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CUMULATIVE COSTS OF CARIES PREVENTION AND TREATMENT IN CHILDREN

- with Special Reference to Work Division and Cohort Effect

by

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To Mikko and Riikka

ABSTRACT

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Cumulative Costs of Caries Prevention and Treatment in Children - with Special Reference to Work Division and Cohort Effect

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The aim of the present study was to calculate the cumulative costs of caries prevention and treatment in children by comparing two operational models of caries management in the public health centres of Kemi and Tornio. In addition, the dental health of children was observed. The study was carried out from the viewpoint of the public provider.

Data were collected from the files of the Public Health Centres. In Kemi, the cohorts born in 1980, 1983 or 1986 (n = 600), and in Tornio, the cohorts 1980 and 1992 (n = 400) represented the conventional operational model. The cohorts 1989, 1992 and 1995 (n = 600) in Kemi represented the new model. The cohorts and towns were compared in relation to dental health (dmft/DMFT = 0 and mean dmft and DMFT scores at the ages 5 and 12 years), and resources used. The mean cumulative numbers of caries treatment visits by providers and total cumulative costs related to caries treatment were used in determining resource use. Cumulative costs in relation to caries experience were assessed in cost-effectiveness analysis.

The operational model had a major effect on the cumulative costs of caries treatment in children. Early prevention and control of caries carried out by dental hygienists was associated with lower cumulative costs and better or equally good dental health as conventional prevention with less work division. The cost-effectiveness in caries treatment of children in the Public Health Centres had significantly improved during the study years.

The early risk-based approach for control of caries enables cost-effective use of personnel resources.

Key words: costs and cost analysis, delegation/professional, dental caries/prevention and control, dental team, distribution of work, patient care team, practice management/ dental

TIIVISTELMÄ

Tiina Joensuu

Lapsen karieshoidon kustannuskertymän muutokset ja karieshoidon toiminta-käytäntöjen yhteys kustannuksiin

Sosiaalihammaslääketieteen osasto, Hammaslääketieteen laitos, Turun yliopisto, Turku, Suomi.
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Tutkimuksen tavoitteena oli mitata terveyskeskuksessa hoidettavien lasten karieshoidon kumulatiivisia kustannuksia ja verrata niitä kahden erilaisen toimintatavan välillä. Lisäksi tarkasteltiin lasten hampaiden terveyttä. Tutkimus tehtiin julkisen palvelutuottajan näkökulmasta.

Tutkimusaineisto kerättiin Kemin ja Tornion terveyskeskusten suun terveydenhuollon potilaskertomuksista. Kemin kohortit 1980, 1983 ja 1986 (n = 600) ja Tornion kohortit 1980 ja 1992 (n = 400) edustivat perinteistä ja Kemin kohortit 1989, 1992 ja 1995 (n = 600) uutta toimintatapaa työnjaon ja ehkäisyn ajoituksen suhteen. Kohortteja ja kaupunkeja verrattiin hampaiden terveyden (dmft/DMFT = 0 ja dmft ja DMFT keskiarvot 5 ja 12 vuoden iässä) ja voimavarojen käytön suhteen. Panoskäyttö johdettiin käyntimäärien avulla laskennallisen työajan kautta. Kustannuskertymät muodostettiin käyttämällä henkilöstömenoista laskettuja suorittajakohtaisia yksikkökustannuksia. Panoskäytön ja yksikkökustannusten kautta muodostettiin kustannuskertymät. Kustannusten ja terveysvaikutusten suhteita arvioitiin kustannus-vaikuttavuusanalyysissä.

Suuhygienistien työpanosta hyödyntävällä varhaisen ehkäisyn toimintamallilla saavutettiin vähäisemmin kustannuksin alle kouluiässä parempi ja kouluiässä yhtä hyvä hammasterveys kuin perinteisellä, enemmän hammaslääkärien työpanokseen perustuvalla tavalla. Karieksen hoitoon liittyvien käyntien määrä oli nuorimmissa syntymävuosikohorteissa pienempi kuin vanhimmissa kohorteissa. Käynnit hammaslääkärissä vähenivät eniten. Toimintatavalla oli merkittävä vaikutus lapsen karieshoidon kokonaiskustannuksiin. Herkkyysanalyysin mukaan karieshoidon kustannukset olivat työnjakoa hyödyntämällä kolmanneksen pienemmät, kuin jos hoidon suorittajana olisi ollut ainoastaan hammaslääkäri-hoitaja työpari. Lasten karieshoidon kustannusvaikuttavuus kohentui molemmissa terveyskeskuksissa nuoremmissa kohorteissa vanhempiin verrattuna.

Suun terveydenhuollon potilaskertomuksia olisi hyödynnettävä toiminnan kehittämisessä. Varhaisen ehkäisyn avulla voitaisiin kaikkien suun terveydenhuollon ammattihenkilöiden työpanos kohdentaa kustannustehokkaasti.

Asiasanat: ammatillinen delegointi, hammaslääkärin vastaanoton johtaminen, hoitotiimi, karies/ennaltaehkäisy ja hallinta, kustannukset ja kustannusanalyysi, tiimityö, työnjako

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Kemi, April 2009

Tiina Joensuu

CONTENTS

ABBREVIATIONS

CEA	Cost-effectiveness analysis
CHX	Chlorhexidine
CI	Confidence interval
dmf(t)	Number of decayed, missing or filled deciduous teeth
DMF(T)	Number of decayed, missing or filled permanent teeth
ICER	Incremental cost-effectiveness ratio
MS	Mutans streptococci
PDS	Public Dental Service
SEK	Swedish crown
STAKES	National Research and Development Centre for Welfare and Health
WHO	World Health Organization

1. INTRODUCTION

Health policy strives for two main goals; available resources should be allocated to allow as low an occurrence and as even a distribution of health problems as possible in the population. Striving for efficiency in health care means striving for judicious use of scarce resources. Therefore, knowledge about the cost-effectiveness of health care services is of crucial importance for the decision makers.

The occurrence of dental caries has decreased in recent decades in most of the economically developed countries, but it still remains a major oral health problem among children and adults. The costs of diagnosing and managing dental caries are still considerable in these countries.

In Finland, the growing demand for public oral health services has meant that decision makers, administrators and clinicians face a continuous challenge to provide dental care more efficiently. Consequently, there have been several changes in conventional clinical and administrative routines over the recent decades. Individually oriented preventive dental care based on risk assessment in early childhood and work division among dental professionals has become more frequent. When trying to improve cost-effectiveness in the public oral health service, it is vital to know the cumulative costs of dental caries prevention and treatment from early childhood to adulthood, and to know how changed operational models of clinical work affect the costs and health outcome. The cost of personnel forms approximately 75% of the total costs in the Finnish public oral health service. Thus, it should be of special interest to try to create operational models where the skills and knowledge of all personnel are used in the most efficient and cost-effective way.

2. REVIEW OF THE LITERATURE

2.1 Caries trends

Caries figures have decreased in most of the economically developed countries in recent decades (Petersen 2003). In 2004, according to World Health Organization (WHO) statistics, the weighted mean number of decayed, missing or filled permanent teeth (DMFT) among European 12-year-olds was 2.6 (WHO 2007). In Denmark, Norway and Sweden, more than one half of 5-year-olds had deciduous dentitions free of decayed, missing or filled teeth (dmft = 0) (Marthaler et al. 1996). After a continuous decline, the pattern of caries occurrence has shown a levelling-off trend in the Nordic countries (von der Fehr 1994, Marthaler et al. 1996). Recently, the Nordic countries have reported mean DMFT levels of 0.9–1.5 among 12-year-olds; the percentages of children having healthy dentitions (DMFT = 0) varied between 38 and 63% (Widström et al. 2005).

In Finland, the dental health of children and adolescents has also improved markedly since the 1970s (Nordblad et al. 2004). In clinical practice, caries refers to dentinal caries, in accordance with the way the dmft/DMFT index is assessed in Finland. Based on national statistics, the mean DMFT among 12-year-olds was 6.9 in 1975, and 1.2 in 1994. The average dmft figures for 5-year-olds were 5.0 and 1.1, respectively. Another indication of the favourable trend in the dental health of children is the increased proportion of children with healthy dentitions (dmft/DMFT = 0). In 1976, 20% of 5-year-olds and 1% of 12-year-olds had healthy dentitions, whereas in 2000, the respective figures were 65% and 38% (Nordblad et al. 2004). In the 1990s, the declining trend in the occurrence of caries levelled off. In 2000, the mean DMFT for 12-year-olds was 1.2, and the mean dmft for 5-year-olds 0.9. The differences between regions in dmft/DMFT figures detected earlier in Finland disappeared in the 1990s (Nordblad et al. 2004).

While the caries rates have declined, the occurrence of caries now has a more skewed distribution among children and adolescents. Many children have healthy teeth, but some still have a serious caries problem (Nordbland 1986, Bjarnason et al. 1993, Vehkalahti et al.1997, Seppä et al. 2000). A continuous and increasingly uneven distribution of caries over time in children aged 5 or 15 years was seen in a series of cross-sectional studies carried out over a 30-year period in Sweden. In 1973, caries was quite evenly distributed and the majority of children had some caries, whereas in 2003, the majority had no or fewer than six decayed or filled surfaces in deciduous or permanent teeth (Hugoson et al. 2008). In a recent Finnish study, where follow-up data on the permanent teeth of children from the age of 5-7 years up to the age of 18 years were analysed in four age cohorts, the uneven distribution of caries became more pronounced towards the younger age cohorts. In the 1965 age cohort, 20% of the subjects produced 35% of the total caries burden. In

the 1970, 1975, and 1980 age cohorts, 20% of the subjects produced about 43%, 66% and 75% of the total caries burden, respectively (Meriläinen 2004).

Even though caries occurrence has declined it remains a significant oral health problem. The levelling off of the declining trend has raised the question of whether a reversal is to be expected (Downer 1994, von der Fehr 1994, Vehkalahti et al. 1997). Some observations suggesting this have been reported (Pitts et al. 2003, Haugejorden and Birkeland 2005, 2006). Improvements in dental health may have reached their attainable limits with the current prevention methods (Suni et al. 1998).

2.2 Oral health services in Finland

In Finland, the municipalities are responsible for providing oral health care free-of-charge to children and adolescents under 18 years of age. The systematic and comprehensive services include regular dental examinations, preventive care such as oral hygiene instruction and fluoride applications, and all other treatment. The services are financed by general and local taxation and delivered by public health centres. The participation of children and adolescents in the public oral health services has traditionally been high. Practically all children use the services of the public system (Milén et al. 1990, Honkala et al. 2002, Nordblad et al. 2004).

The national health policy guidelines have emphasised health promotion, equity in health level, and availability of public health care services and programmes for all people who would benefit from them. In recent years, regarding public oral health services, the implication has been that more resources should be spent on the care of those at high risk of oral disorders and fewer resources on children with good dental health. General health care needs were to be considered in the provision of public oral health care services.

The availability of publicly funded oral health care services for the adult population has been expanded progressively by legislative amendments since the introduction of the Primary Health Care Act of 1972. Nearly half of the Finnish adult population uses private dental services, the rest receive care at public dental offices. In 2004, almost every second adult had used the public oral health services or subsidised private services. One half of them were seen by dentists in public dental offices, and the other half were seen by private dentists (Niiranen et al. 2008). The private services are reimbursed by the Social Insurance Institution of Finland. At the public health centre dental offices, adults pay fees subsidized by local municipalities. The aim of the national oral health care policy has originally been to give patients the possibility to choose between the two systems of care delivery. However, the fees collected in health centres are less than half of the patients' own share after reimbursement in the private sector. This actually affects patients' choices. The ability of the public health centres to provide oral health

services for the whole population is diverse. Health centres in rural areas and small towns have mainly been able to provide treatment for all patients. In large cities, the focus of treatment among adult patients has been on the most immediate needs and on treatment of some special patient groups such as diabetics, the disabled and older persons.

Up to 1985, obligatory policies on the frequency of oral health examinations and preventive measures for children and adolescents receiving care in public health centre dental offices were determined by The National Board of Health. Since 1991, the National Research and Development Centre for Welfare and Health (STAKES), has given guidelines for the practices. The guidelines constitute recommendations and advice on good professional practice, but they are not obligatory. The municipalities are quite independent in their local decision making though they are expected to respect the national guidelines. Flexible planning and implementation of operational models is, therefore, possible to a certain extent.

The systematic and free public oral health care for children and adolescents is well accepted and appreciated. Because the public resources are both scarce and limited, the issue is how to provide good quality care at reasonable cost. The need to provide services efficiently and for larger numbers of patients has called for changes in clinical and administrative practices in the public oral health care service.

Work division between dental professionals and individually determined examination intervals have been suggested as ways to adjust the public oral health services to the improved dental health of children and economic requirements (Wang 1994a, Hannerz and Westerberg 1996, Riordan 1997, Jokela and Pienihäkkinen 2003). The early risk-based approach to control dental caries presents one model to implement them (Holst et al. 1997, Wendt et al. 2001, Pienihäkkinen and Jokela 2002). It seems rational to apply work division in a way that supports the maintenance of dental health already from infancy by utilizing the health-promoting skills of dental hygienists and preventive dental nurses. The concept of caries management is closely connected to the operational practices.

2.3 Production process

In the production process, inputs are combined and transformed into a variety of outputs in a production unit, e.g. a dental office. The resources consumed form the input of the production process. Examples of inputs in dentistry are dentist and dental hygienist time, equipment and materials. The input is usually measured in money and referred to as costs. The output consists of products, services and technologies, but it can also consist of behaviour and attitudes. The output can also be expressed in monetary terms. The products and services that are not actually sold on the market can be referred to as

benefits. The benefits are usually gains in health status (direct benefits) or non-health benefits, e.g. production gains (indirect benefits) (Cunningham 2000). Most often it is not possible or necessary to measure and value all the costs and consequences of the alternatives under comparison (Drummond et al. 1997).

The productivity reveals the unit's ability to transform resources to products and services, whereas the effectiveness of the production process is related to the net achievement of the objectives attributable to the production process (Sintonen et al. 1997). In health care, effectiveness is usually understood as a change in health status in the customary operational environment of the health care system (Sintonen et al. 1997). The dimension of efficiency in the production process addresses the relationship between the output (results of the intervention) and the resources used to deliver the intervention. Two possibilities have been commonly used to express efficiency in a functional form. Efficiency can be formulated into a ratio of effectiveness and input (costs) or a difference between benefit and costs expressed in equal terms and addressed as net-benefit. Efficiency in health care can be accomplished in two ways. One either tries to achieve the best possible outcome with the resources given, or to reach a certain health outcome with a minimum amount of resources. The efficiency of a process may be poor though the productivity is good. This is the case when effectiveness is weak. If the costs of the process are very high efficiency is inadequate even if effectiveness is excellent (Sintonen et al. 1997).

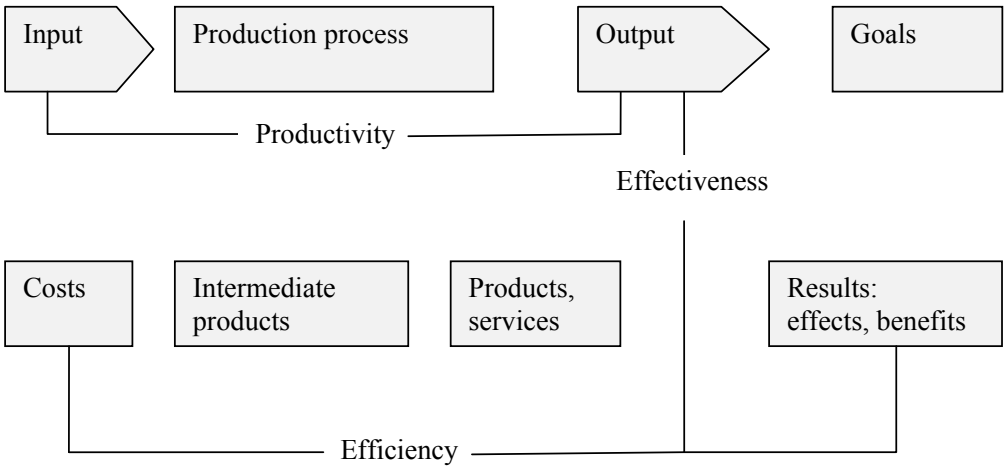


Figure 1 The essential concepts of the production process and their relations to each other (Vehmanen 1993) (reprinted with the author's permission)

2.3.1 Efficiency and ethics

The production process and its efficiency can be looked at from the ethics point of view. The ethics of medicine is classically concerned with the individual's benefit. Health care at large is seeking the benefit of the society. "By providing information on who

accrues the benefits and incurs the costs of resource allocation decisions, as well as the magnitude of such costs and benefits, health economics is also concerned with equity or 'fairness' of healthcare delivery" (Donaldson 1998). In the ethics sense, pursuing efficiency should not cause anxiety. Instead one should be concerned if efficiency is not strived for (Donabedian 1990, Sintonen et al. 1997).

