CARIES RISK DETERMINATION AND COST-EFFECTIVENESS OF TARGETED PREVENTION IN ADOLESCENTS

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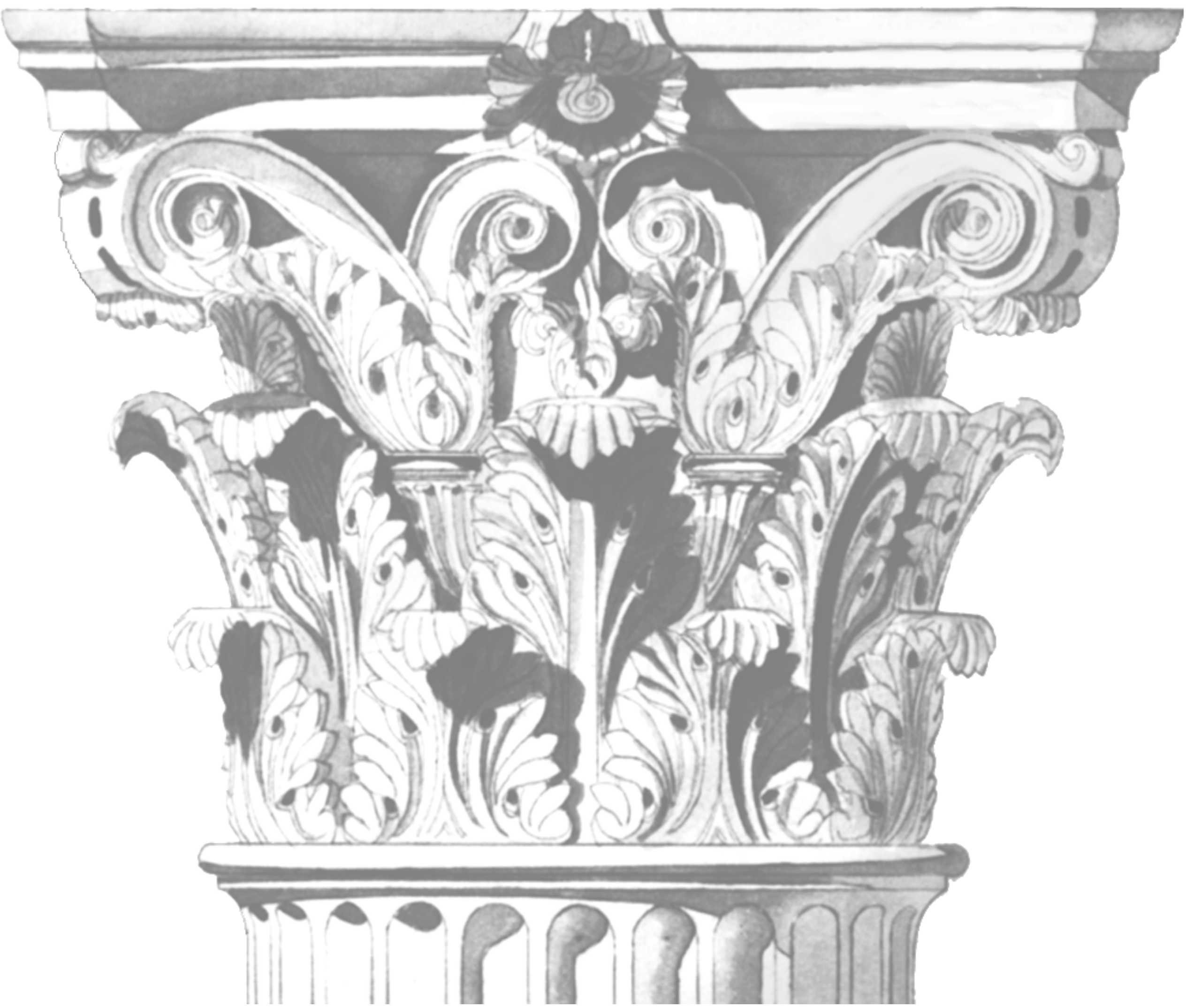

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Abstract

The aim of this study was to assess a series of caries risk indicators to find a suitable model for screening adolescents for risk cases, and to evaluate the long-term efficacy and cost-effectiveness of an one-year intervention programme provided for the resulting risk groups.

To reduce the spread of infectious diseases at 20 day-care centres, risk factors for the occurrence of salivary mutans streptococci were surveyed in 345 children before and after 8 months of intervention, i.e. withdrawal of tooth brushing in 10 centres. Dental health habits were evaluated by means of questionnaires. Four clinical and six salivary tests were related to 11-month caries increment in 181 adolescents. The 109 high-risk subjects presenting four or more risk factors were provided either with chlorhexidine or fluoride treatment, the low-risk group receiving basic prevention. An age and sex-matched control group was chosen. Life-long data on all 390 subjects were collected from their dental records. Survival analysis was applied, taking as the starting point the time of tooth eruption and as the event the first filling due to caries. The costs of the intervention and the number of fillings were compared between the groups.

The dental health of the risk groups tended to approach the average level for the control group. One tooth surface per subject was saved from filling. The costs of fillings for the control group were twice as great as those for the risk groups at the end of the intervention, but only slightly more after the five-year follow-up period.

The model (DFS, Candida and sucrase) offers additive information for finding adolescents at risk of caries, and for targeting preventive measures at the individual level and for the motivation of patients. The results stress the importance of dental age and of providing preventive procedures at the time of tooth eruption. The present risk-based strategy proved to be of moderate benefit to dental health by comparison with the costs of normal preventive and restorative care and cannot be recommended as such for a target population with a high risk of caries.

Keywords: risk assessment, dental caries, prevention, economic assessment

To my family

Acknowledgements

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Abbreviations

CHX	chlorhexidine
CE	cost-effect
CEA	cost-effectiveness analysis
DCC	day-care–centre
DFS	decayed filled permanent tooth surfaces index
ΔDFS	caries increment that was calculated as the difference between two examinations, DFS1 and DFS2
DMF	decayed, missed, filled permanent tooth index
dmf	decayed, missed, filled deciduous tooth index
DMFT	decayed, missed, filled permanent teeth
dmft	decayed, missed, filled deciduous teeth
DMFS	decayed, missed, filled permanent tooth surface
dmfs	decayed, missed, filled deciduous tooth surface
DS	decayed permanent tooth surface
DT	decayed permanent tooth
€	Euro = 5.94573 FIM (Finnish Mark)
F	fluoride
LB	lactobacilli
LR	low risk
ms	mutans streptococci
OR	Odds ratio
Ref	reference (= control)
RR	relative risk
SM	Streptococcus mutans
Sucrase	sucrase-enzym-activity

List of original publications

This thesis is based on the following publications, which are referred to in the text by their Roman numerals.

I Raitio M, Möttönen M & Uhari M (1995) Toothbrushing and the occurrence of salivary mutans streptococci in children at day care centres. Caries Res 29: 280–284.

II Raitio M, Pienihäkkinen K & Scheinin A (1996) Assessment of single risk indicators in relation to caries increment in adolescents. Acta Odontol Scand 54: 113–117.

III Raitio M, Pienihäkkinen K & Scheinin A (1996) Multifactorial modeling for prediction of caries increment in adolescents. Acta Odontol Scand 54: 118–121.

IV Raitio MA, Virtanen JI & Larmas MA (1999) Longitudinal evaluation of the efficacy of an one-year preventive intervention. Ital J Paediatric Dent 2: 79–84.

V Raitio MA, Virtanen JI & Larmas MA (2001) An assessment of the cost-effectiveness of intensive caries prevention program for at risk subjects. Eur J Paed Dent 2: 67–72.

Contents

1 Introduction

Dentists have been emphasizing preventive measures and health promoting education programmes in schoolchildren for decades, which probably has contributed to the decline in caries, so that in many countries, including Finland, the goals of the World Health Organisation have been achieved even faster than expected. Though the reduction in caries and polarisation of its occurrence, are indisputably a fact in industrial countries all over the world, there still exists a minority in young population who account for most of the demand for dental treatment (Petersson & Bratthall 1996).

Caries is an infectious disease, and the prevention of infection in early childhood and also later is important with respect to its future progression in the individual. The multicausality of caries makes the problem of prevention complicated. It has been deemed important in caries prevention to intervene in the main causal factors. Different methods have been studied and adopted for common use in preventive dentistry in recent decades in order to reduce caries, and as a result of research in the areas of remineralization therapy and caries risk assessment, tools for improved diagnosis and treatment or prevention of early caries lesions will be available in the future in order to achieve adequate control over dental health.

Two main strategies exist for targeting preventive methods, the population strategy, which means that the effort is focused at the whole population in order to reduce exposure to a common disease to a more healthy level, e.g. the fluoridation of water supplies to reduce caries, and the risk strategy, in which prevention is focused on a selected group or number of individuals at risk (Rose 1985). Public dental services in the Nordic countries have traditionally been based on population strategies, and prevention programmes have been offered to the total population or to defined subgroups. Administrative strategies for the promotion of dental health in children and adolescents have shown to be adopted in the Finnish public dental health care system that demand a lot of auxiliary personnel and additional time, but in spite of this, the available methods of prevention have not been focused accurately enough on schoolchildren in Finland (Kärkkäinen 1997).

The cost of caries prevention could be greatly reduced and their efficiency increased if practitioners or public health administrators were able to identify in advance those subjects who run the greatest risk of developing caries. Consequently, reliable methods for identifying caries-prone children should be available for practical implementation. It is also of great importance to choose the right preventive methods for targeting at the risk subjects or groups in order to achieve the best possible economic benefit for health promotion.

It has been suggested that oral health treatment policy should be revised and dental health-care staff should be educated towards more evidence-based knowledge and flexible attitudes (Sheiham 1984). A new approach to caries prevention is needed as far as more cost-effective use of resources and methods is concerned. Staff resources in health care centres should be directed in an appropriate way and be used more effectively to produce the greatest possible improvement in dental health without over-treatment. For decision-makers in the administrative and practical field of dentistry, it is important to choose the most effective methods with acceptable low costs. For this purpose longitudinal studies on cost-effectiveness studies should increasingly be conducted of preventive programmes.

2 Review of the literature

2.1 Aetiology of caries

Caries can be viewed as an infectious disease and mutans streptococci are considered to be important bacteria for its development (Emilson & Krasse 1985, Loesche 1986), although no single type of micro-organism has been identified as the primary cause of either enamel, root or crown caries (Nyvad & Kilian 1987). The bacteria attach to the first primary teeth to erupt, especially to the fissures of the molars in 2–3-year-old children (Alaluusua & Renkonen 1983). The time of contamination is of a certain importance, as the later a child is infected, the less caries lesions develop in early childhood and later on (Alaluusua & Renkonen 1983, Köhler *et al.* 1988). Mutans streptococci are transmittable from the primary dentition to the permanent dentition (Gibbons 1984, Alaluusua *et al.* 1987), and also between individuals (Köhler & Bratthall 1978, Rogers 1981).

The transmission occurs through contamination of the saliva (Rogers 1981) so that mothers are considered to transfer the infection to their child (Köhler & Bratthall 1978, Aaltonen *et al.* 1990). It has been found that 20–50% of mothers in the Scandinavian countries have high counts of salivary mutans streptococci (Berkowitz & Jones 1985, Paunio *et al.* 1988). Habitual xylitol consumption by mothers has been shown to lead to a significant reduction in mother-child mutans bacteria transmission when assessed in two-year-old children (Söderling *et al.* 2000).

Carious lesions increase the counts of mutans streptococci, while reductions can be achieved by restriction of sucrose-sweetened products (Rugg-Gunn & Edgar 1984, Birkhed *et al.* 1990) and the use of xylitol (Isokangas *et al.* 1989, Söderling *et al.* 2000), together with anti-microbial preventive procedures (Loesche *et al.* 1989, Tenovuo 1992). Dietary habits and dental caries have shown to be of importance for caries development (Kleemola-Kujala & Räsänen 1979, Birkhed 1990), but the frequency of brushing the teeth was more related to caries than were dietary factors in some studies (Schröder & Granath 1983, Stecksén-Blicks 1985a, Stecksén- Blicks & Holm 1995).

The frequency of consumption of sugar-containing products relates to caries, and the ingestion of fermentable carbohydrates is associated with its prevalence (Rugg-Gunn & Edgar 1984, Holbrook *et al.* 1995, Gibson & Williams 1999). Significant correlations between sugar consumption and caries increment have also been observed by Rugg-Gunn

& Edgar (1984), while a clear correlation was observed between the occurrence of "rampant" caries in young children and the use of sweetened dummies and prolonged use of “dinky feeders” containing sugar (Walker 1987). Social and demographic factors such as race, knowledge, schooling and financial status have all been linked with the occurrence of caries (Hunt 1990, Powell 1998, Gibson & Williams 1999). In addition, the time needed for the development of caries is also an important consideration (Alaluusua & Renkonen 1983, Köhler *et al.* 1988).

2.2 Occurrence of caries

Klein *et al.* (1938) introduced the DMF index as a measure of cumulative caries experience in the permanent dentition of children. Since then caries occurrence has been described in terms of the numbers decayed, missing and filled teeth (DMFT) or tooth surfaces (DMFS), and correspondingly in the primary teeth below the age of six years (dmft) or (dmfs). One of the drawbacks is that these indices, which are still widely used as measures of the outcome of dental programmes, ignore changes in the quality of the teeth (Birch 1986). In the past three decades some authors have expressed criticism of their use (Spencer 1997) in the sense that the application of the traditional DMF index to the skewed data on caries that frequently emerge nowadays is one of the factors contributing to the underestimation of the prevalence of caries and the overestimation of the temporal change. Thus it places limitations on the population strategy to be used in caries prevention, and contributes to a lack of discrimination between individuals with differences in caries activity.

Caries occurrence in a population can be described in terms of mean values for the caries indices by percentages of subjects with past and present caries (DMFT > 0) or current caries (DT > 0), and in terms of the frequency distribution of such subjects (Varsio 1999). A modified form of the DMF index is known as the caries increment or correspondingly dmf for primary teeth. This refers to the number of new caries lesions within a specified time interval, either for an individual or averaged over a population (Nikiforuk 1985).

The occurrence of caries in children and in adolescents is related to social factors, those in the highest social class experiencing the lowest caries in both high and low-fluoride areas (Hausen *et al.* 1981). Although high-caries individuals in the present decade have fewer caries lesions than did high-caries subjects two decades ago, caries in industrialized countries has not decreased as much as the figures show (Fejerskov 1997).

2.2.1 Occurrence of caries by type of tooth and surface

The number of teeth and surfaces at risk varies with age (Hausen *et al.* 1983, Nordblad & Larmas 1985a, Vehkalahti *et al.* 1991, Virtanen 1997), as also does the maturation age of tooth (Nordblad & Larmas 1985b). Nowadays the eruption of teeth occurs at an earlier chronological age than earlier (Helm 1969, Virtanen 1994, Eskeli *et al.* 1999). Most caries attacks on fissures occur during the first three years after eruption, and the survival of the first and second permanent molars immediately after eruption and filling increments in the upper incisors are good indicators of dental health. A distinction should be made between chronological and dental age, however. The post-eruptive filling placement curves for individual teeth, obtained using the survival analysis method, evidently follow the pattern of caries attack. (Virtanen 1997)

The occlusal surfaces of permanent teeth are those most frequently attacked by caries (Nordblad & Larmas 1985b, Vehkalahti *et al.* 1990, Li *et al.* 1993, Virtanen & Larmas 1995), and more caries lesions have been demonstrated in pits and fissures of posterior teeth than on other surfaces (Dummer *et al.* 1990, Kingman 1993). The highest caries experience of all has been found in permanent molars (Nordblad & Larmas 1985b, Greenwell *et al.* 1990, Vehkalahti *et al.* 1990), whereas caries is seldom seen in teeth, such as canines, lower incisors and premolars (Nordblad 1986, Greenwell *et al.* 1990, Vehkalahti *et al* 1990, Virtanen & Larmas 1995). The risk of occlusal caries is highest during and after tooth eruption (Härkänen *et al.* 2002), between 6 and 9 years of age for the first permanent molars, and after the age of 13 for the second permanent molars (Nordblad 1986, Ripa *et al.* 1988, Vehkalahti *et al.* 1991, Larmas *et al.* 1995). Approximal surfaces of permanent molars have been found to become carious after 12 years of age (Nordblad 1986, Ripa *et al.* 1988, Virtanen & Larmas 1995), and a correlation has been shown between past caries on approximal surfaces and the developing of new approximal caries lesions (Mejàre *et al.* 2001). Fifteen is an important age because of newly erupted second molars and the increasing role of approximal decay in the dentition (Vehkalahti *et al.* 1990).

2.2.2 Decline of caries

There is general agreement that a marked reduction in caries prevalence among children and young adults has occurred in most of the developed countries in recent decades (Petersson & Bratthall 1996), the reduction being especially marked in the Nordic countries (von der Fehr 1994). In Finland caries experience has been declining since the 1970`s at both a national and provincial level (Nordblad *et al.* 1993). The proportion of 12-year-olds in the city of Espoo with DT = 0 increased from 52% to 73% during the period 1980–1988, and the proportion of 16-year-olds with DT = 0 from 33% to 62% (Luoma & Rönnberg 1991). Meanwhile, the mean DMFT index for 15-year-olds in Helsinki declined from 12.1 in 1976 to 5.1 in 1986, and their DT index from 3.0 to 1.4 (Vehkalahti *et al.* 1990). In the study of Vehkalahti *et al.* (1997) data on children's dental state from 1976 to 1993, were evaluated. During the 17 years, mean dmft for 5-year-olds decreased from 4.6 to 0.8 and mean dt + DT from 0.9 to 0.6. In 1993, 78% had their dmft = 0, whereas 8% of the patients accounted for 76% of all decayed teeth. For 15 year-olds the decrease was even greater, their DMFT fell from 12.1 to 3.0 and their DT from 3.1 to 0.8. However, only 26% had their DMFT = 0 in 1993, with 55% of all dt + DT occurring in 10% of the patients. The prevalence of caries among 3-, 6-, 12- and 19-years-olds in Sweden was followed during the period 1985–1994 through country council report to the National Board of Health and Welfare. The proportion of caries-free 3- and

6-year-olds increased. In 1994, 91% of the 3-year-olds and 64% of the 6-year-olds were free of caries in the deciduous dentition. DFT for 12-year-olds sank from 3.1 to 1.5 during 1985–1994. For 19-year-olds, DFT changed from 8.5 to 5.2, while the proportion of individuals who were caries-free on approximal surfaces increased from 3.4 in 1985 to 1.6 in 1994. The proportion of severely carious individuals decreased greatly during the 10-year period studied. (Sundberg 1996)

Some studies indicate a halt or slowing down in the progress of caries reduction (Speechley & Johnston 1996, Poulsen & Scheutz 1999) and it has also been shown that the decline in caries in deciduous teeth has stopped or even reversed slightly in recent years (Truin *et al*. 1993, Pitts & Palmer 1994).

The decrease in caries index (DMFT) of 12-year olds in the Nordic countries in years between 1985 and 2000 are shown in Table 1.

Table 1. DMFT-indexes in 12-year olds, from 1985 to 2000, in Finland, Sweden, Norway, Denmark, according to Widström et al. 1997, Norblad et al. 1991, Varsio 1999, Helsedirektoratet/Statens helsetilsyn 2000, Socialstyrelsen 2000

Country	1985	1990	1991	1994	1997	1999	2000
Finland	3	-	1.2	1.2	1.1	-	-
Sweden	3.1	2.0	-	1.5	1.0	0.9	1.2
Norway	3.4		2.3	2	1.7	1.6	
Denmark	3.4	-		1.3	-	-	-

2.2.3 Polarisation of caries

Dental caries has not been eliminated in the population but continues to be a major public health problem (Bowen 1991). Despite the dramatic reduction in caries rates over the last decades and the increase in emphasis on preventive dentistry it still affects a great proportion of the population (Newbrun 1992). In many countries, especially in the Nordic countries caries has decreased in schoolchildren, while at the same time the distribution of severe caries has been accumulating in a small proportion in all age groups (Burt 1994, von der Fehr 1994, Spencer 1997, Vehkalahti *et al*. 1997). In Finland the increase of caries-free subjects has stabilized, accompanied by the continued presence of subjects with high caries experience, leading to a skewed distribution of caries prevalence in children and adolescents (Luoma & Rönnberg 1991, Vehkalahti *et al*. 1997). The recent estimates in Sweden and in Finland show that at least 60% of caries develops in only 20% of the young population (Hugoson *et al*. 2000, Seppä *et al*. 2000).

2.2.4 Reasons for the decline and polarisation of caries

The factors lying behind changes in caries prevalence in children and adolescents have been discussed at many international dental forums (Petersson & Bratthall 1996). The occurrence of caries has been declining in communities with and without organized preventive programmes or fluoridation (Hargreaves 1987, Seppä *et al.* 2000). It is assumed that the reasons are related to the use of fluorides, to improvements in oral hygiene, or to a change in microbial, host and salivary factors, or to dietary changes (Marthaler 1984). It is suggested, however, that the most probable reason is related to the increased use of fluorides (Marthaler 1984, Bratthall *et al.* 1996), while according to Renson *et al.* (1985), the organized availability of dental resources and oral health education programmes may be one explanation. The decline in caries may also have been due in part to new diagnostic and treatment criteria (Nadanowsky & Sheiham 1995). More recently, it has been reported that the decline in caries seems not to be associated with professional preventive measures performed in dental clinics (Seppä *et al.* 1998), but there is nevertheless a good deal of agreement on the preventive effect of fluoride toothpastes in this respect (Bratthall *et al.* 1996). Probably the most effective caries prevention treatment available today is fluoridation of municipal water supplies and the use of fluoride toothpastes (Winston & Bhaskar 1998). According to Mandel (1996), the protective properties of fluoride dominate and host resistance wins out as an explanation for the decline in caries.

The opinions of experienced chief dental officers at the health centres in Finland suggested that the most significant factors in the decline in caries were improved socio-economic standards accompanied by the placement of a high value on dental health and the role of the National Health Act (Luoma & Widström 1997). This was thought to guarantee public oral health services for all children and adolescents from birth to 19 years of age, with dental treatment free of charge, systematic dental health programmes with fluoride mouth rinses, fluoride tablets, fluoride varnishes and sealing, and also with dental health education for groups and individuals. (Varsio 1999)

2.3 Risk of caries

Risk is the probability of an individual to develop a given disease or to experience a health status over a specified period (Kleinbaum *et al.* 1982). According to Hausen *et al.* (1994) caries risk is the probability of an individual to develop least a certain number of caries lesions and reaching a given stage of disease progression during a specific period of time, conditional on his or her exposure status remaining stable during the time in question.

