee and Gent were compounded by differences in dentist treatment modalities with many more deciduous teeth extracted in Scottish children.

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Chapter 11: The value of a baseline multiple caries risk assessment model in the primary dentition for the prediction of caries incidence in the permanent dentition.

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Abstract

To establish a reliable screening method for caries prediction and to identify predominant risk factors, this study tested whether a cross-sectional caries risk model assessed at the age of 7 could be used to predict future caries onset in the permanent first molars at the age of 10 in 3303 children born in 1989. As prediction variables, assessing the believed risk, baseline data at age 7 on oral health status, oral hygiene level, oral health behaviour and socio-demographic factors were used. The assessment of the real risk, based on data collected for the first permanent molars during the follow-up, was performed using different approaches. Cumulative incidence during the 3-year observation period was 31.6% and ranged from 22.4% in the believed low risk group to 43.2% in the believe high risk group. A stepwise logistic regression analysis was performed with net caries increment as outcome measure and adjusted for the real time at risk, using eruption times of the involved teeth. The baseline dmfs ($P < 0.001$) and the occlusal and buccal plaque indices ($P < 0.01$) were highly significant for having a high caries increment in permanent first molars with respectiv odds ratios of 1.07, 1.43 (PlI_O) and 1.35 (PlI_B) for an increase of their value by 1 unit. Brushing less than once a day ($P < 0.001$) and the daily use of sugar containing drinks between meals ($P < 0.05$) were confirmed as risk factors (or respectively 2.43 and 1.25). The logistic regression analysis provided a sensitivity ranging from 59% to 66% and a specificity between 65.7% and 72.8%, which indicates that the risk marker does not have an important predictive power. Even when it is quite plausible and evidence based that different risk indicators, if present, are responsible for an increase in caries incidence, none of the socio-demographic and behavioural variables have enough predictive power at community level to be useful for identifying caries susceptible children. Even the power of dmfs at baseline must be considered modest.

Introduction

The caries decline and the polarised distribution of caries experience drive us to develop a specific strategy to target preventive care or treatment to those individuals or groups identified as being at high risk for future caries development (Spencer, 1997). The development of new and powerful diagnostic and bio-statistical technologies would help us in this identification process. Together, the merging of these considerations forms the rationale for attempting to predict future caries increment by risk models based on longitudinal data (Stamm *et al*., 1991).

The most recent reviews and states of art on caries prediction showed that:

- ❖ Due to the complex and multifactorial etiology of the caries process, multiple risk models are needed to identify important risk factors and their interaction (Hausen, 1997; Beck, 1998).
- ❖ Probable and putative risk factors, detected in cross-sectional studies, need to be confirmed by longitudinal studies (incidence rather than prevalence) (Powell, 1998; Beck, 1998).
- ❖ Clinical variables are stronger predictors than non-clinical variables and past caries experience is the most valuable (Disney *et al.*, 1992; Hausen, 1997, Powell, 1998).
- ❖ Only a weak or no association could be demonstrated for socio-demographic variables (Disney *et al.*, 1992), with the exception of prediction models for young children (Demers *et al.*, 1990; Powell, 1998).
- ❖ When cariogenic bacterial levels are included they only moderately improve the fit of most prediction models (Disney *et al.*, 1992; Hausen, 1997).
- ❖ Logistic regression models using multiple factors and longitudinal data are the preferred analysis (Stamm *et al.*, 1992; Powell, 1998; Beck, 1998).

Caries increment is the primary outcome measure in most longitudinal studies (Slade and Caplan, 2000). There is no general agreement on which factors are most useful in identifying subjects with a high caries risk (FDI, 1988; Holbrook *et al.*, 1993), or which is the best age group to screen at baseline (Demers *et al.*, 1990; Demers *et al.*, 1992; Powell, 1998). Criteria are often determined by practical and theoretical considerations. It is reasonable to predict future caries and caries risk before the onset of any primary caries lesion (Hausen, 1997). On the other hand, from a practical point of view it is more convenient to screen children when they start primary school. A caries screening program for young children at the age of 6 was proposed to be the most economically feasible (Demers *et al*., 1992). Because of compulsory school attendance and the minor chance of moving and migration, children attend mostly the same school during several years between 6 and 12 years of age.

Some limitations in the prediction literature have been observed. Caries incidence is mostly assessed using the caries increment among children attending both the baseline and the final examination, without taking into account the real time at risk. Some authors proposed incidence measures, such as cumulative incidence or incidence density, providing a more sensitive mean of detecting high caries activity or risk (Slade and Caplan, 1999; Slade and Caplan, 2000). Furthermore, with the exception of the North Carolina study (Disney *et al*., 1992) and the Zürich study (Steiner *et al*., 1992), small sample size groups were used to identify high risk groups.

In Flanders (Northern Federal State of Belgium) the Signal-Tandmobiel® project was started in 1996 (Vanobbergen *et al*., 2000). One of the objectives of this 6-year longitudinal project was to determine the oral health condition of primary schoolchildren between the ages of 7 and 12 years, both cross-sectionally and longitudinally. In an earlier cross-sectional study the impact of a set of risk indicators on caries prevalence in the primary dentition of 7-year-old Flemish children was defined. Gender, oral hygiene habits, use of fluorides, dietary habits, geographic factors and parental modelling were evaluated in a multiple model (Vanobbergen *et al*., 2001).

In order to establish a reliable screening method for the prediction of caries and in order to test the validity of risk indicators, identified in cross-sectional studies, the aim of the present study was to evaluate, in a large sample, gradually and longitudinally the caries incidence predictive ability of this baseline risk assessment model with respect to caries development in first permanent molars between the ages of 7 and 10 years.

Material and Methods

The present report is a 3-year longitudinal analysis of Signal-Tandmobiel® data. The general set-up, along with a detailed description of the study sample and research methods used, is presented elsewhere (chapter 5) (Vanobbergen *et al*., 2000). Briefly, data was obtained from Flanders (5900000 inhabitants), where a cohort of schoolchildren, representative for Flemish 7-year-olds (born in 1989) was selected from school data. Over 6000 children (including longitudinal and cross-sectional control groups) were selected using cluster sampling without replacement, stratified by province and educational system. Schools were selected with a probability proportional to their size, i.e. the number of children in the first year. They represented approximately 7% of the total target population. The experimental cohort was followed for a period of 6 years in a prospective investigation (1996-2001).

The selection criteria for the children to be included in the present study were: being born in 1989, belonging to the study group and having no missing covariates for the predictive model. They needed to have been examined at baseline and then at least once more during the following years (second, third or fourth examination). The baseline material consisted of 3303 children, of whom 2691 (81%) remained at the final (fourth) examination. The effective sample size for the present analyses, being the number of children present for at least two examinations, including the first examination, was 3002.

The mean age at baseline and at the fourth (final) examination were respectively 7.07 (SD 0.41) and 9.80 (SD 0.39) years.

Annually each child participated in oral health examinations on school premises in a mobile dental clinic. The dental examinations were conducted following standardised and widely accepted criteria, as recommended by the WHO report on oral health surveys (WHO, 1987). The diagnostic criteria for caries prevalence were these of the British Association for the Study of Community Dentistry (Pitts *et al*., 1997). No radiographs were taken and decay was recorded at the level of cavitation, using a WHO/CPITN type E probe.