2.3.2 Production process and quality

The monitoring of quality is an essential element of any production process. Quality can be defined as the totality of features and other characteristics of a product or service that bear on its ability to satisfy stated or implied needs (Komarov et al. 1999). A high quality health care system possesses characteristics that respond to the demands of users, and is able to satisfy the expectations placed upon it in achieving the desired health outcomes, while taking into account current professional knowledge and resources available (Chassin and Galvin 1998).

Assessment of quality in health care can be based on a conceptual framework containing three dimensions: structure, process and outcome (Donabedian 1988). Structure relates to the facilities, equipment, personnel including their number and educational level, and organisation that are available to deliver services. Process describes how the resources are applied, the actions taken in the line of care. Outcome is linked to what results are achieved. It consists of elements related to health status and public and workforce satisfaction (Shaw and Kalo 2002).

Quality improvement focuses on improving an entire health care system's outcomes by constantly monitoring and adjusting the system itself in order to increase the benefit to patients, to improve the system's performance and to enhance professional development (Batalden and Davidoff 2007). The assessment and improvement of quality thus involve the care providers, decision makers and individual patients, and should reflect the underlying values of a given society.

2.4 Productivity in public oral health service

The output in the oral health care system comprises treatment procedures and services. The unit of measurement chosen to quantify the output varies depending on the area of interest and the viewpoint of the study. Various units of measurement (dependent variables) have been used: time spent on treating patients (Wang 1994b); the number of patients with completed treatments (Wang 1994c, Grytten and Rongen 2000, Widström et al. 2004); and/or the number of visits and/or patients (Westerberg 1987, Utriainen and Widström 1990, Vehkalahti and Helminen 1992, Linna et al. 2003).

Studies on productivity in dental care are based on the assumption that the measures of output reflect the ability of the oral health care system to meet the needs of the public. Additionally, it is assumed that the effect of care delivery (health status) is related to measures of output, and that the relation is a positive one.

In the Nordic countries, studies on productivity in the public oral health care sector have shown substantial variation in productivity among public dental service units (Wang 1994b, Utriainen and Widström 1990, Nordblad et al. 1996, Linna et al. 2003, Widström et al. 2004). One Norwegian study reported little variation in productivity between the Public Dental Service (PDS) units on a county level (Grytten and Rongen 2000).

A study in the Norwegian PDS revealed that the time spent per child was associated with the interval between examinations, the gender of dentists, the ratio of dental assistants to dentists, the proportion of child treatment time given by dental hygienists, and the proportion of all treatment time spent on child patients. These variables explained 43% of the variance in the total time spent by dentists and hygienists, and 41% of the variance in dentists' time. No relationship was found between the amount of dental disease and time spent on complete care (Wang 1994b). In Sweden, productivity in dental care was higher in public dental offices treating relatively few children and adolescents (Westerberg 1987), whereas a study in Finland showed greater productivity with a higher share of young patients (Vehkalahti and Helminen 1992).

The personnel resources in the clinics explained 75–82% of the variation in the number of treated patients in the Norwegian PDS. Clinics without dental hygienist treated on average 600 fewer children per year than the clinics with dental hygienist (Wang 1994c). In another study in Norway, the number of children treated in PDS clinics increased with the dentists' hours, whereas the number of man-labour years of dental hygienists and dental surgery assistants had no effect on output (Grytten and Rongen 2000). The results indicated that the proportion of dentists to hygienists and assistants was close to optimal. Consequently, the authors suggested that improvement in productivity was not likely to take place unless the man-labour years of dentists and other dental professionals were increased simultaneously. Studies in Sweden (Westerberg 1987) and Finland (Vehkalahti and Helminen 1992) reported greater productivity in clinics with a high ratio of dental assistants or hygienists to dentists. The findings are contrary to a Finnish study where an increase in the number of auxiliaries was reported to lower productivity (Utriainen and Widström 1990). Some studies in the Nordic countries indicated that higher productivity could not be obtained by centralizing treatment of children in large public dental service units (Westerberg 1987, Wang 1994c). Contrary to these findings, Grytten and Rongen (2000) reported a gain in productivity with an increasing number of dental chairs in clinics.

In Finnish health centres, the productivity of dentists, measured using the number of patient visits as output, was associated with additional work outside the normal working hours, the total clinical work time, the dental chair's age, and the dentist's work experience in years. The amount of preventive work, the amount of clinical working hours, and the number of dental assistants working at the clinic were associated with dental hygienists' productivity (Utriainen 1994). In another Finnish study, in which the output was measured as the value of treatment procedures using private dentists' fees, it was found that the number of hours spent at work without treating patients was the most important factor explaining the 14% lower productivity of public compared to private dentists (Sintonen 1986).

Two recent Finnish studies assessed the weight of various factors explaining productivity in the public oral health care system. Low productivity was associated with high state-subsidy levels and a high proportion of young patients, whereas low socioeconomic conditions and a young population in the municipality predicted high productivity (Widström et al. 2004). The results conflict somewhat with the study by Linna et al. (2003) where good dental health of the population, high rates of unemployment and high per capita expenditure on primary care in the municipality were associated with low productivity, and state subsidies were not significant determinants of productivity.

Though it is important to explore the relation of various elements in the production process and the output, evaluation of the process as an entity is of even greater importance. If the rationality of the process itself is not assessed, there is a clear danger that productivity will be confused with efficiency. In Finland, there may have been some tendency toward this confusion because national and municipal statistics have mainly reported on the productivity of public oral health care system using indicators such as cost per visit or visits per dentist, regardless of how relevant such indicators are in recognising the ability of the system to meet with the needs of the public at reasonable cost. The public dental professionals have probably felt pressure from the national and local administrators and political decision makers to produce more visits or treatment procedures in order to make productivity figures look good. As healers, their ultimate goal, regarding an individual patient, is just the opposite: to be able to take such actions that eventually the patient's health status and health-related behaviour is improved in such a way that he or she will need fewer visits. As public servants, they are obliged to strive for the ultimate goal also on the population level. This means being involved in the planning and implementation of the production process. To make it possible for the dental professionals and the decision makers to weigh the costs and benefits of different alternative means of providing services, studies are needed that, instead of productivity, assess the cost-effectiveness of the system.

2.5 Work division

Improved dental health and the reduced progression rate of dental caries in children have made it possible to reconsider the tasks of personnel in public oral health care. Riordan stated that: "Today's children in the developed countries generally have much reduced needs for dental care in terms of both quantity and complexity". Consequently, there is an inconsistency "between the high knowledge and skill levels of dentists and the very simple items of care required by most schoolchildren" (Riordan 1997). Concurrently, there has been growing interest in public spending and rational use of resources allocated for the provision of oral health services.

Studies in the United Kingdom revealed that the majority of procedures carried out by dentists were classified as simple, and that many of the tasks could be undertaken by dental hygienists (professionals complementary to dentistry) (Harris and Haycox 2001). A study among schoolchildren in Western Australia reported similar findings (Riordan 1995). In a Finnish study among 0–18-year-olds, it was found that 53% of all dentists' treatments in public health centre dental offices were given to this patient group (Läärä et al. 2000). The authors suggested that nearly half of the treatments provided by the dentists could be classified as either short in duration or not demanding, and could probably to a great extent be delegated to dental hygienists. However, in many health centres, the structure of the personnel was not favourable for work division. It is worth mentioning here that the authors aimed to gain information on treatment measures carried out in health centre dental offices, and to assess how this kind of information could be used in planning oral health services. The aim was not to make suggestions about which dentists' treatment procedures could or should be delegated to other dental professionals. A considerable proportion of children will need dentist expertise for general or oral health reasons (Wang 1994d, Riordan 1997). Nevertheless, many such children can be identified early, and be given special clinical attention (Riordan 1997).

Increasing the role of dental hygienists and preventive dental nurses in child dental care can be implemented by work division among the dental professionals forming a dental team. The members of a dental team possess an interchangeable mix of skills that can be utilized in the care chain. Several terms have been used in the dental literature on the topic: work distribution (Wang 1994c, Wang 1994d), division of labour (Hannerz and Westerberg 1996), work division (Pienihäkkinen et al. 2005) and task sharing (Suominen-Taipale and Widström 2006). The words that highlight the co-operation of dental professionals such as team dentistry (Baltutis and Morgan 1998, Harris and Haycox 2001) and skill-mix (Dyer and Robinson 2008) have been gaining ground. The possibility to apply work division in the dental services depends on legislation, the competencies of the personnel groups, cost considerations, the availability of personnel, and the attitudes of dentists (Wang 1994a). In Finland, in a questionnaire study among dental hygienists and assistants in public health centres, the attitudes of personnel, insufficiencies in the

planning and implementation of new processes, and deficiencies in professional skills were regarded as the most prominent obstacles to advances in operational practices (Suonsivu 2000).

Examining a patient, making a diagnosis and planning treatment are tasks which demand substantial knowledge in the field of dentistry, and are in Finland the legislative duties and rights of dentists. Dental hygienists are certified dental professionals whose competencies focus on disease prevention and oral health promotion. The rights and duties of dental hygienists are also defined by legislation. Additional municipal instructions and practices apply to dental hygienists and assistants working in the public health centre dental offices where they work as members of dental teams under the general supervision of dentists.

The training of dental hygienists started in 1976 in Finland as training of expanded-duty dental assistants. Nowadays, a dental hygienist has a polytechnic degree. The education takes an average of three and a half years. Much emphasis is put on skills in health education and nursing science. Dental hygienists are trained to carry out procedures such as dental health check-ups, placing fissure sealants, fluoride and chlorhexide treatments, and scaling. Customarily, the dental hygienists work without a chair-side assistant.

Dental assistants are indispensable members of dental teams. Their training usually lasts two and a half years, and the profession is registered with a protected title. As chair-side assistants they work closely together with dentists. Those dental assistants who provide patient care independently have received special training in health promotion and preventive dental care. They may be called preventive dental nurses.

In the Nordic countries, increasing the role of dental hygienists and preventive dental nurses in child dental care has been encouraged by the health authorities (Norway: Sosialdepartementet 1988, Sweden: Socialstyrelsen 1998, Finland: Ministry of Social Affairs and Health 1993, Mattelmäki 2001).

Nonetheless, the long and strong tradition of dentist-based treatment has been difficult to break, and the role of the dental hygienist in child dental care depends greatly on the attitudes of dentists. Patients and their needs have changed, and the dental professionals have not necessarily felt comfortable with the new operational models. In Finland, economic incentives have been used to ease the adopting of new responsibilities and the individualizing of examination intervals, but in general they have been applied only to dentists.

One issue brought up when work division has been discussed is whether dentists and dental hygienist share similar views on diagnosing and treating caries. In a Canadian study, dentists and dental hygienists reached a good level of agreement on the dental treatment they proposed for children with a high need of dental care (Rolland 2005). The author suggested that dental hygienists could probably serve as the first point of contact

for these children. Dentists and dental hygienists in Norwegian (Wang and Riordan 1995) and Swedish (Öhrn et al. 1996) public dental services were in good agreement in examining and recording dental decay in children and adolescents. Furthermore, the studies indicated that both the dental health outcome and the provision of operative treatment were independent of whether a dentist or a dental hygienist had evaluated the patient. In a Finnish study, among children and adolescents, the ability of dentists and dental hygienists to identify caries risk subjects was comparable, though variation between individuals was noticeable in both groups (Alanen et al. 1994).

Studies on caries preventive programmes of children where dental hygienists have had a substantial role have shown favourable results on dental health (Hannerz and Westerberg 1996, Wendt et al. 2001, Pienihäkkinen and Jokela 2002). In Sweden, an organisational model for the dental care of children and adolescents in which dental hygienist had a significant preventive role proved to be both effective in reducing caries occurrence and also economically beneficial (Hannerz and Westerberg 1996).

In the PDS in Norway, dental hygienists provided check-ups and preventive care for all children and adolescents aged 5–18 years. The hygienists referred to dentists those children who required care only the dentists were qualified to provide (Wang 1994d). The hygienists spent 44% of all the time used for the dental care of the children, and the dentists used the remaining 56% of all clinical time spent. The time dentists spent per child increased with the number of new decayed teeth and with recall intervals longer than planned. More than 40% of the dentist time was consumed by the 10% of the children with the highest numbers of decayed teeth. Nearly one half of all children and 74% of children without new caries received dental care from dental hygienists only. Saving dentist time and being able to use it for the dental care of other groups was discussed as one good reason to apply work distribution. Another reason mentioned was the potential to reduce costs due to the lower salary of a hygienist working alone compared to the combined salaries of a dentist and a dental assistant.

The rationality of work division does not arise solely from the fact that dental hygienists are less expensive to train and have lower salaries than dentists. Treatment that is not effective does not become more acceptable if it costs less to carry out by lower salaried staff. Therefore, careful consideration should be given to the design of operational models and treatment processes. Flexible work division improves opportunities to use and develop professional skills and may enhance work satisfaction among the dental professionals. Moreover, released dentist time in child dental care can be used for other tasks, e.g. treatment of adults. Rational use of personnel resources may improve oral health in the total population without increasing costs.

2.6 Dental examinations

Following the substantial decline in caries occurrence combined with the increasingly skewed distribution and better understanding of the complex course of the disease, it has been suggested that the dental services should reconsider their examination policies especially in child dental care (Wang et al. 1992, Riordan 1997, Lahti et al. 2001).

In Finland, children and adolescents receive a regular public oral health care programme including clinical examination, preventive services, and necessary treatment. Until 1985, the national guideline specified that all children should have a dental examination once a year (Guideline of National Board of Health 1972, Guideline of National Board of Health 1985). The current guideline recommends that the examination and check-up intervals should be based on clinical assessment of individual treatment need (Eerola et al. 1998). The recommendation was based on studies on and experiences of examination intervals in various health centres in Finland, and on a comprehensive review of the literature on dental examination intervals by Lahti and Hausen (1998). They concluded that longer examination intervals could be applied to low-risk individuals considering the slow progression of caries lesions. The examination intervals for individuals with low risk of caries could be extended to 18–24 months without jeopardising children's oral health (Eerola et al. 1998). A similar practice has been applied in Norway and Sweden (Wang et al. 1998). In Denmark and Iceland, examination intervals shorter than 12 months have been commonly applied (Wang et al. 1998). Recent guidelines recommend a basic examination interval of 12 months at the longest in the United Kingdom or of 6 months in the United States; nevertheless, individualizing the frequency and content of recall examinations is emphasized in these guidelines (National Institute for Clinical Excellence 2004, American Academy of Pediatric Dentistry 2007).

In the Finnish oral health care terminology, a clinical examination is defined as a thorough inspection of teeth, oral cavity and masticatory system, including the inspection of teeth and the periodontium, oral mucosa and soft tissues, occlusion and temporomandibular joint, as well as checking facial and submandibular lymph glands (Eerola et al. 1998). This kind of examination is usually understood to be carried out by a dentist. A dental check-up is a less comprehensive account or control of oral health status, and can be carried out by other dental professionals (Eerola et al. 1998). However, the terminology is not firmly established, and in every-day life, practices vary.

Several studies in the Nordic countries indicate that dental professionals have been somewhat hesitant to adopt individual examination intervals (Vehkalahti et al. 1992, Wang and Holst 1995, Kärkkäinen et al. 2001). There are several probable reasons for the slow adoption of the practice. One of the concerns has probably been the fear of deterioration of dental health if established routines are altered. Practical reasons have also counted: examinations of schoolchildren have been easily carried out according

to school class lists rather than individually. However, some lengthening of mean examination intervals has been found in more recent reports (Helminen and Vehkalahti 2002, Wang 2005).