High risk can be defined as a group of people with the greatest percentage of teeth, surface or sites with evidence of disease. One could follow the clinical diagnosis model of presence or absence of the disease or determine a clinically significant cut-point, such as number of caries lesions being, for example, more than two. (Beck 1998)

Quantitative estimates of caries risk are based on observations of past caries experience which can be obtained from longitudinal studies. The most common way of doing this is to divide the number of the new diseased cases detected during the observation time by the number of caries-free subjects at the start. In follow-ups of caries incidence the development of new caries lesions (the average number of newly detected cavities or other stages of the caries process) is usually summarized in terms of mean caries increment. Estimates of cumulative incidence can be derived from the increment figures by setting arbitrary cut-off points. For example, one might consider as newly detected cases, subjects who may develop from one to two, three or any other number of new DMF surfaces during the follow-up. (Hausen *et al.* 1994)

2.3.1 Identifying individuals at risk

A four-step process for identifying high-risk individuals was presented as a result of the study conducted in North Carolina (Beck 1988): The first step is to determine whether the disease is distributed randomly or whether there are identifiable factors that are associated with it. The second step is to develop a risk assessment model that would be able to distinguish efficiently between those with a high risk and those with a low risk. The third step is screening population groups for the factors contained in the risk assessment model and using the model to predict each individual's risk of developing caries. This process is called assessment. The fourth step, targeting, consists of the provision of a health promotion/disease prevention regimen or treatment procedure for the individuals at risk, usually with concomitant development of data on the cost-effectiveness of the intervention. When a disease is known to have multiple risk factors, testing the ability of one factor at time in order to identify individuals at risk will give an incomplete picture. Thus the development of a risk assessment model becomes necessary.

The following terms and definitions have been presented in the context of caries risk

A risk factor — Environmental, demographic, behavioural, or biological factor confirmed by a temporal sequence, usually in longitudinal studies, which, if present, directly increases the probability of contracting a given disease, so that its absence or removal will reduce the probability. Risk factors are part of the causal chain (Beck 1998). When the disease occurs, removal of a risk factor may not result in a cure (Kleinbaum *et al.* 1982).

Risk indicator — The term is used to differentiate factors that have only been identified by means of prevalence data (often in cross-sectional studies) and can be defined as probable or putative risk, and used as tools for selecting individuals with a high risk of contracting a given disease (Beck 1988). Risk-indicators for caries can be used for diagnosis and screening purposes and for patient motivation (Larmas 1992, Pienihäkkinen 1987).

A risk predictor — A risk marker that is a characteristic factor associated with an elevated risk of the disease in question (i.e., it predicts well) but is not thought to be part of the causal chain. Beck *et al.* (1998)

A risk model — A multivariable model developed when it is important to identify one or more risk factors for the disease, so that likely points for intervention can be planned. Risk models should not include risk predictors.

A prediction model A multivariate model that can be developed when we think that we understand the aetiology of the disease and are mainly interested in identifying who is at risk.

2.3.2 Risk assessment and caries prediction

Hausen *et al.* (1994) expressed the difference in principle between caries assessment and caries prediction as follows: “For establishing the value of potential predictors, methods applicable to the assessment of the accuracy of diagnostic tests are called for. This means that in everyday practice risk assessment rather than caries prediction is called for. The mere prediction of the future caries increment in the case of an individual, meaning how many caries lesions he or she might develop in a certain time, is not the proper way. Instead, the level of caries risk should be assessed”. When the objective is to maximize the ability of a model to identify high risk and low risk individuals, i.e. to maximize sensitivity and specificity (the proportions of people correctly classified as having or not having the disease), models allowing both indicators and risk factors need to be employed. These are called prediction models (Beck *et al.* 1992). “Risk estimates could be refined by follow-ups in subgroups of study populations of different exposure status, and this is what prediction of caries is about” (Hausen *et al.* 1994).

In view of the multifactorial nature of caries aetiology and the fact that the course of the disease is determined by the interaction of different factors of attack and resistance it is expected that multivariate approaches rather than the use of single parameters may improve the prediction of caries risk for individuals and for groups of subjects (Beck *et al.* 1992, Hausen *et al.* 1994). Multivariable prediction models are generally used when considering more than three predictors simultaneously. Longitudinal studies using multi-factorial regression analyses in a search for acceptable models have been implemented for this purpose (Graves *et al.* 1991) and have proved valuable, especially in view of the fact that the prediction of caries cannot be assessed through prevalence studies (Beck 1990). There are essentially two types of variables that can be used in the development of multivariable models: risk factors, and risk predictors.

The statistical considerations involved in developing risk models have been reviewed by Koch & Beck (1990). The methods applicable to the assessment of caries risk include various regression techniques or discriminative models (Koch & Beck 1990). Risk models should not include risk predictors (past disease, number of teeth, etc.), as these are powerful and may mask the potential risk factors (Beck 1998).

A variety of indicators, consisting of clinical, microbial, salivary and socio-economic variables, have been analysed and discussed in relation to caries prediction in children and adolescents (Powell 1998). The most extensive attempt to produce statistical models for the assessment of caries risk has been made in connection with the Caries Risk Assessment Study at the University of North Carolina (Abernathy *et al.* 1987, Beck *et al.* 1988, Disney *et al.* 1992). The tests and methods proposed or used for the prediction of caries in adolescents have resulted in a sensitivity of 70% to 80% at best (Powell 1998), however, in children Leverett *et al.* (1993) showed higher predictive values. In general, the accuracy of multivariate approaches seems to be much lower than one would expect on the basis of the performance of the individual predictors. Age has been shown to be a significant factor in prediction models, and socio-demographic variables are also important (Powell 1998).

2.3.3 Evaluating the risk

Sensitivity (Sn) is the proportion of individuals with the disease who are correctly identified by the test. Specificity (Sp) is the proportion of individuals without the disease who are correctly identified by the test. Positive predictive value (PV+) is the proportion of individuals with a positive test result who have the disease. Negative predictive value (PV-) is the proportion of individuals with a negative test result who do not have the disease. (Petrie & Sabin 2000) If the disease is concerning individuals at risk of caries: Sensitivity is the proportion of subjects who were believed to have a high caries increment among those whose actual caries increment during the follow-up was high and specificity is the proportion of subjects who were believed to have a low-risk among the ones whose actual caries increment during the follow-up was low. False positive rate and negative rate have exactly the same information as sensitivity and specificity, but in contrast to them, they reveal proportions of misclassified subjects. (Hausen 1997)

All the above measures should always be considered as pairs. For instance it has no meaning if one knows the sensitivity but not the respective specificity. If both the sensitivity and specificity were 80 per cent, every fifth individual with a true high risk would remain undetected in a screening and thus fail to receive the intensified prevention. Correspondingly every fifth individual with low risk would be included in high-risk group and receive measures of prevention for no purpose. This would lead to a high rate of misclassifications. (Hausen *et al*. 1994)

Accuracy (A) is the proportion of correctly classified subjects. One should not consider it for the only measure for evaluating the predictive power of risk markers (Hausen 1997). The level of accuracy of a prediction regarding the future incidence of caries can be assessed using data from follow-up studies. It is usually quantified in terms of sensitivity, specificity, positive predictive value and negative predictive value (Kleinbaum 1982).

Odds is the ratio of the probabilities of two complementary elements, typically the probability having a disease divided by the probability of not having a disease. The odds ratio (OR) is the ratio of two odds (e.g. the odds of disease in individuals exposed and unexposed to a factor). It is often taken as an estimate for relative risk in a case-control study. Because patients are selected on the basis of their disease status, it is not possible to estimate the absolute risk of disease. The odds ratio can be calculated in the following way:

Odds ratio = Odds of being a case in the exposed group/Odds of being a case in the unexposed group

Relative risk (RR) is the ratio of the risk occurrence of a disease among exposed people to that among the unexposed. RR shows for instance, how many more times disease occurs in those with positive test than in those with negative test. The relative risk measures the increased (or decreased) risk of disease associated with exposure to the factor of interest. A relative risk greater than one indicates that there is an increased risk in the exposed group, compared with the unexposed group. (Petrie & Sabin 2000)

2.4 Risk strategies

2.4.1 Population strategy

In general, a population strategy seeks to control common causes of caries incidence, whereas a high-risk strategy seeks to protect susceptible individuals (Fejerskov 1995). A population strategy, providing preventive treatment for all subjects, is thought to be useful in populations with high caries occurrence, because its goal is to change the distribution of the disease by controlling the determinants of caries in the whole population. The purpose is to move the risk level to the more favourable level of the distribution of the disease in the population (Rose 1985). This applies to traditional health programmes focussed at the whole population. One example is the fluoridation of water supplies, to which all subjects are exposed (Newbrun 1996). The disadvantages are that it does not confer any benefit at the individual level and the motivation of the individual for health promotion is not high. Also the motivation of the auxiliary personnel may be weak, because of the lack of instant effects at individual level. Also the pros and cons of the matter may sometimes cause discrepancies, and inconvenient problems may arise especially in industrial and commercial fields. (Rose 1985) Such strategies become questionable in most industrialized countries today, because of the skewed caries distribution in their populations.

2.4.2 High-risk strategy

According to the high-risk strategy, individuals with a high risk of caries are identified and preventive measures are taken to diminish their risk. There are three basic prerequisites for the successful application of such a strategy. First, the occurrence of caries in the target population must be low enough justifying the effort and expense of identifying individuals who are believed to develop a high number of caries lesions. Secondly, accurate, acceptable and feasible measures for identifying the subjects with the highest risk of developing new caries lesions must be available. Thirdly, interventions that aim at bringing down the increased risk of caries in a high-risk group should be based on methods that are effective and feasible. (Hausen 1997)

2.5 Measures for assessing caries risk

2.5.1 Past caries experience

Past caries experience is probably the factor that is most commonly used to assess caries risk (Demers *et al*. 1990), although its sensitivity in adolescents has seldom been more than 60%. It has usually been the most reliable single predictor of future caries development (Alaluusua *et al*. 1990, Russell *et al*. 1991, Scheinin *et al*. 1992), but is not acceptable enough as a single test at either the group or the individual level (Wilson & Ashley 1989, Russell *et al*. 1991). However, it is the most useful tool for dentists in daily praxis (Alanen *et al*. 1994).

2.5.2 Salivary tests

The salivary tests used for clinical purposes are un-stimulated and stimulated saliva flow rates, buffering capacity and the growth of colony-forming micro-organisms, i.e. mutans streptococci, lactobacilli and yeasts/*Candida*. In addition methods for determining sucrase activity have been reported (Hämäläinen *et al*. 1988).

Salivary and microbiological dip-slide tests are useful for diagnostic assessment and as tools for patient motivation (Larmas 1975, Helminen *et al*. 1981, Wikner & Nedlich 1985, Murtomaa *et al*. 1987). By comparison with conventional agar plate techniques, dip-slide tests and strip tests have been shown to be reliable methods for determining salivary levels of lactobacilli and mutans streptococci (Alaluusua *et al*. 1984, Jensen & Bratthall 1989, Davenport *et al*. 1992).

No measure of salivary factors as such can lead to a reliable diagnosis of caries, but a lack of one or more factors will predispose individuals to high caries activity (Larmas 1992). The salivary tests, alone or in combination, are easy to perform in everyday dental practice, but they have rather seldom been used in health centre clinics in Finland (Vehkalahti *et al*. 1992, Kärkkäinen 1997, Helminen *et al*. 1999), perhaps because of the high commercial price and the lack of time for the staff to perform the tests. Further, single-point salivary measures have a large individual variation and are therefore in that sense not reliable enough in caries prediction (Tukia-Kulmala & Tenovuo 1993). Hausen *et al*. (1994), indicated in their study that salivary tests have a weak or only moderate ability to predict future caries. Salivary tests are recommended for detecting high-risk patients and for motivating patients to change their attitudes and adopt more precise patterns of home care. The assessment of micro-organisms in saliva is based on the assumption that there is an association between types and numbers of bacteria and dental caries (Russell *et al*. 1991).

The two most commonly measured salivary factors are flow rate and buffer capacity (Wilson & Ashley 1989). It is well known that severe reduction of the saliva flow rate can favor the progression of caries. Poor salivary buffering capacity and low salivary flow, are also known to be host factors closely related to high lactobacillus counts (Parvinen & Larmas 1981).

Mutans streptococci (ms). Determination of the level of salivary mutans streptococci has been used for the assessment of caries risk and an association has been shown between the number of caries lesions and the level of mutans streptococci in saliva and plaque in both children and adults (Klock & Krasse 1979, Beighton 1991).

It is notable, that a dramatic decline in caries has occurred in 12-year-old Icelandic schoolchildren without any apparent changes in salivary mutans levels (Bjarnason *et al.* 1993). The predictive value of mutans streptococci in saliva has not been shown to be any better than that of past caries experience (Wilson & Ashley 1989, Alaluusua *et al.* 1990, Russell *et al.* 1991, Disney *et al.* 1992), with the reported sensitivities generally below 50%. Thus, the test alone cannot be considered useful for the assessment of caries risk. It has been suggested that regular use of xylitol inhibits the formation of plaque, even though mutans streptococci is found in the saliva (Söderling *et al.* 1991, Trahan *et al.* 1992). Therefore the salivary SM test may be an unreliable indicator, if tested after pre-stimulating saliva, among those children who are regular xylitol users.

All the commercial dip-slide methods available at the present to assay the concentration of mutans streptococci in saliva are based on the fact that bacitracin inhibits the growth of all other oral streptococci except mutans on a mitis salivarius medium. Mutans streptococci colonise the SM dip-slide (Jensen & Bratthall 1989) in proportion to their amount in saliva.

According to Larmas (1992) SM tests are useful for the following purposes: for the pre-selection of patients for dental examination, demonstration of cariogenic infection, evaluation of the effectiveness of chlorhexidine or other mouth rinses as medication, providing an objective measure of the treatment, health education, and diagnosis of parents with high counts of mutans streptococci in a family before eruption of their child's deciduous teeth.

Lactobacilli (LB). In order to make proper use of the Lactobacillus (LB) count for caries prediction, it is important to be acquainted with certain facts concerning their ecology. These organisms constitute a relatively small proportion of the total microflora found in both plaque and saliva (Crossner 1981). They probably do not play any significant role in the initiation of dental decay. Once the lesion has been established, however, the proportion of lactobacilli in the microflora is seen to increase (Klock & Krasse 1977). Their presence can be considered a consequence of the circumstances that normally lead to dental caries.

The density of the LB colonies is important, and an individual Dentocult-LB count is an important educational aid for motivation and dietary counselling among patients (Larmas 1992). For this purpose it is essential to show the test results to the patient and to explain their meaning. These can be used to control the efficacy of dietary counselling. Sometimes a high, steady lactobacillus count is found in medically compromised patients (Larmas 1992). A high salivary flow-rate will reduce high LB counts without affecting lactobacillus infection (Parvinen & Larmas 1981). Other factors independent of sucrose consumption have also been shown to affect the level of salivary lactobacilli including erupting teeth, open carious lesions, orthodontic bands, poor salivation and poor buffer capacity (Sakamaki & Bahn 1968, Parvinen & Larmas 1981, Meurman *et al.* 1987).

Salivary yeasts. Yeasts are aciduric and slightly acidogenic (Lilienthal 1950). The *Candida* (Cand) species have been found to be the most common yeasts in the mouth, and the prevalence of carriers of yeasts varies from 27% to 80% (Martin & Wilkinson 1983, Pienihäkkinen 1987). Orthodontic appliances increase the densities of yeasts in saliva (Addy *et al*. 1982), as also can the use of antibiotics. Yeasts have been shown to be more prevalent in the saliva and the plaque of caries-active subjects than of caries-free ones (Krasse 1954). Russell *et al*. (1990) found a significant correlation between the presence of yeasts and retrospective 1-year caries incidence, while Russell *et al*. (1991) reported a significant correlation between *Candida* and one-year caries increment. Pienihäkkinen (1987), in their study showed salivary yeasts (*Candida* species) to predict caries better than lactobacilli.

A method for estimating yeasts was presented by Nickerson (1953). A dip-slide system, Oricult-N, is available for measuring of oral yeast infection (Parvinen & Larmas 1981). Indications for its clinical use, for example are: 1. to determine the presence of yeast infection in the oral cavity, even before clinical signs 2. to confirm the hypo-salivation status of a patient, because yeast infection and the number of salivary yeasts are depending on salivary flow 3. to control the effectiveness of anti-fungal therapy (Larmas 1992).

Salivary flow rate. The stimulated salivary flow rate by chewing paraffin wax averages 1 - 2 ml/min. The saliva collection time has been suggested to be 5 minutes, after one minute of pre-stimulation by chewing paraffin wax, whereupon the stimulated flow in adult females is 8.6 ml/5 min and that for males 10. 1 ml/5 min (Larmas 1992). In children, aged from 5 to 15 years, the rate of mixed whole saliva stimulated by chewing, was shown to increase with age, and boys had consistently higher rates than girls (Crossner 1984). The most common alterations in salivary flow rate involve reduced secretion (hypo-function), which may be connected with medication, pathological changes in the salivary glands, hormonal changes, sports, diet (e.g. anorexia), sex and age (Parvinen & Larmas 1981, Crossner 1984, Meurman & Rantonen 1994). It is important to identify the individuals with reduced salivary secretion in order to control their oral health.

Buffer effect. Buffer effect is one of the best indicators of caries susceptibility, because it reveals the host response, and a low buffer effect is inactive with reduced flow rate leading to a reduced response of the host to causal factors for caries (Murray 1986). The buffer effect of the saliva has been found to correlate with the flow rate (Klock & Krasse 1977). Patients with a high buffer effect are quite resistant to the caries process, because a high host response can even compensate for active caries habits (Larmas 1992). Wikner & Moum (1986) did not find any age difference in the distribution of buffering capacity categories in 7-15 years old children.

Buffer effect can be measured easily by the Dentobuff method (Frostell 1980, Orion Diagnostica, Espoo, Finland), in which a dip-slide is coated with chemical indicators and immersed in the saliva, the resulting colour being indicative of the capacity of the saliva for buffering acids and bases.

Sucrase test. A simple test for the determination of salivary sucrase activity has been reported (Hämäläinen *et al*. 1988). However, this test has been of limited use in praxis. It has been shown that strict reduction of dietary sucrose over a two-week period effectively reduced high salivary sucrase, i.e. invertase-like activity (Karjalainen *et al.* 1989). They also found that salivary sucrase activity reflects the amount of sucrose consumed, variations in this and the intake frequency at a group level. As sucrose consumption increases, enzyme activity also increases, especially in plaque and saliva (Mäkinen & Scheinin 1972, Birkhed *et al.* 1994). Sucrase activity is induced by the presence of the substrate sucrose, and frequent consumption of sucrose is connected with high salivary sucrase activities (Mäkinen & Scheinin 1972).

2.5.3 Dietary, hygiene and socio-demographic factors

Diet. There is evidence that frequent ingestion of fermentable carbohydrates is associated with the prevalence of caries (Rugg-Gunn 1984, Walker 1987, Birkhed *et al.* 1994, Holbrook 1995). However, there are also studies showing none or only a weak correlation between dietary habits and caries in industrialized countries (Rugg-Gunn *et al.* 1984). It has been demonstrated that the risk of caries increases significantly with increased amount of sugar consumption only when oral hygiene is simultaneously poor (Kleemola-Kujala & Räsänen 1982, Gibson & Williams 1999). It has been shown that poor oral hygiene usually is connected with high sucrase values (Mäkinen & Scheinin 1972, Karjalainen *et al.* 1989). Self-reported sucrose intake seems to be of little value for caries research, as the relationship between caries and the amount of plaque or the frequency of self-reported oral hygiene measures is uncertain (Bellini *et al.* 1981). Results of a systematic review (Burt & Pai 2001) showed that the relationship between sugar consumption and caries is much weaker in the modern age of fluoride exposure than it used to be.

Oral hygiene. Effect of oral hygiene measures on caries has been considered controversial in many extensively quoted reviews (Bellini *et al.* 1981). Similarly there has been a notable failure to demonstrate any consistent relationship between dental plaque scores and caries prevalence, probably because the two indices measure phenomena that occur over considerably different time intervals (Reich *et al.* 1999). In spite of the discrepancies concerning plaque and caries, dental plaque has been shown to be a risk factor for caries (Emilson & Krasse 1985), and mechanical oral hygiene provided by dental staff has proved to be effective in reducing caries (Axelsson *et al.* 1993). A study of oral hygiene in 3-year-old children has shown that those with clean teeth had lower caries scores than those whose teeth were not clean (Schröder & Granath 1983). Tooth brushing has been shown to reduce caries only with simultaneous use of fluoride toothpaste (Ainamo *et al.* 1989, Bratthall *et al.* 1996). Regular brushing with fluoride toothpaste may have a greater impact on caries in young children than restricting sugary foods (Gibson & Williams 1999).

Socio-demographic factors. Dietary and health habits are affected by income, education and social environment (Milén 1986, Powell 1998). People of low socio-economic status have more caries lesions than do people of high socio-economic status (Hausen *et al.*

1981, Hunt 1990, Bolin 1997, Gibson & Williams 1999). Risk indicators for caries identified by logistic regression analysis, comprising samples of 5- and 12-year-old children from eight EU countries were social class of the family, the mother's smoking habits and the number of siblings in the case of 5-year-olds (Bolin *et al.* 1997). The survey of oral health habits in 11 European countries by Honkala *et al.* (1990), including hygiene habits, sugar snacks and the use of fluorides, indicated that about half of all adolescents consumed sweets at least daily, in contradiction to Sweden, Norway and Finland, were the use of sweets were not so high. They also showed that the Nordic countries had the highest figures for daily use of fluoride toothpaste. The frequency of tooth brushing was highest in Sweden and Switzerland, but it was consistently less frequent in boys than in girls in all the countries concerned.

In some caries prediction studies socio-demographic variables have been involved with clinical variables in relation to caries and the former have been shown to be important for caries prediction in young children and adults (Powell 1998).