In order to register the level of oral hygiene, buccal surfaces of the Ramfjord teeth (primary alternatives) 16(55), 21(61), 24(64), 36(75), 44(84), 41(81) were scored according to the plaque index described by Silness and Löe (1964). Where present, permanent teeth were examined. Plaque on occlusal surfaces of first permanent molars was assessed using a simplified version of the index of Carvalho et al (1989) (chapter 5).

For each year (= examination) and each permanent tooth, the eruption stage was recorded using the following coding:

0 = non erupted or extracted

1 = eruption stage 1: occlusal surface only partially erupted (one cuspid).

2 = eruption stage 2: occlusal surface fully erupted, but less than half of the buccal surface erupted.

3 = eruption stage 3: more than half of the buccal surface erupted, no antagonistic contact.

4 = eruption stage 4: fully erupted and full occlusal contact.

To ensure reliability, attention was paid to an intensive training of the examiners and to a continuing reinforcement of the diagnostic criteria during annual calibration exercises. According to Landis and Koch (1977), for all sixteen dentist examiners involved the level of intra- and inter-examiner agreement obtained was acceptable(kappa > 0.6).

Additional to the clinical examination, data was collected on reported oral hygiene and dietary habits, use of fluorides, dental attendance, medical history and socio-economic background of the children using questionnaires completed by parents and school health care centres. All data was entered directly into a lap-top computer at the site of the examination by a trained recorder.

Variables

The assessment of *the real risk*, was performed using different approaches. Based on data collected for the *four first permanent molars* at each examination ($DMFS_6$-scores), different outcome measures were calculated and compared: net caries increment, cumulative caries incidence and caries incidence density.

Net caries increment was determined for each child by subtracting the baseline $DMFS_6$ score from the last available $DMFS_6$ score.

Cumulative incidence represents the proportion of children who developed new caries within the total observation period. This proportion is calculated by counting the number of children whose caries increment exceeded zero during the observation period, and then dividing by the total number of children.

Caries incidence density represents the average change in caries status per unit time relative to the number of surfaces at risk, in this study based on the eruption stages of the teeth. Incidence density was expressed in newly affected surfaces (increment) per 100 surface years (Slade and Caplan, 2000). For each child the 'real exposure time' or time at risk for the first permanent molars was approximated by an index based on the eruption stage of the teeth and the period under investigation. The index was calculated as the sum of the eruption stages over the 4 teeth (first permanent molars) and over the available observation period.

As prediction variables, assessing *the believed risk*, baseline data on oral health status, oral hygiene level, reported oral health behaviour and socio-demographic factors were used. Baseline oral health status was expressed using the baseline dmfs and baseline oral hygiene level using the plaque index on the occlusal (PlI_O) and buccal (PlI_B) surfaces. Baseline oral health behaviour and socio-demographic factors were investigated in an earlier cross-sectional multiple regression study (Vanobbergen *et al.*, 2001) (chapter 7). Statistical values without random school effect are presented in table 11.1. Based on this model the probability of being affected by caries at the age of 7 ('$score^7$') was determined for each child and used as an indicator for future caries onset. The values of '$score^7$' were normally distributed.

Table 11.1.: Statistical values for significant variables in a cross-sectional multiple logistic regression analysis with dmft (caries versus no caries) as dependent variable in 7-year-olds in Flanders 1996 (n = 3303).

Variable	***Estimate***	***SE***	***P-value***	***Odds ratio***	***95% CI***
Intercept	-3.093	0.647	<0.001	0.04	0.01-0.16
Province					
Antwerp				1	
Limburg (easternmost province)	+0.250	0.114	0.028	1.28	1.03-1.60
W-Flanders (westernmost province)	-0.332	0.109	0.002	0.72	0.58-0.89
Age (years)	+0.317	0.089	<0.001	1.37	1.15-1.63
Frequency of brushing					
≥once a day					
< once a day	+0.229	0.107	< 0.03	1.26	1.01-1.55
Age at start of brushing (years)	+0.199	0.035	<0.001	1.22	1.14-1.30
Regular use of systemic fluoride supplements					
yes				1	
no	+0.437	0.073	<0.001	1.54	1.34-1.78
Daily use of sugar Containing drinks					
no				1	
yes	+0.315	0.074	<0.001	1.37	1.18-1.59
In between meal snacks					
≤ 2 a day				1	
> 2 a day	+0.214	0.078	0.006	1.24	1.06-1.44

This model included gender, educational system and province (stratification variables)

Statistical analysis

In order to quantify the real risk for caries development in first permanent molars in Flemish primary schoolchildren between the ages of 7 and 10, the cumulative incidence was calculated for the whole study group and for three classes of children based upon the quartiles of the risk indicator 'score[7]'. The three classes (< Q1; Q1 – Q3; > Q3), represent a low, a moderate and a high believed risk group. The statistical significance for the difference in cumulative incidence was assessed by a χ_ test.

To evaluate the predictive value of the independent variables, a multiple logistic regression analysis was performed with different outcome measures, both in an ordinal way and dichotomised with different cut-points. The best fitting model (see discussion), as reported in the section 'results', was obtained using net caries increment as outcome measure including the 'real exposure time' as covariate. In agreement with the literature (Hausen, 1997) and considering the distribution, the net caries increment was dichotomised as 0 and 1 additional surface affected (83% of the subjects) versus 2 or more additional surfaces affected (17%). Analyses with either the composite risk indicator 'score[7]' and with the separate variables directly and separately in the model were used. Odds ratios are reported together with their 95% CI . The level of significance was set at $P < 0.05$.

To get an idea of the predictive power different dichotomies were formed so that the selected threshold levels were distributed throughout the range of the independent variables. Such, the artificial dichotomising of both predictor and outcome allowed the generation of 2 x 2 tables. For each level of 'believed high' versus 'believed low risk', the sensitivity, specificity, true positives (TP), true negatives (TN), false positives (FP), false negatives (FN), positive predictive value (PPV) and negative predictive value (NPV) were calculated.

The information in the prediction models was summarised as ROC-curves (receiver operating characteristic curves) and an index called: 'the area under the curve' (A_z). The diagonal line corresponds to a pure chance prediction (0.50), while a perfect prediction is obtained at a value of 1, which means that all members of a high/low risk pair were correctly classified. The analyses were conducted using SAS, version 8 (SAS, 2000).

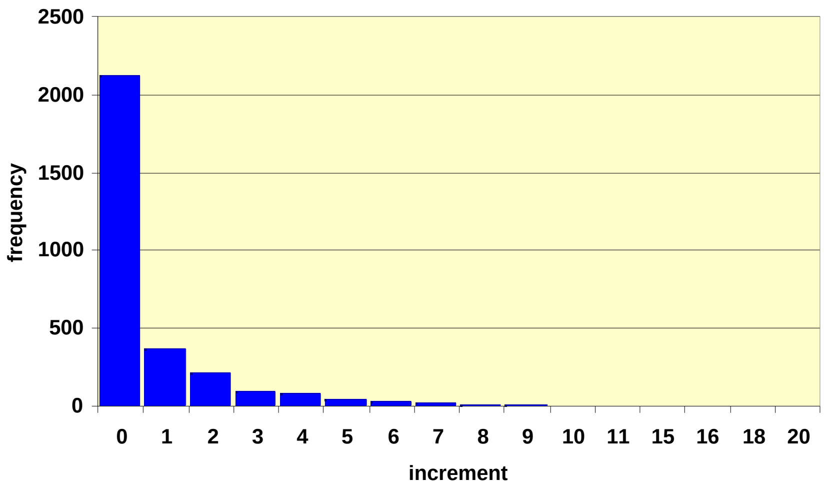
Results

At baseline, 7.8% of the children had not a single erupted first permanent molar and 36% had four fully erupted permanent first molars. Of the 2691 children examined at the final examination, 97.5% had four fully erupted first permanent molars (table 11.2.). The net caries increment ranged from 0 (68.4% of the children) to 20 surfaces (0.1% of the children) over the study period, corresponding with the extreme minimum and maximum of this value (figure 11.1.).