According to a study based on answers to a questionnaire, dental hygienists or preventive dental nurses performed routine examinations of children and adolescents in the majority of Norwegian (74%) and Swedish (86%) public dental offices, while in Denmark and Iceland, dentists carried out most of the examinations (Wang et al. 1998). In Finland, in 2000, nearly all 0–3-year-olds and 55% of 4–6-year-olds were seen by a dental hygienist or a preventive dental nurse (Suonsivu 2000). Dentists carried out the majority (86%) of clinical examinations of school-aged children (Suonsivu 2000).

Studies on clinical examinations have quite frequently focused on the relation of examination intervals and dental health. The findings have indicated potential for resource savings (Wang et al. 1992, Ketomäki and Luoma 1993, Wang and Holst 1995). The savings have often been reported as reductions in personnel time, while estimations of cost savings in monetary terms have been scarce.

In a study in the Norwegian PDS, no difference in time-adjusted caries increment was found in children examined at an interval of 24 months compared to children examined at a 12-month interval (Wang et al. 1992). The participants in the study were aged 3, 16 or 18 years, and all children classified as high caries risk patients were excluded. A dental hygienist examined the 3-year-old children and a dentist the older children. The mean annual time used for examinations and treatment was 30% less for the patients examined every 24 months than for the patients examined every 12 months. When adjusted for the entire study population, the shorter clinical time implied an annual 15% reduction in time spent on child dental care by the dental professionals. In another Norwegian study, dentists and dental hygienists were advised to individualize and extend examination intervals up to 18 months based on clinical judgement. The average examination interval increased from 12.5 to 13.7 months. Most commonly, children were recalled at intervals of 6, 12 or 18 months. In a study period of two years, the time spent on the dental care of the children by dentists decreased by 14%, and the time spent by dental hygienists increased. The total treatment time decreased by 15% in the group of children without new decayed teeth, which in turn resulted in a 7.5% reduction in all personnel resources spent in the dental care of the children (Wang and Holst 1995). In line with the Norwegian studies, no indication of an increased caries frequency was found in a Finnish study where the recall interval of 12-year-old children was prolonged from 13.0 months to 18.1 months (Kärkkäinen et al. 2001).

In a three-year follow-up study conducted among 3–12-year-old children in Finland, it was found that the use of individual examination and check-up intervals made it possible to detect and treat caries lesions earlier compared to customary annual examinations.

Among those children who were examined according to an individual plan the mean number of dental visits was 13% lower, and the average total treatment time shorter (Ketomäki and Luoma 1993). Helminen and Vehkalahti (2002) found that compared to earlier findings the examination intervals in the public oral health service for 0–18-year-old children and adolescents in Helsinki had lengthened from 13.7 months in 1986 to 16.4 months in 1999 on average. The longer intervals seemed not to have threatened the patients' dental health since the mean caries indices in Helsinki had been in continuous decline during the study period. Helminen and Vehkalahti also reported wide variation in check-up intervals among patients with the same or similar caries indices. Based on this observation they questioned dentists' superiority in assessing appropriate intervals between dental examinations.

2.7 Changes in caries treatment – clinical tools for work division

It is generally understood that dental caries is caused by the interaction of several factors leading to tooth demineralization. The disease has been described as an endogenous multi-bacterial infection (Fejerskov and Nyvad 2003). High proportions of mutans streptococci (MS) and/or other acidogenic and aciduric bacteria may be considered biomarkers of sites of accelerated caries progression (Takahashi and Nyvad 2008). Most children acquire MS bacteria from their parents, most likely mothers, by saliva contacts in early childhood (Köhler and Bratthall 1978, Berkowitz et al. 1981, Köhler et al. 1983, Alaluusua 1991, Caufield et al. 1993).

Our understanding of the complex nature of the dental caries has affected caries management in the Nordic countries in the 1980s and 1990s (Bryhni et al. 1985, Heidmann et al. 1988, Fejerskov 1995, Edward 1997, Gimmestad et al. 2003). Consequently, the definition of caries treatment has expanded to include not only restorative care of decayed teeth, but also and more importantly, diagnosing the disease, and planning and applying various preventive means to control caries as early as possible. The new strategies focused on delaying mutans streptococci acquisition by suppressing the MS counts in mothers of infants and in children, enhancing dental tissue resistance to decalcification, and enhancing remineralisation. The measures included, e.g. oral health counselling on hygiene and diet, placing of fissure sealants, topical fluoride applications, chlorhexide (CHX) treatments, and promoting the use of xylitol products.

An antibacterial approach to control dental caries has been regarded as appropriate. In the 1980s and 1990s, the use of CHX as an antimicrobial agent was considered a means to control caries in individuals or groups assessed to be at elevated risk of caries. Caries activity was significantly decreased in highly caries-active children by repeated and controlled CHX-fluoride rinsing solution (Luoma et al. 1978) and CHX gel treatments (Zickert et al. 1982). Also the concept of interfering with the mother-child transmission

route of MS as a primary preventive measure by using CHX aroused interest (Köhler et al. 1983, 1984, Tenovuo et al. 1992, Köhler and Andréen 1994). Although CHX possesses considerable antimicrobial properties against caries-causing bacteria, its potential as an anticaries agent is more controversial. The evidence for the anticaries effect of CHX-containing varnishes was evaluated as inconclusive for caries-active schoolchildren and adolescents with daily exposure to fluoride, as well as for root caries arrest in older adults (Twetman 2004).

Xylitol became known as an effective non-cariogenic sugar substitute in the "Turku sugar studies" in 1971–73 (Scheinin and Mäkinen 1975). Since then, numerous clinical studies with xylitol have suggested reductions in caries occurrence (Scheinin et al. 1985, Kandelman et al.1988, Isokangas et al. 1988, Mäkinen et al. 1995, Alanen et al. 2000, Deshpande and Jadad 2008). In Finland, daily use of xylitol-sweetened gum or lozenges is widely recommended by the dental professionals. The habit appears to be well adopted among schoolchildren. Honkala et al. (1999) found that 43–69% of 11–15-year-old Finnish schoolchildren used xylitol chewing gum daily.

The long-term effects should be considered when evaluating the costs and benefits of a caries preventive programme. The cost-effectiveness of caries treatment leading to a long-term preventive effect is closely related to the timing of prevention. The decision to apply preventive programmes has to be made in advance, whereas the assessment of their cost-effectiveness can only be carried out afterwards.

2.8 Approaches to caries prevention

There are two main strategies for prevention and health promotion: the population strategy and the high-risk strategy (Rose 1985). The population strategy seeks to control common causes of disease incidence, to lower the mean level of risk factors and to move the "whole distribution of exposure in a favourable direction" in the population as a whole (Rose 1985). In its modern form, the population strategy also attempts to alter some behavioural norms of society. The high-risk strategy aims to identify high risk susceptible individuals and direct preventive measures at them. In the Nordic countries, the approach to caries treatment has conventionally been based on population strategies. Preventive dental care has been provided for the whole population or has been targeted to specific subgroups of the population, e.g. school-aged children. While individually oriented, preventive dental care based on risk assessment has become more frequent in recent years (Fejerskov 1995, Gimmestad et al. 2003), offering basic prevention to all patients has still been considered important.

Caries risk can be defined as the probability of an individual developing at 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 period in question. Previous caries experience and the presence of incipient caries lesions have been found to be significant indicators of future caries development in children and adolescents (Powell 1998). In young children, however, early MS colonization has been shown to be strongly associated with future caries experience (Alaluusua and Renkonen 1983, Köhler et al.1988, Tenovuo et al. 1990, Thenisch 2006).

According to Hausen (1997), there are three basic prerequisites for the application of a high-risk strategy in controlling dental caries. First, the occurrence of caries in the target population has to be reasonably low. Secondly, accurate and practical measures for identifying the subjects with the highest risk of developing new caries lesions must be available. Thirdly, effective and feasible measures for caries preventive efforts are needed (Hausen 1997). Additionally, employing a high-risk strategy calls for an existing and well-functioning care delivery system reaching the whole target population (Spencer 1994).

Currently available screening methods for caries risk have been found to be fairly inaccurate in older children and adolescents (Powell 1998, Zero et al. 2001, Hausen 2003). However, identification of children at high risk of caries has been more successful among toddlers (Köhler et al. 1988, Holbrook et al. 1993, Alaluusua and Malmivirta 1994, Pienihäkkinen and Jokela 2002).

2.9 Treatment of early childhood caries

Several studies indicate that caries treatment in children should be focused on early childhood (Alaluusua and Renkonen 1983, Köhler et al. 1988, Tenovuo et al. 1992, Pienihäkkinen et al. 2005). Children with early childhood caries are more likely to develop caries in their permanent teeth (Poulsen and Holm 1980, Seppä et al. 1989, O'Sullivan and Tinanoff 1996, Li and Wang 2002, Skeie et al. 2006). Some sociodemographic factors have been shown to be associated with caries development in young children (Demers et al. 1992, Grindefjord et al. 1995, Mattila et al. 2000). Parents' attitudes towards oral health care and their health related-lifestyle affect the dental health of their children (Kinnby et al. 1991, Mattila et al. 2001, Mattila et al. 2005a, Poutanen et al. 2007). Parents are more likely to adopt healthy dental habits for their child and hopefully also for themselves when the child is a toddler than in later years of childhood. Caries-related habits established during infancy are maintained throughout childhood (Wendt et al. 1996, Mattila et al. 2005b), and even in adolescence (Alm et al. 2008). The clinical effectiveness of early dental health education has been demonstrated in the socio-economically challenged/high caries districts of Leeds and Glasgow in the United Kingdom (Kowash et al. 2000, Blair et al. 2006). A preventive dental programme started in pregnant mothers, and continued until their children were six years of age,

had beneficial effects on the dental health of the children in early childhood (Gomez and Weber 2001). Prolonged benefits were found when the children were ten years of age (Gomez et al. 2007). Kowash et al. (2006) observed that the mothers of infants participating in the dental health education programme also improved their own dental health-related habits.

In a study among Medicaid-enrolled children in the United States, those children who had their first preventive dental visit by the age of one year were more likely to have subsequent preventive visits. They were less likely to have subsequent restorative or emergency visits compared to children who had their first preventive visit at the age of two or three years. The average dentally-related costs for children who had received preventive care before the age of one year were approximately one half of the costs for children who had received their first preventive care at the age of three to four years (Savage et al. 2004).

Some studies in the Nordic countries indicate that in populations with overall low level of caries occurrence, early risk-based prevention can be effective in reducing both costs and dental caries in pre-school children, provided that the screening and preventive measures are delegated to preventive dental assistants (Holst et al. 1997, Wendt et al. 2001, Pienihäkkinen and Jokela 2002, Jokela and Pienihäkkinen 2003).

In Blekinge, Sweden, children were screened for high caries risk at the age of one, two and three years by specially trained dental assistants using background factors such as eating habits and use of fluorides as the screening criteria. Children assessed as having a high risk of caries were provided with individual caries preventive measures including fluoride and antimicrobial treatments, as well as fissure sealants in primary molars. The children were examined by a dentist at the age of four years. The proportion of children with no caries lesions in the test clinic was 92.9% compared to a county mean of 76.4%. Total treatment time for each child up to four years of age was higher than the county mean, but less dentist's time was spent on the treatment of the risk assessment group (Holst et al. 1997).

In a field study in Jönköping, Sweden, 167 children (the intervention group) were followed up from age one to age six. At ages one and two years, the parents of the children had an appointment with a dental assistant. The parents were interviewed and they received instructions on the dental care of their child. At the age of three years, the children were examined by a dentist and assessed for caries risk. The children were divided into four risk groups: no risk, low, intermediate or high risk, on the basis of clinical examinations and interviews with parents. Individual preventive programmes were designed for all children assessed as being at elevated risk of caries. At the age of six years, 81% of the children in the intervention group were free from manifest caries lesions, compared with 55% in an earlier birth cohort group used as control. The annual mean treatment time

needed for each child between one and six years of age was for the most part spent on preventive care carried out by the dental assistant (Wendt et al. 2001).

In a Finnish study with 2–5-year-old children, a risk-based prevention programme was effective in reducing dental caries in a low-caries community when compared with conventional prevention. At baseline, the 2-year-old children in the risk-based group were examined by a dentist and divided into three caries risk categories: low, intermediate or high. The assessment for caries risk was based on the presence of MS in plaque and incipient caries lesions. In the risk-based group, the intensity of the prevention increased with the increasing estimated risk, and all preventive measures were carried out by preventive dental assistants. In the conventional prevention group, the children received prevention when the examining dentist considered it necessary, and it was partly delegated to dental hygienists. By the age of five, the proportion of children with cavitated caries or fillings was significantly lower in the risk-based than in the routine prevention group. In the risk-based group, eight subjects had to be treated to avoid one subject having cavitated caries or fillings at the age of five years (Number Needed to Treat = 8, 95% CI 5–20). However, among those children who were assessed as belonging to the high-risk category, only two subjects needed to be treated. The proportion of correct predictions of the target grouping (in a dichotomised setting) was quite acceptable: 76% if the low-risk group was considered as negative and the intermediate and the high-risk groups as positive, or 83% if low-risk and intermediate groups were considered as negative and the high-risk group as positive. The total time spent on dental treatment was identical in the prevention groups during the three-year follow-up. In the risk-based group, the time spent by preventive dental assistants was longer and the time related to restorative treatment shorter than in the routine prevention group. The costs per child were significantly lower in the risk-based group than in the conventional group (Pienihäkkinen and Jokela 2002, Jokela and Pienihäkkinen 2003).

Studies among schoolchildren and adolescents in Finland and Sweden, countries with a low overall level of caries experience, have suggested that even relatively successful identification of risk subjects and application of appropriate preventive care, routine methods of prevention such as fissure sealing and topical fluorides may not yield an additional dental health benefit in high-risk individuals who are already receiving a high level of basic prevention (Seppä et al. 1991, Hausen et al. 2000, Källestål 2005). Shaping the health-related behaviour of a group of schoolchildren or adolescents may be easier than trying to change the habits of one individual. Preventive efforts based on the targeted population approach may be more favourable in this age group (Rose 1985, Splieth et al. 2004, Hausen et al. 2007, Pine et al. 2007).

2.10 Health economic evaluation

2.10.1 Health economics

According to Mooney and Drummond (1982), economics is about getting better value from the use of scarce resources. The basic principles of economics apply to the provision of health care: choices have to be made because resources – people, time, facilities, equipment, and knowledge – are and always will be scarce and they have alternative uses (Drummond et al. 1997). In health economics, the economic aspects of different options in the financing, planning and management of health care are considered. Health economics is concerned with obtaining the best possible health outcome from the allocation and use of available resources (Sintonen et al. 1997).

2.10.2 Methods of health economic evaluation

Health economic evaluation provides information useful for planning services; it is used in order to allow systematic consideration of the resource costs consumed in relation to the health benefits achieved by the use of various health care interventions, programmes or technologies (Weinstein 1981). The choice of the viewpoint of a health economic evaluation has an effect on the valuation of costs and benefits. The perspective may be that of the provider of the publicly funded service, the individual recipients of care, or society at large (Donaldson 1998). The concept of cost which is important is opportunity cost: the benefit that would have been obtained from the resources in their next-best, alternative, use (Donaldson 1998).

In health care, not all costs and benefits occur at the same point of time. Individuals and society tend to prefer to receive benefits sooner rather than later and pay costs later rather than sooner. Therefore, the costs and benefits of a health care intervention should be weighed in relation to the moment in time they are encountered (Sintonen et al. 1997). The valuation of costs should reflect the opportunities forgone by incurring costs now, and the opportunities made available by delaying costs to some future date (Claxton et al. 2006). The differential timing of costs and consequences can be done either by discounting future costs to the present period or any other date, or equivalently compounding current costs to an appropriate future period (Claxton et al. 2006). The recommendations concerning the discounting of health outcomes are more controversial, and the matter is currently being debated (Brouwer et al. 2005, Claxton et al. 2006). Claxton et al. (2006) argue that health, like wealth, is tradable over time, and both should be discounted at a common rate. They point out that for a society it is possible to "trade wealth now for health in the future or preserve wealth now at the price of reduced future health". The issue of discounting in health care is thus closely related to resource allocation (Claxton et al. 2006). Most of the recent guidelines and practical studies agree

on using an equal discount rate of 3–5% for discounting health effects and costs (Smith and Gravelle 2001).