2.6 Targeting preventive treatment

The numerous preventive programmes, including school-based supervised fluoride brushing and rinsing, which were increasingly established during the 1960s, combined with improved treatment coverage, have probably been the decisive factors behind the remarkable improvements in dental health in Finland and the other Nordic countries from the early 1970s onwards (Wang *et al.* 1998). Acceptable measures for preventing caries have been tested and targeted at both individuals and groups (Axelsson *et al.* 1987, Isokangas 1989, van Rijkom *et al.* 1996, Riordan 1997, Dennison *et al.* 2000, Belfrán-Aquilar *et al.* 2000). There has been a tendency in the Nordic countries to provide preventive care similarly for all children without any supplementary high-risk strategy (Kärkkäinen 1997, Wang *et al.* 1998). Poor targeting of intensified preventive measures at high-risk caries patients and over-treatment of those with a low caries risk has been reported in previous studies (Vehkalahti *et al.* 1992, Kärkkäinen 1997, Varsio *et al.* 1999). No significant differences in the strategies for preventing caries were found between the municipal health care centres in Finland in the early 1990s, at a time when it was recommended that they should reduce prevention measures aimed at groups and extend the time between the dental check-ups in schoolchildren (Kärkkäinen 1997). It has also been shown in multivariate analysis that the time spent on preventive care varies by country and is not associated with the DMFT of the children (Wang *et al.* 1998).

The rapid and substantial decline in caries prevalence in some industrialized countries can in part be attributed to multiple fluoride application, but other factors must also have exerted a beneficial effect (Marthaler *et al.* 1996). There are several risk indicators to be considered when planning preventive procedures. These include risk ages, time of risk, risk teeth and surfaces, medical risk and social risk (Bader *et al.* 1986, Nordblad & Larmas 1986, Virtanen 1997, Vehkalahti *et al.* 1997, Meurman 1997, Powell 1998).

2.7 Preventive methods

2.7.1 Remineralisation therapy

Demineralisation and remineralisation are dynamic processes characterized by the flow of calcium and phosphate out of and back into the tooth enamel (Silverstone 1977). Normal oral bacteria adhere to the pellicle covering the enamel surface and a bacterial mass called plaque is formed. Mutans streptococci and lactobacilli in particular are involved in caries development, converting ingested sugars to weak organic acids by glycolysis (e.g. lactic, acetic and formic acids). These acids diffuse through the plaque into the tooth, leaching calcium and phosphate from the enamel and eventually causing collapse of the tooth structure and the formation of a cavity. Caries lesions do not develop all at once but usually over several months or years. (Winston & Bhaskar 1998)

After intake of sugar, the pH of the plaque decreases as the bacteria metabolize the sugar to acids and within minutes it can reach 4.0 or lower and the neutralization of plaque acids by the alkaline buffer system in the saliva can take as long as two hours (Jensen *et al.* 1986, Trahan 1995). It is only when the plaque acids have been neutralized that the remineralising process can take place (Winston & Bhaskar 1998). Remineralised early carious lesions are more resistant to acid attack than sound enamel (Koulourides & Cameron 1980). The maturation of teeth has been observed to last about three years after eruption, and even over 3 years between 13 and 16 years of age (Edward 1997). Since the critical period for teeth to decay is immediately after the eruption according to (Carvalho *et al.* 1992, Härkänen *et al.* 2002), preventive measures should evidently be provided at the time and instantly after tooth eruption (Virtanen *et al.* 1996).

2.7.1.1 Fluoride in caries prevention

Fluoride reduces the progression of caries and helps the remineralisation of initial, manifest caries (Belfrán-Aquilar *et al.* 2000). The substance has been studied in vitro for its remineralizing effect (ten Cate 1990), and its caries-reducing effect has been verified (Klein *et al.* 1985, Kalsbeek & Verrips 1990, Belfrán-Aguilar *et al.* 2000). Fluoride ions inhibit bacterial growth and can have a lytic effect on some cariogenic strains. The presence of fluoride can reduce the quantity of acid produced by cariogenic bacteria (Marquis 1990). Some authors have concluded that the combined use of various fluoride sources is more effective against caries than the application of just one (Marthaler 1990, Seppä *et al.* 1982, Axelsson *et al.* 1987). A variety of fluoride products have been developed for school-based preventive programs, clinical or home use over the last twenty years, such as rinses, gels, varnishes, toothpastes and tablets (Table 2).

Table 2a. Examples of vehicles and methods of fluoride use in caries prevention in Finland.

Vehicle (systemic)	Product	Concentration	Dosage mgF/day/ persons weight/kg according to the instructions of STAKES 1995 and by water fluoride concentration			
			mg/l < 0.04		mg/l 0.4-0.8	
			mg	years-old	weight/kg	mg
Tablets	Fluorilette®	0.25 mg/tabl	0.25	< 3	8-15	-
	Natr.fluorid. 0.553 mg		0.50	3-6	21-35	0.25
			0.75	7-12	16-20	0.50
			1.0	13-15	36-50	0.75
			1.50	> 16	> 50	1.0
Lozenges	Fludent® Natr.fluorid.0.25 mg Xylitol 155.6 mg Sorbitol 148.6 mg	0,25 mg/tabl	*			
	Fludent® 0.75 mg		**			

PTD (Probably Toxic Dose) = 5.0 mg F/kg LD (Letal Dose) = 15 mg/kg
* over the counter, and dosage according to the instructions of Stakes 1995.
** prescription drug

Table 2b. Examples of vehicles and methods of fluoride use in caries prevention in Finland.

Vehicle (topical)	Product	Concentration	Type of application
Dentifrices	NaF, MFP, AMF	1 or 1.5 mg/ml	brushing 1-2 / day
Rinses	0.05% NaF solution	0.23 mg/ml	rinsing 1-2 / day
	0.2% NaF	0.9 mg/ml	rinsing 1-2/ day
	F-chlorhexidine solution (fluoride 0.02% / CHX 0.2%)	0.22 mg/ml	rinsing 1-2 /day / by 2 weeks
Gels	0.2% NaF	0.9 mg/ml	application or brushing 1-2 / day
	1.1% NaF	5.0 mg/ml	application or brushing 2 / day
	Elmex-gel; AMF-NaF	12.5 mg/ml	brushing 1-2 / month
Pastes	33.3% NaF	150.6 mg/ml	for application of sensitive teeth
Varnishes	Duraphat®, NaF	22.6 mg/ml	application 1-2 times a year or application 3-6 times a year

Fluoride toothpastes were introduced in 1955, but came into common use in most developed countries, including Finland, in the 1970s. The role of fluoride in toothpastes is important in the prevention of dental caries (Bowen 1995). Today many researchers assume that fluoride toothpastes alone are responsible for the reduction in caries observed in schoolchildren in the Western world (Jenkins 1984, Bratthall *et al.* 1996, Winston & Bhaskar 1998).

Fluoride tablets have been increasingly adopted in Europe in the 1970s according to country-specific preventive policies. The correct dosage concerning fluoride concentration in ppm (= mg/l) must be determined on the basis of the patient's age and the fluoride content (optimal 1 ppm, WHO 1994) of the main water source. In Finland, fluoride tablets were provided or recommended systematically for children from the age 1/2 to 15 years during the 1970s and 1980s, but the dosage was restricted in the 1990s because of new information on questionable effects of fluoride ingestion and claims that the best remineralisation effect could be achieved with external application of fluoride directly to the enamel (Thylstrup 1990). The proportion of 0 to 6-year-old children receiving fluoride tablets in European countries ranged from 5 to 35% (Kalsbeek & Verrips 1990). The consumption of fluoride tablets was higher in Norway and Finland than elsewhere, but decreased markedly with increasing age, and there were no differences between boys and girls. The benefit of fluoride tablets as a preventive procedure among pre-school children has been confirmed in a clinical trial (Driscoll *et al.* 1992).

Fluoride rinsing at schools began in the 1950s. However, there is no evidence that fluoride mouth rinses would provide additional benefits for people who are regularly using fluoride toothpaste (Leverett 1989), and the school-based rinsing procedures were mostly discontinued in Finland in the 1990s, because of staffing restrictions and new information on the low effectiveness of the preventive programmes (Wei & Yiu 1993, Riordan 1997). They were replaced with more intensive health education programmes for advising groups on home dental care and encouraging individuals to brush their teeth with fluoridated toothpastes.

Fluoride varnishes were developed in the 1960s, when the aim was to provide an improved product alongside the existing topical fluoride vehicles, such as fluoride gels and mouth rinses, that would prolong contact between the fluoride and the tooth enamel. The clinical efficiency of fluoride varnishes, their clinical use, cariostatic mechanism and their safety, have been demonstrated in many connections (Belfrán-Aquilar *et al.* 2000). Fluoride varnishes had become widely used in the European countries by the 1980s and have continued to be popular since then. Fluoride varnishes are not intended to adhere permanently to the teeth but to remain in close contact with the enamel for several hours. As the varnish sets in contact with intra-oral moisture, careful drying is not required before application. Fluoride varnish needs to be reapplied to maintain its preventive effect, however (Seppä *et al.* 1984). Caries reduction has usually been greater with fluoride varnishes than with any other topical fluoride (Axelsson *et al.* 1987, Seppä & Pöllänen 1989). Fluoride varnish has been shown moderately cost-effective (Petersson & Westerberg 1994). Its frequent use is now common, especially in all the Nordic countries (Kalsbeek & Verrips 1990), Duraphat® varnish, being most widely used of all preventive methods in Finnish public dental clinics in the 1990s (Kärkkäinen 1997). Although many topical fluorides have been shown to have preventive effects on caries (Axelsson *et al.* 1987), the cariostatic effect of the Duraphat® and Fluor Protector® fluoride varnishes has been shown to be no longer detectable two years after the treatment was terminated (Seppä *et al.* 1984)

Applications of the Duraphat® 1-2 times a year have been accepted as normal prevention for schoolchildren at the municipal health centres of Finland, according to the latest information available on the optimal use of fluoride varnish (Seppä & Tolonen

1990). Fluoride varnish provides additional benefits for children with high caries activity even when the intake of fluoride from other sources is optimal (Seppä *et al.* 1982). Applications on a more frequent basis than half-yearly were recommended in some reports (Modéer *et al.* 1987, Axelsson *et al.* 1987, Seppä & Tolonen 1990). A meta-analysis of eight randomised clinical trials out of 30 studies of Duraphat® varnish resulted in a caries reduction of 38% (Helfenstein & Steiner 1994a). More recently, a review of fluoride varnishes has concluded that their efficacy for caries prevention in school-aged children is equal to that of other topical fluoride vehicles (Belfrán-Aguilar *et al.* 2000). It is possible that improved oral hygiene and the use of fluoride may have a synergistic effect (Rølla & Øgaard 1991), but it has also been shown that none of the fluoride-methods altered the pre-established patterns of caries development among children (Bruun *et al.* 1985).

2.7.2 Antimicrobial therapy

2.7.2.1 Chlorhexidine in caries prevention

Antimicrobial preventive procedures have the effect of reducing the development of caries (Loesche *et al.* 1989, Tenovuo *et al.* 1992). The bis-biguanide chlorhexidine selectively suppresses the growth of some types of micro-organism which are associated with the development of caries lesions (Maltz *et al.* 1981, Marsh 1993), and constitutes an effective caries preventive method because the bacteria involved in the decay process, especially mutans streptococci, are sensitive to it (Malz *et al.* 1981 Meurman 1988, Tenovuo *et al.* 1992, Emilson 1994). The effectiveness of chlorhexidine on caries prevention has been reviewed (Kidd 1991, Emilson 1994). Chlorhexidine has been shown to reduce mutans streptococci in saliva and plaque, the effect lasting only from three to six months and therefore the treatment should be repeated after 4–12 weeks (Malz *et al.* 1981, Zickert *et al.* 1987). Only a slight long-term cariostatic effect was found two years after discontinuation of chlorhexidine treatment (Zickert *et al.* 1987), whereas it has been shown that mutans streptococci in saliva can be greatly reduced by repeated short-term applications of chlorhexidine (Maltz *et al.* 1981, Ostela & Tenovuo 1990).

Prophylactic methods with fluoride or chlorhexidine affect caries mostly on smooth surfaces, fairly in approximal sites, but not on fissure caries (Axelsson *et al.* 1987, Petersson *et al.* 1998). Among the individually used clinical preventive measures, the effectiveness of the application of fluoride varnish to the enamel of permanent teeth has been studied (Seppä *et al.* 1994), and the effect of treatment with chlorhexidine on the oral flora has been tested in clinical trials (Ostela *et al.* 1990, Tenovuo *et al.* 1992).

Chlorhexidine has been used in dentistry in three ways: in water solutions, in a gel, or in toothpastes. Its effect on mutans streptococci is about the same in all cases, including tooth brushing with a gel or solution, varnish or a gel applied with an individual tray.

A meta-analysis of the caries-inhibiting effect of chlorhexidine treatment resulted in an inhibiting effect of 46%, and multiple regression analysis showed no significant influence of the variables "application method", " application frequency", "caries-risk", "fluoride regime", "caries diagnosis" or "tooth surface" (van Rijkom *et al.* 1996). (Table 3)

Table 3. Vehicles and methods for application of chlorhexidine (CHX) according to Rijkom et al. *(1996) and Splieth* et al. *(2000).*

Vehicles	Authors	Application methods	Application frequences	Risk group	Tooth surfaces	Follow-up years	Age group year	Prevent. fraction %
CHX-mouthtrinses	Spets-Happonen *et al.* 1991	0.05% rinse 1/day at school + 1/ day at home	2/day 5 days/ every 21 days	high	all	2.75	11	11
CHX-gel	Linquist *et al.*1989	1% gel professionally applied	every 90 days includ. floss	high	all	2.0	13	52
	Gisselsson *et al.*1988	1% gel professionally applied		high	approx.		12	44
	Zickert *et al.* 1982	1% gel professionally+ 1/day at home applied	14 consec. days, every 120 days	high	approx.	1.8	13-14	68
	Lundström & Krasse 1987	1% gel	2/day, every 30 days	high + orthod.	all	1.8	11-15	26
CHX-gel + CHX-rinse	Axelsson *et al.* 1987	0.2% rinse supervised + gel profession. applied	every 180 days	high	approx.	2.5	13	38
CHX-toothpaste	Dolles & Gjermo 1980	2% toothpaste at home	2/day every day	non selected	all	2.0	13	no
CHX-varnish	Splieth *et al.* 2000	1% CHX-V Cervitec®	3 monthly	high	surfaces at risk	1.0	8-10	42.3

High = selected high-risk groups
Prevented fraction = (new DFS (control) - new DFS [exp.1])/ new DFS (control). (Rijkom *et al.*1996)
1% CHX-gel brushing +1% CHX-1%Thymol* varnish application, 3 min/3monthin the high-risk children (n = 29) and in the control group (n = 25) 1%
CHX-gel brushing only. No significant differences between the groups in respect to caries reduction (Splieth *et al.* 2000).

2.7.3 Counselling for diet and oral hygiene

The importance of regular meals, restriction of sugar consumption and replacement of sugar with non-fermented sugar substitutes, avoidance of juices sweetened with sugar, use of fluoride tablets and regular brushing of the teeth with fluoride toothpaste, have been the main topics in counselling schoolchildren and their parents in dental health at the health centres in Finland. Instruction of tooth brushing with fluoride containing toothpaste was provided in groups at schools and at day care centres in the 1990s, and small children have been supplied with fluoride tablets free of charge since the 1970s. These procedures have been gradually discontinued, however, because of staff restrictions and new information of the low effectiveness of preventive programmes (Klein *et al.* 1985, Wei & Yiu 1993, Riordan 1997). Nevertheless, it has been suggested that the habit of daily tooth brushing is important as a form of health education at day care centres (Schröder & Granath 1983, Paunio *et al.* 1993), and the topic is now addressed in the form of more intensive counselling for better home care, including the use of xylitol as the best substitute for sugar and a recommendation for brushing the teeth with a fluoride toothpaste. According to the current knowledge, xylitol chewing gum and tablets are nowadays widely recommended for caries control in infants and schoolchildren in Finland (Isokangas 1989, Birkhed 1994, Kärkkäinen 1997, Alanen *et al.* 2000).

The risk of caries has been shown to increase significantly with increasing sugar consumption only when oral hygiene is simultaneously poor (Kleemola-Kujala, & Räsänen 1982), so that children with clean teeth have little caries. Schröder & Granath (1983) observed dental plaque to be a risk factor but some authors have reported no significant correlation between oral hygiene and dental caries (Ainamo & Parviainen 1989). The frequency of tooth brushing has shown to be more closely correlated with caries than dietary factors, however (Stecksén-Blicks & Holm 1995). The 12-month results of a study to control occlusal caries in the first permanent molars by means of hygiene suggested that there were no significant differences between the preventive effects of a professional tooth cleaning application and oral health education programme, and a programme based on selective fissure sealing and the application of topical fluoride (Arrow 1997). Axelsson *et al.* (1993), in their study have reported good results obtained with a needs-related preventive programme for caries in schoolchildren provided by hygienists.

Pupils' dental health has been explained by their self-care practices in combination with their wish to adopt positive patterns of dental health behaviour in the future (Freeman *et al.* 1993). Parents of healthy children had a statistically higher level of education than those of diseased children (Milén *et al.* 1986, Hunt 1990). The awareness of a population is more important than merely teaching facts (Kinnby *et al.* 1991), and it has been suggested that increased dental awareness and regular professional and home oral health care have contributed to the sharp decline in dental caries in many parts of the world (Splieth & Mayer 1996, Axelsson *et al.* 1993, Wei & Yiu 1993). Self-care in the form of the substitution of xylitol for sugar products (Isokangas *et al.* 1989, Birkhed 1994, Alanen *et al.* 2000) and tooth brushing with fluoride toothpastes (Ainamo & Parviainen 1989, Bratthall *et al.* 1996) may be the right way to promote dental health.

2.7.4 Sugar substitutes

One of the main conclusions of the "Vipeholm study" is that sugar in sticky between-meal products is associated with high caries activity (Birkhed 1989). This finding also stimulated research on sugar substitutes, which do not support acid formation in dental plaque. On the other hand, using chewing gum as agent for sugar substitutes, simultaneously the protecting and healing properties of saliva came in use, and favourable results have been achieved (Birkhed 1994, Edgar 1998, Alanen *et al.* 2000). Comparison of fermentable sugars with non-fermentable sugars and artificial sugar substitutes are shown in Table 4.

Table 4. Comparison of sugars with fermentable, non-fermentable polyols and artificial sugar substitutes. (Imfeld 1994, Edgar 1998)

Chemical characteristics of carbohydrates	Sugars and sugarsubstitutes	Cariogenicity	Antibacterial activity	Sweeteness related to sucrose = 1	kJ/g kcal/g
Sucrose	glucose+fructose,	highly cariog.	no	1.0	17 (4)
(disaccharide)	fructose,	cariogenic	no	1.6	
(monosacharide)	lactose	cariogenic	no	1.0	
Hexitols	sorbitol*, mannitol	low cariogenic	no	0.6	17 (4)
Pentitols	xylitol**	non-cariogenic	yes	1.0	17 (4)
12- carbon polyols	maltitol, lactitol	low cariogenic	no		
Mix. of two 12-carbon polyols	palatinit	low cariogenic	no		
Hydrogenated starch hydrolysate	lycasin	low cariogenic	no		
Artificial sweeternes	saccharin, cyclamat, aspartam	non-cariogenic	no	200-500	0 (0)

*sorbitol is non-cariogenic in chewing-gum
**cariogenic bacteria do not ferment xylitol

The "Turku sugar study" started as an attempt at finding substitutes for sucrose (Scheinin *et al.* 1975). Xylitol emerged as the best non-fermentable sweetener. Xylitol appears to promote the conversion of mutans streptococci to less acidogenic strains and enhances remineralisation (Winston & Bhaskar 1998). Xylitol-sweetened gum, in addition to stimulate saliva flow, also exerts an antimicrobial effect in plaque (Edgar 1998).

Restriction of the consumption of products sweetened with sucrose (Scheie *et al.* 1998) and the use of xylitol (Isokangas *et al.* 1989, Mäkinen *et al.* 1996, Söderling *et al.* 2000) can reduce the counts of mutans streptococci for a certain period. Xylitol sweetened gum has been well accepted, thus eliminating the possibility of caries development (Nordblad *et al.* 1995, Edgar 1998, Alanen *et al.* 2002). Recently, the effect of xylitol for caries reduction has been shown to be superior to that of biannual CHX or F varnish applications (Söderling *et al.* 2000). Due, to the evidence based knowledge of the effect of xylitol on caries, chewing gum and tablets have recently been widely recommended in Finland for infants and schoolchildren, and for all patients with a high caries risk. Even xylitol-campaignes have been organised at schools as an educational tool (Nordblad *et al.* 1995).

2.7.5 Sealants

Sealants are used to prevent caries and the need for dental restoration on the occlusal surfaces of the posterior teeth, which are those at the greatest risk of developing caries. The population at risk of developing occlusal caries is the target group for sealant therapy, while the population with a low risk of developing caries may be over-treated with the use of sealants (Swango & Brunelle 1983). The long-term benefit of using sealants on permanent teeth has been well documented in studies lasting as long as six to 15 years (Houpt & Schey 1983, Vehkalahti *et al.* 1991, Dennison *et al.* 2000). Occlusal sealants reduced the number of carious surfaces by one or two over four years (Klein *et al.* 1985), and in a recent five-year retrospective study of a population with low caries incidence, fifteen sealed first molars or 10 sealed second molars resulted in the prevention of one occlusal restoration. This latter result cannot be considered sufficient in terms of the cost-benefit ratio of the interventions, and it is clear that for sealants to be effective, they must be allocated to children at risk and not routinely (Dennison *et al.* 2000). Both fissure sealing and fluoride can be highly effective against fissure caries in newly erupted teeth. Fluoride-releasing sealants, representing a new preventive method, have proved to be effective for caries prevention (Murray 1993). An evaluation of sealant programmes (Llodra *et al.* 1993) showed that their effectiveness is higher in populations exposed to fluoridated water, but that they do not perform well relative to other dental care programmes.

2.8 Economic evaluation

The importance of the costs of promoting health has been under discussion for many decades, and the recent literature on health services contains many statements that stress the importance of cost-benefit (CB) and cost-effectiveness (CE) analyses for the allocation of resources to or within the health sector (Garcia 1989, Sintonen & Linnosmaa 2000). Health economics is involved with problems of priority and the application and combination of resources (Sintonen *et al.* 1997). The input consists of all resources consumed, e.g. personnel, time, facilities, equipment and knowledge, and can also be expressed in monetary terms, i.e. as costs (Drummond 1987). The production process comprises the combined resource activity needed to generate the output, i.e. products or services. The effectiveness of the production process is related to the net achievement of the goals, while the efficiency of the production process is a function of both its effectiveness and the actual input. (Sintonen *et al.* 1997) Both effectiveness and efficiency are relevant when considering whether to implement a preventive programme in a population. It must be emphasized, however, that the economic comparison of different preventive activities is only relevant if the outcome is of the same financial value (Drummond 1987).