Table 11.2.: Eruption time table of first permanent molars in a cohort of initially 7-year-old Flemish children.

Examination	***n children***	***Mean age (SD)***	***Not a single first permanent molar erupted***	***Four fully erupted permanent first molars***
Examination 1	3002	7.07(0.41)	7.8%	36%
Examination 2	3002	8.08(0.39)	0.5%	79.2%
Examination 3	2874	8.95(0.39)	0.1%	95.7%
Examination 4	2691	9.80(0.39)	0.1%	97.5%

Figure 11.1.: Distribution of the net caries increment (DMFS) in first permanent molars in Flemish primary schoolchildren over a 3-year observation period.



The cumulative incidence for the children included in this study was rather high (31,6%). The distribution according to the ‘believed risk' groups, based upon the quartiles of 'score^{7}', ranged from 22.4% in the 'believed low risk' group to 43.2% in the 'believed high risk' group. Their differences were statistically significant (P < 0.001) (table 11.3.).

Table 11.3.: cumulative caries incidence for the first permanent molars in a cohort of initially 7-year-olds in Flanders, according to different groups of 'believed risk', based on risk indicator 'score^{7}). (n = 2691)

Outcome measure	***Whole study group (n = 2691)***	***Sub-groups according to the believed risk estimate based on a base line risk assessment model***		
		(<Q1) (n = 673)	(Q3-Q1) (n = 1340)	(>Q3) (n = 678)
3-year cumulative incidence (% of children)	31.6%	22.4%	32.4%	43.2%

Overall and all pair-wise differences were significant (P <0.001)

The results of the stepwise multiple logistic regression analysis reported in this paper were based on the best fitting model, using net caries increment as outcome variable and the 'real exposure time' as covariate. Baseline dmfs, plaque indices and 'score^{7}' were used as predictors. The logistic model with the separate behavioural and socio-demographic factors was useful for evaluating the different cross-sectional baseline indicators and predictors in a longitudinal way (table 11.4.). The baseline dmfs (P < 0.001) and the plaque indices (P < 0.01) were highly significant for having a high caries increment with respectively odds ratios of 1.07, 1.43 (PlI_O) and 1.35 (PlI_B) for an increase of their value by 1 unit. Behavioural and socio-demographic variables significant in the cross-sectional risk assessment model were checked one by one by stepwise inclusion. The stratification variables 'educational system' and 'province' were kept fixed in the model.

Table 11.4.: Odds ratio estimates and 95% confidence intervals after stepwise multiple logistic regression with net caries increment on first permanent molars as independent variable (no or 1 additional surface affected versus 2 or more additional surfaces affected) and real exposure time as covariate in at baseline 7-year-old primary schoolchildren (3 years follow up)
(n = 3002)

Variable	***Estimate***	***SE***	***P-value***	***Odds ratio***	***95% CI***
Intercept	-5.221	1.082	< 0.001		
dmfs at 7	+0.065	0.006	< 0.001	1.07	1.05-1.08
PlI_O	+0.355	0.120	0.003	1.43	1.28-1.80
PlI_B	+0.301	0.113	0.007	1.35	1.08-1.68
Risk score at 7	+0.558	0.117	<0.001	1.75	1.39-2.20
Educational system					
Free (ref)				1	
Community	+0.013	0.181	0.943	1.01	0.71-1.44
Municipal	+0.348	0.134	0.009	1.42	1.09-1.84
Province					
Antwerp (ref)				1	
Limburg (easternmost province)	+0.264	0.159	0.098	1.30	0.95-1.78
West Flanders (westernmost province)	-0.478	0.177	0.007	0.62	0.44-0.88
Gender	+0.170	0.180	0.320	1.11	0.90-1.38
Frequency of brushing					
≥ once a day (ref)				1	
< once a day	+0.808	0.141	<0.0001	2.43	1.70-2.96
Age at start of brushing (years)	+0.070	0.050	0.156	1.07	0.97-1.18
Regular use of systemic fluoride supplements					
Yes (ref)				1	
No	+0.005	0.110	0.963	1.01	0.81-1.25
Daily use of sugar containing drinks					
No (ref)				1	
Yes	+0.223	0.114	0.049	1.25	1.00-1.56
In between meal snacks					
≤ 2 a day (ref)				1	
> 2 a day	-0.189	0.118	0.106	0.83	0.66-1.04

Brushing less than once a day ($P < 0.001$) and the daily use of sugar containing drinks between meals ($P < 0.05$) were confirmed as risk factors for developing a high caries increment in permanent first molars with odds ratios of respectively 2.43 and 1.25. The following variables, significant in the cross-sectional model, could not be confirmed in a longitudinal way: the regular use of fluoride supplements, the consumption of more than 2 between-meal snacks per day and the child's age at start of brushing. The demographic factor 'province' remained an important risk predictor, with a lower risk when living in the western part of Flanders ($P < 0.01$). The variable 'educational system' also came out significant, with an increased risk when attending municipal schools ($P < 0.01$). These variables may include confounding environmental factors, such as social and geographic influences.

The assumption that the effect of a covariate on a logistic scale was equal for the transition from no caries to moderate caries increment (1 or more additional surfaces affected) and for the transition from moderate to high caries increment (2 or more additional surfaces affected) was verified in an ordinal logistic regression model for all variables and was not rejected at the 5% level.

Table 11.5 provides the information to answer the question how accurately future high caries increment can be predicted by using the studied explanatory variables. Different threshold levels were selected throughout the range of the predictor estimate score and were analysed in a logistic procedure with net caries increment as outcome measure and the real exposure time as covariate. The caries increment was dichotomised as none or one additional surface affected versus two or more additional surfaces affected.

Each row in the table corresponds to a 2 x 2 table. For the first row, believed risk of new caries was considered high if the threshold of the predictor estimate selected 10% of the study cohort as high caries susceptible subjects. Correspondingly, the last row represents a prediction where risk was believed high for 80% of the children.

Table 11.5.: Prediction of high caries increment (> 2 newly affected surfaces) adjusted for real time at risk by baseline risk indicators and predictors* in a cohort of 3002 initially 7-year-old children in Flanders (approximately 17% of the children belonging to the true high risk group).

Threshold probability level of believed high risk**	***TP*** True positives	***FP*** False positives	***FN*** False negatives	***TN*** True negatives	***Se*** Sensitivity	***Sp*** Specificity	***PV+*** Positive predictive value	***PV-*** Negative predictive value
10%	125	164	351	2079	26.3	92.7	43.2	85.5
15%	159	223	317	2020	33.4	90.1	41.6	86.4
20%	200	332	276	1911	42.0	85.2	37.6	87.4
25%	244	462	232	1781	51.2	79.4	34.6	88.4
30%	281	610	195	1633	59.0	72.8	31.5	89.3
40%	314	769	162	1474	66.0	65.7	29.0	90.0
50%	335	955	141	1288	70.4	57.4	25.2	90.1
60%	370	1211	106	1032	77.7	46.0	23.4	90.7
70%	417	1546	59	697	87.6	31.1	21.2	92.2
80%	445	1865	31	378	93.5	19.6	19.2	92.4

missing values: 283

*base line risk indicators and predictors, assessing the believed risk were based on baseline data on oral health status, oral cleanliness, reported oral health habits and socio-demographic factors.