The most widely applied methods in economic evaluation are cost analysis, which is based on the comparison of costs of two or more alternate interventions equal in health consequences, cost-effectiveness analysis (CEA), cost-benefit analysis, and cost-utility analysis (Drummond et al. 1997). CEA assumes that alternative courses of action are compared, and they are worthwhile and acceptable (Sintonen et al. 1997). The question asked is: what is the best way of producing the desired service. In a CEA, resource costs are usually measured in monetary units, whereas health effectiveness may be measured in any of several units that, however, must be common to the alternatives being compared (Weinstein 1981). Results of cost-effectiveness analyses are usually expressed in terms of incremental cost-effectiveness ratios (ICER) which represent the ratio of the difference in mean cost to the difference in mean effectiveness between two health care strategies (Sendi et al. 2002). Sensitivity analysis is used to identify important areas of uncertainty around the results of the CEA. The results of the evaluation are re-worked after systematically substituting high and low values for each of the variables of interest, e.g. discount rate (Shiell et al. 2002).

Nine possible situations that can arise when data on costs and effects are brought together for two interventions can be presented in a nine-cell matrix (Drummond et al. 1997). The cost-effectiveness plane makes it possible to assess the relation of changing costs and effectiveness resulting from a change in treatment. In Figure 2, each of the nine cells represents an area bounding the 95% confidence limits on observed differences in mean costs and effects of two treatments. Where the cells cross the axes of the cost-effectiveness plane a “non-significant” difference in cost or effect difference is indicated (Briggs and O’Brien 2001).

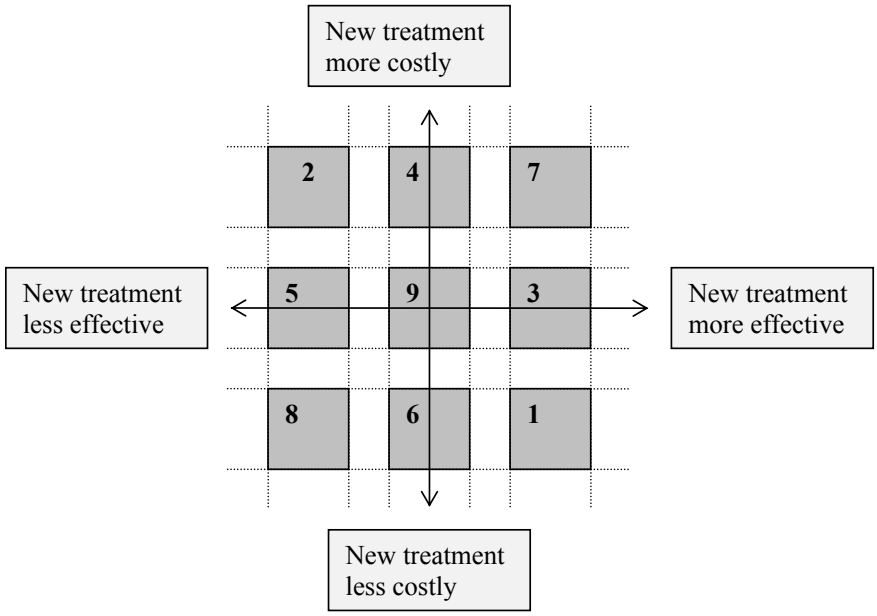


Figure 2 Nine possible situations that can arise concerning the significance (or otherwise) of cost and effect differences illustrated on the cost-effectiveness plane (modified from Briggs and O'Brien 2001)

Decision-making situations in the cells are as follows:

Situations in cells 1 and 2 represent cases of strong dominance. In cell 1, costs are saved and better effectiveness is achieved relative to existing care, making the new treatment explicitly the treatment of choice. In cell 2, the current treatment is the better choice.

In cells 7 and 8, one treatment is both more effective and more costly. In decision-making, appraisal of additional effectiveness in relation to additional cost is needed. Judgement is required in deciding the threshold for accepting higher costs in return for better effectiveness.

In cells 4 and 6, there is no difference in effects but there is in costs. These situations illustrate conventional cost analysis where the effectiveness is assumed to be comparable and the least costly treatment is likely to be chosen.

In cells 3 and 5, where there is no difference in costs, the more effective treatment is the treatment of choice.

Cell 9 represents an equivalent situation where no difference in costs or effects is observed.

Drummond et al. (1997) point out that any economic evaluation method represents only partial analysis of any specific choice or programme. The evaluations improve the

quality and consistency of decision-making only if value judgement and responsibility are included in the process (Drummond et al. 1997).

2.10.3 Economic evaluation in the prevention of dental caries

The role of economic evaluations in oral health care is increasing as the public and the healthcare decision-makers ask for useful and reliable data on the cost-effectiveness of oral health care interventions and programmes. In Finland, the need for economic appraisals has been recognized, e.g. by Sintonen (1986), Isokangas et al. (1989) and Vehkalahti and Helminen (1992).

Theoretical issues of health economics and techniques of economic evaluations including examples of their applications to oral health care have been presented in several articles (Yule et al. 1986, Antczak-Bouckoms et al. 1989, Donaldson 1998, Buck 2000, Cunningham 2000). Many articles have addressed more specific issues in the application of economic evaluation to dental health programmes. Horowitz and Heifetz (1979), Niessen and Douglass (1984) and Forbes and Donaldson (1987) concentrated particularly on economic appraisal of preventive dental care. Doherty and Crakes (1985) focused on the estimating and handling of costs, and Birch et al. (1996) on resource allocation. In Finland, an article by Sintonen (1986) is of special value as it presented, in Finnish, applications of health economics to dental care. All of these articles have stressed the need for economic evaluations in oral health care to make it possible to plan and provide services in a way that is of maximum benefit to the community. However, this calls for collaboration between economic and oral health care researchers.

The economic evaluations on dental caries prevention vary widely in their structure according to their specific area of interest and point of view. Several methods have been used for the estimation of costs in economic evaluations. Fees for services as an approximation of cost calculation have been used in quite a few studies (Downer et al. 1981, Leverett et al. 1983, Doessel 1985, O'Rourke et al. 1988, Simonsen 1989, Weintraub et al. 1993, Griffin et al. 2001, Quiñonez et al. 2005). Labour costs correlated to the time used in the provision of care have also been used for the estimation of operating costs (Gisselsson et al. 1994, Morgan et al. 1998, Arrow 2000, Jokela and Pienihäkkinen 2003). Some quite detailed cost estimations have included investments, maintenance, material and travel costs (Sköld et al. 1994, Werner et al. 2000, Kowash et al. 2006). In general, the more recent studies have used more detailed and advanced techniques in cost estimation. Few studies have included productivity losses such as time missed from school or work (Sköld et al. 1994, Griffin et al. 2001, Oscarson et al. 2003). These studies have often been conducted from a societal viewpoint. In Sweden, Oscarson et al. (1998) assessed three methods of calculating direct dental care costs: average treatment time cost and two methods where overhead costs were allocated by the care provider (dentist, dental hygienist, dental assistant). All three methods used for

calculating unit costs were most sensitive for altering salary costs and treatment time. For example, decreasing treatment time by 10% and 30% increased treatment time cost by approximately 10% and 40%, respectively. Depending on the method used, an increase in salary of 10% and 30% increased unit cost by 4–10% and 12–28%, respectively. The methods were not as sensitive for other resources such as capital, materials and services. Additionally, the results indicated that patient charges were not suitable as a proxy for real costs in Swedish public oral health care (Oscarson et al. 1998). The benefits from preventive measures, usually caries reduction, have been expressed in several ways: saved teeth or tooth surfaces (Goggin et al. 1991, Morgan et al. 1998, Werner et al. 2000, Oscarson et al. 2003), avoided restorations (Stephen and Campbell 1978, Klock 1980, Blinkhorn et al. 1981, Downer et al. 1981, Donaldson et al. 1986, O'Rourke et al. 1988), or reduction in cost of all caries-related treatment (Gisselsson et al. 1994, Sköld et al. 1994, Arrow 2000, Zavras et al. 2000, Jokela and Pienihäkkinen 2003).

While the period of study is restricted to a certain number of years, economic evaluations of preventive procedures or programmes are not considered representative if the observation period is short (Drummond et al. 1997). Obtaining longitudinal data with detailed follow-up of the same study subjects over many years is laborious and time-consuming. To overcome this obstacle, researchers have used data from other published studies, epidemiological studies or national surveys (Doessel 1985, Birch 1990, Crowley et al. 2000, Griffin et al. 2001, Quiñonez et al. 2005, Splieth and Flessa 2008), or hypothetical communities (Niessen and Douglass 1984, Kowash et al. 2006). The use of such data for theoretical modelling may be very practical, especially in countries with a heterogeneous population and diverse systems of delivering oral health services.

Several health economic evaluations have focused on dental caries prevention in children and adolescents. School-aged children have been the main target group in these studies. There are few economic evaluations of early caries prevention among pre-school children (Donaldson et al. 1986, Gisselsson et al. 1994, Jokela and Pienihäkkinen 2003, Kowash et al. 2006). The fluoridation of public water supplies has been studied, e.g. by Downer et al. (1981), Doessel (1985), Birch (1990) and Griffin et al. (2001). Fissure sealant placement has aroused considerable interest (Leverett et al. 1983, Simonsen 1989, Goggin et al. 1991, Weintraub et al. 1993). Werner et al. (2000) suggested that the operational model of sealant placement, either clinic or school-based, had a significant effect on the economic analysis results. Quiñonez et al. (2005) studied the cost-effectiveness of sealant placement by using a theoretical model. Sköld et al. (1994) found a 44 SEK (4.68 € March 2008) difference in total caries treatment cost per subject in favour of a test group receiving additional fluoride varnish applications by dental nurses. Petersson and Westerberg (1994) assessed the long-term effect of an intensive fluoride varnish programme compared to standard biannual fluoride varnish application using saved fillings to calculate benefit. Their analysis over a time span of 10 years

showed net total costs of 3,880 SEK (413€) and net benefits of 5,000 SEK (532€) for the programme using a 5% discount rate. Stephen and Campbell (1978) and O'Rourke et al. (1988) found contradictory results on the use of fluoride tablets in primary school children. This may be explained by differences in the time periods of trials, indicating differences in caries occurrence. Cost analysis of intensive chlorhexide gel treatments in 4-year-old children showed better dental health in the deciduous dentitions and a 32 SEK (3.41 €) difference in cost per child in favour of the test group compared to the control group (Gisselsson et al. 1994).

Economic aspects of preventive programmes have been explored in some studies (Klock 1980, Blinkhorn et al. 1981, Klein et al. 1985, Donaldson et al. 1986). Morgan et al. (1998) compared a comprehensive preventive programme comprising sealant placement, fluoride mouth rinsing and oral hygiene instruction with oral hygiene instruction only and reported a cost-effectiveness ratio of 11.80 Australian dollars (7.16 € March 2008) per saved tooth surface in a three-year study. Crowley et al. (2000) presented a theoretical analysis where they extrapolated the results of the former trial by Morgan et al. (1998) to report estimates of the potential economic benefits of a ten-year period. The incremental benefit-to-cost ratios improved with each successive year of the programme. In a study among 6-year-old Australian schoolchildren, a programme of professional cleaning and oral health education (test) compared with a preventive programme including fissure sealing and topical fluoride application (control) yielded, after two years, an incremental cost-effectiveness ratio of 40 Australian dollars (24.27 €) per treated child per year (Arrow 2000). The author concluded that the results did not support the adoption of the test programme. Zavras et al. (2000) performed a theoretical cost analysis on a dental care programme for toddlers based on MS screenings and early treatment of caries. Their cost analysis model predicted savings of 7.3% from screening and early intervention. In Sweden, Oscarson et al. (2003) compared the cost-effectiveness of four different caries preventive programmes with increasing levels of fluoride treatment from tooth brushing with fluoridated tooth paste to individual prevention. The study revealed no significant effect on decayed dentine, or filled tooth surface level but if decayed enamel was taken into account, the fluoride varnish group showed one surface lower caries increment compared to the tooth-brushing group. The incremental cost-effectiveness ratios per averted enamel lesion depended on the perspective (societal or dental health care) and the profession of the care provider (dental nurse, dental hygienist or dentist). The costs of programmes were highly sensitive to changing treatment time and salaries. In Leeds, England, an out-reach dental health education programme for the prevention of early childhood caries in infants, running for three years, had favourable health results as only 4% of the children developed early childhood caries. The cavities saved indicated a benefit-cost ratio of 5.21 for the programme. The cost to save one carious surface was £1.92 (2.20 € March 2008) (Kowash et al. 2006). Splieth and Flessa (2008) used

epidemiological data in a model to assess the lifelong costs of caries treatment in a German population with or without fluoride use. In lifelong use, the combination of fluoride salt, fluoride toothpaste, and fluoride gel reduced the costs of caries treatment to 214 € (present value, 5% discounting) compared to 932 € (present value, 5% discounting) without fluoride prevention. The authors pointed out that these amounts would have to be invested at the age of 6 years at the discount rate of 5% in order to cover the payment of lifetime dental treatment. In a Swedish study on the organisation of dental care based on extensive use of dental hygienists and a reduced role of dentists, the economic assessment showed a benefit-cost ratio of 1.48 resulting from a 546 SEK (58.14 €) net benefit, measured as saved fillings, and a 369 SEK (39.29 €) net cost per treated child in the test group (Hannerz and Westerberg 1996). A comprehensive review of health economic studies on dental caries prevention assessing both the odontological and health-economic quality, and including many of the above articles, has recently been published (Källestål et al. 2003).

In Finland, only few economic evaluations in preventive dental care have been carried out. An economic evaluation of self-applied chlorhexidine-fluoride mouth rinses and professionally applied fluoride varnish programmes proved that both methods were acceptable in the economic sense over a four-year period (Vehmanen 1993). The actions required to run the programmes were performed either by a dentist-assistant pair or by any dental professional alone. Both methods yielded minor preventive effect compared to basic prevention. The results revealed that the benefits gained from the intensified preventive measures would have been doubled if they had been carried out by a preventive dental nurse. A caries preventive programme where xylitol gum was delivered to 3–6-year-olds at day-care centres indicated that the day-care centres could be one channel for delivering xylitol gum in a way that is favourable in terms of both economic and dental health (Kovari 2002). Two recent reports (Jokela and Pienihäkkinen 2003, Pienihäkkinen et al. 2005) assessed the economic aspects of a field study which compared a risk-based caries prevention programme with conventional prevention. The actual prevention programme started when the subjects were two years of age and ended when they were five years of age. The risk-based programme resulted in a higher proportion of children with healthy deciduous dentitions and a lower proportion with cavitated caries or fillings (Pienihäkkinen and Jokela 2002). The economic analysis included the actual running costs of the programme based on the time spent on dental visits by the provider of care: a team consisting of a dentist with an assistant or a preventive dental assistant. After a three-year follow-up period, the costs per treated child were significantly lower (54 €) in the risk-based group than in the conventional group (69 €) (Jokela and Pienihäkkinen 2003). A sensitivity analysis showed that the costs would have been twice as high if all care had been provided by a dentist-assistant team. At the seven-year follow-up, when the children were 12 years of age, DMF was still significantly related to the risk category

determined ten years earlier. For the children in the former risk-based group the absolute risk reduction for caries in permanent dentition was 0.13 (95% CI 0.06–0.21). The total number of preventive and restorative visits in this group was lower than in the former routine prevention group. The estimated running costs were lower in the former risk-based group (505 €) than in the routine prevention group (656 €) (Pienihäkkinen et al. 2005).

2.11 Use of dental records

Data obtained from individual patient histories of public oral health care service have been used in several Finnish studies (Hausen et al. 1983, Seppä et al. 1989, Vehkalahti et al. 1992, Varsio and Vehkalahti 1996, Virtanen et al. 1996, Suni et al. 1998, Helminen et al. 1999, Korhonen and Larmas 2003, Leskinen et al. 2007). Vehkalahti et al. (1992) found that dental status of patients was adequately recorded in Finnish public dental offices. In the studies by Seppä et al. (1989) and Hausen et al. (2001), caries data collected from public health records were found to be reliable when compared with data based on examinations by trained examiners. Finnish public dentists followed the instructions on oral health record keeping well (Helminen et al. 2002). Nevertheless, the records could be more complete, and dentists should be encouraged to pay more attention to record keeping (Helminen et al. 1998).