Economic evaluation provides a comparative analysis of alternative courses of action in terms of both their costs and their consequences (Drummond *et al.* 1987). Dental health is easier to measure than is the output of most other health programmes. Measures of the success of programmes or changes in clinical measures in the field of dental health, and of the savings in terms of costs, are the aspects most frequently studied. When it comes to collective measures, certain criteria must be met. The measures should be technically uncomplicated, easy to administer, inexpensive and highly effective. With such comprehensive programmes, cost-efficiency is essential. (Yule *et al.* 1986)

A fairly small proportion of the economic evaluations that have been carried out of public health care apply to the field of dentistry (Warner 1989). Some economic evaluations of the productivity in the field of dentistry, in Finland, include a productivity comparison between private and public dentists (Sintonen *et al.* 1986), comparison of dental care in health centres (Utriainen & Widström 1990), and a study on the productivity of public oral health care in seven health centres (Vehkalahti & Helminen 1994). In addition, Nordblad *et al.* (1996) studied technical efficiency in public health centres in Finland using the Data Envelopment Analysis (DEA).

2.8.1 Cost-effectiveness analyses

Analyses in which costs are related to a single common effect that may differ in magnitude between the alternative interventions are usually referred to as cost-effectiveness analyses (Drummond *et al.* 1987). The results of such comparisons may be expressed either in terms of cost per unit effect or in terms of effect per unit cost. Cost-effectiveness analysis (CEA) tries to find which of the alternatives exhibits the highest cost-effectiveness ratio (Sintonen *et al.* 1997). Evaluations that measure both costs and consequences of the alternatives in terms of money are usually called cost-benefit analyses (Drummond 1987). Studies using cost-benefit analysis (CBA) in dentistry typically measure the outcome in terms of the savings associated with the health programmes being evaluated. The problems entailed in CBA led to a decline in its use in the late 1970s, when analysts became more interested in CEA (Gaspari 1983). By comparison with other dental health programmes for the prevention of caries, fluoridation programmes tend to perform well (Sintonen & Linnosmaa 2000). Comparisons of cost-benefit (CB) and cost-effectiveness (CE) ratios have been made between community water fluoridation, school water fluoridation, weekly fluoride mouth rinses at school and sealant programmes conducted at schools with the result that the community water fluoridation programme had the highest benefit-cost ratio among the programmes studied (Niessen & Douglas 1984). In a cost-effectiveness assessment of Klein *et al.* (1985), analysis of the dental examination data of 20 052 schoolchildren showed that dental health lessons, brushing and flossing, fluoride tablets and mouth rinsing, and professionally applied fluoride were not effective in reducing caries essentially, even when all these procedures were used together. Children who were especially susceptible to decay did not benefit appreciable more from any of the preventive measures than did children in general. Annual direct per capita costs were $23 for sealant or fluoride gel applications and $3.29 for fluoride mouth rinsing. Communal water fluoridation was reaffirmed as the most cost-effective means of reducing caries. Manau *et al.* (1987), in their study compared the CE of a fluoridation programme with corresponding measures for school mouth rinsing and tooth brushing programme and came also to the conclusion of the superiority of water fluoridation.

Mitchelle & Murray (1989) concluded from early clinical trials that fissure sealants were cost-effective relative to fillings, but that they were inferior to other fluoride programmes in terms of their CB and CE ratios. When targeted at the subpopulation of high-risk children, however sealants can become cost-effective for protecting pit and fissure surfaces (Akehurst & Sanderson 1993). Fluoride tablets in a pre-school program, showed to be most effective in primary dentition, the cost-effect ratio being 1:1 for both primary and secondary dentition (Widenheim & Birkhed 1991). In an economic evaluation of three caries preventive strategies, including fluoride varnish, a CHX-fluoride solution, and the usual prevention provided for a control group, Vehmanen (1993) in her randomised field study, in children aged 13-14 years with a risk of caries, did not find any statistical difference between the groups in terms of net caries increments or caries restoration costs over two-year and four-year periods. The use of xylitol chewing gum in adolescents was shown to be moderately cost-effective first after 10 years ahead from the start of the trial (Virtanen *et al*. 1996).

3 Aim of the present research

The possibility of transmission of mutans streptococci from child to child was studied in the course of a programme to reduce the spread of infectious diseases among children at the municipal day-care centres (I). The purpose was to analyse the predictive value of a series of caries risk indicators with respect to the 11-month caries increment, and the combined effect of the risk indicators and their interaction on the caries increment in adolescents, in order to find the most suitable model for screening caries risk subjects and for directing an intensive prevention programme at them (II, III). Further the efficiency of intensified prevention targeted at the selected risk groups was analysed (IV), and the cost-effectiveness of the preventive measures was assessed (V).

3.1 Hypotheses

1. Tooth brushing at day-care centres is one risk factor for the transmission of mutans streptococci (ms) from one child to another, increasing the risk for caries. (I)
2. A series of caries risk indicators tested in adolescents result in a suitable model for screening purposes. (II, III)
3. The strategy of targeting prevention at selected risk groups leads to a reduction in caries in these groups, and comparison of the groups by the survival analyses method enables the long-term effect on dental health to be determined. (IV)
4. In the long term the intensified preventive procedures provided for the risk groups and an appropriate reference group are more cost-effective than the conservative treatment model of filling the teeth. (V)

4 Materials and methods

4.1 Subjects (papers I, II, III)

Paper I. Oral health factors were surveyed in 677 children aged from 1 to 8 years, mean 4.9 years, divided more or less equally between a set of 10 intervention day-care centres and 10 control day-care centres in the city of Oulu. The numbers and ages of the children were similar in each group of centres.

Paper II, III. The baseline population (II) consisted of 221 schoolchildren born in 1974, 1975 and 1976, their mean age being 13 years 3 months, range 11 years 10 months to 14 years 11 months, who were provided with free public oral health services at dental clinics close to their schools in 5 areas of the city of Oulu. The population base of the city was about 110 000 inhabitants. There were sixteen drop-outs due to change of address, illness or medication, so that 205 subjects, 114 boys and 91 girls, were observed over the 11-months period, including 24 children receiving orthodontic treatment (II, III).

4.2 Risk groups (IV, V)

Paper II, IV. After the 11-month observation time and the obtaining of the test results, the risk groups were selected. All 109 individuals with four or more positive risk indicators were considered to have a high risk of caries and were provided with intensive prevention for one year, using either chlorhexidine (CHX group) or fluoride varnish (F group). The 86 subjects with three or fewer positive tests were regarded as forming the low risk group (LR group) and were provided with basic prevention. In order to obtain a reference (Ref) group representing the normal health centre population provided principally with basic prevention, a sex and age-matched control was chosen for each test subject. The patients' records at Oulu Health Centre, where all the 390 participants were examined and treated, were used as documents. The measure of effectiveness of the intervention was the number of fillings saved in the test groups relative to those in the control group. Cost-effect analysis was assessed for the test groups in respect to the additional costs of the preventive procedures.

4.3 Description of the study (I, II, III, IV, V)

Summary of subjects and description of the papers (I, II, III, IV, V) is presented in Figure 1.

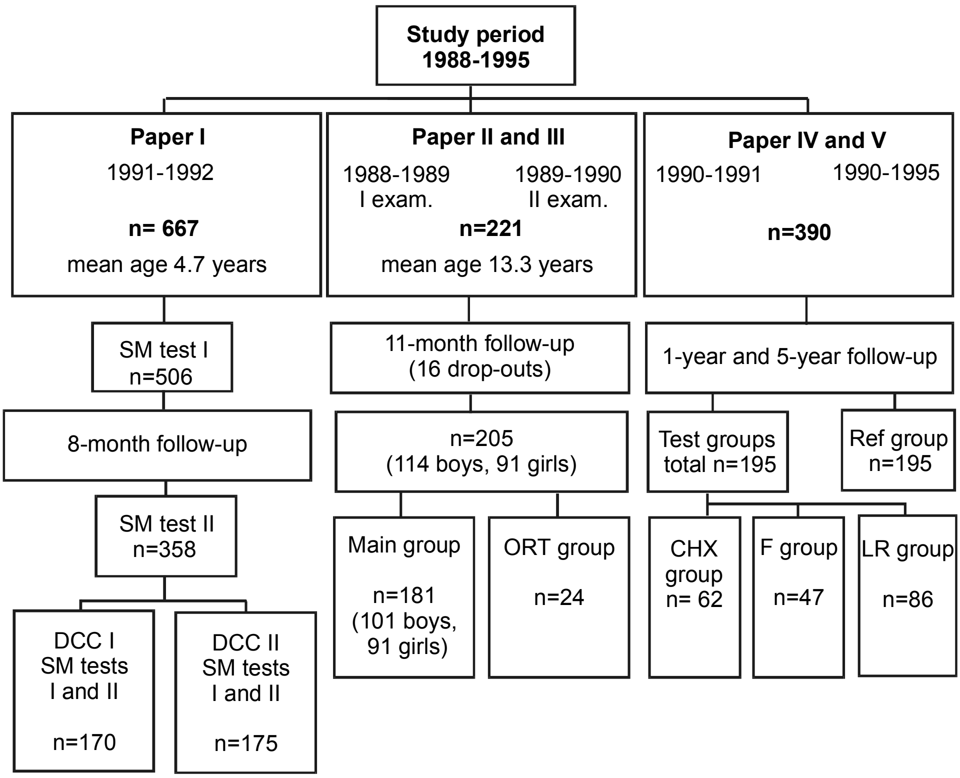

Fig. 1. Summary of study periods including the number of participants, follow-up periods and subgroups

Paper I. A follow-up survey of infectious diseases and oral health factors was conducted at 20 municipal day-care centres chosen at random from the total of 53 such centres in the city of Oulu, 10 serving as intervention centres and the other ten as control centres. Since the evaluation of the occurrence of mutans streptococci in children at the day-care centres was directed towards reducing the spread of infectious diseases, the intervention included the withdrawal from tooth brushing.

Children, older than two years of age, had individual toothbrushes and mugs at the day-care centres, where the staff supervised daily tooth brushing. No toothpaste was used, because the personnel at the day-care centres were not able to control the adequate use of it. Dental nurses instructed at least once a year the children and day-care staff in tooth brushing. Pre-school children usually visit a local municipal health clinic once a year when instructions concerning nutrition, tooth brushing and the use of fluoride, and xylitol products as sugar substitute, are given to the parents. Children over 4 years of age are recommended to use a little amount of fluoride toothpaste or low-fluoride toothpastes.

Papers II and III. The initial aim was to conduct a pilot study to serve the author's own clinical interests, but the project was later expanded into a follow-up study covering the years 1988-1991. The participants for the study were chosen from five areas and schools in the city of Oulu. The children had a yearly dental examination and received treatment in all fields of clinical dentistry at the local Municipal Health Centre clinics. Fluoride varnish was applied topically once or twice a year for all subjects. Before commencement of the research in November 1988, all the necessary restorative procedures were completed. According to the study protocol the subjects were asked to refrain from eating and smoking for one hour before the salivary tests were performed, and not to brush their teeth on the morning of the examination. Anyone who had taken medication that was likely to reduce the salivary secretion rate and/or antibiotics within two weeks prior to the day of examination was to be excluded. No subjects had to be excluded for violating the protocol with respect to smoking, and those who had to be excluded were recalled after an appropriate interval. The subjects did not receive topical applications of chlorhexidine before or during the study. The clinical examinations were carried out in the mornings over a three-month period at the clinic closest to the schools of the participants. One experienced dentist (M.R.) interpreted the saliva tests, and aided by a dental assistant kept the clinical records and performed the diagnostic tests.

The clinical examination and the salivary tests were performed three times at intervals of about one year. The results of the first examination were not explained either given to the participants or to the dentists in charge of treatment at the clinics. When the second examination was conducted, after 11-month observation period, the individual tests were interpreted, and this time the participants were informed of the results. However, the analyses required for the multi-factorial modeling had not yet been completed or reported. Thus it was decided that intensive preventive measures should be targeted at those children who were considered to have a high risk of caries. The implementation of the risk strategy was started as soon as possible for ethical reasons, in order not to drop the standard of prevention in general. The criteria for selecting the subjects at risk on the basis of the results of the tests were gathered from the available literature.

Paper IV. Later an interest arose in evaluating the long-term effect of the preventive methods provided for the intervention groups. The risk groups were compared with an age and sex matched reference group chosen from the normal population of schoolchildren

Paper V. The economic evaluation included the material and salary costs involved in the prevention measures focused on the risk groups and the costs of fillings in all the groups. The costs of the fillings in the risk groups were compared with those for a reference group representing the normal school population provided with basic prevention at the end of the intervention and after the follow-up. The costs of prevention were calculated for periods before, during and after the intervention and were compared with the costs of fillings, determined respectively for the intervention groups.

4.4 Methods

4.4.1 Evaluating the occurrence of mutans streptococci in children at day-care centres

At the beginning of the follow-up the first test with Salivary strip Mutans was performed, and tooth brushing was withdrawn at the intervention DCCs. The Dentocult® SM Strip Mutans method (Orion Diagnostica, Espoo, Finland) was used to estimate the counts of salivary mutans streptococci (Jensen & Bratthall 1989), after pre-stimulation of salivary secretion by chewing paraffin wax for 2 min. The tests were performed at the day-care centres in the mornings by oral hygienists or dental nurses from the local Municipal Health Centre and covered a total of 506 children in September 1991 and 358 in May 1992. Altogether 170 children at the intervention centres and 175 children at the control centres underwent both tests at an interval of 8 months. The results were expressed on a scale 0, 1, 2 and 3, corresponding to no growth, $< 10^5$, $10^{5\text{-}6}$ and $> 10^6$ colony forming units per ml (CFU/ml), respectively. One experienced dentist (M.R.) interpreted all the tests. The data for past caries experience in the deciduous teeth (dmf) were taken from the children's dental records. This data was available for 177 children as was data on caries lesions (ds) for 162 children. Before the commencement of the study a pilot study was conducted with 37 children aged 3–7 years on two occasions. The first SM test resulted in 58% positive tests and the second SM test respectively in 48%. Dental health habits were evaluated by means of a questionnaire with multiple-choice items to be filled in by parents at home and returned to DCCs.

4.4.2 Clinical evaluation (II, III)

Coronal caries, including deep enamel and dentinal caries lesions, was recorded on a tooth surface basis (WHO codes 2-4; WHO 1979). White spot lesions located on buccal and lingual tooth surfaces were recorded when the cervical border was 1.0 mm from the gingival margin (WHO code 1; WHO 1979).

Filled surfaces, sealants and the numbers of erupted teeth were recorded clinically. White spots were not included in the DFS index. The caries increment ΔDFS was calculated as the difference between the results of the 11-month and baseline examinations. Any increase in the DFS index was considered as a sign of caries activity.

Visible plaque index was calculated as the percentage of teeth with visible plaque buccally and/or lingually. Gingivitis index was based on clinical signs of inflammation, i.e. bleeding, swelling and redness, and was calculated as the percentage of teeth with one or more signs.

4.4.3 Salivary tests (II, III)

Salivary tests were performed for salivary secretion rate, buffer effect, sucrase, mutans streptococci, lactobacilli and yeasts/*Candida*.

Salivary secretion rate. Salivary secretion was first pre-stimulated by chewing paraffin wax for 2 min, followed by the inoculation for the mutans test and a continuation of chewing for 5 min. Saliva was collected during the latter phase, its buffer effect and sucrase activity were measured. The rest of the saliva was used for the dip-slide tests for lactobacilli and yeasts/*Candida*. All these procedures will be described below.

Buffer effect. The buffer effect was measured using Dentobuff® (Orion Diagnostica, Espoo, Finland), which is based on a colorimetric screening method (Frostell 1980). In this the colour of the sample was matched to a model chart supplied by the manufacturer and the result expressed in terms of nine pH scores at 0.5 intervals, range pH 3.0 to 7.

Sucrase activity. The activity of sucrose-cleaving enzymes was measured by adding 50 mg of crystalline sucrose to 1.0 ml of stimulated saliva, shaking the sample until the crystals had dissolved and leaving it to stand at room temperature for 30 min. (Hämäläinen *et al.* 1988). The glucose content was measured with a Dextrostix TM strip (Ames Division, Miles, Algol AB, Helsinki, Finland), which was interpreted by reference to the manufacturer's colorimetric chart. The result was expressed in scores of 0, 1.5, 2.5, representing sucrase activity values, ≥ 50 $\mu mol/min^{-1}\ mg^{-1} \times (10^{-3})$.

Mutans streptococci (ms). The Dentocult® SM Strip Mutans (Orion Diagnostica, Espoo, Finland) was used to estimate salivary counts of mutans streptococci (Jensen & Bratthall 1989). Salivary secretion was stimulated, by chewing paraffin wax for 2 min. before the MS test was performed. Both sides of the strip were brought alternately into light contact with the tongue several times and drawn out through lightly closed lips. The strip was incubated at 36°C for two days in its vial, and the colony density was read using the manufacturer's density chart. The result was expressed as scores 0, 1, 2, and 3, corresponding to no growth and about $< 10^5$, $< 10^6$, and $> 10^6$ colony forming units per ml (CFU/ml), respectively. (I, II, III)

Lactobacilli (LB). The Dentocult®-LB method (Orion Diagnostica, Espoo, Finland) was used to determine the salivary lactobacilli counts (Larmas 1975). The inoculated slides were incubated in their vials at 36°C for four days, and the colony density was read off from the manufacturer's density chart. The results were grouped into five categories corresponding to no growth and about 10^3, 10^4, 10^5 and 10^6 CFU/ml, respectively.

Yeasts. Oricult®N (Orion Diagnostica, Espoo, Finland), a dip-slide method for estimating yeasts (Larmas & Parvinen 1981), was used to determine the salivary counts of yeasts/*Candida*. The slide was incubated at 36°C for two days in a loosely closed tube, and the density of *Candida* colonies was read off from the Dentocult-LB density chart.

4.4.4 Evaluation of preventive treatment (IV)

Long-term effect of the preventive methods provided either with chlorhexidine or fluoride varnish for the risk groups was evaluated. The risk groups were compared with an age and sex matched reference group chosen from the normal population of schoolchildren. It has been shown that the documents maintained in the Finnish dental health care system are reliable for research purposes (Vehkalahti *et al.* 1992, Virtanen 1997, Helminen *et al.* 1998, Hausen *et al.* 2001). For a long-term follow-up data on all 390 participants were collected from their dental records at the Oulu Health Centre and survival analysis was used according to Virtanen *et al.* (1996). The longitudinal analysis was applied separately to each tooth and tooth surface to describe the dental health of the subjects. The observation time was expanded to a life-long retrospective analysis of dental health, i.e. before, during and after the intervention.

Chlorhexidine (CHX) group. Chlorhexidine treatment was provided for 62 children with 4 or more risk factors including one or more white spots (WS) indicating caries activity and a high salivary mutans streptococci (ms) score. The subjects undergoing orthodontic treatment were also included in the CHX group.

The 1% chlorhexidine gel (Hibitane® Dental, ICI Pharma, Espoo, Finland), was applied by dental hygienists to both jaws using standard trays (DS-Fluoride Jelly Applicator No.1; Dental Systems, Helsinki, Finland). The treatment was given three times daily on two consecutive days or twice daily on three consecutive days. After six months a control test for salivary mutans streptococci was performed and the chlorhexidine treatment was repeated in those cases where the finding was still positive. Thereafter the subjects were provided with fluoride lozenges (Fludent® 0.25 mg, Alpharma AS, Oslo, Norway) for use at home for a further year. The F-lozenges were obtained in packages of 7 x 28 tablets, free of charge from the manufacturer. The hygienists checked, that the lozenges had been taken according to the instructions.

Fluoride varnish (F) group. The 47 subjects who had 4 or more other risk factors including white spots but not high counts of mutans streptococci, were provided with applications of varnish containing 2.3% fluoride (Duraphat®, Woelm, Germany. The treatment was given at least 4 times a year by dental hygienists. (Ten subjects who refused the CHX treatment because of duties at school and lack of time were included in the F group).

Low risk (LR) group. The 86 children with no more than three of positive tests were considered to form a low risk group with regard to caries and were subjects to basic prevention measures.

Reference (Ref) group. In order to obtain a reference group representing the normal health centre population receiving mainly basic prevention, a sex and age-matched control was randomly chosen, individually for each test subject (n = 195) so that date of birth was within one month of the subject's birthday.

4.4.5 Economic evaluation (V)

The aim of the cost-effectiveness analysis (CEA) was to compare the value of the dental health benefit achieved by means of the intervention with the material and salary costs entailed in the preventive procedures provided for the risk groups. Thus the costs considered here were the additional costs of preventive procedures directed at caries alone, and the measure of effectiveness was the number of fillings in the test groups relative to those in the reference group at the end of the intervention and after the whole follow-up period.

4.4.5.1 Costs of the intervention

The costs of the preventive methods were calculated separately for the groups provided with applications of either chlorhexidine gel (CHX group) or fluoride varnish (F group and LR group), including both the costs of materials and the salary costs of the dental hygienists, at the 1991 level.

Chlorhexidine (CHX) group (n = 62). Each 1% chlorhexidine tube (Hibitane® Dental, ICI Pharma, Espoo, Finland) contained 100 ml gel, and the gel was applied with trays to both jaws at a rate of 5 ml 3 times on two consecutive days or twice on three consecutive days (Ostela *et al.* 1990), i.e. 5 ml gel x 6 treatments = 30 ml gel for each subject. The time reserved per person for each treatment and other relevant procedures was 15 minutes. The counts of mutans streptococci were checked after half a year with the SM strip test (Zickert *et al.* 1987), and the 40 subjects who still had high values ($SM \geq 3$) were retreated. The costs of materials, including the price of the chlorhexidine gel (2.5 €/tube) and the SM strip test (2.6 €/test) and the working hours of the hygienists were counted. The time required to perform the SM test and other relevant procedures, such as incubation, keeping the records etc., was estimated to be 15 minutes per subject. The salary cost of one working hour for a hygienist was 8.7 €. After the one-year intervention, prevention was continued in the CHX group for a further year with the fluoride lozenges (Fludent® 0.25 mg F, Alpharma AS, Oslo, Norway), administered at home. The dealer provided the lozenges for the study free of charge for one year.

F group (n = 47). The subjects in the F group received applications of fluoride varnish from dental hygienists four times a year. The price of a Duraphat® tube (30ml) was 71.7 €, and each application contained about 1.2 ml and took 15 minutes to perform, including other relevant procedures. The costs of four Duraphat® applications per subject were calculated.

LR group (n = 86). The costs of applications of 1.2 ml fluoride varnish (Duraphat®) twice a year, taking 10 minutes per subject/treatment, were calculated.