** proportion of children believed to have a high caries risk.

The distribution of the subjects among the true positives, false positives, false negatives and true negatives varies strongly. Taking into account that the sensitivity cannot be useful if this value falls below 50% and that a balance with the specificity is desired, only two rows remain available to identify a manageable percentage of high-risk susceptible subjects, applying the cross-sectional baseline estimates as predictor. These rows provided a sensitivity ranging from 59% to 66% and a specificity between 65.7% and 72.8% and selected 30% à 40% of the children being of believed high risk. The positive predictive value and negative predictive value ranged respectively from 29% to 31.5% and from 89.3% to 90%.

The Receiver Operating Characteristic curve (ROC), presented in figure 11.2., summarises the predictive power of our risk marker. The values of true positive rates (sensitivity) were plotted against the false positive rates (1 – specificity) at the respective threshold levels. The curve lay above the diagonal and resulted in an A_z of 72%, indicating rather low predictive power.

The information provided by baseline dmfs, separately or in combination with plaque indices on buccal and occlusal surfaces, and with 'score[7]' was summarised in table 11.6. and visualised in figure 11.2. The power of the risk function including all predictors was very similar to that of baseline dmfs score alone. Almost all predictive power of the logistic regression function came from the baseline dmfs, but the additional impact of the remaining predictors or indicators was statistically significant ($P < 0.001$).

Discussion

Outcome measure

An important issue in the evaluation of caries risk assessment is the use of an accurate and appropriate outcome measure.

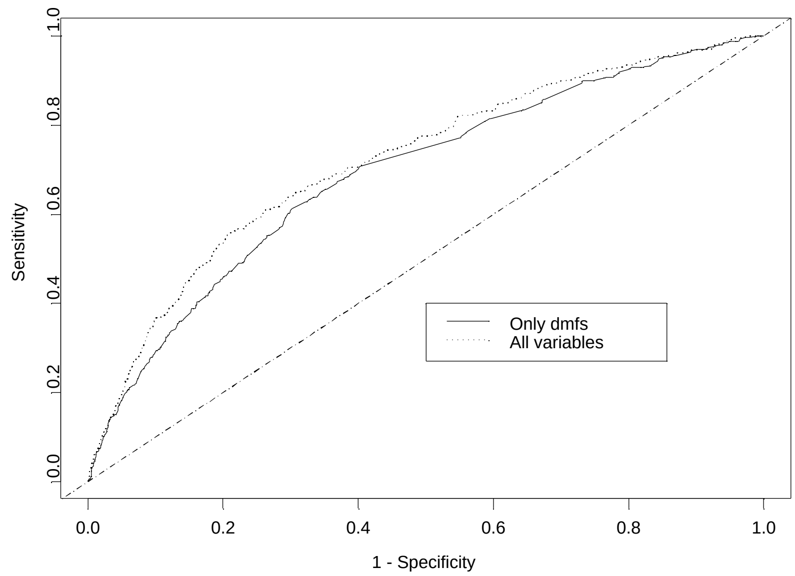
Cumulative incidence, as a proportion of children who developed caries within the 3-year observation period, forms a good notion of caries risk (Slade and Caplan, 2000). In fact, in 32% of Flemish primary schoolchildren the first permanent molars tend to become carious during the first 1 to 3 years after eruption.

Table 11.6.: Percentage area under the curve in the ROC-curves constructed by a stepwise logistic regression model with all predictors and risk indicators included as independent variables for predicting a caries increment of > 2 newly affected surfaces and adjusted for the real time at risk (17% of the children belonging to the high risk group).

	Stepwise multiple logistic regression
Base-line dmfs only	0.691 (p < 0.001)
+ Plaque index occlusal surfaces and plaque index buccal surfaces	0.695 (p < 0.001)
+ Score [7] *	0.719 (p < 0.001)

* prediction variable, assessing the believed risk at baseline, based on reported oral health habits and socio-demographic factors, investigated in a cross-sectional multiple logistic regression model.

Figure 11.2.: ROC-curves illustrating the relationship of sensitivities and specificities at different threshold levels (table 11.5.) when baseline dmfs only or all baseline risk indicators and predictors were used as predictor for a caries increment of > 2 newly affected surfaces, adjusted for the real exposure time (area under the curve respectively 0.69 and 0.72)



Cumulative incidence varied significantly throughout the range of ‘believed risk’ groups, from 22.4% in the 'believed low risk' to 43,2% in the 'believed high risk' group and could in this way give an indication of the predictive value of the studied prediction model, at least at community level. However, several factors, not included in the cumulative incidence measure, have to be taken into account: the loss of subjects, the substantial differences in real risk period, depending on different emergence timing and available observation time, and the large group of children with no caries increment (68.4%). Caries incidence density includes the real exposure time and minimises the loss of children, but cannot point out the differences in risk within the large group of children with no caries increment during the investigation period but having different exposure times for the different involved teeth. For that reason the final choice for the present analyses was the logistic procedure with net caries increment, adjusted for the real exposure time, as outcome measure. This procedure gave us the best fitting models and the most useful results. The loss of children (9%) was minimised but the remaining dropout continued to be important. From the initial selection (3303 children), 3002 were left for the logistic regression procedure. This was mainly due to refusals, moving or children who had to stay down in a class for an extra year. To check the influence of this loss of children, the distribution of the children with and without a follow-up was compared with regard to the variables age, province, educational system, gender and baseline dmfs and ‘score [7]’. In most of these variables no significant difference was observed (5% level). Only in the stratification variables ‘educational system’ and ‘province’ a significant different was found (*P* values = 0.001). More children in the study group belonged to the ‘free’ educational system.

Validation of risk indicators

Within the objectives of this study a variety of identified risk indicators, assessed in a previous cross-sectional study, were investigated. Potential positive risk factors and potential protective factors were combined as proposed in the scientific literature (Leverett *et al.*, 1993). ‘Daily use of sugar containing drinks’ was confirmed to be a behavioural risk factor. ‘Frequency of brushing’ was the most important protective factor. The fact that the majority of the children (99%) used a fluoridated toothpaste could indicate the major importance of the topical effect of fluorides in the prevention of dental decay in the permanent dentition. 'Age at start of brushing' and 'regular use of systemic fluoride supplements', found to be highly significant for explaining presence of caries in the primary dentition at age 7, were no longer significant risk factors in the permanent dentition. In the 80s in several studies the absence of relationship between dietary habits and caries increment was observed (Lachapelle *et al*., 1990). In more recent studies (Holbrook *et al*., 1993; Grindefjord *et al*., 1995) misuse of sugar was found to be an important risk factor for caries increment in pre-school children. The compensatory mechanism of regular use of fluorides for the misuse of sugar has been demonstrated in earlier studies in pre-school children (Holbrook *et al.,* 1993)

Gender-related differences have been demonstrated in small sample studies (Raitio *et al.,* 1996). In the present study no association with gender has been observed, which is conform with the findings of large sample studies (Disney *et al*., 1992).