2.12 Background and hypothesis

On the basis of the previous studies, it can be concluded that there are not enough results to be shown to the decision-makers for the planning of cost-effective oral health care. The management of dental caries is a lifetime process. The outcome of preventive and interceptive measures carried out in early childhood may become evident only after several years. The decision to use resources for preventive and early interceptive purposes, however, has to be made earlier. Some previous studies have indicated that, in children, the early risk-based management of dental caries can be correctly targeted, clinically effective and economically beneficial in the public oral health care (Holst et al. 1997, Jokela 1997, Wendt et al. 2001, Pienihäkkinen and Jokela 2002, Jokela and Pienihäkkinen 2003). However, in general, there is a lack of studies with long-term follow-ups on clinical and economic effects of risk-based early caries prevention programmes.

To be able to recognize and create cost-effective models of providing public oral health care services it is important to know in which way the input and the output in the production process are linked, and what features affect this connection. It is assumed that work division improves cost-effectiveness but studies in this field are scarce. The

cumulative costs of management of dental caries and the long-term health outcome are essential elements in the evaluation of the public oral health care system. Yet, the cumulative costs of the management of dental caries for one person from early childhood to adolescence in the public oral health service in Finland are unknown, even though the annual costs and treatment measures are well documented both at local and national level. It would also be important to know how the organisational model affects costs and its relation to the health outcome. The monitoring of successive time-series is needed, because it enables examining the differences in costs and health outcomes between birth cohorts. This information has been uncovered, because the cumulative costs of caries treatment of birth cohorts have not been examined so far.

The long-term frame is a particular advantage of the Finnish public oral health care records. The public oral health care records in Finland go back to 1956 when the first public oral health care system was set up. The individual patient histories make it possible to carry out historic cohort studies. Studies of this kind enable the evaluation of the cost-effectiveness of health care interventions.

In Finland, the dentists' input in the public dental care of children has conventionally been high. The practice goes back to the 60s and 70s when caries occurrence was high and restorative treatment and even extractions of decayed permanent teeth formed a significant part of treatment measures in children's dental care. However, improved dental health and the new concept of caries management made it necessary and possible to reconsider the operational practices. Demands for improved cost-effectiveness in the public oral health care and for increased availability for all citizens have emphasized the need for new operational models. The role of dental hygienists has grown, because helping patients to maintain good dental health by supporting self-care, promoting healthy lifestyle and providing preventive clinical measures is a rational way to utilize their core competence.

At the Public Health Centre of Kemi, two different operational models had been applied in oral health care for children in the years 1980–2004. The "Conventional" model was based on high dentist input and annual examinations, whereas the "New" model was based on utilising the skill-mix of dental professionals and the early risk-based approach for control of dental caries, including screening for high caries risk. The new model had been implemented since 1989. The aim at that time was to make use of the new knowledge about management of dental caries, to use the resources more efficiently, and to improve the motivation and commitment of the personnel by local decision-making. The change in the operational practice provided an opportunity to compare the dental health outcome and the accumulation of costs of the two practices. The Public Health Centre of Tornio, where the conventional operational model without screening and

work division had been applied throughout the time period could be used as an outside reference to control the secular trend.

In the present study, the hypothesis was that in the public oral health care of children the cost-effectiveness of prevention and treatment of caries is associated with the operational model of clinical work.

3. AIMS OF THE STUDY

The aim of the present study was

- to find out how the timing of preventive visits and work division have changed in the management of caries in children and adolescents in recent decades, and to observe the dental health over the time period,
- to calculate and compare the cumulative costs of caries treatment of children,
- to investigate the association between the concepts of caries prevention and control and the cost-effectiveness,
- and to explore possible changes in cost-effectiveness between birth cohorts.

by comparing the new model in the management of caries in children and adolescents in the public health centre of Kemi to the former conventional model, and further to the operational model in public health centre of Tornio.

4. MATERIAL AND METHODS

4.1 General background

The study was carried out at the Public Health Centres of the towns of Kemi and Tornio in northern Finland. The study covered a period of 24 years; from 1980 to 2004. No major economic and social structure changes occurred in the two towns during that period. These neighbouring towns are industrial, and both have some 23,000 inhabitants. The soil in the area contains a low level of fluoride. Caries occurrence in 12-year-old children in these towns was comparable with the national average (Figure 3).

The target population consisted of all children born in 1980, 1983, 1986, 1989, 1992 or 1995 with an almost complete dental treatment history at the Public Health Centre of Kemi, and of all children born in 1980 or 1992 with an almost complete dental treatment history at the Public Health Centre of Tornio at the time of the data collection.

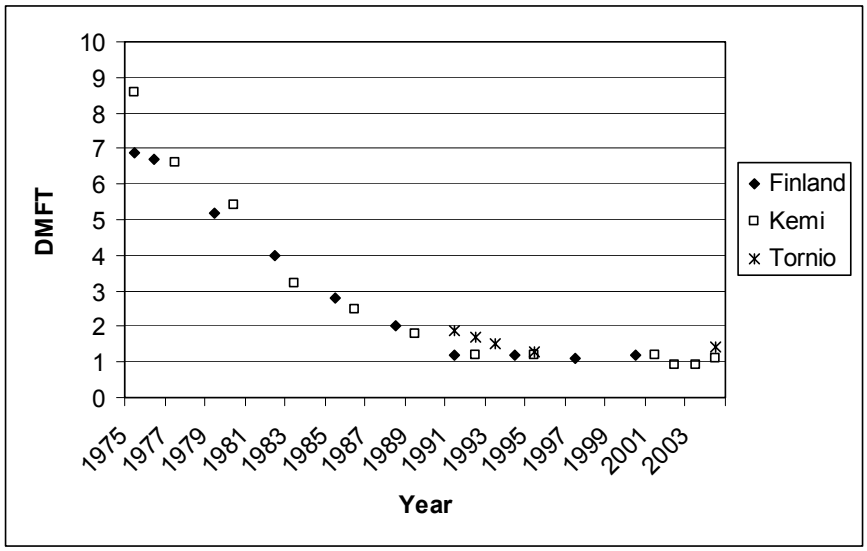


Figure 3 The mean DMFT indices at the age of 12 years in Finland (Nordblad et al. 2004), and Kemi and Tornio (annual oral health care reports of Kemi and Tornio) during the years 1975–2004

4.2 Patient history records

Data for the historic cohort study were collected from the files of the Public Health Centres. The number of patient treatment histories varied between 206 and 348 in Kemi, and between 230 and 323 in Tornio (Table 1).

The inclusion criteria were that a patient history covered an age range at least from three years of age to the cut-off point, and included continuous and complete information on the treatment history of the dental care of the child. This included examinations at regular intervals and description of treatment measures. The cut-off point was 15 years of age for the cohorts 1980, 1983, 1986 and 1989, 12 years for the cohort 1992, and 9 years for the cohort 1995. The exclusion criteria were an incomplete patient history, a deficient observation period, or one examination interval longer than 36 months.

A sample size of 200 was considered appropriate for estimating the number of caries treatment visits and the cost of caries treatment from early childhood to teenage years. The patient histories were randomly assessed and the criteria-fulfilling records, 100 of both genders in each cohort, were included. In Kemi, to include 200 subjects, the 1992 cohort was completed with 11, and the 1995 cohort with 34, randomly picked patient histories of children born in 1991 or 1994, respectively. In Tornio, the 1992 cohort was completed with six patient histories of children born in 1991. The final sample size, n = 1200 in Kemi and n = 400 in Tornio, covered 60–80% of the patient histories (Table 1).

Table 1 The number of patient histories (Total) at the Public Health Centres in Kemi and Tornio, and the number of included histories (Sample size) in the study cohorts

Kemi	1980	1983	1986	1989	1992	1995
Total	348	325	300	295	279	206
Sample size	200	200	200	200	200	200
Tornio						
Total	230				323	
Sample size	200				200	

4.3 Oral health examinations, treatment and preventive measures in the dental care of children at the Public Health Centres

In Kemi, descriptions of the processes of examinations and preventive measures at the Public Health Centre were obtained from administrative instructions and policy documentations. Many members of the staff had been there for the foregoing 15–25 years, and they were interviewed by the author. In Tornio, the local administrative instructions emphasized the care of schoolchildren. Descriptions of processes were obtained by interviewing experienced members of the staff including the chief dental officer, dentists, dental hygienists and dental assistants.

4.3.1 Public Health Centre of Kemi

4.3.1.1 Model 'Conventional' for the cohorts born in 1980, 1983 or 1986

Children had paid their first visit at the age of 6 months, when they were seen by a dental hygienist or a preventive dental assistant. Dentists or dental hygienists had examined the

2–5-year-olds and dentists the 6–15-year-olds annually. Dental hygienists and assistants referred children with signs of illness to dentists for diagnosis, treatment plan and treatment.

Assessment of caries risk had been based on previous caries experience, presence of incipient enamel lesions, and/or visible plaque and frequent use of sweets or other sucrose-containing products. A family caries history, unfavourable dietary habits and general disorders with frequent medication having an effect on oral health had also been taken into account.

Tooth brushing with fluoride toothpaste twice a day had been the recommendation for fluoride use from the age of three years. Fluoride tablets (Fluorilette® 0.25 mg, Leiras, Finland) had been recommended and provided free-of-charge for children under three years of age, as well as for older children, if toothpaste was not used.

The basic preventive measures given by professionals had been fluoride varnish (Duraphat® 22.6 mg F^-/ml, Colgate-Palmolive A/S) application once a year after three years of age, sealing of fissures of first and second permanent molars, dietary counselling, and oral hygiene instructions. An assistant employee of the health centre (with non-dental education) had visited schools every two weeks up to the year 1992, and the 7–12-year-old children had received a fluoride mouth rinse (0.2% NaF) treatment. Preventive dental assistants had visited day-care centres several times a year and instructed the 5–6-year-olds in tooth brushing with fluoride gel (Elmex® 12.5 mg F^-/g, GABA GmbH). Schoolchildren had brushed with fluoride gel in the dental office when they had had an appointment. Preventive dental assistants had lectured on oral health care at schools.

Additional preventive measures for a child estimated to have an elevated risk of caries had been semi-annual application of fluoride varnish by a dental assistant and sealing of the fissures of first and second deciduous molars by a dental hygienist or a dentist.

4.3.1.2 Model 'New' for the cohorts born in 1989, 1992 or 1995

Nurses at the public well-baby clinics had informed parents-to-be about the possibility of receiving dental care at the Public Health Centre. Professionals at well-baby and dental offices had encouraged parents to form the habit of having regular, healthy meals and avoiding snacking for themselves and the baby. Water had been recommended for thirst instead of sugar-containing drinks. A series of prenatal coaching lessons for small groups of parents-to-be had included an oral health care lesson by a dental hygienist. Parents had been given information about early transmission of mutans streptococci (MS) through salivary contacts between parents and small children. Parents who had received dental care at the Public Health Centre and had been assessed as likely to benefit from additional preventive measures had been given CHX treatments if they had been highly motivated toward self-care. CHX treatments had not been used during pregnancy or breast-feeding.

Children had paid their first visit at the age of 6 months. At the visit, the Dentocult-SM® Strip Mutans test (Orion Diagnostica, Finland) had been used to determine the salivary mutans streptococci counts of mothers and sometimes also fathers. Parents had also received dental health and hygiene instructions for the child. The visit had been carried out by a dental hygienist or a preventive dental assistant.

Dental hygienists or preventive dental assistants had carried out check-ups of the 2–5-year-olds. Dentists or dental hygienists had examined the 6–15-year-olds according to an individual treatment plan outlined by dentists. Children had been screened for high caries risk at the age of 18 months. The presence of mutans streptococci in plaque, applying the Dentocult-SM® test, and incipient caries lesions, had been the screening criteria. The habit of using xylitol products, the frequency of sucrose intake, the presence of visible plaque, a family caries history, unfavourable dietary habits and general disorders with frequent medication having an effect on oral health had also been taken into account in the evaluation of caries risk. Children had been categorized as having a low, intermediate or high risk of caries. MS-negative and caries-free children had been assessed as belonging to the low risk category, MS-positive but caries-free children to the intermediate risk category, and children with any caries (incipient lesions, decay, restorations) to the high risk category. The category had been re-assessed at every check-up and examination based on clinical findings. The Dentocult-SM® test had been repeated at the age of three years if the presence of mutans streptococci in plaque had not been detected in the first test at the age of 18 months.

The children in the low risk category had been examined at 18–24 month intervals and they had received basic prevention. The basic preventive measures given by professionals to children over three years of age had been a fluoride varnish application once between examinations, advice to brush teeth with fluoride toothpaste twice a day, and dietary counselling, including a recommendation for daily use of xylitol products. The children in the intermediate risk category had been examined annually and had received additional preventive measures: they had been invited for check-ups and counselling semi-annually, and the dentition of the child had been treated with fluoride varnish. The children in the high risk category had been examined annually, and they had received intensive preventive measures. Pre-school children in the high risk category had been invited for check-ups, counselling and fluoride varnish application 2-4 times a year, and schoolchildren semi-annually. Fissure sealants had been applied to the first and second permanent molars of high-risk children. Fluoride lozenges (Fludent® 0.25 mg F^-, Actavis Oy, Finland) had been recommended and distributed to children at elevated risk of caries. CHX-gel treatments had been provided at the dental offices two to four times a year from the age of four years. The additional preventive measures had been carried out by dental hygienists or preventive dental assistants. All restorative treatment had been carried out by dentist-assistant pairs.

Xylitol chewing gum had been delivered once a day after lunch at schools and day-care centres to almost all 3–15-year-olds. One school had refused to accept xylitol chewing gum delivery. At first, xylitol chewing gum had been provided by the public oral health care service. Later on, the xylitol products, gum or lozenges, had been provided by the school (for schools) and social (for day-care centres) departments of the town of Kemi, or by the parents of children who attended a day-care centre or school. The purpose had been to teach the routine of using xylitol chewing gum after every meal. Xylitol-containing products as alternative sweets had been recommended on an individual basis. An extensive campaign about the beneficial effects of xylitol on dental health was carried out in the local media and at schools in the beginning of the 1990's.

Towards the end of the nineties, the use of professional preventive measures such as CHX treatments carried out at dental offices had been reduced. More emphasis had been put on supporting the resources of parents and children in self-care and on coaching to maintain their own oral health.

4.3.2 Public Health Centre of Tornio

4.3.2.1 Model 'Conventional' for the cohorts born in 1980 or 1992

In Tornio, parents-to-be had had an opportunity to attend pre-natal group lessons at the public well-baby clinics. Toddlers and pre-school children had been invited for oral health examinations either individually or through announcements in local newspapers and on well-baby clinic announcement boards. Nurses at well-baby clinics had also informed the parents about the examinations. Annual examinations had been recommended for toddlers and pre-school children, but no recall had been organized. It had been up to the parents to make an appointment. At the age of six months, the children were seen by dental hygienists, as was the case at the second visit at the age of two years. Dentists had examined 3–15-year-olds annually. Recall of schoolchildren had been based on school class lists.

Standard procedure had included examination, fluoride varnish application from the age of three years, oral hygiene instructions and dietary counselling, once a year. Children assessed as having an elevated risk of caries had been invited for an additional check-up and fluoride varnish application semi-annually. First and second permanent molars had been routinely fissure-sealed. Preventive measures had mainly been provided by dentists. Dentists had been accountable for diagnosis and treatment plans. All restorative treatment had been carried out by dentist-assistant pairs.

Fluoride toothpaste twice a day had been the recommendation concerning fluoride use from the age of three years. Fluoride tablets (Fluorilette® 0.25 mg F^-, Leiras, Finland) had been recommended and provided free-of-charge for children under three years of age, as well as for older children, if toothpaste was not used.