4.4.5.2 Costs of basic prevention

Fluoride varnish (Duraphat®) was applied to the teeth of all schoolchildren once or twice a year at the health centre clinics. It was assumed that a mean of one application per subject was provided, although the low-risk group in the present trial received applications twice a year. The costs of this regular procedure were not counted, other than for the low-risk group, at the rate of one fluoride application per subject.

4.4.5.3 Costs of fillings at estimated prices

The costs of filling teeth or tooth surfaces were counted at the 1991 price level, according to Virtanen *et al*. (1996). Restoration on one surface of a molar or premolar was estimated to cost 25.2 €. An additional restoration on the same tooth was estimated to cost 8.4 € per surface. Restoration of one approximal surface of an incisor or canine was considered to cost 33.6 € and the additional surfaces 16.8 € each.

4.4.5.4 Cost-effectiveness of the intervention (V)

In the cost-effectiveness analysis (CEA) the price of the dental health benefit achieved through the intervention was compared with the material and salary costs used for the preventive procedures in the risk groups, yielding the additional costs of the preventive procedures because of caries alone. The measures of effectiveness were the numbers of fillings in the risk groups as compared with the reference group at the end of the intervention and after the follow-up period.

The costs of the prevention methods were counted for the groups provided with applications of either chlorhexidine gel (CHX group) or fluoride varnish (F group and LR group), including both the costs of materials and the salary costs of the dental hygienists, at the 1991 level.

4.5 Statistical evaluation

4.5.1 Analysis of mutans streptococci (ms) affecting the occurrence of caries in the children at day-care centres (I)

The χ^2-test was used for comparing frequencies, and the t-test for analysing the differences in dmf values between those with ms in their saliva and those without ms. Multivariate logistic regression modeling was used to analyse the factors explaining dmf, and multivariate logistic regression analysis to determine the associations of all the risk factors with the occurrence of mutans streptococci. The results of the SM test were classified as negative or positive. If the test was positive on only one of the occasions it was interpreted as positive in the logistic regression analysis and bivariate analysis.

4.5.2 Analyses of single indicators in relation to caries increment (II)

All the variables were evaluated for dichotomization at several cut-off points on the basis of the best combination of sensitivity and specificity (Thorner & Remein 1961). The variables were further analysed through ratios measuring the accuracy of prediction (percentage of correct predictions), positive and negative predictive values (Vecchio 1960), as the RR and the OR (Fleiss 1981). The significance of the observations and the effects of age, sex and orthodontic treatment were evaluated using the χ^2-test or t-test, at the significance level $p < 0.05$. The SAS statistical software was used for data management and the statistical tests (SAS Institute Inc., 1985). Fisher's exact tests were performed for testing the hypothesis of independency between the study groups (ORT and Main, n = 181) and microbiological tests.

4.5.3 Multi-factorial modeling (III)

The 11-month caries increment ΔDFS was used as the dependent variable in the multi-factorial modeling. All the risk factors, together with past caries experience, sex and age, the latter dichotomised into < 13 and ≥ 13 years, were used as independent variables. Logistic regression analysis was used to estimate differences in the logarithmic risk of caries activity. The models were developed in accordance with Kleinbaum *et al.* (1982) using the BMDP statistical software (Dixon 1990). Initially, all univariate factors were included, and subsequently, all possible two-factor interaction terms were added one by one, and those found significant and "rational" were included. Non-significant terms were then excluded from the model. The final model was the most parsimonious and clinically rational one. As sex had a significant effect on caries increment, the analyses were initially performed for boys and girls separately.

Although the analyses resulted in different models for boys and girls, they were also carried out for both sexes combined. Additionally, a separate analysis of initially caries-free subjects was carried out. Odds ratios (OR) for a risk of caries and their confidence intervals were calculated for the variables in the final model (Fleiss 1981). In addition, sensitivity, specificity (Thorner & Remein 1961) and positive and negative predictive values (Vecchio 1966) were calculated, together with the percentage of correct predictions and the relative risk associated with the final model when the best clinically practicable criterion was used for screening.

To summarize the information obtained, Receiver Operating Charasteristic (ROC) curves were employed (Helfenstein & Steiner 1994b, Hausen 1997). The values of the true positive rate (sensitivity) at different cut-off levels of the predictors were plotted against the false positive rate (100-specificity) at the respective levels and presented as ROC curves.

4.5.4 Analysis of dental health in the study groups (IV)

The risk groups were compared with an age and sex matched reference group chosen from the normal population of schoolchildren, and life-long data on all 390 participants were collected from their dental records at the health centre. An application of survival analysis method (Virtanen *et al*. 1996) was considered suitable for a follow-up evaluation of the effect of the short-term intervention. The analysis was applied taking as the starting point the time of tooth eruption and as the event the first filling due to dental caries. The observation time was expanded to a life-long retrospective analysis of dental health, i.e. before, during and after the intervention. Event history analysis was then employed to obtain the estimated time-to-filling curves for each tooth and tooth surface (Larmas *et al*. 1995, Virtanen & Larmas 1995). The curves (cumulative distribution function), which were produced separately for the different groups of patients, represent the proportion of new fillings at a certain point of time and are expressions of the speed and timing of caries attack. The statistical significancies of differencies between the groups were determined by the log-rank statistics. The number of new fillings, from the start of the intervention to the end of the follow-up were calculated for the intervention and reference groups and compared using the t-test.

5 Results

5.1 Evaluation of the occurrence of mutans streptococci in children at day-care centres

The proportion of the children at the day care centres who had used the municipal health services was 96% and a dental health examination at a local health clinic had been performed on 93% of the children. Pre-stimulation of saliva and sampling were successful even among the youngest children. The rate of positive SM tests in the children varied from 43% to 48%, with no differences between the control and intervention day-care centres. The questionnaire for evaluating dental health habits achieved a response rate of 84%. The children brushing their teeth regularly at home were less to have mutans streptococci (ms) than those brushing irregularly (46.4% vs. 65%), whereas tooth brushing at the day-care centre was not associated with the presence of ms. Tooth brushing at home ($p < 0.001$), older age ($p < 0.01$) and female sex ($p < 0.05$) were significantly associated with a positive SM test in the logistic modeling. The consumption of sweets containing sucrose increased the occurrence of ms, as did irregular use of fluoride tablets. The proportion of children with intact teeth was 72%, and that of children with no caries lesions 76%. The dmf values were similar in the intervention and control groups. The children with positive SM tests had significantly higher mean dmf figures than those with negative tests ($p < 0.001$). The older age of the child ($p < 0.001$) was associated significantly with dmf in the multiple regression analysis, whereas consumption of sucrose sweets, the taking of fluoride tablets and the use of xylitol were not associated with dmf.

5.2 Baseline observations (II)

Past caries experience was observed in 60.2% of the 221 participants at the start of the study. The mean values and standard deviations for age, number of teeth, decayed and filled surfaces (DFS), filled surfaces (FS), decayed surfaces (DS), and number of sealants at the baseline examination, are presented for all the subjects in Table 5.

Table 5. Mean values and standard deviations of age, number of teeth (T), past caries experience (DFS), filled surfaces (FS), decayed surfaces (DS) and sealants in all children, in boys and girls, in the main group (Main), and in the orthodontic subgroup (ORT).

Variable	All N = 221		Boys N = 122		Girls N = 99		Main N = 195		ORT N = 26	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Age	13.3	0.9	13.4	0.9	13.1	0.8	13.3	0.9	12.5	0.8
T	26.1	3.3	25.8	3.5	26.5	3.0	26.3	3.2	24.8	3.9
DFS	3.0	4.4	3.2	4.4	2.9	4.4	2.8	4.1	4.8	5.7
FS	2.8	4.0	3.0	4.2	2.5	3.7	2.6	3.8	4.4	5.1
DS	0.2	0.8	0.2	0.5	0.3	1.0	0.2	0.8	0.4	0.8
Sealants	5.5	2.8	5.3	2.7	5.7	2.8	5.6	2.8	4.9	2.6

Significant differences between the boys (n = 122) and girls (n = 99) were recorded for visible plaque (≥ 10%), salivary secretion rate (≤ 0.9 ml/min) and buffer-effect (≤ 4.5 pH) so that the boys had higher scores than girls for visible plaque ($p < 0.001$), salivary secretion rate ($p < 0.013$) and buffer effect (< 0.001).

Fisher's exact tests were performed for testing the hypothesis of independency between the study groups (ORT and Main, n = 181) and microbiological tests. Only yeast/*Candida* resulted statistically significantly, $p = 0.002$. The distribution of the subgroups and all subjects into the categories, determined by the microbial diagnostic variables at the baseline examination, are presented in Table 6.

Table 6. Distribution (%) of participants in different classes of salivary mutans streptococci (ms), salivary lactobacilli (LB) and yeasts/Candida (Cand) at the baseline examination, including the Main and orthodontic (ORT) subgroups.

Microbiological variables	Classes	Main n = 181	ORT n = 24	All n = 205
ms	0	50.3	29.2	47.8
	1	14.9	4.2	13.6
	2	25.4	25.0	25.4
	3	9.4	41.6	13.2
LB	0	11.6	0.0	10.2
	10^3	34.8	12.5	32.2
	10^4	20.4	8.3	19.0
	10^5	17.7	20.8	18.1
	10^6	15.5	58.4	20.5
Cand	0	70.7	37.5	66.8
	10^3	21.6	37.5	23.4
	10^4	5.5	8.3	5.9
	10^5	2.2	8.3	2.9
	10^6	0.0	8.3	1.0

5.3 Follow-up observations (II, III)

The mean caries increment, ΔDFS for the 21% of the subjects (the orthodontic subgroup not included) who developed new caries was 2.4 surfaces, during the 11-month follow-up period. The proportion of subjects with past caries experience who developed caries was 29%, whereas 10% of the initially caries-free subjects did so. Candida ($p < 0.01$) and white spots ($p < 0.05$) were significantly associated with ΔDFS in the initially caries-free children, but only sucrase ($p < 0.05$) in those with past caries experience (II).

The cut-off points when relating the risk indicators to the caries increment were ≥ 1 for white spot lesions, ≥ 1 for past caries experience, ≥ 25% for visible plaque, ≥ 1% for gingivitis, ≤ 0.9 ml/min for salivary flow rate, ≤ 4.5 pH for salivary buffer effect, ≥ 1.5 mmol/min x g prot 10^{-3} for salivary sucrase activity, ≥ 10^5 for mutans streptococci, ≥ 10^5 for lactobacilli and ≥ 10^3 for yeast/*Candida* (II, III)

(II) Visible plaque, gingivitis, salivary secretion rate, buffer effect and mutans streptococci had no significant association with ΔDFS, but sex did significantly influence the relations between the test variables and caries increment. The boys showed significant correlations for *Candida* and white spot lesions ($p < 0.01$) and mutans streptococci ($p < 0.05$), and the girls for past caries experience and gingivitis ($p < 0.01$), and lactobacilli ($p < 0.05$). When the boys ($n = 101$) and girls ($n = 80$) were analysed together past caries experience ($p < 0.01$), white spot lesions ($p < 0.01$), lactobacilli ($p < 0.5$), *Candida* ($p < 0.01$) and sucrase ($p < 0.05$) were significantly correlated with ΔDFS.

(III) In the multifactorial modeling the final model for the boys included white spot lesions and yeasts/*Candida*, with a significant interaction between these variables, whereas the final model for girls included age and past caries experience, again with an interaction between them. The estimated OR of being caries active, at the 95% confidence level, in ≥ 13 years old girls was 8.4, when the subject was DFS-positive in comparison with DFS-negative subjects, while DFS had no effect on caries activity in the younger girls. When all the 181 subjects were analysed together, the final model included DFS, yeasts/*Candida* and sucrase, with interaction between DFS and sucrase. When evaluated for dichotomization at several cut-off points, the best practical criterion proved to be the presence of past caries. The more strict criteria for ΔDFS ≥ 2 or ≥ 3 produced higher sensitivity and specificity combinations, than the model DFS, yeasts/*Candida* and/or sucrase presenting an accuracy of only 75%. The ability of the model to identify subjects developing caries was 55%, and those not developing caries 80%. Analysis of the caries-free subjects resulted in a model including white spots and yeasts/*Candida*, with interaction between the variables, and with the criterion "both tests positive", this model resulted in an accuracy of 88%. When the orthodontic group ($n = 24$) was included, and 205 subjects in total were analysed, the accuracy of the final model (DFS, *Candida*, sucrase) was 74%, and respectively for the model of the 75 caries-free subjects 86%. Sensitivity (Sn), specificity (Sp), positive (PV+) and negative (PV-) predictive values, percentage of correct predictions (A) and relative risk (RR) for the final model (DFS, Candida and sucrase) in 205 subjects, and respectively in 75 caries-free subjects for the model (white spots and *Candida*), are presented in Table 7. The ROC-curve illustrating the relationship of sensitivities and specificities of the variables (DFS, *Candida*, sucrase) of the final model, where risk scores from a logistic risk function, including the three predictors, were used for prediction of 11-month caries increment ≥ 1, in 205 adolescents, and the ROC-curve for baseline DFS for comparison, are presented in 2.

Table 7. Sensitivity (Sn), specificity (Sp), Positive (Pv+) and negative (Pv-) predictive values, percentage of correct predictions (A) and relative ratio (RR) of the predictors DFS, yeast/Candida (Cand) and sucrase activity in the final model when related to the 11-month caries increment ≥ 1 in 205 adolescents, mean age 13.3, in Oulu, Finland. Figures are also given for the 75 initially caries-free (DFS = 0) individuals.

Subjects	Model and criterion	Sn %	Sp %	PV+	PV-	A	RR
N = 205	DFS, Cand, Sucrase	60	78	44	87	74	3.5
N = 75	White spots, Cand	63	88	36	96	86	8.3

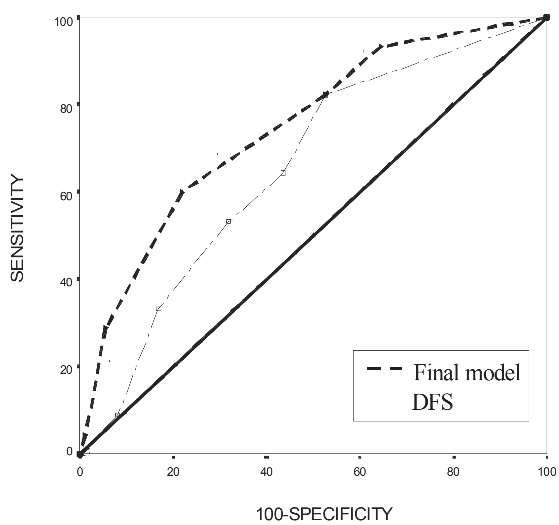

Fig. 2. ROC-curve illustrating the relationship of sensitivities and specificities of the final model (DFS = decayed filled surfaces, yeasts/Candida, sucrase activity) where risk scores from a logistic risk function including all the three predictors were used for prediction of 11-month caries increment ≥ 1, in 205 adolescents. The ROC-curve for baseline DFS has been for comparison.

5.4 Evaluating the efficacy of the one-year intervention (IV)

The highest filling scores at the age of sixteen were found on the occlusal surfaces of the molar teeth, followed by the mesial surfaces of the first molars and the occlusal surfaces of the second premolars. The only totally caries-free teeth were the lower canines. (IV). In the longitudinal analysis the cumulative distribution function (CDF) curves for the homologous teeth on the right and left sides of the mouth were found to be similar in all groups analysed and were combined in the figures. Much lower filling scores were observed for the proximal and smooth surfaces than for the fissures in all the risk groups, and there was also a lengthy time lag before the first restorations in the longitudinal follow-up after the intervention. Survival analysis showed that the CDF curves were highest in the high-risk group treated with chlorhexidine, the LR group had the lowest increments and the F group and Ref groups were intermediate. No effect was observed in the case of the fissures of the first molar teeth, which had erupted 5-7 years prior to the intervention.

An improvement in dental health in the high-risk subjects was obtained after the intensified prevention, especially in the second molars and premolars, where the results approached the average level for the reference group. An average of 243 new restorations were placed altogether in the three intervention groups, compared with 351 in the Ref group, indicating that one surface per subject was saved on average by virtue of the intensified prevention (IV).

The filling placement rates in CHX + F, LR and Ref groups for the lower first and second molars in males and females, are presented in Figure 3.

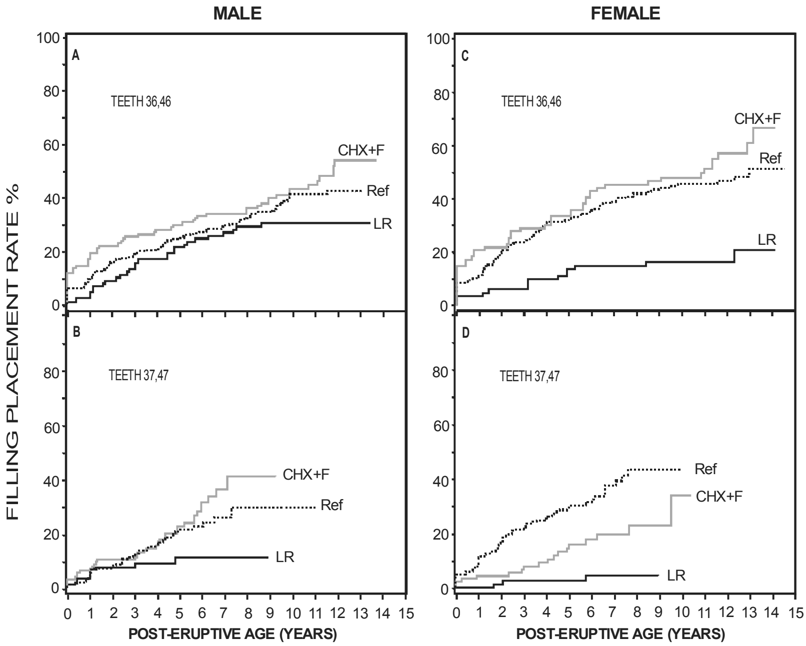

Fig. 3. Annual filling placement rates calculated post-eruptively for occlusal surfaces of first and second lower molars for males and females in the chlorhexidine (CXH) group and fluoride (F) group together, low risk (LR) and reference (Ref) groups.

5.5 Cost-effectiveness of the preventive methods (V)

The costs per person for the 62 subjects in the CHX group were 27 €, including 1.2 € in material costs, 2.6 € for the SM tests, and 21 € for the hygienists' working time, and 2.2 € in connection with the SM-tests. In the F group the costs for each of the 47 subjects were 20.1 €, including 11.4 € in material costs and 8.7 € for the hygienists' working time, while the costs per person for the 86 subjects in the LR group were 4.4 €, including 2.9 € for the Duraphat® varnish and 1.5 € in working time. The cost of the intervention in the test groups (CHX + F + LR) was 15.3 € per person.

5.6 Price of fillings in the test groups and the reference group

The numbers of fillings recorded (per 100 subjects) on all surfaces taken together in the test groups (CHX, F and LR) were: a) 408 at the start of the intervention, b) 38 new fillings after the intervention and c) 208 new fillings from the start of the intervention to the end of the whole follow-up. The corresponding numbers in the Ref group were 468, 91 and 262.

The total costs of the fillings in the test groups were 714.8 € at the end of the intervention, and 3674.9 € at the end of the whole follow-up, calculated according to estimated prices at the 1991 level (Virtanen *et al*. 1996). The corresponding figures in the Ref group were 1564.2 € and 4566.3 €.

The total costs of preventive procedures in the risk groups at the end of the intervention were 2990.5 € and (1.5 € per person), and the costs of restorative treatment 798.9 €. At the end of the intervention the costs of fillings were more than twice as great for the Ref group as for the risk groups, and after the whole 5-year follow-up period the costs were 891.4 € more for the Ref group than for the risk groups.

The prices of the fillings in molar and premolar tooth surfaces, and for canines and incisors, in the risk groups (CHX, F, LR) and the reference group, at the end of the 5-year follow-up, are presented in Table 8.

Table 8. Prices of restoring of molar and premolar tooth surfaces per 100 subjects in the test groups (CHX + F + LR), and reference group calculated from the formula: (Fissure surface n^1 x 25.2 €) + (other tooth surfaces = n^{2345} x 8.4 €) = total in €. The prices for approximal and additional surfaces (n^{135}) of canines and incisors were 33.6 € + 16.8 €, after the 5-year follow-up.

Tooth	n^1	€	n^{2345}	€	total €
Test groups					
1	1	16.82	8	269.10	285.92
2	2	33.64	5	168.19	201.83
3	2	33.64	4	134.55	168.19
4	10	252.28	15	126.14	378.42
5	23	580.25	24	201.83	782.07
6	23	580.25	39	327.97	908.21
7	28	706.39	29	243.87	950.26
Total		2203.27		1471.65	3674.92
Reference group					
1	2	33.64	9	302.74	336.38
2	3	50.46	9	302.74	353.19
3	2	33.64	9	302.74	336.38
4	9	227.05	15	126.14	353.19
5	27	681.16	36	302.74	983.90
6	22	555.02	52	437.29	992.31
7	36	908.21	36	302.74	1210.95
Total		2489.18		2077.13	4566.30

6 Discussion

6.1 Background

The tasks of those in charge of preventive dentistry at the municipal health centres in Finland are to plan strategies for dental health promotion, especially in children and adolescents, to give the personnel guidelines on strategies and methods for this, and to react to the changes brought about by new diagnostic methods and treatment designs. In practice, the interpretation of the diagnostic signs of caries and the incorporation of information on risk factors into the plans for prevention have mainly been based on the dentists' motivation and clinical experience, and the methods that they have chosen to use. Therefore, the accuracy with which preventive measures have been targeted at the right individuals or groups has probably often been a matter of chance. This assumption was found to be correct in a study of children at the Helsinki Health Centre (Vehkalahti *et al*. 1992). The clinical use of salivary tests in preventive dentistry became common in Finland in the 1980s. Some of them, such as those for lactobacilli and mutans streptococci, were well accepted because they motivated patients. The common experience, however, was that the changes in patients' health behaviour were only temporary. No model existed that was specific or reliable enough to identify caries-prone or caries-active individuals in practical situations and the cost-effectiveness of the existing tests was questionable. Accordingly, the issue of this research posed a real challenge for the Municipal Health Centre of Oulu.

The purpose of the work reported here was to find the most suitable model from among the known caries risk indicators for identifying caries-prone and caries-active children. Resources should be targeted rationally at those patients who have been found to be at risk for caries. Especially since the 1980s, the demand for correct use of personnel and consideration of the costs of dental health methods has been emphasized (Yule *et al*. 1986).