Socio-demographic factors, such as 'province' and 'educational system' were found to be important confounders in the caries risk assessment model. More in depth investigations need to be done to find out the underlying reasons for this relationship. Results from initial cross-sectional analyses indicated the importance of deprivation levels and social inequalities (Vanobbergen *et al*., 2001). Previous risk assessment surveys found significant differences in caries increment in young children by social environmental factors such as parental education (Lachapelle *et al*., 1990; Demers *et al*., 1992; Grindefjord *et al*., 1995).

Risk predictors

Both past caries experience and oral cleanliness were found to be very important risk predictors. This is in full agreement with previous findings (ter Pelkwijk *et al*., 1990; Helfenstein *et al*., 1991; Steiner *et al*., 1992; Disney *et al*., 1992; Mattiasson-Robertson and Twetman, 1993;)

Predictive ability

In order to evaluate how accurately children with high future caries increment can be identified by using the combined baseline risk indicator (dmfs, plaque indices and 'score 7'), the information in table 11.5. needs to be analysed more in depth. The considerations mentioned in the results section leave us only two rows to be useful. This corresponds with a group of children, that has to be treated as high risk susceptible, whose size equals 30% à 40% of the target population. This is the utmost limit to justify the efforts and the expenses of a high risk preventive strategy rather than a whole population strategy (Hausen, 1997). Even more, for none of the cases did the predictive power reach the proposed combined sensitivity and specificity of 160%, which has been suggested to be the minimum for a caries risk for targeting individualised prevention (Kingman, 1990). The present best combination equalled 132. In previously published studies a number of workers have attempted to identify high caries individuals and groups with varying degrees of success, depending on the age group, the baseline caries experience and the caries incidence rate of the study group. Several studies use a combination of tests for caries prediction, stressing on past caries experience or salivary counts (ter Pelkwijk *et al*., 1990; Helfenstein *et al*., 1991; Leverett *et al*., 1993]. Several other studies have examined the use of a wider range of factors in caries prediction, involving behavioural and socio-demographic factors. They were included in the prediction models (Demers *et al*., 1992; Disney *et al*., 1992 Holbrook *et al*., 1993) or used as confounders in mutans streptococci tests (Mattiasson-Robertson and Tweetman, 1993; Petti and Hausen, 2000). Their analyses predicted between 48.4% and 82.8% of high increment children (sensitivity) and between 70 % and 93.7% of the low increment children (specificity). Comparable to the results presented in this paper with regard to age, sample size or incidence rate of the studied population are the prediction models of Disney et al. (1992) (wider range of factors, age and sample size) and Petti and Hausen (2000) (behavioural and demographic variables, age and incidence rate) with sensitivities of respectively 59% and 48.4% and sensitivities of 83% and 76.3 %.

The positive predictive value, or the probability that a child with a believed high risk actually had a high caries increment, was 29% or 31,5% dependent on the threshold level chosen. This indicates that only approximately 1 out of 3 children, referred for possible extra preventive measures, actually needed them. In this particular case, in a population of children with a baseline caries prevalence of 56%, this value is rather low. The negative predictive value shows that 90% of the children who tested negative remained in fact without caries increment, what is fairly good for a high prevalent disease. These values are comparable with the large sample study values of the University of North Carolina with a PPV of 0.49 and a NPV of 0.88 (Disney *et al*., 1992). From the proportional area of 0.72 under the ROC curve, the predictive power of the compound baseline indicator is far from being perfect.

Although the stepwise multiple logistic regression analysis indicate a statistically significant improvement for all predictors upon the baseline dmfs score, this improvement did not add a biological relevant increase to the accuracy of the prediction model.

Finally the author wants to emphasise that the 3-year increment that this prediction model describes is that based on data from children in the intervention group A (see chapter 5), what means that this has occurred against the background of the intervention. Furthermore the ability to compare the developed model with data generated from other longitudinal studies with no systematic intervention must be limited.

Conclusion

This longitudinal study confirmed several of these risk indicators, assessed by a baseline cross-sectional survey. Brushing less than once a day and daily consumption of sugar containing drinks were the key behavioural risk factors for the development of high caries rates in Flemish primary schoolchildren. On the other hand the multifactorial aetiology of dental caries hampers the construction of models for identifying high caries susceptible children in a more accurate way. Yet, none of the demographic, clinical and behavioural variables in this study have enough predictive power at community level to be useful as good caries predictors. Even the power of dmfs at baseline must be considered to be modest. Different outcome measures have been discussed within this paper with regards to their accuracy for application in a high risk preventive strategy. Measures taking into account the real exposure time seem to be the most accurate.

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General Discussion and conclusion

General discussion and conclusion

The aim of this section is to discuss the most important findings, answering the questions put in the objectives of this thesis. This can be summarised as:

First, the description and estimation of the oral health condition of Flemish primary schoolchildren, aged 7 to 10 years, with regard to caries experience.

Secondly, the definition and quantification, in a cross-sectional study, of a set of risk indicators and predictors.

Thirdly, the confirmation of these risk indicators and predictors and their usefulness in identifying high risk groups in a longitudinal study.

Furthermore, conclusions are drawn integrating the most important aspects and results of this investigation.

Finally, a lot of priorities and continuing work for further research are suggested.

Oral health condition of Flemish primary schoolchildren, aged 7 to 10.

In conformity with the literature, changes in the distribution of dental caries over the last 20 years in Flanders include a decline in prevalence in child population and an increasingly skewed distribution, with most disease now found in a small number of children (Spencer, 1997; Powell, 1998; Vanobbergen *et al.*, 2000; Vanobbergen *et al.*, 2001).

The data for the deciduous dentition (chapter 6) of Flemish children shows moderate caries experience levels with mean dmft values between 2.24 and 2.68 for 7 to10-year-olds. Exactly 44% of the 7-year-olds are caries free. Total caries experience showed only minor fluctuations between the age of 7 and 10 years, but there is a shift from untreated towards treated disease. This is confirmed by the rise in restorative index (43% to 58%). The restorative level of deciduous teeth, however, is rather low, indicating the importance of informing parents (and dentists) about the necessity and possibilities of treatment of primary teeth. Most of the disease is found in a limited proportion of the children. In our sample 27% of the children bear 75% of the caries lesions. This finding stresses the necessity of early caries detection, risk assessment and introduction of risk management strategies, adapted to the actual situation..

In the permanent dentition (chapter 6) the DMFT for 7-year-olds is 0.17 and for 10-year-olds 0.75. By the age of 10 one out of three children developed caries within three years after eruption. Most of the lesions (77%) were localised on first permanent molars. The restorative index for 7-year-olds was 37% and reached 69% by the age of 10 years. Difference between the two thirds of the population with the best caries situation, and the one third of the most affected children, is obvious. In the age group of 10-year-olds the unfavourable group has 88 times more caries than the favourable group with a mean DMFT of respectively 2.20 and 0.026. The mean DMFT of the one third of the most affected children constitutes the Significant Caries Index, as proposed by Brathall (Brathall, 2000).

The definition and quantification of risk indicators and predictors.