4.3.3 Summary of the models

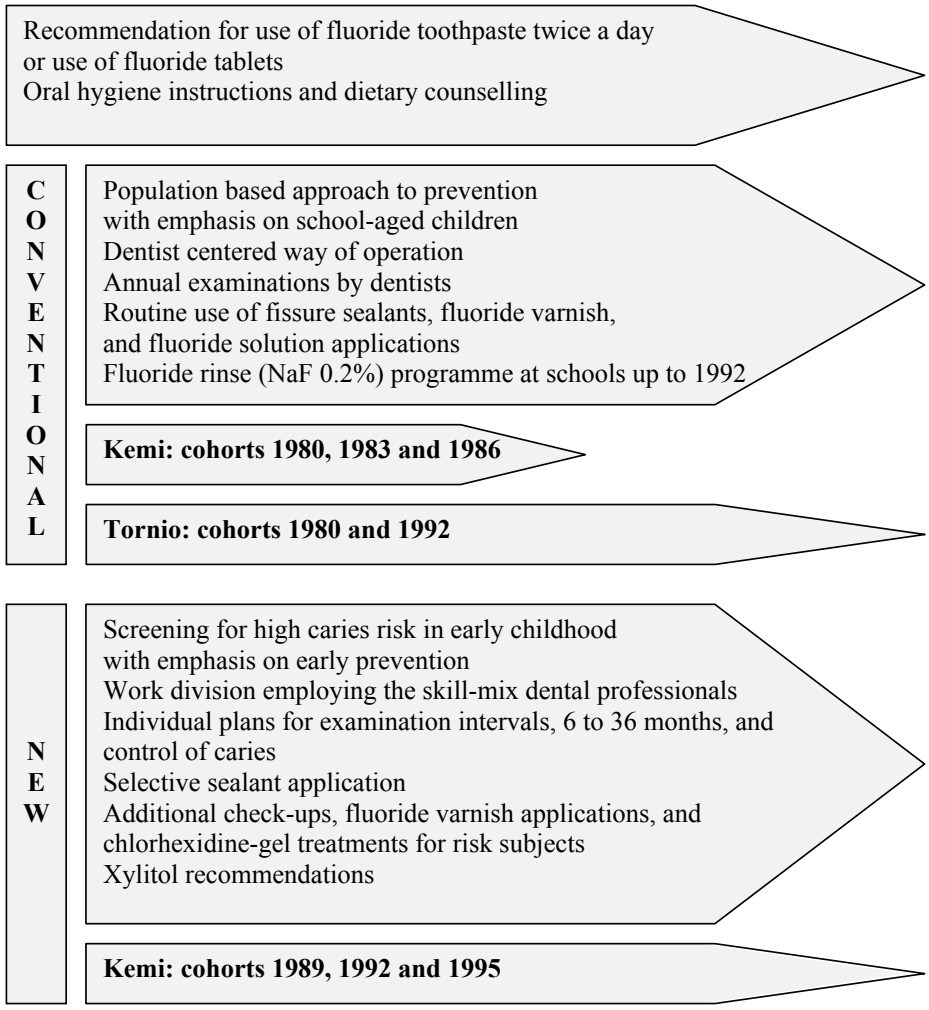


Figure 4 Major features of the operational models in Kemi and Tornio

4.4 Methods

4.4.1 Data handling

Data had been recorded on structured oral health examination sheets either in handwriting or electronically. They were collected according to a predetermined scheme at annual individual level visit by visit. Data were first registered using a specially developed electronic form (Access for Windows release 97). The data were transferred to SPSS for Windows program (release 12.0) for management and statistical analyses. The completed data were checked for atypical values by examining the frequencies and dispersion of

each variable value. If an atypical value was found the original patient history was reviewed and if the value was erroneous it was corrected.

4.4.1.1 Demographic background

Birth cohort, gender, town and age to an accuracy of one year were recorded as background information.

4.4.1.2 Dental health

Individual annual dmft and DMFT scores were collected as the measure of total caries experience. Missing indices were obtained by interpolation for ages 5, 9, 12, and 15 whenever an earlier and later corresponding index value was available. Five-year-old or younger subjects with dmft = 0 and 6-year-old and older subjects with DMFT = 0 were defined as having healthy dentitions. The mean dmft and DMFT scores and percentages of subjects having healthy dentitions were used as measures of dental health.

4.4.1.3 Input

The number of visits to the Public Health Centre dental offices was used as the measure of resources used (input), and a basis for estimating treatment costs. Examination (E), preventive (P) and restorative (R) visits were classified as caries treatment (CT) visits. The profession of the provider (*p*) for each visit was recorded as a dentist (*d*), a dental hygienist (*h*) or a dental assistant performing preventive care (*n*). In Kemi, also the number of orthodontic (O), dental trauma (DT) and any other type (A) of visits was registered and categorized by provider, as well as the number of no-show incidents (NS). The cumulative (cum) numbers of different kinds of visits (V) to providers at each age $_{(a)}$ were calculated as sums of number of visits to a provider at age a.

The equation is expressed: $\mathrm{cumV}p_a = \Sigma\, \mathrm{V}p_a$

The cumulative numbers of caries treatment visits to providers were computed by adding the cumulative numbers of examination, preventive and restorative visits at each age.

The equation is expressed: $\mathrm{cumE}p_a + \mathrm{cumP}p_a + \mathrm{cumR}p_a = \mathrm{cumCT}p_a$

The cumulative numbers of caries treatment visits to dental hygienists and preventive dental assistants were pooled to cumCThn_a. For the cumulative numbers of all caries treatment (CT*all*) visits the cumulative numbers of visits to providers were combined.

The equation is expressed: $\mathrm{cumCT}hn_a + \mathrm{cumCT}d_a = \mathrm{cumCT}all_a$

For Kemi the cumulative numbers of total visits (T) were computed by combining cumulative numbers of all caries treatment and other visits and no-show incidents.

The equation is expressed: cumCTall_a+cumOall_a+cumDTall_a+CumAall_a+cumNSall_a = cumTall_a

Each visit stood for a treatment time of 30 minutes and indicated one input unit (i). Thus, one cumulative visit stood for one cumulative unit input (cumVp_a = cumi_a). Treatment time included the time spent with each patient, the time taken to clean up the unit after every patient, and the time spent on administrative work in relation to each patient. No-show incidents were counted as treatment time, because time for a patient was reserved but not used as intended. The use of 30 minutes as an input unit was based on administrative instructions on the topic. The time reserved had been 30 minutes for all dental hygienist and preventive dental assistant visits, as well as restorative visits to dentist-assistant pairs. In the years 1980–1989 and 2003–2004, when 20 minutes was reserved for an examination visit to a dentist in Kemi, the number of these visits was multiplied with a coefficient 0.67.

4.4.1.4 Unit costs

Labour costs (LC) were calculated to estimate unit costs (UC). The labour costs included salaries and 33 percent indirect employee costs, such as social insurance (4.014%) and pension payment (17.65%). Data for the calculation of unit costs were obtained from the 2004 accounts of the town of Kemi and these figures were used for the entire study and for every year. For each provider, dentist, dental hygienist and assistant, the yearly labour costs were divided by yearly working hours, and then divided by two for the unit cost of 30 minutes.

The equation is expressed: 1 unit cost (UC) = LC : WT : 2, where WT = yearly working time in hours.

The unit cost for a dental assistant was added to the dentist unit cost for a unit cost of a dentist-assistant pair. The mean unit costs were calculated to be 18.71 € for a dentist, 6.98 € for a dental assistant, and 25.70 € for the dentist-assistant pair. Unit cost for a dental hygienist was calculated to be 8.05 €.

4.4.1.5 Treatment costs

By multiplying the input units (i) with unit cost UC, it was possible to estimate cumulative costs related to caries treatment (including examination, preventive and restorative visits) for the subjects and cohorts for the study years. Caries treatment costs were calculated for a dentist-assistant pair and for other provider, i.e. either a dental hygienist or a dental assistant performing preventive care. The costs of a dentist-assistant pair and other provider were summed to total caries treatment costs.

4.4.2 Analysis of data

To describe the implementation of operational models, the mean numbers of annual visits were calculated by provider for all cohorts in both towns. The 1992 cohort in Kemi represented the 'New model', the 1980 cohort in Kemi and Tornio and the 1992 cohort in Tornio the 'Conventional models'.

The cohorts and towns were compared in relation to dental health and resources used; the dental health by using the mean dmft or DMFT figures and the percentages of subjects with healthy dentitions, and the use of resources by using the mean cumulative numbers of caries treatment visits by providers and total cumulative costs related to caries treatment. For comparisons in relation to dmft or DMFT figures, the ages 5, 9, 12 and 15 years were used. For comparison of cumulative visits and costs, the ages 5 and 12 years were used.

The dental health outcome (dmft or DMFT scores) and the total costs related to caries treatment at the ages 5 and 12 years were used in the cost-effectiveness analysis: the mean differences between the 1992 and 1980 cohorts in Kemi, and between the 1992 cohort in Kemi and Tornio, and their 95% confidence intervals were calculated. The health outcome at the age of 12 years was the main point of observation in the CEA, while the age of 5 years served as a point to monitor effectiveness over a 5-year time horizon.

The effect of the operational model on the total costs related to caries treatment was studied in a sensitivity analysis by estimating hypothetical total costs, i.e. as if all caries treatment was carried out by dentist-assistant pairs and no dental hygienists were used, for the 1980 and 1992 cohorts at the age of 12 years.

4.4.3 Statistical methods

The effect of gender on dmft at the age of 5 years and on DMFT at the age of 12 years was evaluated in the 1980 and 1992 cohorts in both towns (Mann-Whitney U-test), and was found to be non-significant. Consequently, in all analyses, genders were pooled.

The effect of cohort and town and their interaction term on dmft and DMFT were analyzed using logistic regression analysis for ordinal data. For this the dmft and DMFT indices were re-classified into three categories: dmft/DMFT = 0, dmft/DMFT = 0.1–2.5 and dmft/DMFT > 2.5.

For statistical analyses, natural logarithmic transformation was applied to the number of visits and cumulative costs at ages 5 and 12 years to control for the positive skewness of the original values, and after that the effect of cohort and town and their interaction term were tested in the 1980 and 1992 cohorts using analysis of variance. If the interaction term was significant, the necessary differences between towns or cohorts were tested with

Student's t-test using the natural logarithmic values. Differences between the cohorts in relation to the cumulative caries treatment costs up to 15 years of age in Kemi were tested at different ages with Student's t-test using the natural logarithmic values.

All statistical analyses were performed with SPSS for Windows statistical program, release 15.0. P-values less than 0.05 were considered statistically significant.

5. ETHICAL CONSIDERATIONS

The study protocol was approved by the Ethical Committee of the Hospital District of Länsi-Pohja, the Health Board of Tornio, and the Head of the Health Services Department of Kemi. The ethical regulations for utilizing data from patient records in Finland were followed, i.e. the names and social security codes were obliterated. The study data and their security copies were protected with passwords and stored in a locked place. All the data collection and recording was performed by the author.

6. RESULTS

6.1 Dental health

6.1.1 Proportion of healthy dentitions

In both towns, the proportion of subjects having healthy dentitions (dmft = 0) at the age of five years was higher in the younger cohorts compared with the 1980 cohorts. The proportion of subjects having healthy dentitions at the age of five years was higher in Kemi than in Tornio. In the 1992 cohort in Kemi, 80% of the subjects had no cavities in their deciduous teeth at the age of five years. In all cohorts, approximately half of the 12-year-olds and one third of the 15-year-olds had healthy teeth in these towns (Table 2, Appendix Table A1 for all cohorts in Kemi).

6.1.2 Caries experience

6.1.2.1 Deciduous teeth

The dmft scores of the 5-year-olds improved from the 1980 cohort to the 1992 cohort (cohort effect, $p < 0.001$). The improvement was similar in Kemi and Tornio (interaction term town*cohort, non-significant, $p = 0.893$). Lower values were detected in Kemi than in Tornio (town effect, $p < 0.001$) (Table 2, Appendix Table A2 for all cohorts in Kemi). In Kemi, a declining trend from older to younger cohorts was observed in the annual dmft means from infancy up to the age of five years (Figure 5). The progression was slower and the level of caries occurrence lower in the younger cohorts where the new concept of early prevention in caries treatment was applied.

6.1.2.2 Permanent teeth

In permanent teeth, the DMFT scores developed in a similar way in Kemi and Tornio [interaction term town*cohort, non-significant, at the age of 9 years ($p = 0.861$) and 12 years ($p = 0.796$)]. In general, the DMFT scores remained at a stable and low level (Table 2, Appendix Table A2 for all cohorts in Kemi). At the age of nine years, the DMFT scores were lower in the younger cohorts (cohort effect, $p < 0.001$). No change was detected in 12-year-olds' scores between the cohorts (cohort effect, non-significant, $p = 0.207$), but lower values were detected in Kemi than in Tornio (town effect, $p = 0.017$) (Table 2).

Table 2 Percentage of subjects having healthy dentitions (dmft or DMFT = 0) and the number of dmf or DMF teeth (mean, standard deviation (SD)) at the age of 5, 9 and 12 years by cohort and town. Statistical significance (p) for dmft/DMFT (logistic regression analysis: town and cohort effect and interaction term town*cohort)

		Kemi			Tornio			Kemi vs. Tornio	
		dmft or	dmft		dmft or	dmft		dmft or	dmft
	Cohort	DMFT=0	DMFT		DMFT=0	DMFT		DMFT=0	DMFT
		%	Mean	(SD)	%	Mean	(SD)		
Age 5	1980	55.6	2.2	(3.4)	37.0	2.9	(3.5)	+18.6	-0.7
	1992	80.4	0.8	(1.9)	67.0	1.4	(2.8)	+13.4	-0.6
		+24.8	-1.6		+30.0	-1.5			
Age 9	1980	67.0	0.6	(1.1)	65.5	0.7	(1.2)	+1.5	-0.1
	1992	77.0	0.4	(0.8)	75.0	0.5	(0.9)	+2.0	-0.1
		+10.0	-0.2		+9.5	-0.2			
Age 12	1980	52.0	1.2	(1.7)	45.0	1.7	(2.3)	+7.0	-0.5
	1992	55.4	1.0	(1.6)	47.5	1.3	(1.6)	+7.9	-0.3
		+3.4	-0.2		+2.5	-0.4			

at the age of 5 years: difference between cohorts p< 0.001 and towns p < 0.001, interaction term non-significant

at the age of 9 years: difference between cohorts p <0.001 and towns p = 0.215, interaction term non-significant

at the age of 12 years: difference between cohorts p = 0.207 and towns p = 0.017, interaction term non-significant

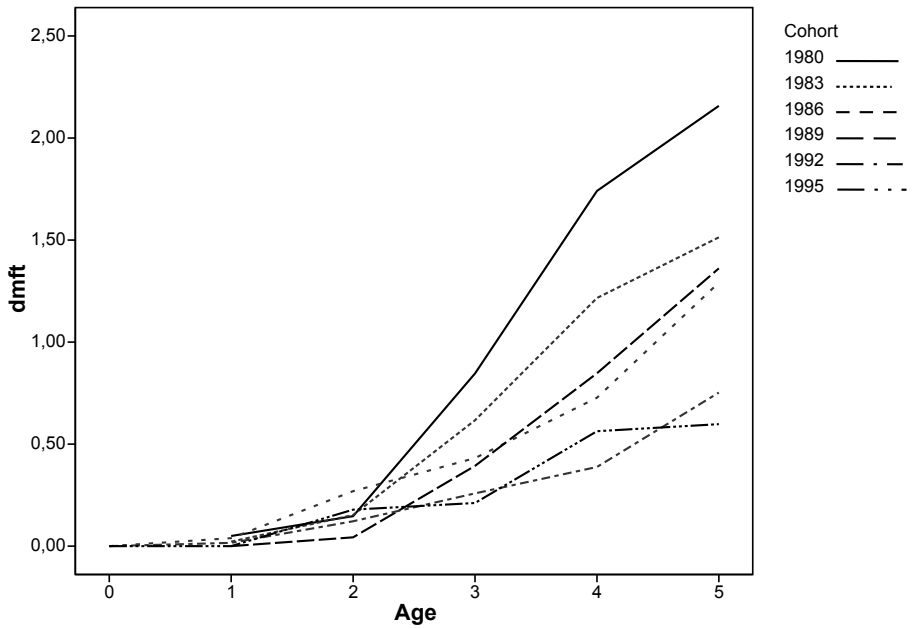


Figure 5 Annual dmft means in relation to age by cohort in Kemi

6.2 Implementation of operational models and the timing of visits

6.2.1 Mean annual number of caries treatment visits by provider

Visits to dentists dominated both pre-school and school-age children's visits in both towns in the 1980 cohorts. In Kemi, an increasing tendency to apply work division by utilizing the input of dental hygienists in child dental care was observed towards the younger cohorts. In the younger cohorts, a noticeable change in the timing of visits was seen: the emphasis in dental hygienist visits gradually changed to early childhood, while the emphasis in dentist visits moved towards school age. In Tornio, an increasing trend for early childhood visits to dental hygienists was also seen but not so clearly as in Kemi (Figure 6a-d, Figure 7 a-f).