An important change that took place in the administrative field in the 1990s concerned the treatment needs of schoolchildren. An extension of the check-up interval for low-caries children to avoid over-treatment and to direct resources to those at risk, were discussed. This change was not adopted successfully enough in the health centres in

Finland, however (Wang *et al.* 1992). It was found that dentists doubted their ability to assess patients' risk level and thus were afraid to individualise their check-up intervals (Wang & Holst 1995). The provision of empirical information for dental clinicians may be important in enabling them to change their attitudes and think more in cost-benefit terms.

6.2 Subjects and risk groups

Teenagers are commonly considered to represent a particular risk group for caries (FDI 1988, Nordblad & Larmas 1985c), and consequently such age groups were randomly selected for the present analysis, just as children receiving orthodontic treatment were also included (II, III, IV, V). Data on the children's past caries experience were available from documents at Oulu Municipal Health Centre, where the participants had been examined and treated (I). Their caries experience represented an average level for the same age groups in the Finnish school population (Vehkalahti *et al.* 1991, Nordblad *et al.* 1993). (II) Documents available from Finnish health centres have been used previously for studying caries in teenagers (Vehkalahti *et al.* 1992, Virtanen 1997, Helminen *et al.* 1998).

The different disease levels, applying to the intervention groups at the onset were clearly demonstrated, and had evidently existed from the time of eruption of the teeth. The subjects chosen for the low-risk group were found to have relatively low caries prevalence in both the pre-intervention and post- intervention periods, which is in line with the findings of Seppä *et al.* (1991), whereas the other risk groups showed higher caries rates, e.g. in the first permanent molars. Thus the selection of the risk groups on the basis of salivary tests, the occurrence of dental plaque, and white spot lesions and the possession of high DMF scores were found to be successful (IV).

6.3 Risk indicators as single tests

Past caries experience, which has proved previously to be the strongest single indicator of the risk of future caries increment in schoolchildren (Honkala *et al.* 1984, Pienihäkkinen 1987, Wilson & Ashley 1989, Alaluusua 1993, Russell *et al.* 1991), yielded a higher OR than the other indicators in the present analysis, although this effect was restricted to the girls (II). Similar sex-related differences have been shown earlier (Honkala *et al.* 1984, Kolehmainen *et al.* 1985). The present association between past caries experience and caries increment is also in line with previous reports (Honkala *et al.* 1984, Russell *et al.* 1991, Tukia-Kulmala & Tenovuo 1993, Virtanen *et al.* 1997, van Palenstein Helderman *et al.* 2001) (II). The recently reported study of van Palenstein Helderman *et al.* (2001) involved the testing of a new method with various variables representing caries experience in an eight-year forecast at different age-intervals in a mixed dentition, and it was observed that the correlation between caries increment and the number of affected approximal surfaces of permanent first molars or the number of other affected surfaces on the permanent dentition appeared to increase with age. It has also been shown that the caries status of the most recently erupted/exposed tooth surface predicts caries well for newly emerging teeth surfaces in general (Virtanen *et al.* 1997, Powell 1998, van Palenstein Helderman *et al.* 2001).

Most of the salivary tests are incapable of predicting caries either as single test or even in combination. The present observations showing the lack of any association between visible plaque, gingivitis, salivary secretion rate or buffer effect and caries increment, also concur with previous findings (Pienihäkkinen 1987, Wiktorsson *et al.* 1992, Tukia-Kulmala & Tenovuo 1993), yet they are in contradiction to the earlier results of Parviainen *et al.* (1977) and Stecksén-Blicks (1985). According to Hausen (1997), no appreciable effect was shown when additional predictors such as mutans streptococci and lactobacilli counts, salivary flow rate, sucrose intake frequency, brushing frequency and social group were included in combination with past caries experience. In the material of Vehkalahti *et al.* (1996), the salivary LB test or a combination of the LB and SM tests was found to predict caries increment well, whereas salivary flow rate and buffer effect were observed to be the least accurate predictors. A discrepancy with salivary tests has been shown, in that simultaneous changes in teenagers with developing denture, behavioural, hormonal and dietary factors, make single-point-measurements of salivary factors unreliable for diagnostic and predictive purposes (Tukia-Kulmala & Tenovuo 1993).

The present study found a significant correlation between white spot lesions and caries increment as also shown earlier (Pienihäkkinen 1987, Seppä & Hausen 1988, Graves *et al.* 1991), and similarly confirmed that white spot lesions had a slightly lower predictive value than past caries experience (II).

White spot lesions were closely related to caries increment, especially in the boys, possibly because of their high plaque indices (II). According to Neilson & Pitts (1991), incipient smooth surface lesions provide a valuable caries risk indicator, especially in individuals with poor oral hygiene. When the indicators were analysed separately white spots and yeasts/*Candida* were significantly associated with caries increment in the initially caries-free cases (II). Both variables may indicate a change in the health behaviour of the subjects towards poor oral hygiene and/or higher sugar consumption or even increased tobacco smoking because adolescents may periodically change their lifestyle and attitudes. The change in lifestyle has been shown to affect microbial scores in the oral cavity, e.g. tobacco smoking increases the scores of *Candida* and lactobacilli in adults (Sakki & Knuuttila 1996).

The fact, that the children receiving orthodontic treatment had higher counts of mutans streptococci, lactobacilli and yeasts/*Candida,* than the other subjects (II) partly confirm to earlier conclusions, emphasizing that erupting teeth, overt caries lesions, low salivation and buffer capacity, orthodontic banding and other retentive sites are able to increase the counts of microbiological flora (Sakamaki & Bahn 1968, Parvinen & Larmas 1981, Addy *et al.* 1982, Meurman *et al.* 1987). Since school classes in these age groups include numerous children who are receiving orthodontic treatment, the LB test may not be a relevant diagnostic test in these groups nor a sufficient motivation for restricting sugar consumption. This discrepancy could be avoided by using the salivary sucrase test in schoolchildren instead of the LB test, because salivary sucrase activity reflects the amount and variation and frequency of sucrose consumption at the group level (Karjalainen *et al.* 1989).

Surprisingly, mutans streptococci did not show any significant association with caries increment, although this measure has generally been found to be of value for caries prediction (Stecksén-Blicks 1985b, Alaluusua 1990, Russell *et al.* 1991, Vehkalahti *et al.* 1996). This may be attributable to the low caries experience of the participants, but it may also be associated with their frequent use of xylitol (Trahan *et al.* 1992). A relation of caries increment to lactobacilli and yeasts/*Candida* has also been shown previously (Pienihäkkinen 1987, Wilson & Ashley 1989, Beck *et al.* 1990, Russell *et al.* 1991). The associations between the microbiological salivary counts observed here are also in accordance with observations obtained in several earlier studies (Pienihäkkinen 1987, Alaluusua 1990, Russel *et al.* 1991, Tukia-Kulmala & Tenovuo 1993) (II).

The results of the present assessment of single indicators in relation to caries in adolescents strongly indicate the importance of past caries experience and white spot lesions for the prediction of future caries (II).

The occurrence of mutans streptococci varied in the children at day-care centres, which result is in agreement with earlier findings in corresponding age groups (Köhler *et al.* 1988, Alaluusua *et al.* 1983, Tenovuo *et al.* 1993) (I). The present correlation between ms and caries experience (dmf) is likewise in agreement with earlier reports (Burt *et al.* 1983, Granath *et al.* 1993, Holbrook 1995). (I) According to Burt *et al.* (1983), high levels of ms infection are related to the subsequent development of caries when the ms counts themselves remain stable. Low ms counts are more predictive of low rates of caries than are high counts of high rates of caries (Granath *et al.* 1993), but maternal caries activity is closely associated with the occurrence of caries in the child, suggesting that factors transmitting infections, such as ms, are crucial for the initiation of caries in infants (Aaltonen 1990). The present children (I) with a positive SM test had significantly higher mean dmf than those with a negative test, in line with the findings of Alaluusua & Renkonen (1983) and Alaluusua *et al.* (1987). The age of the child was significantly associated with the occurrence of ms in the present logistic regression model (I), as also found by Alaluusua *et al.* (1987). Most of the factors related to oral health and the presence of ms found here were interrelated (I). The SM test, when related to age, may provide information on the susceptibility of small children to caries (Burt *et al.* 1983, Alaluusua *et al.* 1990, Granath *et al.* 1993, Tenovuo *et al.* 1993), but the salivary SM test may not be a reliable predictor in children who frequently receive xylitol products (Trahan *et al.* 1992). Holbrook *et al.* (1995), in their study showed, that the SM test when used as a single measure of caries activity in pre-school children could not predict caries well, although it was more accurate in combination with other variables. Since the day-care centres had been randomly allocated to the intervention and control groups, and no other changes were made in oral health practices, it was concluded that the discontinuation of tooth brushing had not influenced the incidence of mutans streptococci.

6.4 Multifactorial modeling

The multifactorial nature of the disease and the polarization of caries in young populations make it difficult to find correct classified methods for caries prediction in children. Combinations of factors have been observed to be more predictive than the additive benefit of individual factors (Pienihäkkinen 1987, Disney *et al.* 1992). This also proved to be the case in the present study (II, III). The validity of a method for predicting caries was improved by including the indicators in a somewhat corrected prediction model, and using longitudinal designs and more appropriate statistical methods (Kolehmainen *et al.* 1985, Abernathy *et al.* 1987, Pienihäkkinen 1987).

Various indicators covering clinical, microbiological, salivary and socio-demographic factors have been analysed and discussed in relation to caries prediction in children and adolescents (Demers *et al.* 1990, Hausen *et al.* 1994, Powell 1998). Even though past caries experience was shown to be the strongest predictor of future caries, it had limited value as the sole indicator at an individual level which is in line with previous studies (Pienihäkkinen 1987, Wilson & Ashley 1989, Alaluusua 1990, Russell *et al.* 1991 (II, III). According to a recent review (Powell 1998), past caries experience is the most significant predictor, while other important variables are socio-economic status, fluoride exposure, tooth mortality and microbial agents. Regression models in which the preferred analysis made use of multiple factors and data on clinical variables showed clinical variables to be stronger predictors than non-clinical ones (Powell 1998).

The relationship between caries risk indicators and caries increment is not necessarily similar in boys and girls (Honkala *et al.* 1984, Bader *et al.* 1986). This was confirmed in the present study (II, III). However, these results are inconsistent with the findings of previous large field studies involving numerous other explanatory variables, in which no association with sex has been observed (Abernathy *et al.* 1987, Disney *et al.* 1992). The present analysis (III) resulted in different models for girls and boys. The model for the boys, which included white spots and yeasts/*Candida,* with a significant interaction between these variables, resulted in 78% accuracy, and that for the girls, including age and past caries experience, in 76% accuracy. The accuracy of both models can be accepted as reasonable, although below the 80% target level. When the boys and girls were analysed together, the final model included DFS, yeasts/*Candida* and salivary sucrase, with an interaction between DFS and sucrase, and the ability of this model to identify subjects correctly was 55% for those developing caries and 80% for those not developing caries. The figures are comparable also with those of earlier studies (Powell 1998). However, as shown with the ROC–curve, the model (DFS, yeasts/*Candida*, Sucrase) predicted slightly better than DFS alone (Figure 2). When analysed separately in caries-free subjects, the final model included white spots and yeasts/*Candida,* with an interaction between the two variables, and resulted in an accuracy of 88%. Most previous prediction studies have failed to achieve the target level of 80% (Powell 1998). The most accurate prediction models have been those that include bacterial levels, while socio-demographic variables have proved most important in caries prediction models for young children and old people (Powell 1998). The present findings indicate the importance of past caries experience for the prediction of caries, but also show that even this variable is not acceptable as a single test at either the group or the individual level (III), which is in line with previous studies (Wilson& Ashley 1989, Russell *et al.* 1991, Powel 1998). Yeasts/*Candida* were causally associated with caries, the presence of the yeasts being merely an indication of unfavourable conditions in the oral cavity. The activity of salivary sucrase, as the third risk indicator in the final model, may also be of potential value for caries prediction in adolescents. In caries-free subjects the presence of incipient caries lesions and salivary yeast counts would seem to be indicative of an increased risk of the development of caries. (III)

6.5 Efficacy of intensive prevention

The statements that the first and second molar teeth are the main determinants of the total caries increment among the school-aged population and that more lesions develop on the pit and fissure surfaces of posterior teeth than on other surfaces (Nordblad & Larmas 1985a, Carvalho *et al.* 1992, Virtanen & Larmas 1995) were corroborated by the present findings (IV). An improvement in both fissure and proximal caries on the erupting teeth was shown when preventive measures were initiated during the second phase of tooth eruption, indicating that a high risk can be reduced. In the present risk subjects, however, the start of the intervention was far too late with respect to the teeth in the first phase of eruption, which had been filled to a high degree by the onset of the intervention (IV).

Life-long dental health comparisons, tooth by tooth at the surface level involving all the test groups and the reference group, showed that the increments for both the risk groups were above the level for the reference group before the intervention but approached this level during the post-intervention period. Thus, indicating that the intervention had an effect of promoting dental health (IV). This can be considered an acceptable achievement for a risk strategy (Hausen *et al.* 1994).

The present findings (IV) show that if intensified prevention of caries is planned for young age cohorts, preventive measures should be provided during the first and second phases of tooth eruption (Nordblad & Larmas 1986, Carvalho *et al.* 1992, Virtanen *et al.* 1996, Varsio 1999). In fact, it has been suggested recently, that risk strategies should be implemented in early childhood to prevent the child from becoming prone to caries (Pienihäkkinen & Jokela 1995, Söderling *et al.* 2000).

To reduce the risk of caries in individuals at high risk has been shown to be difficult (Seppä *et al.* 1991). The questions to whom prevention should be targeted at and what costs should be regarded as justified still remain open (Seppä *et al.* 1998). The present outcome, that one surface per subject was saved from being filled in all the risk groups by comparison with the reference group, can be considered a moderate achievement. The input of manpower and other resources that was needed for the selection of the risk groups and for the preventive procedures was excessive in the context of current welfare policies in Finland (IV).

In conclusion, the tooth-by-tooth survival analysis indicated that even short-term intervention, especially at the time of tooth eruption, can promote dental health in high risk groups and bring them more to the level with the average school population. The results stress the importance of dental age and of providing preventive procedures at the time of tooth eruption (IV).

6.6 Cost-effectiveness of the intervention

Arguments for preventive dental care are often supported by comparisons between the estimated costs of the preventive procedures and the costs of restoring the tooth surfaces that would otherwise have been affected by decay (Riordan 1997). The present economic assessment was based on the price of the one-year intensified prevention programme and the dental health benefits achieved in the form of fillings saved by the end of the follow-up. The result that after a five-year post-intervention period, one tooth surface per subject was saved from being filled in the test groups, presenting four or more risk indicators, and provided with either chlorhexidine or fluoride treatment for one year, was rather modest. (V) After the intervention the costs of the fillings in the test groups were nearly 25% of the total expenses of the intensified prevention, but over the whole follow-up period the costs of the intensified prevention seemed to even out to the same level as the costs of the increasing numbers of fillings (V). The clinical effectiveness of many caries prophylactic agents has been demonstrated, but their public health value has often been questioned from the viewpoint of economic efficiency.

It has been suggested that the cost-effectiveness of caries prevention will improve only if a long-term effect can be achieved (Klock, 1984, Virtanen 1996). Donaldson *et al.* (1986), comparing the CE of a preventive health programme with that of the ordinary restorative treatment of carious teeth, observed that the cost per unit of DMFS was higher for the preventive programme than for the restorative treatment, as also shown in the present case (V), but that the situation changed once the quality differences between the restored and healthy teeth were taken into account, i.e. if a healthy tooth is regarded as 1, that of a restored tooth is less than 0.85, making the preventive programme more cost-effective.

During the 5-year follow-up period the fillings increased in the test groups, so that the costs were nearing the level of the costs of the intervention. The reference group had incurred about twice the costs of the fillings in comparison with those of the test groups by the end of the intervention, whereas after the whole follow-up period the costs of their fillings were only 891.4 € higher. In view of its expense, intensive prevention cannot be considered sufficiently cost-effective, as the benefit in terms of dental health is no more than modest, a result which is in agreement with the report of Hausen *et al.* (2000) (V). Helfenstein & Steiner (1992) also state that intensive prevention programmes for the small percentage of children with a relatively high risk of caries would cost more than they would save in terms of financial expenditure.

If the test groups had been provided with only basic prevention, the expenses would have been about a half of the costs of the intervention, given the prices used here, which is in line with the findings of Källestål *et al.* (1997). For the present target population, basic prevention would have been a more cost-effective risk strategy than the intensified intervention, again in line with earlier reports (Vehmanen 1993, KalleståI *et al.* 1997, Hausen *et al.* 2000) (V). The cost of basic prevention, and also that of intensive prevention, could be somewhat lower if it were provided for the children at their existing check-up and treatment appointments at the clinics rather than separately as in this case (V). According to Wang *et al.* (1998), basic prevention provided for schoolchildren at clinics by dental hygienists or dental nurses would be more cost-effective, even as a risk strategy. It is significant that salaries account for over 70% of the total costs of dental health care at health centres in Finland (Utriainen & Widström 1990). In the present study only the additional costs of the intervention in the test groups over and above the normal preventive programme were counted. The expenses would be far greater in financial terms if all the running and administrative costs of the municipal health care system were taken into account (V).

The results of the present study show that it was too late to provide intensified prevention for the children at the age when the first molar teeth had mostly been filled (IV). Numerous risk indicators should be considered when planning caries prevention procedures in addition to salivary factors, including risk ages, teeth and surfaces at risk, time at risk, medical risks and social risks (Bader *et al.* 1986, Virtanen *et al.* 1996, Vehkalahti *et al.* 1997, Meurman 1997, Powell 1998, Härkänen *et al* 2002). Preventive care should be initiated before the first phase of tooth eruption and during maturation of the enamel, in order to prevent the children from becoming high-risk cases in adolescence, as stated previously (Klock 1984, Pienihäkkinen & Jokela 1995, Virtanen *et al.* 1996). It has even been shown that preventive care should be focused on early childhood, to prevent the adherence of caries bacteria to the newly erupted primary molars and their growth there (Alaluusua & Renkonen 1983, Köhler *et al.* 1988, Tenovuo *et al.* 1992), and also that parents' attitudes towards dental care affect oral health of small children (I, Kinnby *et al.* 1991, Gibson & Williams 1999).

The moderate cost-effectiveness of most risk strategies used to control caries may arouse philosophical thoughts regarding the value of dental health. Yule *et al.* (1986) pointed out that the cost savings approach tends to underestimate the true benefits to society, because it typically ignores time and travel costs and increasing physical uneasiness, including pain and discomfort.

It may be difficult in an era in which evidence-based health care is the accepted modern attitude to convince administrators of the need for resources for large preventive programmes if the methods cannot be shown to be sufficiently cost-effective (McGlone *et al.* 2001). Preventive procedures have been systematically used in schoolchildren, in Finland, but have not been adequately targeted (Vehkalahti *et al.* 1992, Kärkkäinen 1997, Helminen *et al.* 1999, Varsio 1999). Relatively modern methods of caries prevention are practised in public dental clinics, but prevention often has little relevance to the actual needs of the individual patient (Kärkkäinen 1997). In spite of that the occurrence of caries in Finnish schoolchildren is one of the lowest in the world, and on a par, with figures for the other Nordic countries (von der Fehr 1994).

Low caries prevalence in a population makes the planning and focusing of preventive procedures difficult. One discrepancy in the planning of preventive care has been that the procedures are chosen before their effectiveness has been evaluated and the persons at risk accurately selected (Varsio & Vehkalahti 1996). The biological aspects of caries have been well studied, and methods of prevention have been chosen on a cause-and-effect basis. But when considering the limited community resources available, preventive methods should be acceptable and cost-effective, and no over-treatment should be allowed. The control of caries is of major importance in dentistry and will continue to be so for the foreseeable future (Winston & Bhaskar 1998). As stated by Renson (1985), there is an urgent need for regular monitoring of oral health status in all countries, for the sake of better personnel planning and procedures. Adequately oriented decisions by dentists, and especially the motivation of parents to encourage their children to care for their teeth appropriately at home, would lead to more cost-effective use of the limited resources available for public oral health. Changes in staff attitudes in the field of dental care are needed for any new approaches to planning strategies for caries prevention at either the individual or group level to emerge.

7 Conclusions

1. The results indicate the importance of past caries experience and white spot lesions for caries prediction. The other risk indicators analysed, although significant as single tests, do not provide any additional information for risk assessment. The effect of past caries experience on the association of risk indicators with caries increment, also reflects to the difficulties of caries prediction in populations with different caries prevalences.
2. The present multifactorial model for prediction of 11-month caries increment, in which the most accurate indicators were DFS, *Candida* and salivary sucrase enzym activity gives additive information of adolescents at risk of caries, and for targeting preventive measures at an individual level and for motivating these patients. In subjects with earlier or present caries experience, for instance, the use of two tests, one for salivary *Candida* and the other for salivary sucrase activity, would provide additive, semi-quantitative information on the caries risk. The present findings indicate the importance of past caries experience for the prediction of caries, but also show that this variable is not acceptable as a single test at either the group or the individual level. The risk of caries increases with the number of positive test results, but the high accuracy of the prediction model in caries-free children points to the importance of monitoring the dental health of those children not believed to be at risk as well.
3. The discontinuation of tooth brushing at day-care centres did not influence the occurrence of salivary mutans streptococci in children, but SM counts increased with age and were correlated with caries experience, so that they constituted a risk factor for caries.
4. Survival analysis conducted tooth by tooth indicated that, especially at the time of tooth eruption, even short-term intervention could promote dental health in high-risk groups and bring them more into line with the average school population. The results stress the importance of dental age and of providing preventive procedures at the time of eruption and maturation of the teeth.
5. The effect of the intensified caries prevention provided for adolescents with a high risk was shown to be acceptable in the long term, but the salary and material costs entailed in such an intervention can be regarded as relatively high. Basic prevention would be more cost-effective as a risk strategy. Considering the small fraction of population

with a high risk, more emphasis should be placed on the individual indications for preventive procedures at clinics and in home care. The benefit of the present risk strategy in terms of improved dental health proved to be moderate by comparison with the difference in costs between preventive and restorative care, and cannot be recommended for common use as such among target populations with a high risk of caries.

References

Aaltonen AS (1990) Maternal caries incidence and salivary close-contacts with children affect antibody levels to Streptococcus mutans in children. Oral Microbiol Immonol 5: 12–18.

Abernathy JR, Graves RC, Bohannan HM, Stamm JW, Greenberg BG & Disney JA (1987) Development and application of prediction model for dental caries. Community Dent Oral Epidemiol 15: 24–28.

Addy M, Shaw WC, Hansford P & Hopkins M (1982) The effect of orthodontic appliances on the distribution of candida and plaque in adolescents. Br J Orthod 9: 158–163.