The main objectives of the development of a risk assessment model within this study were twofold: first the investigators sought to identify risk factors, responsible for the development of caries in children, and second, to identify children or groups of children at high risk of developing caries. For decades different medical disciplines have been developing methods to answer these questions or to reach these goals. The majority of risk assessment efforts, applied to one of the major dental diseases, i.e. caries, started only in the early 1980's, when the prevalence of caries was decreasing constantly and when it became obvious that some individuals were more likely to be affected than others. In Flanders, up to now, no investigation was done on caries risk assessment.

The strongest evidence for causality in humans can only be determined by means of randomised controlled trials. Such, observational epidemiology may be seen as a weaker science in the assessment of risk factors. On the other hand, since experimentation on human beings is restricted by informed consent issues, including ethical and risk/benefit considerations, there usually is no experimental evidence to fall back on when determining the causes of a complex and multifactorial disease, such as caries. Consequently, for the present investigation, an observational study, conducted following formal criteria, will provide the evidence, supporting a causal interpretation.

The database of the Signal-Tandmobiel® project (chapter 5) offers unique possibilities for reaching the pursued goals. The data generate both cross-sectional and longitudinal analyses, using a broad spread of explanatory variables in a representative sample involving a high number of children. According to Beck (Beck, 1998), first, variables thought to be risk factors were uncovered through associations seen in a cross-sectional analysis. The term “risk indicator” was used to differentiate these factors identified by means of prevalence data and defined as: probable and putative risk factors. Additional to these risk indicators, socio-demographic risk factors were included. They were perhaps more likely to expose the children to the causal chain than be part of the causal chain. In a succeeding longitudinal study they will be confirmed by incidence data.

The results of the cross-sectional risk assessment study (chapter 7) demonstrated the importance of age as a significant factor in the development of prediction models in children. Even within the range of 12 months, which differentiates the children in the cross-sectional analysis, this variable represented an increase of risk corresponding with an odds ratio of 1.39 for an increase by one year.

The importance of oral health habits in caries development was reflected in the significant variables: ‘regular use of fluoride supplements’, ‘age at start of brushing’, ‘frequency of brushing’, ‘daily use of sugar containing drinks’ and ‘the number of in between meal snacks’. An early start of brushing and a brushing frequency of at least once a day need to be encouraged, while the use of sugar containing drinks and snacks between meals needs to be restricted to a maximum of 2 per day.

The amount of dental plaque was found to be correlated to the caries experience (chapter 8), but the high variability in caries experience among children with the same amount of plaque, clearly confirmed the multifactorial cause of caries. Four parameters were determining for the amount of plaque: the start of brushing, the frequency of brushing, the number of between meal snacks and the daily consumption of sugar containing drinks. Girls proved to have significantly less plaque than boys.

The variable 'province' showed that geographical variations in Flanders are all-important. Living in the western part of the country results in a decrease of risk for having caries, compared to the eastern part.

Beside the expected high significant correlation between social context and caries experience (chapter 9), two important observations were made during the analysis of oral health related behaviour linked to the different socio-economic groups: first, a cumulative negative effect of decreasing occupational level of both parents and reported unfavourable oral health related behaviour on caries risk in children, and second, a remaining negative effect of occupational level of both parents, even in cases with reported good oral health behaviour. Social inequalities in oral health were confirmed in Flemish children.

The multiple analyses combining the impact of individual and socio-demographic effects were completed by the analysis of random effects. Intra-class correlation, indicating the correlation of caries experience between children attending the same class (school) was checked. Children having the same characteristics, but belonging to a different school, could not have the same probability of having caries or plaque. The present analyses resulted in a significant but weak intra-class correlation for the presence of caries and a significant high correlation for the amount of plaque.

The confirmation of risk indicators and predictors in a longitudinal caries incidence study.

This longitudinal study (chapter 11) confirmed several of the risk indicators, assessed by the baseline cross-sectional survey. A lot of explanatory variables, either with a direct or indirect causal impact, contributed significantly to the increase of DMFT between 7 and 10 years. The most important were the baseline dmfs at 7 and the oral cleanliness. The socio-demographic factors, province and educational system, reflected the significant impact of the social environment of the children. The reported frequency of brushing and the reported daily use of sugar containing drinks were the most important behavioural factors. These findings were consistently confirmed in the

Academic Research Collaboration project between Flanders and Scotland (chapter 10). Although the dental health situation of the children in Scotland and Flanders differed considerably between both cities under investigation, the impact of socio-economic factors remained important in both groups and the same explanatory variables contributed significantly to the increase of DMFT between 7 and 10 years, i.e.: the baseline dmf at 7, the age at start of brushing and the oral cleanliness.

On the other hand the described multifactorial aetiology of dental caries in our communities hampers the construction of sufficiently accurate models for identifying children who will experience a high caries rate in the future. Yet, none of the socio-demographic and behavioural variables have enough predictive power at community level to be useful as good caries predictors. Even the power of dmfs at baseline must be considered only modest (chapter 11). The terms commonly used to describe the accuracy of a risk model are sensitivity and specificity. Generally most risk models are better at selecting children who will not develop caries, than they are selecting people who will (Powell, 1998). The model with the highest predictive power in the present investigation reached a sensitivity of 59% and a specificity of 72%. The believed high caries susceptible children needs to be 30% à 40% of the target population to find any predictive power. This is the utmost limit to justify the efforts and the expenses of a high risk preventive strategy rather than a whole population strategy. Even more, for none of the cases did the predictive power reach the proposed combined sensitivity and specificity of 160%, which has been suggested the minimum before a caries risk marker can be considered as valuable for targeting individualised prevention (Kingman, 1990). The optimal combination in the presented material equalled 131.8.

Integrated conclusions

Changes in the distribution of caries in children as seen in developed nations have also occurred in Flanders over the last 20 years, including a decline in prevalence, an increasingly skewed distribution with most disease in a small number of children, and an equal but symmetric concentration of caries in fissure and proximal patterns in the deciduous dentition. Prevention should remain more and more the prime activity of oral health promotion policies starting in very young age groups, and these preventive policies should be critically examined and evaluated in the light of the actual conditions. Changes in occurrence of dental caries makes focusing solely on high risk groups very tempting. Nevertheless, a basic prevention should be aimed continuously at the whole population emphasising oral hygiene. A brushing frequency of twice a day, an early start before the age of two years and daily use of fluoride toothpaste are the principal preventive advises. Additional dietary counselling involving the frequent use of sugar containing drinks are meaningful in younger age groups. Due to the rather low predictive power of risk assessment models, more expensive preventive activities should be targeted at groups of children in chosen geographic areas with low socio-economic levels, rather than to individually selected children. In these selected areas, additional fluoride programs, sealing programs and oral health education programs that emphasise oral hygiene and diet can improve oral health and reduce oral health inequalities and inequities. The importance of geographical, socio-economic and environmental effects, revealed in the present study, confirms the criticism formulated by several authors with regard to the biomedical perspective, using an individualistic approach in explaining health related behaviour (Shy, 1997; Duncan, 1996). Within this perspective, behaviour is regarded as a matter of free choice and individual responsibility. The risk factors are therefore seen as being autonomous and unconnected with broad socio-structural factors (Duncan *et al.*, 1996). Such, epidemiology has to cross the boundary of this individualistic approach and add a macro-epidemiology to its scope, a study of causes from a truly holistic perspective, considering health and disease within the context of the total human environment (Shy, 1997). These considerations formed the background to include and study random effects in the present analyses.