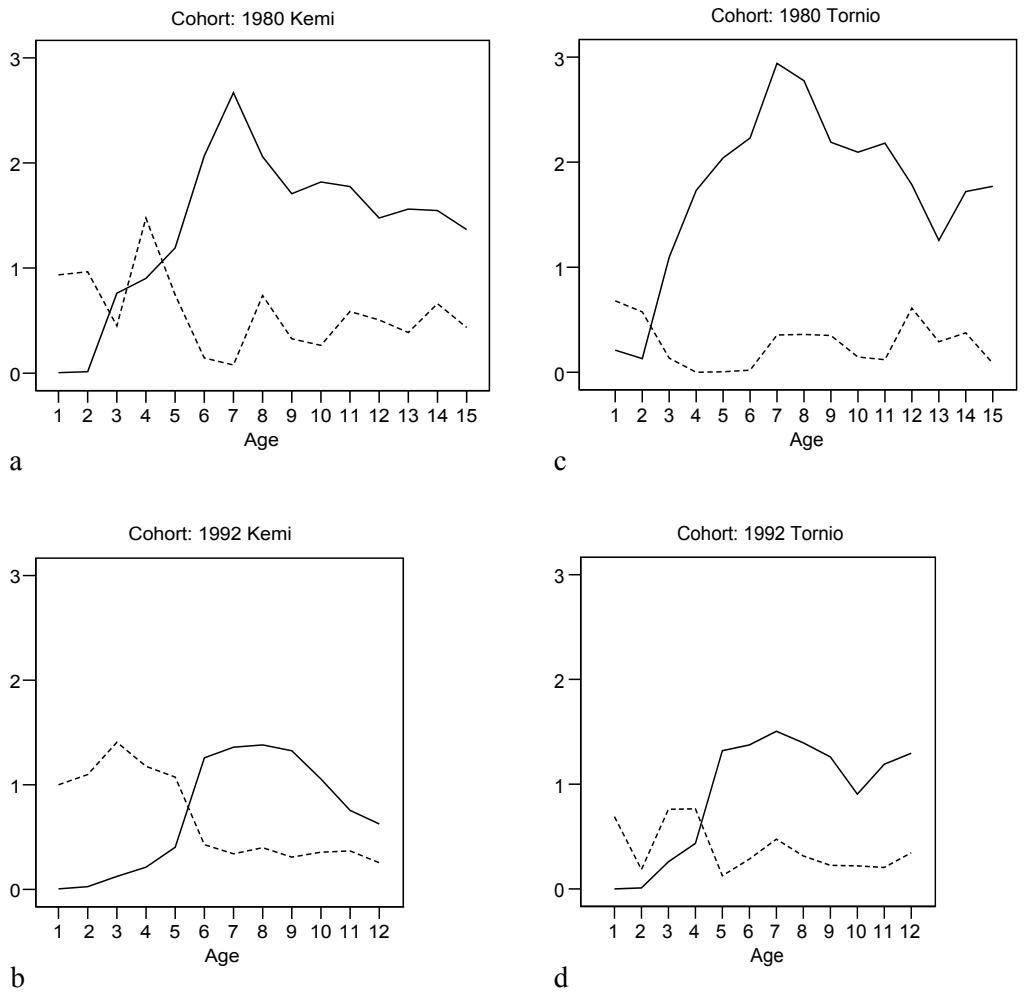
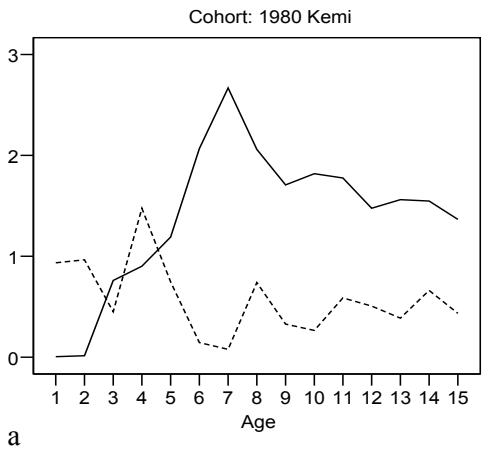


Figure 6a-d Mean annual number of caries treatment visits by provider in relation to age of the child in the 1980 and 1992 cohorts in Kemi and Tornio (in all figures: solid line = visits to dentist, dotted line = visits to dental hygienist)



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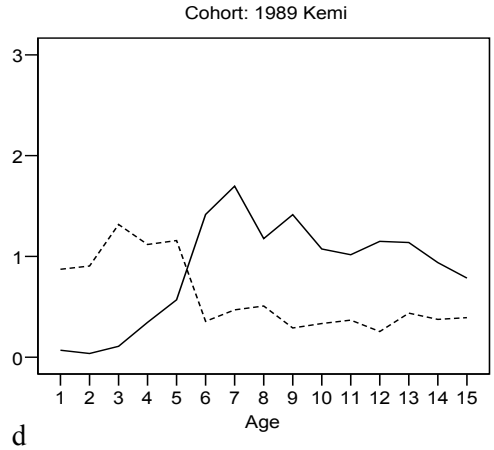

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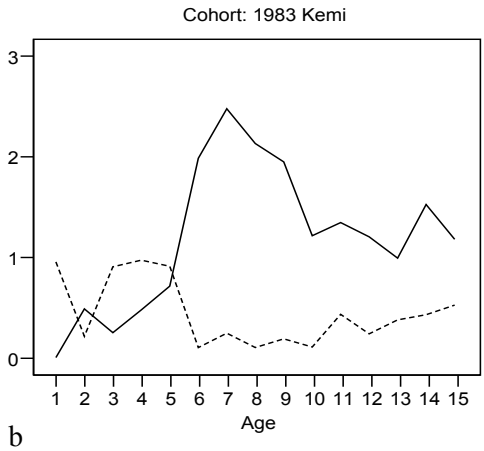

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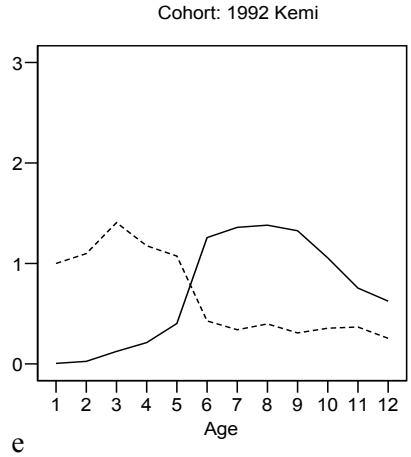

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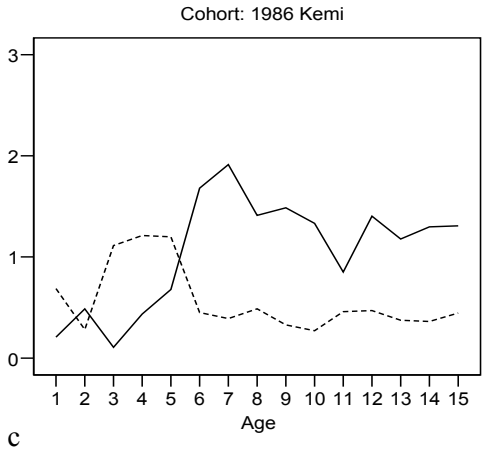

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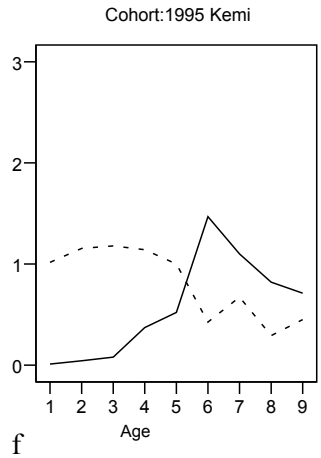

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Figure 7a-f Mean annual number of caries treatment visits by provider in relation to age of the child in Kemi (in all figures: solid line = visits to dentist, dotted line = visits to dental hygienist)

6.3 Cumulative number of caries treatment visits by provider

6.3.1 Comparison of Kemi and Tornio, and 1980 and 1992 cohorts, at the age of 5 and 12 years

6.3.1.1 Visits to dentists

The cumulative number of pre-school children's visits to dentists dropped to approximately one third in the 1992 cohorts compared to the 1980 cohorts. The number of visits by the age of 12 years fell to one half. At the age of 5 years the reduction in the number of dentist visits was more intense in Tornio than in Kemi (interaction term town*cohort, $p = 0.027$), but on the other hand, the number of visits was lower in Kemi than in Tornio in both cohorts ($p < 0.001$). At the age of 12 years, the decline was similar in these towns (interaction term town*cohort, non-significant, $p = 0.642$), but fewer visits occurred in Kemi than in Tornio (town effect, $p < 0.001$) (Table 3, Figure 8a-d, Appendix Table A3 for statistical significances).

6.3.1.2 Visits to dental hygienists

The number of visits to dental hygienists rose slightly in both towns. In Kemi, visits to dental hygienists shifted towards early childhood. In the 1992 cohort, most of the dental hygienist visits by the age of 12 years had taken place at pre-school age. In Tornio, the increase was distributed more evenly, and was not particularly concentrated on early childhood. In general, the number of dental hygienist visits was higher in Kemi than in Tornio [town effect, at the age of 5 years ($p < 0.001$) and 12 years ($p < 0.001$)]. Despite the differences in the accumulation of visits, the increase phenomenon was comparable in these towns (interaction terms town*cohort, non-significant, at the age of 5 and 12 years) (Table 3, Figure 8a-d, Appendix Table A4 for statistical significances).

6.3.1.3 Total number of visits

The increase in the number of dental hygienist visits and the reduction of dentist visits resulted in a decrease in the total number of visits of pre-school children in Tornio, but not in Kemi (interaction term town*cohort, at the age of 5 years $p < 0.001$). In the comparison between the towns, no difference was found in the total number of visits at the age of five years in the 1980 cohort ($p = 0.104$), whereas in the 1992 cohort, pre-school children had paid more visits in Kemi than in Tornio ($p < 0.001$).

The number of school-aged children's visits dropped in both towns. In the 1980 cohort, visits to dentists dominated, but in the 1992 cohort dental hygienist visits formed half of the visits in Kemi and one third in Tornio by the age of 12 years.

At the age of 12, the change from the 1980 to the 1992 cohort in the total number of visits was more intense in Tornio than in Kemi (interaction term town*cohort, $p < 0.001$). In

Table 3 Cumulative number of visits per subject: the number of visits by provider and all visits (mean, standard deviation (SD)) at the age of 5, 9 and 12 years by cohort and town

		Cumulative number of visits per subject								
	Cohort	**Kemi**			**Tornio**			**Kemi vs. Tornio**		
		to dentist	to hygienist	all	to dentist	to hygienist	all	to dentist	to hygienist	all
Age 5	1980	2.3 (2.7)	3.8 (1.6)	6.1 (3.1)	5.2 (3.7)	1.4 (0.8)	6.6 (3.6)	-2.9	+2.4	-0.5
	1992	0.7 (1.7)	5.5 (1.4)	6.2 (2.5)	2.1 (2.5)	2.5 (1.1)	4.6 (2.5)	-1.4	+3.0	+1.6
		-1.6	+1.7	+0.1	-3.1	+1.1	-2.0			
Age9	1980	10.3 (6.8)	5.0 (2.7)	15.3 (7.2)	15.3 (7.5)	2.5 (1.4)	17.8 (7.4)	-5.0	+2.5	-2.5
	1992	5.4 (4.0)	6.8 (2.2)	12.2 (5.3)	7.6 (4.7)	3.8 (1.5)	11.4 (4.9)	-2.2	+3.0	+0.8
		-4.9	+1.8	-3.1	-7.7	+1.3	-6.4			
Age 12	1980	15.0 (8.3)	6.2 (3.4)	21.2 (9.6)	21.4 (9.7)	3.9 (2.1)	25.3 (9.6)	-6.4	+2.3	-4.1
	1992	7.6 (5.1)	7.8 (2.8)	15.4 (6.8)	11.0 (5.9)	4.7 (2.2)	15.7 (6.5)	-3.4	+3.1	-0.3
		-7.4	+1.6	-5.8	-10.4	+0.8	-9.6			

the 1980 cohort, the total number of visits by the age of 12 years was higher in Tornio than in Kemi ($p < 0.001$), but in the 1992 cohort the difference had diminished ($p = 0.467$) (Table 3, Figure 8a-d, Appendix Table A5 for statistical significances).

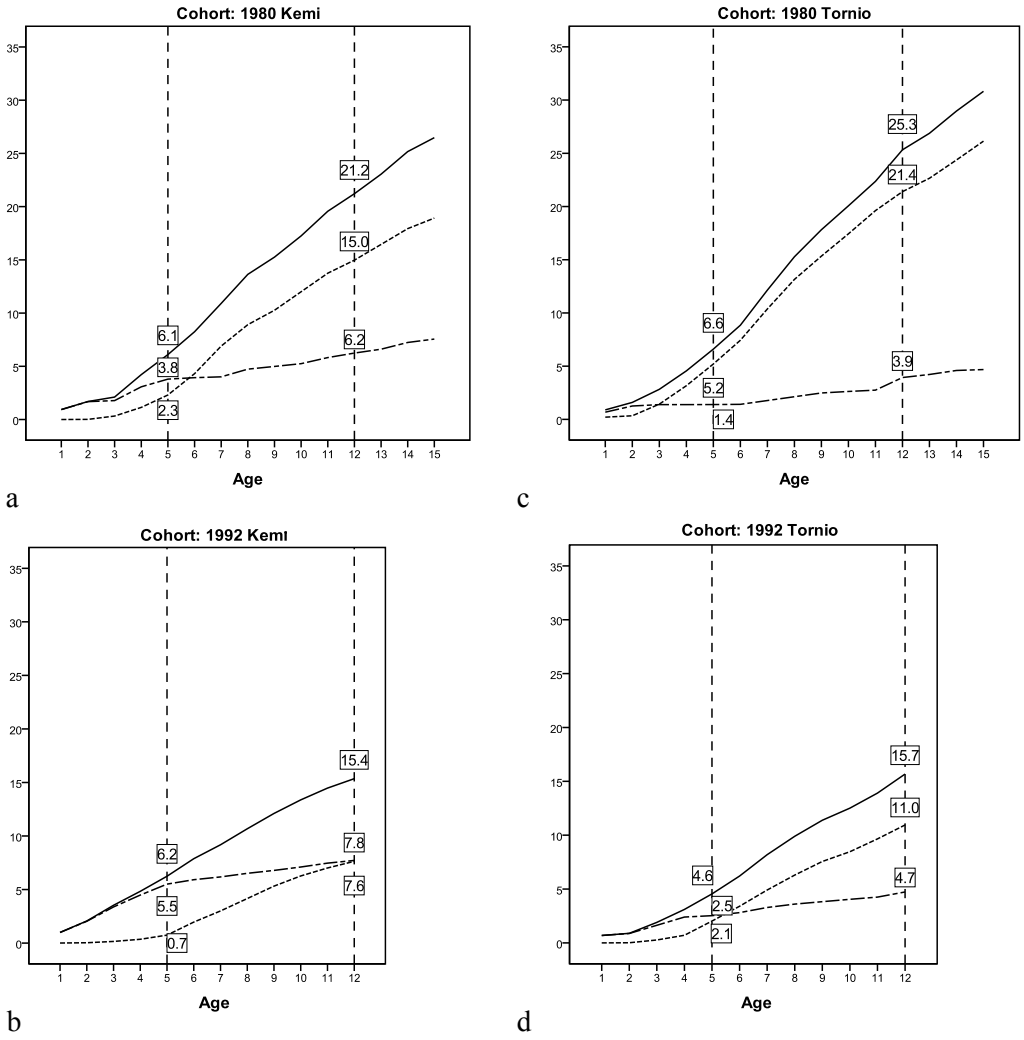


Figure 8a-d Cumulative mean numbers of caries treatment visits by provider in the 1980 and 1992 cohorts in Kemi and Tornio (in all figures: solid line = total visits, dotted line = visits to dentist and solid-dot-solid line = visits to dental hygienist)

6.4 Cumulative number of caries treatment visits of cohorts in Kemi

In Kemi, a decreasing trend in the total number of caries treatment visits by the age of 12 years was seen in other cohorts compared with the 1980 cohort. The proportion of dentist and dental hygienist visits changed. Visits to dental hygienists in early childhood became

more dominant towards the younger cohorts, whereas visits to dentists at an early age decreased. The number of dentist visits exceeded the number of dental hygienist visits at age 6 in the 1980 cohort and at age 9 in the 1989 cohort. In the 1992 cohort, the number of dentist visits did not exceed the number of dental hygienist visits by the age of 12 years (Appendix Tables A3-5). The change in the timing and number of visits is illustrated in Figure A1a-f in the Appendix.