Ainamo J & Parviainen T (1989) Influence of increased toothbrushing on dental health in low, optimal, and high fluoride areas in Finland. Community Dent Oral Epidemiol 17: 296–299.

Akehurst R & Sanderson D (1993) Cost-effectiveness in dental health. A review of strategies available for preventing caries. Discussion paper 106. University of York, Centre for Health Economics, Health Economics Consortium.

Alanen P, Hurskainen K, Isokangas P, Levänen J, Pietilä I, Saarni UM & Tiekso J (1994) Clinician's ability to identify caries risk subjects. Community Dent Oral Epidemiol 22: 86–89.

Alanen P, Isokangas P & Gutmann K (2000) Xylitol candies in caries prevention: results of a field study in Estonian children. Community Oral Epidemiol 28: 218–224.

Alaluusua S (1993) Salivary counts of mutans streptococci and lactobacilli and past caries experience in caries prediction. Caries Res 27 (Suppl 1): 68–71.

Alaluusua S, Kleemola-Kuja E & Evälahti M (1990) Salivary caries-related tests as predictors of future caries increment in teenagers. A three-year longitudinal study. Oral Microbiol Immonol 5: 77–81.

Alaluusua S, Kleemola-Kujala E, Nyström M, Evälahti M & Grönroos L (1987) Caries in primary teeth, and salivary Streptococcus mutans and lactobacillus levels as indicators of caries in permanent teeth. Pediatr Dent 9: 126–130.

Alaluusua S & Renkonen O-V (1983) Streptococcus mutans establishment and dental caries experience in children from 2 to 4 years old. Scand J Dent Res 91: 453–457.

Alaluusua S, Savolainen J, Tuompo H & Grönroos L (1984) Slide-scoring for estimation of Streptococcus mutans levels in saliva. Scand J Dent Res 92: 127–133.

Arrow P (1997) Control of occlusal caries in the first permanent molars by oral hygiene. Community Dent Oral Epidemiol 25: 278–283.

Axelsson P, Paulander J, Nordqvist K & Karlsson R (1987) Effect of fluoride containing dentifrice, mouthrinsing and varnish on approximal dental caries in a 3-year clinical trial. Community Dent Oral Epidemiol 15: 177–180.

Axelsson P, Paulander J, Svärdström G, Tollskog G & Nordensten S (1993) Intergrated caries prevention: effect of a needs-related preventive program on dental caries in children, County of Värmland, Sweden. Results after 12 years. Caries Res 27 (Suppl 1): 83–94.

Bader JD, Graves RC, Disney JA, Bohannan HM, Stamm JW, Abernathy JR & Lindahl RL (1986) Identifying children who will experience high caries increments. Community Dent Oral Epidemiol 14: 198–201.

Beck JD (1990) Identification of Risk Factors. In: Bader JD (ed) Risk assessment in dentistry. Chappel Hill: University of North Carolina, Dental Ecology, p 8–13.

Beck JD (1998) Risk revisited. Community Dent Oral Epidemiol 26: 220–225.

Beck JD, Kohout F & Hunt RJ (1988) Identification of high-risk adults: attitudes, social factors and diseases. Int Dent J 38: 231–238.

Beck JD, Weintraub JA, Disney JA, Graves RC, Stamm JW, Kaste LM & Bohannan HM (1992) The University of North Carolina caries risk assessment study: Comparisons of high caries risk prediction, any risprediction, and etiologic models. Community Dent Oral Epidemiol 20: 313–321.

Beighton D (1991) The value of salivary bacterial counts in the prediction of caries activity. In: Johnson NW ed. Risk markers for oral diseases, risk groups and individuals. University Press. Cambridge, p 313–326.

Belfrán-Aquilar ED, Goldstein JW & Lockwood SA (2000) Fluoride varnishes: A review of their clinical use, cariostatic mechanism, efficacy and safety. J Am Dent Assoc 131: 589–596.

Bellini HT, Arneberg P & von der Fehr FR (1981) Oral hygiene and caries. A review. Acta Odont Scand 39: 257–265.

Birch S (1986) Measuring dental health improvements on the DMF-index. Community Dental Health 3: 303–311.

Birkhed D (1990) Behavioural aspects of dietary habits and dental caries. Caries Res 24: 27–35.

Birkhed D (1994) Cariologic aspects of xylitol and its usein chewing gum: A review. Acta Odont Scand 52: 116–127.

Bjarnason S, Finnbogason SY, Hoolbrok P & Köhler B (1993) Caries experience in Icelandic 12-year old urban children between 1984 and 1991. Community Dent Oral Epidemiol 21: 194–197.

Bratthall D, Hänsel-Pettersen G & Sundberg H (1996) Reasons for the caries decline: what do the experts believe? Eur J Oral Sci 104: 416–422.

Bolin AK, Bolin A, Jansson I & Calltorp J (1997) Children's dental health in Europe. Swed Dent J 21: 25-40.

Bowen WH (1995) The role of toothpastes in the prevention of dental caries. J Soc Med 88: 50–57.

Bowen WH (1991) Dental caries: Is that an extinct disease? J Am Assoc 122: 49–52.

Bruun C, Bille J, Hansen KT, Kann J, Qvist V & Thylstrup A (1985) Three-year caries increments after fluoride rinses or topical applications with fluoride varnish. Community Dent Oral Epidemiol 13: 299–303.

Burt BA, Loesche WJ, Eklund SA & Ernest RW (1983) Stability of Streptococcus mutans and its relationship to caries in a child population over 2 years. Caries Res 17: 532–542.

Burt BA (1994) Trends in caries prevalence in North American children. Int Dent J 44 (Suppl 1): 403–413.

Burt BA & Pai S (2001) Sugar consumption and caries risk: systematic review. J Dent Educ 65: 1017–1023.

Carvalho JC, Thylstrup A & Ekstrand KR (1992) Results after 3 years of non-operative occlusal caries treatment of erupting permanent first molars. Community Dent Oral Epidemiol 20: 187–192.

Crossner C-G (l981) Salivary lactobacilli count in the prediction of caries activity. Community Dent Oral Epidemiol 9: 182–190.

Crossner, C-G (1984) Salivary flow rate in children and in adolescents. Swed Dent J 8: 271–273.

Dixon WJ ed. (1990) BMDP statistical software manual: to accompany the 1990 software release. Vol. 2. Berkeley: University of California Press.

Demers M, Brodeur J-M, Simard PL, Mouton C, Veilleux G & Fréchette S (1990) Caries predictors suitable for mass-screenings in children: a literature review. Community Dent Health 7: 11–21.

Dennison JB, Straffon LH & Smith RC (2000) Effectiveness of sealant treatment over five years in insured population. J Am Dent Assoc 131: 597–605.

Disney JA, Graves, RC, Stamm JW, Bohannan HM, Abernathy JR & Zack DD (1992) The University of North Carolina Caries risk assessment study: further developments in caries risk prediction. Community Dent Oral Epidemiol 20: 64–75.

Donaldson C, Forbes JF, Smalls M, Boddy FA, Stephen KW & McCall D (1986) Preventive dentistry in a health centre. Effectiveness and cost. Soc Sci Med 23: 861–868.

Drummond MF, Stoddart GL & Torrance GW (1987) Methods of the economic evaluation of health care programmes. Oxford University Press, Oxford.

Driscoll WS, Wowjack-Raymer R, Schlwitz RH, Li SH & Heifetz SB (1992) A comparison of the caries preventive effects of fluoride mouthrinsing, fluoride tablets, and both procedures combined: Final results after eight year. J Public Health Dent 52: 111–116.

Dummer PMH, Oliver SJ, Hicks R, Kingdon A, Addy M & Shaw WC (1990) Factors influencing the initiation of carious lesions in spesific tooth surfaces over a 4-year period in children between ages 11-12 years and 15-16 years. J Dent 18: 190–197.

Edgar WM (1998) Sugar substitutes, chewing gum and dental caries – a review. Br Dent J 184: 29–32.

Edward S (1997) Changes in caries diagnostic criteria over time related to the insertion of fillings. A comparative study. Acta Odont Scand 55: 23–26.

Emilson C-G (1994) Potential efficacy of chlorhexidine against mutans streptococci and human dental caries. J Dent Res 73: 682–691.

Emilson CG & Krasse B (1985) Support for implications of the spesific plaque hypothesis. Scand J Dent Res 93: 96–104.

Eskeli R, Laine-Alava MT, Hausen H, Pahkala R. (1999) Standards for permanent tooth emergence in Finnish children. Angle Orthod 69: 529–533.

Federation Dentaire Internationale (1988) Review of methods identifying of high caries risk groups and individuals. FDI Techn Rep No 31. Int Dent J 38: 177–183.

von der Fehr FR (1994) Caries prevalence in the Nordic Countries. Int Dent J 44: 393–401.

Fejerskov O (1995) Strategies in design of preventive programmes. Adv Dent Res 9: 82–88.

Fejerskov O (1997) Concepts of dental caries and their consequences for understanding the disease. Community Dent Oral Epidemiol 25: 5–12.

Fleiss JL (1981) Statistical methods for rates and proportions. 2nd ed. New York: John Wiley & Sons.

Flink A, Källestål C, Holm AK, Allebeck P, & Wall S (1999) Distribution of caries in 12-year-old children in Sweden. Social and oral health related behavioural patterns. Community Dental Health 16: 160–165.

Foch CB (1981) The costs, effects and benefits of preventive dental care: a literature review. N-1732- RWJ. Santa Monica, Ca: Rand Corporation.

Freeman R, Maizels J, Wyllie M & Sheiham A (1993) The relationship between health related knowledge, attitudes at dental health behaviours in 14-16-year-old adolscents. Community Dental Health 10: 397–404.

Frostell G (1980) A colorimetric screening test for evaluation of buffer capacity of saliva. Swed Dent J 4: 81–86.

Gaspari KC (1983) The use and misuse of cost-efectiveness analysis. Soc Sci Med 17: 1043–1046.

Gibbons RJ (1984) Microbial ecology. Adherent interactions, which may affect microbial ecology in the mouth. J Dent Res 63: 378–385.

Gibson S & Williams S (1999) Dental caries in pre-schoolchildren: association with social class, toothbrushing habit and consumption of sugars and sugar-containing foods. Caries Res 33: 101–113.

Granath L, Cleaton-Jones P, Fatti LP, Grossman ES (1993) Prevalence of dental caries in 4- to5-year-old children partly explained by the presence of salivary mutans streptococci. J Clin Microbiol 31: 66–70.

Graves CG, Abernathy JR, Disney JA, Stamm JW & Bohannan HM (1991) University of North Carolina Caries Risk Assessment study. Ш. Multiple factors in caries prevalence. J Public Health Dent 51: 1–10.

Greenwell AL, Johnsen D, DiSantis TA, Gerstenmaier J & Limbert N (1990) Longitudinal eveluation of caries patterns from primary to the mixed dentition. Pediatric Dent 12: 278–282.

Hausen H (1997) Caries prediction - state of the art. Community Dent Oral Epidemiol 25: 87–96.

Hausen H, Heinonen OP & Paunio I (1981) Caries in permanent dentition and social class of children participating public dental care in fluoridated and nonfluoridated areas. Community Dent Oral Epidemiol 9: 289–291.

Hausen H, Kärkkäinen S & Seppä L (2000) Application of the high- risk strategy to control dental caries. Community Oral Epidemiol 28: 26–34.

Hausen H, Kärkkäinen S & Seppä L (2001) Caries data collected from public health records compared with data based on examinations by trained examiners. Caries Res 35: 360–365.

Hausen H, Milen A, Tala H, Nordling H, Paunio I & Heinonen OP (1983) Caries frequency among 6-17-year-old participants of the Finnish publick dental care during 1975-79. Community Dent Oral Epidemiol 11: 74–80.

Hausen H, Seppä L & Fejerskov O (1994) Can caries be predicted? In: Thylstrup A, Fejerskov O, eds. Textbook of clinical cariology. 2nd edn. Copenhagen: Munksgaard, p 393–411.

Helfenstein U & Steiner M (1992) Prediction of costs in a selective caries preventive programme. Community Dent Health 9: 49–55.

Helfenstein U & Steiner M (1994a) Fluoride varnishes (Duraphat): A meta-analysis. Community Dent Oral Epidemiol 22: 1–5.

Helfenstein U & Steiner M (1994b) The use of logistic discrimination and receiver operatingcharasteristics (ROC) analysis in dentistry. Community Dent Health 11: 142–146.

Helm S. (1969) Secular trend in tooth eruption: a comparative study of Danish school children of 1913 and 1965. Arch Oral Biol 14: 1177–1191.

Helminen SKJ, Meurman JH, Koskinen KP & Rytömaa I (1981) Use of chair-side method for salivary lactobacillus count. Quintessence Int 12: 1321–1324.

Helminen S, Vehkalahti M, Murtomaa H, Kekki P & Ketomäki T-M (1998) Quality evaluation of oral health record-keeping for Finnish young adults. Acta Odont Scand 56: 288–292.

Helminen S, Vehkalahti TM, Murtomaa H (1999) Dentist's selection measures for assessment of oral health risk for Finnish young adults. Acta Odont Scand 57: 225–230.

Helsedirektoratet/Statens helsetilsyn (2000) Tannhelsetjenesten i Norge. Årsmelding 1985–1999. Oslo: Helsedirektoratet/Statens helsetilsyn 1986-2000.

Holbrook WP, Arnadottir IB, Takazoe I, Birkhed D & Frostell G (1995) Longitudinal study of caries, cariogenic bacteria and diet in children just before starting school. Eur J Oral Sci 103: 42–45.

Honkala E, Kannas L, Rise J (1990) Oral health habits of schoolchildren in 11 European countries Int Dent J 40: 211–217.

Honkala E, Nyyssönen V, Kolmakow S & Lammi S (1984) Factors predicting caries risk in children. Scand J Dent Res 92: 134–140.

Houpt MI & Shey Z (1983) Cost-effectiveness of fissure sealants. J Dent Child, 50: 210–212.

Hugoson A, Koch G, Hallonsten AL, Norderyd J, Aberg A (2000) Caries prevalence and ditribution in 3-20-year-olds in Jönköpimg, Sweden, in 1973, 1978, 1983, and 1903. Community Dent Oral Epidemiol 28: 83–89.

Hunt RJ (1990) Behavioral and sociodemographic risk factors for caries. In: Bader JD ed. Risk assessment in Dentistry. Chapel Hill: University of North Carolina Dental Ecolology, p 29–34.

Hämäläinen M, Karjalainen S & Söderling E (1988) A simple test for the determination of salivary sucrase activity. Caries Res 22: 174–176.

Härkänen T, Larmas MA, Virtanen JI & Arjas E (2002) Applying modern survival analysis methods to longitudinal dental caries studies. J Dent Res 81: 144–148.

Isokangas P, Tiekso J, Alanen P & Mäkinen KK (1989) Long-term effect of xylitol chewing gum on dental caries. Community Dent Oral Epidemiol 17: 200–209.

Jensen B & Bratthall D (1989) A new method for the estimation of mutans streptococci in human saliva. J Dent Res 68: 468–471.

Jenkins GN (1984) The recent fall in dental caries incidence. Odont Dent 61: 29–32.

Kalsbeek H & Verrips GHW (1990) Dental caries prevalence and the use of fluorides in different European countries J Dent Res 69: 728–732.

Karjalainen S, Hannula P, Söderling E, Hämäläinen M & Mäkinen K (1989) Sucrose consumption and salivary sucrase activity in a 2-year longitudinal study. Scand J Dent Res 97: 401–404.

Kidd EAM (1991) Role of chlorhexidine in the management of dental caries. Int Dent J 41: 279–286.

Kinnby CG, Palm L & Widenheim J (1991) Evaluation of information on dental care at child health: Differences in educational level, attitudes, and knowledge among parents of preschool children with different caries experience. Acta Odontol Scand 49: 289–295.

Kleemola-Kujala E & Räsänen L (1979) Dietary pattern of Finnish children with low and high caries experience. Community Dent Oral Epidemiol 7: 199–205.

Kleemola-Kujala E & Räsänen L (1982) Relationship of oral hygiene and sugar consumption to risk of caries in children. Community Dent Oral Epidemiol 10: 224–233.

Klein SP, Bohannan HM, Bell RM, Disney JA, Foch CB & Graves RC (1985) The cost and effectiveness of school-based preventive dental care. Am J Public Health 75: 382–391.

Klein H, Palmer CE & Knutson JW (1938) Studies on dental caries. I. Dental status and dental needs of elementary school children. Public Health Rep 53: 751–765.

Kleinbaum DC, Kupper LL & Morgenstern H (1982) Epidemiologic Research. Principles and quantitative methods. Belmont: Lifetime Learning Publications.

Klock B (1984) Long-term effect of intensive caries profylaxis. Community Dent Oral Epidemiol 12: 69–71.

Klock B & Krasse B (1977) Microbiological and salivary conditions in 9-12-year old children. Scand J Dent Res 85: 56–63.

Klock B & Krasse B (1979) A comparison between different methods for prediction of caries activity. Scand J Dent Res 87: 129–139.

Krasse B (1954) The relationship between lactobacilli, candida and streptococci, and dental caries. Examination of saliva and plaque material collected on the same occasion. Odontol Revy 5: 241–261.

Koch GG & Beck JD (1990) Statistical consepts: a matrix for identification of model types. In: Bader JD ed., Risk Assessment in Dentistry. Chapel Hill: University of North Carolina Dental Ecology.

Kolehmainen L, Heinonen OP & Haapakoski J (1985) Caries prediction in 13 to 15 year-old schoolchildren. Community Dental Health 2: 15–21.

Köhler B, Andreen I & Jonsson B (1988). The earlier the colonization by mutans streptococci, the higher the caries prevalence at 4 years of age. Oral Microbiol Immunol 3: 102–108.

Köhler B & Bratthall D (1978) Intrafamilial levels of Streptococcus mutans and some aspects of the bacterial transmission. Scand J Dent Res, 86: 35–38.

Källestål C, Flink A, Allebeck P, Holm AK & Wall S (2000) Evaluation of caries preventive measure. Swed Dent J 24: 1–11.

Källestål C, Oscarson N & Holm AK (1997) Costs for prevention of dental caries in a group of Swedish teenagers. Swed Dent J 21: 193–197.

Kärkkäinen S (1997) Caries prevention in Finland in the early 1990's. Acta Univ Oul D 434, Oulu, Finland.

Larmas M (1975) A new dipslide method for the counting of salivary lactobacilli. Proc Finn Dent Soc 71: 31–35.

Larmas M (1992) Saliva and dental caries: diagnostic tests for normal dental practice. Int Dent J 42: 199–208.

Larmas MA, Virtanen JI & Bloigu RS (1995) Timing of first restorations in permanent teeth: a new system for oral health determination. J Dent 23: 347–352.

Leverett DH (1989) Effectiveness of mouthrinsing with fluoride solutions in preventing coronal caries. J Public Dental Health 49 (5 Spec No): 310–316.

Leverett DH, Featherstone JDB, Proskin HM, Adair SM, Eisenberg AD & Munsdorff-Shrestha SA (1993) Caries risk assessment in a longitudinal discrimination study. J Dent Res 72: 538–543.

Li SH, Kingman A, Forthofer R & Swango P (1993) Comparison of tooth surface-specific caries attac patterns in USA schoolchildren from national surveys. J Dent Res 72: 1398–1405.

Lilienthal B (1950) Studies of the flora of the mouth. III. Yeast-like organisms: some observations on their incidence in the mouth. Aust J Exp Biol Med Sci 28: 279–286.

Llodra JC, Bravo M, Delgado-Rodrigues M, Baca P & Galves R (1993) Factors influencing the effectiveness of sealants – a meta-analysis. Community Dent Oral Epidemiol 21: 261–268.

Luoma A-R & Rönnberg K (1987) Twelve-year follow-up of caries prevalence and incidence in children and young adults in Espoo, Finland. Community Dent Oral Epidemiol 15: 29–32.

Luoma A-R & Rönberg K (1991) Caries experience and disribution in relation to treatment needs among teenagers in Espoo, Finland. Community Dent Oral Health 19: 78–81.

Luoma A-R & Widström E (1997) Syyt lasten ja nuorten suun terveydentilan nopeaan kohentumiseen. In: Widström E. Luoma A-R, Isokangas P *et al*. Hammaskaries on vähentynyt Suomessa – syyt ja seurausvaikutukset (Summary in English) STAKES raportteja 209/1997a p 27–44.

Loesche W (1986) Role of Streptococcus mutans in human dental decay. Microbiol Rew 50: 353–380.

Loesche WJ, Eklund SA, Mehlisch DF & Burt B (1989) Possible effect of medically administered antibiotics on the mutans streptococci: Implications for reduction in decay. Oral Microbiol Immunol 4: 77–81.

McGlone P, Watt R & Sheiham A (2001) Evidence-based dentistry: an overview of the challenges in changing professional practice. Br Dent J 190: 636–639.

Maltz M, Zickert I & Krasse B (1981) Effect of intensive treatment with chlorhexidine on number of Streptococcus mutans in saliva. Scand J Dent Res 89: 445–449.

Manau C, Cuenca E, Martinez-Carretero J & Salleras L (1987) Economic evaluation of community programs for the prevention of dental caries in Catalonia, Spain. Community Dent Oral Epidemiol 15: 297–300.

Mandel ID (1996) Caries prevention: current strategies, new directions. J Am Dent Assoc 127: 1477–1488.

Marsh PD (1993) Antimicrobial strategies in the prevention of dental caries. Caries Res 27 (Suppl 1): 72–76.

Marthaler TM (1990) Cariostatic efficacy of the combined use of fluorides. J Dent Res 69 (Spec Iss): 797–800.

Marthaler TM, O'Mullane DM & Wrbic V (1996) The prevalence of dental caries in Europe 1990-1995. Caries Res 30: 237–255.

Marthaler TM (1984) Explanations for changing patterns of diseases in Western world. In: Guggenheim B ed. Cariology today. Int Congr, Zurich 1983 Base: Karger, p 13–23.

Marquis RE (1990) Diminished acid tolerance of plaque bacteria caused by fluoride. J Dent Res 69 (Spec Iss): 672–675.

Mejàre I, Stenlund H, Julihn A, Larsson I & Permert L (2001) Influence of approximal caries in primary molars on caries rate for the mesial surface of the first permanent molar in swedish children from 6 to 12 years of age. Caries Res 35: 178-185.

Meurman J (1988) Ultrastructure growth, and adherence of Streptococcus mutans after treatment with chlorhexidine and fluoride. Caries Res 22: 283–287.

Meurman J (1997) Dental infections and general health. Quintessence Int 28: 807–811.