Further research

As mentioned in the introduction, the present investigation has to be seen in a broader context, aiming to offer a scientific basis for further development of oral health promotion in Flanders, starting with children and continuing in other identified risk groups. The present results provide a good judgement of the actual oral health condition of primary schoolchildren and the key risk factors responsible for this. The caries decline and the resulting low occurrence of dental caries together with the polarisation, could justify the efforts and expenses of a high risk strategy, additional to a basic population strategy. However one has to find out *whether sufficiently accurate measures for identifying high risk susceptible individuals are available* (Hausen H, 1997). As shown dental caries is a multifactorial disease and although key risk factors are known, it is still not possible to fully identify the usefulness of these factors in a risk assessment model. As a result, some individuals may be misclassified. The cross-sectional results gave an indication and an impulse for further investigation in a longitudinal way, the hypothesis that *social factors are important markers* for identifying high risk groups and explaining the geographical variation in dental health. By further improvement on existing methodologies, multilevel modelling techniques and analyses of random effects offer the possibility of *connecting quantitative and qualitative research*. Such in-depth research, which considers both the specific individual and environmental aspects, can reveal the broad patterns of health related behaviour and may be crucial to the essence of changing public health and health promotion policy.

Diagnosis of infection by putative cariogenic organisms, prior to the appearance of clinically apparent lesions, could be a key to improving this risk model. Tody salivary tests are still expensive and are believed to be more effective in identifying caries-inactive children. Further research will be useful to *evaluate the predictive power of salivary tests, especially in very young children and their parents or caregivers* (Messer L B, 2000).

One has to keep in mind that even in models with a high sensitivity and specificity, they will have inherently a rather low probability of detecting disease if the disease has a low prevalence. Therefore, in an attempt to formulate new goals for oral health in a country it is therefore important not only to look at the mean values of dmft/s, but also *to improve the descriptive ability of the caries experience in high susceptible individuals* and to look at the frequency distribution of caries in a population and the spatial distribution of caries in individuals. The 'Significant caries index', proposed by Bratthall (Bratthall, 2000) forms a good example. As soon as data will be available for the 12-year-olds in Flanders a comparative analysis will be valuable in a European context and useful in the evaluation of preventive strategies.

Furthermore any risk strategy must be followed by appropriate preventive interventions. As such, *the availability and effectiveness of preventive measures, offering protection to high risk groups, should be studied* in Flanders. Finally, little is known about the usefulness of the proposed high risk strategy in real life conditions. A *trial to further explore the effectiveness and applicability of a high risk strategy* in specific age groups in Flanders should be undertaken.

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Samenvatting – (Summary in Dutch)

Inleiding

In dit proefschrift, 'de ontwikkeling en toepassing van een cariës risico model bij lagere schoolkinderen in Vlaanderen' wordt mondgezondheidszorg gekaderd in een streven naar algemeen welzijn. Het begrip 'gezondheid' wordt gezien in zijn 'holistische' betekenis, namelijk een toestand van een totaal welzijn, zowel op fysisch, mentaal als sociaal vlak. Het accent ligt evenwel op mondgezondheidszorg bij kinderen en is gefocust op cariës. Ondersteund door het gezondheidspromotie concept van de Wereld Gezondheid Organisatie, wil dit onderzoek zich niet beperken tot een individualistische benadering van het cariës probleem bij kinderen. Cariësvoorkomen en risicogedrag zijn niet enkel een zaak van vrije keuze en individuele verantwoordelijkheid, maar worden veeleer beschouwd als resultaat van een breed gamma socio-structurele factoren.

Het doel van dit proefschrift kan worden samengevat in drie punten:

- Ten eerste, een beschrijving en inschatting van de mondgezondheidstoestand van Vlaamse kinderen tussen 7 en 10 jaar, met betrekking tot cariës.
- Ten tweede, het definiëren en kwantificeren van risico indicatoren en predictoren voor cariës door middel van een dwarsdoorsnede onderzoek.
- Ten derde, de bevestiging van deze risicofactoren in een longitudinaal onderzoek en hun bruikbaarheid in het identificeren van hoog risico groepen.

Het verkennen van het mondgezondheidslandschap in België

Om een inzicht te krijgen in de evolutie en de actuele mondgezondheid van de Belgische lagere schoolkinderen wordt in hoofdstuk 1 een literatuuroverzicht gegeven van de epidemiologische cariës studies gepubliceerd sinds 1980. Alhoewel weinig gegevens voor handen zijn en vergelijkbaarheid niet vanzelf sprekend is kan men stellen dat de cariës in België de laatste 20 jaar sterk is afgenomen en dat de normen gesteld door de Wereld Gezondheid Organisatie, zeker voor wat betreft Vlaanderen en de kindpopulatie, werden gehaald.

Daaraan gekoppeld wil hoofdstuk 2 de mondgezondheidszorg in België kritisch benaderen en plaatsen in een Europese context. De sterke daling van het cariësvoorkomen en het groeiend inzicht in het cariësproces hebben tevens onze houding beïnvloed ten opzichte van risico en risico inschatting. Hoofdstuk 3 wil hier dieper op ingaan, gebaseerd op de recentste literatuur in dit verband. Eén van de belangrijkste bevindingen hierbij is dat het noodzakelijk is cariës risico modellen multifactoriëel op te bouwen, bij voorkeur door middel van regressiemodellen. Reproduceerbaarheid en betrouwbaarheid zijn hierbij van groot belang. In hoofdstuk 4 worden verschillende betrouwbaarheidsmaten en diagnostische criteria besproken en vergeleken.

Het Signal-Tandmobiel® project.

Het tweede thema binnen dit proefschrift geeft een beschrijving van het Signal-Tandmobiel® project in Vlaanderen. Dit interuniversitair project, in samenwerking met de wetenschappelijke beroepsverenging en de wetenschappelijke vereniging voor jeugdgezondheidszorg, en gesteund door de industrie, heeft een drieledig doel: vooreerst het screenen van de mondgezondheidstoestand van de lagere schoolkinderen in Vlaanderen, ten tweede het geven van tandheelkundige gezondheidsvoorlichting en opvoeding en ten derde het verwerken van al de verzamelde data in een longitudinaal epidemiologisch onderzoek. Met dit proefschrift wordt een deel van deze doelstellingen verwezenlijkt. Hoofdstuk 5 omschrijft in detail materiaal en methoden gebruikt binnen het Signal-Tandmobiel® project. Hoofdstuk 6 is gewijd aan de descriptieve gegevens geanalyseerd uit de mondonderzoeken en vragenlijsten in de leeftijdsgroep van 7 tot 10 jaar.

De ontwikkeling en toepassing van een cariës risico model.

Het derde deel vormt het belangrijkste deel van dit proefschrift. In hoofdstuk 7 wordt de impact gedefinieerd van een reeks risico indicatoren voor cariësvoorkomen in het melkgebit van 7-jarigen. De resultaten van dit onderzoek bevestigen het belang van mondhygiëne en voedingsgewoonten. Starten met poetsen op zeer jonge leeftijd en minstens één poetsbeurt per dag met een fluoride houdende tandpasta, samen met het beperken van tussendoortjes tot maximum 2 per dag en het vermijden van dagelijks gebruik van suikerhoudende dranken vormen de sleutelstukken in het risicogedrag. Er worden belangrijke regionale verschillen waargenomen in het cariësvoorkomen in Vlaanderen. Kinderen in het oosten van het land hebben meer cariës dan kinderen in het westen van Vlaanderen. De complexe risicofactoren 'tandplak' en 'sociale context van het kind' vormen aparte hoofdstukken. In hoofdstuk 8 wordt een duidelijk verband vastgesteld tussen de hoeveelheid plak en het voorkomen van cariës in het melkgebit van 7-jarigen. Determinerend voor de hoeveelheid tandplak in het wisselgebit zijn vooral: de leeftijd waarbij met poetsen werd gestart, het aantal poetsbeurten, het aantal tussenmaaltijden en het dagelijks gebruik van suikerrijke dranken. Jongens hebben beduidend meer plak dan meisjes. De hoge variabiliteit in cariësvoorkomen bij kinderen met dezelfde hoeveelheid plak bevestigt nogmaals het multifactorieel karakter van het cariësvoorkomen. Hoofdstuk 9 behandelt het belang van de socio-economische context van het kind in relatie tot de mondgezondheid. Twee belangrijke vaststellingen werden gerapporteerd: vooreerst het cumulatief negatief effect op het cariës risico van een lage sociale klasse met een gerapporteerd ongunstig mondgezondheidsgedrag, en ten tweede, een blijvend negatief effect van sociale context zelfs bij kinderen met een gerapporteerd goed mondgezondheidsgedrag. Als onderdeel van het ‘Academic Research Collaboration Programme’ tussen het Fonds voor Wetenschappelijk Onderzoek en de ‘British Council’ stelt hoofdstuk 10 de resultaten voor van een longitudinaal vergelijkend onderzoek naar mondgezondheid en zijn determinanten bij Vlaamse en Schotse kinderen. In beide groepen wordt ongelijkheid in de mondgezondheid vastgesteld. Alhoewel de mondgezondheid tussen Schotse en Vlaamse kinderen verder sterk verschilt, blijkt de socio-economische impact zeer belangrijk. Verder zijn in beide groepen 'cariës in het melkgebit', 'de startleeftijd van het poetsen', 'het fluoridengebruik' en 'de hoeveelheid tandplak' sleutelfactoren in het bepalen van het risico voor het hebben van cariës in het blijvend gebit. Hoofdstuk 11 tenslotte zoekt naar longitudinale bevestiging van de vooropgestelde risico indicatoren. Het onderzoekt de voorspellende waarde van het risico model voor toekomstige cariës in het blijvend gebit. Meteen wordt nagegaan in hoever dit model in staat is hoog risico kinderen te identificeren (sensitiviteit) en/of laag risico kinderen uit te sluiten (specificiteit) met het oog op specifieke extra preventieve maatregelen. De resultaten leren ons dat minder dan éénmaal per dag poetsen en het dagelijks gebruik van suikerrijke dranken de belangrijkste gedragsfactoren zijn die risicovol zijn voor het ontwikkelen van cariës in het blijvend gebit. Anderzijds blijkt dat door het multifactorieel karakter van cariës het moeilijk is een accuraat risico model op te stellen om hoog risico kinderen te identificeren. Geen enkele van de socio-demografische en gedragsvariabelen hebben genoeg kracht om bruikbaar te zijn als hoog betrouwbaar risico inschattingsmodel. Zelfs de voorspellende kracht van vroegere cariëservaring in het melkgebit is eerder beperkt.

Slotbemerkingen en conclusies

De verandering in de distributie van cariës, zoals ze is vastgesteld in de westerse ontwikkelde landen, vindt ook plaats in Vlaanderen, met inbegrip van de sterke daling van het cariësvoorkomen en een rechts scheve verdeling met de meeste aantasting in een kleine groep kinderen. Er is zowel nood aan een preventieve als aan een curatieve zorg. Een basis preventieprogramma moet op continue wijze de volledige bevolking bereiken met de nadruk op mondhygiëne. Bijkomende dieetadviezen zijn zinvol in jonge leeftijdsgroepen. Meer uitgesproken en complexe preventieprogramma's worden best gericht naar hoog risico groepen in wel gekozen geografische gebieden met een lage sociale status, eerder dan naar individueel geselecteerde kinderen. Het belang van geografische en socio-economische factoren, aangetoond in deze studie, bevestigt de stelling dat epidemiologisch onderzoek de grenzen moet overschrijden van een individuele benadering en determinanten voor cariës moet onderzoeken vanuit een populatie perspectief. Gezondheid en ziekte moet gezien worden binnen een context van de totale leefomgeving en de preventie moet zich richten op zowel persoonlijke kenmerken als op omgevingskenmerken.

Dankwoord – (Acknowledgements in Dutch)

"Zoals woorden. De dingen gebeuren.
Zonder woorden zouden ze ook gebeuren.
Maar dan zonder woorden." *Herman de Coninck*

En toch in dit laatste hoofdstuk een woord van dank, gewoon omwille van het verlangen om het te verwoorden.

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De zoektocht naar een gepaste vorm om mijn dankbaarheid te uiten, passend bij dit werk, leverde een laatste tabel op als sluitstuk van dit proefschrift, een tabel die jammer genoeg onvolledig zal blijven en gebiassed is door de beperktheid van mijn intern geheugen.

De tabel poogt op een bevattelijke en kernachtige wijze een aspect van de verdienste weer te geven, spontaan, zonder lang bij na te denken.

De volgorde speelt hierbij geen enkele rol. De computer rangschikte ze ‘at random’ (professoren zijn schijnbaar moeilijk te randomiseren). Een bijdrage groot of klein hoeft niet gerangschikt.

Tabel Dank.1. Personen die significant ($P < 0.001$) bijdroegen tot het welslagen van dit doctoraatsproefschrift als oorsprong, als teamlid of als belangrijke omgevingsfactor.

Naam	***Bijdrage***
Prof. Dr. A Comhaire	De onuitputtelijke tandheelkundige bron.
Prof. Dr. J De Boever	De weg van Babel naar Pinksteren – het voorzitterschap.
Prof. Dr. Luc Martens	Het promoten, het coachen, vooral de vriendschap.
Prof. Dr. D Declerck	Het rood, het groen, het blauw, de regenboog.
Prof. Dr. E Lesaffre	Zowel de klop op het hoofd als de duw in de rug - het initiatief.
Prof. Dr. R De Moor	De schouderklop op een dag dat het deugd doet.
Prof. Dr. R Verbeek	De zin voor realiteit.
Prof. Dr. L Dermaut Prof. Dr. R Schauteet	Trouwe jaargenoten.
Dr. Luc Marks Drs Johan Aps	Mijn Vlaamse paranimfen.
Miche De Meyer	De opgeraapte draad, het vuur aan de lont.
De kern van de VWGT	Stimulerende omgevingsfactor.
Kris Bogaert	De pure bio-statistiek®.
Mijn vader zaliger	De spirit en de kansen.
Mijn stilaan ouder wordende moeder	De ijzersterke wil.
Prof. Dr. J De Boever, Prof. Dr. L Maes, Dr. C Pine, Dr C Van Looveren, Dr. JP Van Nieuwenhuyze,	De laatste punten en komma’s.
Geert Dermaut	De grafische artistiek.
Lever Fabergé	De Signal-Tandmobiel®.
Anthony Lelliott Dominiek Simoens	Het correcte engelse woord.
JéKaDé-Coda jongerenkoor	Harmonie om van te leven.
Alle mensen van de dienst Tandheelkunde P8	Het vriendelijk woord.

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