Meurman JH, Jousimies-Sommer H, Suomela P, Alaluusua S, Torkko H & Asikainen S (1989) Activity of amine-stannous fluoride combination and chlorhexidine against some aerobic and anaerobic oral bacteria. Oral Microbiol Immunol 4: 117–119.

Meurman JH & Rantonen P (1994) Salivary flow rate, buffering capacity, and yeast counts in 18 consecutive adult patients from Kuopio, Finland. Scand J Dent Res 102: 229–234.

Meurman JH, Rytömaa I, Murtomaa H & Turtola L (1987) Erupting third molars and salivary lactobacilli and Streptococcus mutans counts. Scand J Dent Res 95: 32–36.

Milén A, Tala H, Hausen H & Heinonen O-P (1986) Dental health status, habits and care of Finnish children and youths in 1981-1982. A feasibility study of an information system. (English summary) Health Services Research by National Board of Health in Finland. Helsinki.

Mitchelle I & Murray J (1989) Fissure sealants: A critique on their cost-effectiveness. Community Dent Oral Epidemiol 17: 19–23.

Modéer T, Twetman S & Bergstrand F (1984) Three-year study of the effect of fluoride varnish (Duraphat) on proximal caries progression in teenagers. Scand J Dent Res 92: 400–407.

Murray JJ (1993) Efficacy of preventive agents for dental caries. Systemic fluorides: Water fluoridation. Caries Res 27 (Suppl 1): 2–8.

Murtomaa H, Meurman JH, Rantama A & Levo S (1987) Inter-examiner variation in common reading of Streptococcus mutans dipslides with or without a microscope. Scand J Dent Res 95: 145–150.

Mäkinen KK, Chen CY, Mäkinen PL, Benett CA, Isokangas PJ, Isotupa KP & Pape HR Jr (1996) Properties of whole saliva and dental plaque in relation to 40-month consumption of chewing gums containing xylitol, sorbitol or sucrose. Caries Res 30: 180–188.

Mäkinen KK & Scheinin A (1972) The effect of various sugars and sugar mixtures on the activity and formation of enzymes of dental plaque and oral fluid. Acta Odont Scand 30: 259–275.

Nadanowsky P & Sheiham A (1995) Relative contribution of dental services to the changes in caries levels of 12-year-old children in 18 industrialized countries in the 1970s and early 1980s. Commun Dent Oral Epidemiol 23: 331–339.

Neilson A & Pitts NB (1990) The clinical behaviour of free tooth surface carious lesions monitored over 2 years in a group of Scottish children. Br Dent J 171: 313–318.

Newbrun E (1992) Dental caries in the future: a global view. Proc Finn Dent Soc 88: 155–61.

Newbrun E (1996) The fluoridation war: a scientific dispute or a religious argument. J Public Health Dent 56 (5 Spec No): 155–161.

Nickerson WJ (1953) Reduction of inorganic substances by yeasts. I. Extracellular reduction of sulphide by species of Candida. J Infect Dis 93: 43–56.

Niessen LC & Douglas CW (1984) Theoretical consideration in applying benefit-cost and cost-effectivness analysis to preventive dental programs. J Publ Health Dent 44: 156–168.

Nikiforuk G (1985) Understanding dental caries. 1. Etiology and mechanisms, basic and clinical aspects. Karger, Basel.

Nordblad A (1986) Changes in epidemiologic pattern of dental caries in chohorts of dental caries in Espoo, Finland, during a 3-year period. Community Dent Oral Epidemiol 4:126–7.

Nordblad A & Larmas M (1985a) Timing of the first attack of caries on the permanent teeth in cohorts of schoolchildren in Espoo, Finland. Proc Finn Dent Soc 81: 17–23.

Nordblad A & Larmas M (1985b) A 3-year longitudinal caries study of permanent tooth surfaces at risk in Finnish school children. Caries Res 19: 271–277.

Nordblad A & Larmas M (1985c) A three year study of caries prevalence, incidence and risk ages in cohorts of schoolchildren in Espoo, Finland. Proc Finn Dent Soc 81: 11–16.

Nordblad A & Larmas M (1986) Caries and fillings in the permanent dentition of cohorts of schoolchildren in Espoo, Finland. Community Dent Oral Epidemiol 14:271–273.

Nordblad A, Linna M, Luoma K, Niskanen T (1996) Differencies between cost efficiency scores in oral dental health care centres in Finland in 1992. J Soc Med 33: 307–314.

Nordblad A, Suominen-Taipale L, Murtomaa H, Vartiainen E & Koski K (1995) Smart Habit Xylitol campaign, a new approach in oral health promotion. Community Dent Health 12: 230–234.

Nordblad A, Suominen-Taipale L & Rasilainen J (1993) Oral health care in Finnish health centres in 1991. Helsinki: Stakes reports 115.

Nyvad B & Kilian M (1987) Microbiology of the early colonization of human enamel and root surfaces in vivo. J Dent Res 95: 369–380.

O'Rouke CA, Attrill M & Holloway PJ (1988) Cost appraisal of a fluoride tablet programme to Manchester schoolchildren. Community Dent Oral Epidemiol 16: 341–344.

Ostela I, Tenovuo J, Söderling E, Lammi E & Lammi M (1990) Effect of chlorhexidine-sodium fluoride gel applied by tray or by toothbrush on salivary mutans streptococci. Proc Finn Dent Soc 86: 9–14.

van Palenstein Helderman WH, van´t Hof MA & van Loveren C (2001) Prognosis of caries increment with past caries experience variables. Caries Res 35: 186–192.

Parvinen T & Larmas M (1981) The relation of stimulated salivary flow rate and pH to lactobacillus and yeast concentrations in saliva. J Dent Res 60: 1929–1935.

Parviainen K, Nordling H & Ainamo J (1977) Occurence of dental caries and gingivitis in low, medium and high fluoride areas in Finland. Community Dent Oral Epidemiol 5: 287–291.

Paunio P, Häkkinen P, Tenovuo J, Niva A & Lumikari M (1988) Dip-slide scores of mutans streptococci and lactobacilli in Finnish mothers in Turku area, Finland, during the nursing year. Proc Finn Dent Soc 84: 27–37.

Petersson HG & Bratthall D (1996) The caries decline: a review of reviews. Eur J Oral Sci 104: 436–443.

Petersson LG., Magnusson K, Andersson H, Deierborg G & Twetman S (1998) Effect of semi-annual applications of a chlorhexidine/fluoride varnish mixture on approximal caries incidence in schoolchildren. A three-year radiographic study. Eur J Oral Sci 106: 623–627.

Petersson LG & Westerberg I (1994) Intensive fluoride varnish program in Swedish adolescents: economic assessment of a 7-year follow-up study on proximal caries incidence. Caries Res 28: 59–63.

Petrie A & Sabin C (2000) Medical statistics at a glance. Blackwell Science Ltd. Oxford.

Pienihäkkinen K (1987) Screening for high caries increment in children. Proc Finn Dent Soc 84 (Suppl II): 1–76.

Pienihäkkinen K & Jokela J (1995) A simple method for monitoring mutans streptococci in young children. Eur J Oral Sci 103: 61-62.

Pitts NB & Palmer JD (1994) The dental caries experience of 5-, 12- and 14-year-old children in Great Britain. Surveys coordinated by the British Association for the study of Community Dentistry in 1991/92, 1992/93 and 1990-91. Community Dent Health 11: 42–52.

Poulsen S, Agerbaek N, Melsen B, Korts DC, Glavind L & Rölla G (1976) The effect of professional toothcleansing on gingivitis and dental caries in children after one year. Community Dent Oral Epidemiol 4: 195–199.

Poulsen S & Scheutz F (1999) Dental caries in Danish children and adolescents 1988-1997. Community Dent Health 16: 166–170.

Powell LV (1998) Caries prediction: a review of the literature. Community Dent Oral Epidemiol 26: 361–371.

Reich E, Lussi A & Newbrun E (1999) Caries risk assessment. Int Dent J 49: 15–26.

Renson CE, Crielaers PJA, Ibikunle SAJ, Pinto VG, Ross CB, Sardo Infirri J, Takazoe I & Tala H (1985) Changing patterns of oral health and implications for oral health manpower. Part 1. Report of a working group convened jointly by the Fédération Dentaire International and the World Health Organisation. Int Dent J 35: 235–251.

van Rijkom HM, Truin G.J & vant´ t Hof MA (1996) A meta-analysis of clinical studies on the caries-inhibiting effect of chlorhexidine treatment J Dent Res 75: 790–795.

Riordan PJ (1993) Fluoride supplements in caries prevention: a literature review and proposal for new dosage schedule. J Public Health Dent 53: 174–189.

Riordan PJ (1997) Can organized dental care for children be both good and cheap? Community Dent Oral Epidemiol 25: 119–125.

Ripa LW, Leske GS & Varma AO (1988) Longitudinal study of the caries susceptibility of occlusal and proximal surfaces of first permanent molars. J Public Health Dent 48: 8–13.

Rogers AH (1981) The source of infection in the intrafamilial transfer of Streptococcus mutans in human mouth and their intrafamilial transmission. Caries Res 15: 26–31.

Rose G (1985) Sick individuals and sick populations. Int J Epidemiol 14: 32–38.

Rugg-Gunn AJ & Edgar WM (1984) Sugar and dental caries: A review of the evidence. Community Dent Health 1: 85–92.

Russell JI, McFarlane TW, Aitchison TC, Stephen KW & Burchell CK (1990) Salivary levels of mutans streptococci, *Lactobacillus, Candida, Veillonella* species in a group of Scottish adolescents. Community Dent Oral Epidemiol 18: 17–21.

Russell JI, McFarlane TW, Aitchinson TC, Stephen KW, Burchell CK. (1991) Prediction caries increment in Scottish adolescents. Community Dent Oral Epidemiol 19: 74–77.

Rølla G, Øgard B & de Almeida Cruz R (1991) Clinical effect and mechanism of cariostatic action of fluoride-containing toothpastes: a review. Int Dent J 41: 171–174.

Sakamaki ST & Bahn AN (1968) Effect of orthodontic banding on localized oral lactobacilli. J Dent Res 47: 275–279.

Sakki T & Knuuttila M (1996) Controlled study of the association of smoking with lactobacilli, mutans streptococci and yeasts in saliva. Eur J Oral Sci 104: 619–622.

SAS Institute Inc. SAS Users Guide: Basics, Version 5 Edition. Cary, NC: SAS Institute Inc, 1985.

Scheie AA, Fejerskov & Danielsen B (1998) The effect of xylitol-containing chewing gum on dental plaque and acidogenic potential. J Dent Res 77: 1547–1552.

Scheinin A, Mäkinen KK & Ylitalo K (1975) Turku sugar studies. V Final report on the effect of sucrose, fructose and xylitol in man. Akta Odontol Scand 33 (Suppl 70): 67–104.

Scheinin A, Pienihäkkinen K, Tiekso J & Holmberg S (1992) Multifactorial modeling for root caries prediction. Community Dent Oral Epidemiol 21: 35–37.

Schröder U & Granath L (1983) Dietary habits and oral hygiene as predictors of caries in 3-year-old children. Community Dent Oral Epidemiol 11: 308–311.

Seppä L (1984) Fluoride content of enamel during treatment and 2-years after discontinuation of treatment with fluoride varnishes. Caries Res 18: 278–281.

Seppä L & Hausen H (1988) Frequency of initial caries lesions as predictor of future caries increment in children. Scand J Dent Res 96: 9–13.

Seppä L, Hausen H, Pöllänen L, Kärkkäinen S & Helasharju K (1991) Effect of intensified caries prevention on approximal caries in adolescents with high caries risk. Caries Res 25: 392–395.

Seppä L, Kärkkäinen S & Hausen H (1998) Caries frequency in permanent teeth before and after discontinuation of water fluoridation in Kuopio, Finland. Community Dent Oral Epidemiol 26: 256–262.

Seppä L, Kärkkäinen S & Hausen H (2000) Caries trends 1992-1998 in two low-fluoride Finnish towns formerly with and without fluoridation. Caries Res 34: 462–468.

Seppä L & Pöllänen L (1989) Caries preventive effect of fluoride varnishes and fluoride mouthrinsing. Caries Res 21: 375–379.

Seppä L, Pöllänen L & Hausen H (1994) Caries preventive effect of fluoride varnish with different fluoride cocentrations. Caries Res 28: 64–67.

Seppä L & Tolonen T (1990) Caries preventive effect of fluoride varnish applications performed two or four times a year. Scand J Dent Res 98: 102–105.

Seppä L, Tuutti H & Luoma H (1982) A three-year report on caries prevention using fluoride varnishes for caries risk children in a community with fluoridated water. Scand J Dent Res 90: 89–94.

Sheiham A (1984) Changing trends in dental caries. Int J Epidemiol 13: 142–147.

Silverstone L-M (1977) Demineralisation phenomena. Caries Res 11 (Suppl 1): 59–84.

Sintonen H (1986) Comparing producity of public and private dentistry. In Culyer A & Jönsson B editors. Public and private health services. Oxford (UK): Blackwell, p 219–234.

Sintonen H & Linnosmaa I (2000) Economics in dental services. In: Handbook of Health Economics. Volume 1. Ed Cuiler A.J. & Newhouse, J.P. ©2000 Elsevier Science B.V. 24: 1252–1292.

Sintonen H & Majanen T (1995) Explaining utilisation of dental care. Experiences from Finnish dental care market. Health Economics 4: 453–466.

Sintonen H, Pekurinen P & Linnakko E (1997) Terveystaloustiede.

Socialstyrelsen (2000) Tandhälsan hos barn och ungdomar 1985-1999. Meddelandeblad Nr 12/00 Socialstyrelsen, Stockholm.

Spencer AJ (1997) Skewed distributions - new outcome measures. Community Dent Oral Epidemiol 25: 52–59.

Speechley M & Johnston DW (1996) Some evidence from Ontario, Canada, of reversal in the dental caries decline. Caries Res 30: 323–427.

Splieth C & Mayer G (1996) Factors for changes of caries prevalence among adolescents in Germany. Eur J Oral Sci 104: 444–451.

Splieth C, Steffen H, Rosin M & Welk A (2000) Caries prevention with chlorhexidine-thymol varnish in high risk children. Community Dent Oral Epidemiol 28: 419–423.

Stakes (1996) Suositus fluorin käytöstä hammassairauksien ehkäisemiseksi (Recommendation on the use of fluoride for dental health) Finn Dent J 5: 199–205.

Stamm JW, Disney JA, Graves RC, Bohannan HM & Abernathy JR (1988) The University of North Carolina Caries Risk Assessment Study I: Rationale and content. J Public Health Dent 48: 221–232.

Stecksén-Blicks C (1985a) Dental health, dental care, and dietary habits in children in different parts of Sweden. Acta Odontol Scand 43: 59–67.

Stecksén-Blicks C (1985b) Salivary counts of lactobacilli and Streptococcus mutans in caries prediction. J Dent Res 93: 204–212.

Stecksén-Blicks C & Holm AK (1995) Between-meal eating, toothbrushing frequency, and dental caries in 4-year-old children in the north of Sweden. J Paediatr Dent 5: 67–72.

Swango PA & Brunelle JA (1993) Age- and surface-spesific caries-attack rates from the National Dental Caries Prevalence Survey. J Dent Res 62 (Spec Iss): 270.

Söderling E, Isokangas P, Tenovuo, Mustakallio S & Mäkinen KK (1991) Long-term xylitol consumption and mutans streptococci in plaque and saliva. Caries Res 25: 153–157.

Söderling E, Isokangas P, Pienihäkkinen K & Tenovuo J (2000) Influence of maternal xylitol consumption on acquisition of mutans streptococci by infants. J Dent Res 79: 882–887.

Steiner M, Hefenstein U & Marthaler TM (1992) Dental predictors of high caries increment in children. J Dent Res 71: 1926–1933.

ten Cate JM (1990) In vitro studies on the effect of fluoride on de- and remineralisation. J Dent Res 69 (Spec Iss): 614–619.

Tenovuo J, Häkkinen P, Paunio P & Emilson C-G (1992) Effects of chlorhexidine-fluoride treatments in mothers on the establishment of mutans streptococci in primary teeth and development of dental caries in children. J Dent Res 26: 275–280.

Thorner RM & Remein QR (1961) Principles and procedures in the evaluation of screening for disease. US Public Health Service Publication No 846, Monograph No 76.

Thylstrup A (1990) Clinical evidence of the role of pre-eruptive fluoride in caries prevention. J Dent Res 69 (Spec Iss): 742–750.

Trahan L, Söderling E, Dréan MF, Chevrier MC, Isokangas P (1992) Effect of xylitol consumption on the plaque-saliva distribution of mutans streptococci and the occurrence and long-term survival of xylitol-resistant strains. J Dent Res 71: 1785–1791.

Trahan L (1995) Xylitol: a review of its action on mutans streptococci and dental plaque–its clinical significance. Int Dent J 45 (Suppl 1): 77–92.

Truin GJ, König KG & Kalsbeek H (1993) Trends in dental caries in the Netherlands. Adv Dent Res 7: 15–18.

Tukia-Kulmala H & Tenovuo J (1993) Intra- and inter-individual variation in salivary flow rate, buffer effect, lactobacilli and mutans streptococci among 11- to 12- year-old schoolchildren. Acta Odontol Scand 51: 31–37.

Utriainen P & Widström E (1990) Economic aspects of dental care in Finnish health centers. Community Dent Oral Epidemiol 18: 235–238.

Varsio S (1999) Caries-preventive treatment approaches for child and youth at two extremes of dental health. University of Helsinki. ISBN 952-91-1150-9.

Varsio S & Vehkalahti M (1996) Evaluation of preventive treatment by risk of caries among 13-years-olds. Community Dent Oral Epidemiol 24: 277–281.

Varsio S & Vehkalahti M (1997) Dentists' decisions on caries risk and preventive treatment by dental state among 15-year-old adolescents. Community Dent Health 14: 166–170.

Vecchio TJ (1966) Predictive value of a single diagnostic test in unselected populations. N Engl J Med 274: 1171–1173.

Vehkalahti M & Helminen S (1994) Outcome of public oral health services in relation to treatment mix. Acta Odont Scand 52: 1–6.

Vehkalahti M, Helminen S & Rytömaa I (1990) Caries decline from 1976 to 1986 among 15-year-olds in Helsinki. Caries Res 24: 279–285.

Vehkalahti M, Nikula-Sarakorpi E & Paunio I (1996) Evaluation of salivary tests and dental status in the prediction of caries increment in caries-susceptible teenagers. Caries Res 30: 22–28.

Vehkalahti M, Rytömaa I & Helminen S (1992) Assessment of quality of public oral health care on the basis of patient records. Community Dent Oral Epidemiol 20: 102–105.

Vehkalahti M, Solavaara L & Rytömaa I (1991) An eight-year follow-up of the occlusal surfaces of first permanent molars. J Dent Res 70: 1064–1067.

Vehkalahti M, Tarkkonen L, Varsio S & Heikkilä P (1997) Decrease in and polarization of dental caries occurence among child and youth populations, 1976 - 1993. Caries Res 31: 161–165.

Vehmanen R (1993) An economic evaluation of two caries preventive methods. University of Turku. ISBN 952-90-4998-6.

Virtanen, J (1997) Surface and tooth specific filling increments as indicators of dental health in children and adolescents. University of Oulu, Finland. D Med 407.

Virtanen JI, Bloigu RS, Larmas MA (1994) Timing of eruption of permanent teeth: standard Finnish patient documents. Community Dent Oral Epidemiol 22: 286–288.

Virtanen JI, Bloigu RS, Larmas MA (1996) Timing of the first restorations before, during, and after a preventive xylitol trial. Acta Odontol Scand 54: 211–216.

Virtanen JI, Bloigu RS, Larmas MA (1997) Effect of early restorations of permanent molars on filling increments of individual teeth. J Dent 25: 17-24.

Virtanen JI & Larmas MA (1995) Timing of first fillings on different permanent tooth surfaces in Finnish schoolchildren. Acta Odontol Scand 53: 287–292.

Walker ARP (1987) Perplexities and controversies on diet and dental caries. World Rev Nutr Diet 54: 174–200.

Wang NJ & Holst D (1995) Individualizing recall intervals in child dental care. Community Dent Oral Epidemiol 23: 1–7.

Wang NJ, Källestål C, Petersen PE & Arnadottir IB (1998) Caries preventive services for children and adolescents in Denmark, Iceland, Norway and Sweden: strategies and resource allocation. Community Dent Oral Epidemiol 26: 263–271.

Wang N, Marstrander P, Holst D, Øvrum L & Dahle T (1992) Extending recall intervals – effect on recource consumption and dental health. Community Dent Oral Epidemiol 20: 122–124.

Warner KE (1989) Issues in cost-effectiveness in health care. J Public Health Dent 49 (Spec Iss): 272–278.

Weinstein MC & Stason W (1977) Foundations of cost-effectiveness analysis for dental health and medical practices. N Engl J Med 296 (Spec Iss): 716–721.

Wei SH & Yiu CK (1993) Mouthrinses: recent clinical findings and implications for use. Int Dent J 43: 541–547.

Wikner S & Nedlich U (1985) A clinical evaluation of the ability of the Dentobuff® method to estimate buffer capacity of saliva. Swed Dent J 9: 45–47.

Wiktorsson A-M, Martinsson T & Zimmerman M (1992) Salivary levels of lactobacilli, buffer capacity and salivary flow rate related to caries activity among adults in communities with optimal and low fluoride concentrations. Swed Dent J 16: 231–237.

Wilson RF & Ashley FP (1989) Identification of caries risk in schoolchildren: salivary buffering capacity and bacterial counts, sugar intake and caries experience as predictors of two year and 3-year caries increment. Br Dent J 167: 99–102.

Winston AE & Bhaskar SN (1998) Caries prevention in the 21st century. J Am Dent Assoc 129: 1579–1587.

World Health Organisation (1979) A guide to oral health epidemiological investigations. WHO, Geneva.

World Health Organisation (1994). Fluorides and oral health (Report of a WHO expert committee on oral health status and fluoride use). WHO Technical Report Series No 846. Geneva: World Health Organisation.

Yule BF, Amerongen B & van Schaik M (1986) The economics and evaluation of dental care and treatment. Soc Sci Med 22: 1131–1139.

Zickert I, Emilson C-G & Krasse B (1982) Effect of caries preventive measures in children highly infected with the bacterium Streptococcus mutans. Arch Oral Biol 27: 861–868.

Zickert I, Emilson C-G & Krasse B (1987) Microbial conditions and caries increment 2 years after discontinuation of controlled antimicrobial measures in Swedish teenagers. Community Dent Oral Epidemiol 15: 241–244.