6.5 Cumulative number and proportion of all visits in Kemi

In Kemi, the number of all oral health care visits and the number of no-show incidents were studied. In all cohorts, caries treatment visits accounted for 70% to 80% of visits. Other visits accounted for 10 to 20%, and no-show incidents accounted for approximately 10% of all visits (Appendix Table A6, Appendix Figure A2).

6.6 Cumulative costs related to caries treatment visits

6.6.1 Comparison of Kemi and Tornio, and 1980 and 1992 cohorts, at the age of 5 and 12 years

6.6.1.1 Total costs

The total costs by the age of 12 years decreased in both towns from the 1980 cohort to the 1992 cohort (cohort effect, $p < 0.001$). At the age of 12 years, costs related to caries treatment fell by 40% (176 €) in Kemi and by 45% (259 €) in Tornio. The costs were 33% (142 €) higher in Tornio than in Kemi in the 1980 cohort, and in the 1992 cohort they were still over 20% (59 €) higher (town effect, $p < 0.001$). There was no statistically significant difference between the towns in the pattern of the change (interaction term town*cohort, non-significant, $p = 0.118$) (Table 4).

In the 1992 cohort, at the age of 5 years, the total costs fell by 29% (26 €) in Kemi and by 50% (73 €) in Tornio compared to the 1980 cohort (Table 4). The cumulation of costs related to caries treatment is illustrated in Figure 9a-d.

6.6.1.2 Costs of dentist-assistant pair and dental hygienist

The proportion of dentist-assistant pair costs and dental hygienist costs changed over the study years. The change was seen especially in the early years of childhood. The costs of the dentist-assistant pair formed two-thirds of the total costs in Kemi at the age of 5 years in the 1980 cohort, but in the 1992 cohort, they formed one-third of the costs. In Tornio, the proportion of dental hygienist costs by the age of 5 years increased from 8% to 30% of the total costs. At the age of 12 years, the costs of the dentist-assistant pair formed at least 75% of the total costs in both towns and both cohorts.

The cumulative costs of the dentist-assistant pair by the age of 12 years fell to one half in the 1992 cohort compared to the 1980 cohort. The reduction was 189 € in Kemi and 269 € in Tornio.

The cumulative costs of a dental hygienist at the age of 5 years in Kemi were over twofold compared to Tornio in both cohorts. At the age of 12 years they were over one and a half fold. In both towns, the cumulative costs of a dental hygienist were higher in the 1992 cohort compared to the 1980 cohort. At the age of 5 years, the rise was 45% (14 €) in Kemi, and 82% (9 €) in Tornio. At the age of 12 years, the rise was 26% (13 €) in Kemi, and 37% (10 €) in Tornio (Table 4, Figure 9a-d).

6.6.1.3 Relation of visits and costs

At the age of 12 years, in the 1992 cohort, dental hygienist visits accounted for approximately half of the total cumulative visits in Kemi, whereas the costs of dental hygienist time formed 25% of total costs. In Tornio, one third of visits were dental hygienist visits and they formed 12% of total costs. The cumulative costs of dentist-assistant pair time by the age of 12 years were far higher than the costs of dental hygienist time.

6.6.2 Cumulative costs related to caries treatment visits of cohorts in Kemi

The total costs decreased in all other cohorts compared to the 1980 cohort. The costs of the dentist-assistant pair decreased, whereas the costs of the dental hygienist increased in all cohorts compared to the 1980 cohort (Appendix Tables A7-9). At the age of 9 years, in the 1995 cohort, dental hygienist visits accounted for approximately half of the total cumulative visits, whereas the costs of dental hygienist time formed one third of total costs. At the age of 15 years, the decline in total costs in the 1989 cohort was 167 € or 30% compared to the 1980 cohort. The costs of the dentist-assistant pair formed a major part (80–89%) of costs in all cohorts at the age of 15 year (Appendix Tables A7-9, Appendix Figure A3a-d).

6.7 Cost-effectiveness analysis

6.7.1 Cumulative costs in relation to caries experience

6.7.1.1 The 1992 cohort in Kemi compared with the 1980 cohort in Kemi

At the age of 5 years, a better dental health outcome was achieved, and costs were saved. At the age of 12 years, at least as good dental health outcome was achieved at less cost (Figure 10a).

6.7.1.2 The 1992 cohort in Kemi compared with the 1992 cohort in Tornio

At the age of 5 years, a better dental health outcome was achieved at equal cost. At the age of 12 years, at least as good dental health outcome was achieved at less cost (Figure 10b).

Table 4 Cumulative costs related to caries treatment per subject (mean, standard deviation (SD)) in euros: total costs and costs by provider at the age of 5, 9 and 12 years by cohort and town. Difference in total costs between the towns in euros and expressed as percentual difference. Statistical significance (p) (analysis of variance: town and cohort effect and interaction term town*cohort for total costs)

		Cumulative costs per subject							
	Cohort	Kemi			Tornio			Kemi vs. Tornio	
								total	
		total	dentist- assistant pair	hygienist	total	dentist- assistant pair	hygienist	€	%
Age 5	1980	90 (70)	59 (70)	31 (13)	145 (94)	134 (95)	11 (6)	-55	61
	1992	64 (47)	19 (43)	45 (12)	72 (64)	52 (65)	20 (8)	-8	13
	Change (€)	-26	-40	+14	-73	-82	+9		
	decrease/ increase(%)	29	68	45	50	61	82		
Age 9	1980	304 (175)	264 (175)	40 (22)	414 (192)	394 (193)	20 (11)	-110	36
	1992	192 (110)	137 (103)	55 (18)	225 (121)	194 (121)	31 (12)	-33	17
	Change (€)	-112	-127	+15	-189	-200	+11		
	decrease/ increase(%)	37	48	38	46	51	55		
Age 12	1980	435 (221)	385 (213)	50 (28)	577 (247)	550 (249)	27 (15)	-142	33
	1992	259 (143)	196 (132)	63 (23)	318 (154)	281 (151)	37 (16)	-59	23
	Change (€)	-176	-189	+13	-259	-269	+10		
	decrease/ increase(%)	40	49	26	45	49	37		

at the age of 12 years: difference between cohorts p <0.001 and towns p <0.001, interaction term non-significant

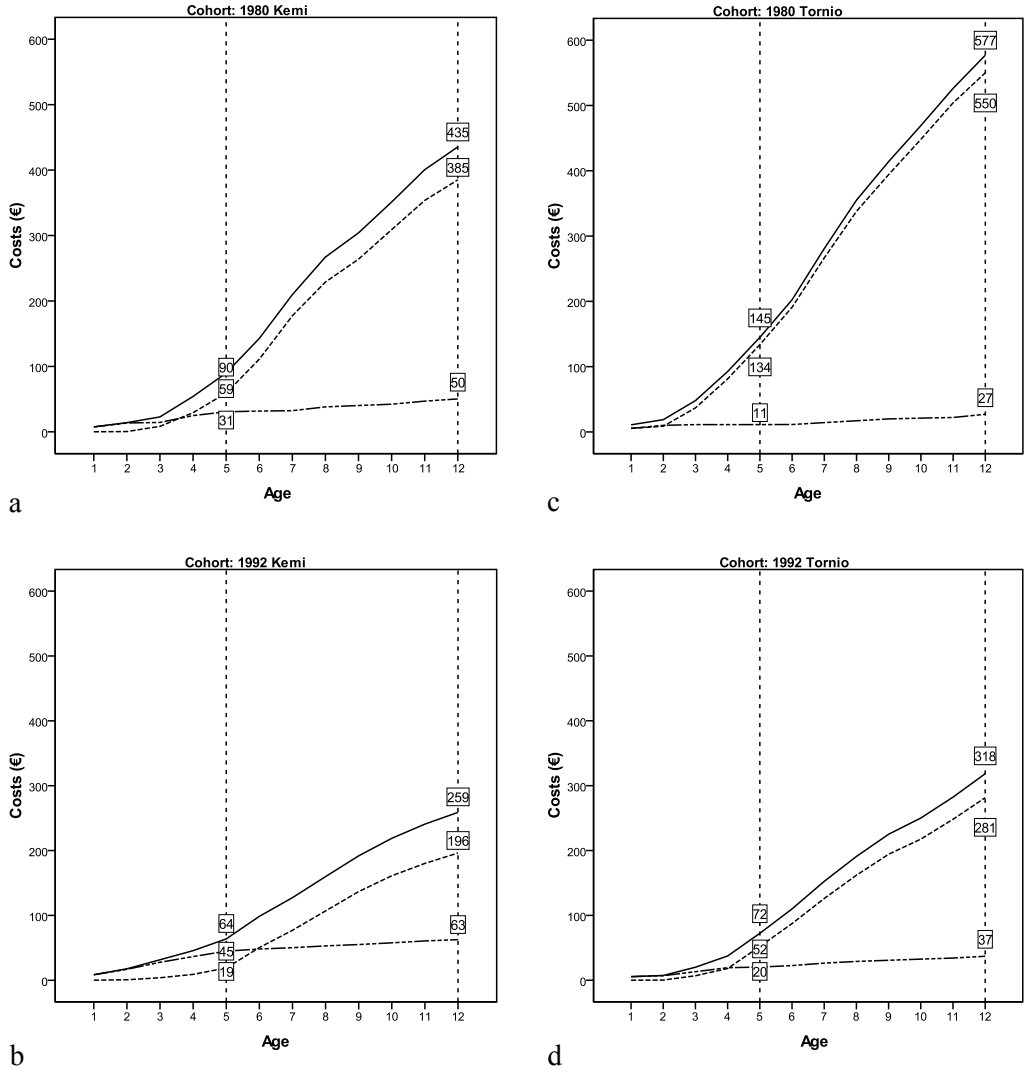
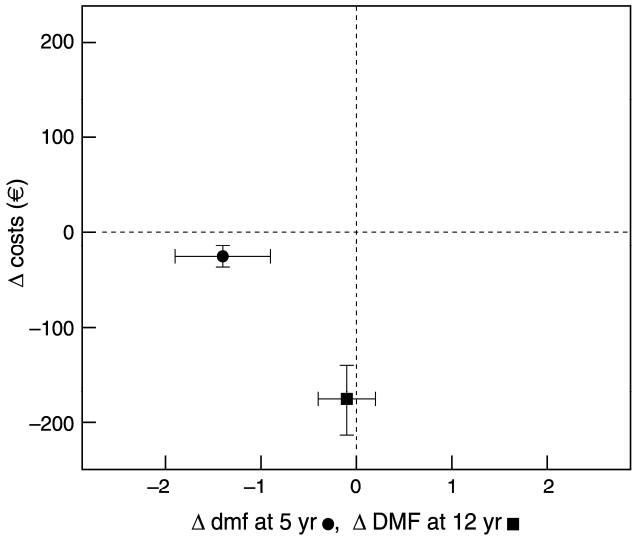


Figure 9a-d Cumulative costs related to caries treatment visits (total and provider-based) by cohort and town (in all figures: solid line = total costs, dotted line = costs based on dentist-assistant pair and solid-dot-solid line = costs based on dental hygienist)



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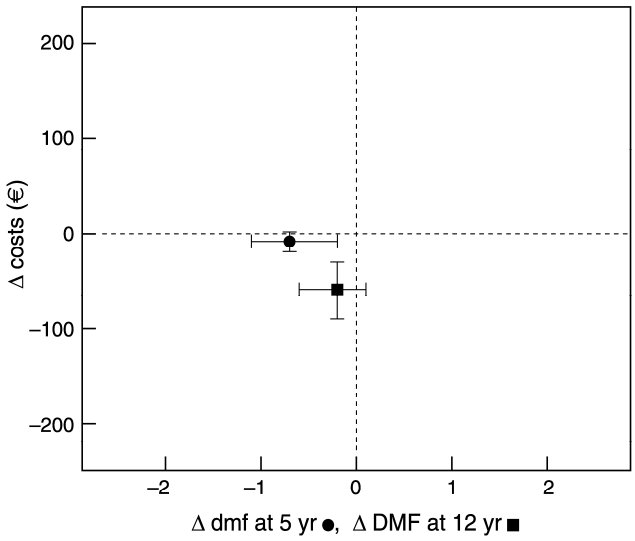

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Figure 10a-b The components of ICER and their 95% confidence intervals (dmft scores at the age of 5 years and DMFT scores at the age of 12 years combined with the total cumulative costs in relation to caries treatment visits at the age 5 and 12 years). The differences between the cohorts 1992 and 1980 in Kemi (a), and between Kemi and Tornio in the 1992 cohort (b). For the mean dmft/DMFT scores see Table 2. For the total cumulative costs related to caries treatment visits see Table 4.

6.8 Sensitivity analysis

6.8.1 Effect of the operational model

The actual cumulative costs related to caries treatment visits at age 12 were compared with the respective hypothetical costs (hypothetical case where all caries treatment was carried out by dentist-assistant pairs) in the 1980 and 1992 cohorts. In both towns and both cohorts, the hypothetical cumulative costs were higher than the actual respective costs. At the age of 12 years, the hypothetical cumulative costs using only a dentist-assistant pair were 25% (110 €) higher than the actual costs in the 1980 cohort in Kemi, and 10% (59 €) higher in Tornio. In the 1992 cohorts, the hypothetical costs were 52% (136 €) higher in Kemi, whereas in Tornio they were 25% (81 €) higher. In comparison between the towns, the hypothetical costs were 91 € lower in Kemi than in Tornio in the 1980 cohort, whereas in the 1992 cohort the hypothetical costs were almost the same (Table 5).

Table 5 Cumulative costs related to caries treatment visits at age 12 by cohort and town calculated as visits to dentist-assistant pairs and dental hygienists (actual), while in hypothetical case all caries treatment was carried out by dentist-assistant pairs (hypothetical). Mean, standard deviation (SD) and statistical significance (p) (Student's t-test) of differences in costs

		Kemi			**Tornio**			**Kemi vs.Tornio**
Age 12	**Model**	N	Mean	(SD)	N	Mean	(SD)	t-test
Cohort	actual	200	435	(221)	200	577	(247)	< 0.001
1980	hypothetical	200	545	(247)	200	636	(247)	< 0.001
Cohort	actual	200	259	(143)	200	318	(154)	< 0.001
1992	hypothetical	200	395	(176)	200	399	(167)	0.776

7. DISCUSSION

7.1 Reliability of the data

The present study was a historic cohort study. This kind of study enables us to obtain longitudinal real-life information within a reasonable time. In the present study, the dental records of subjects served as the source of data. In Finland, structured oral health examination sheets are used nationwide, and the national health authorities have given detailed instructions for the record-keeping. The providers of oral health services are obliged by law to keep individual patient records, including oral health status, treatment plans and measures (Primary Health Care Act 1972, Act on the Status and Rights of Patients 1992, Personal Data Act 1999). Although the written sheets have currently been replaced by electronic versions, the contents are still comparable and uniform. The record-keeping in the public health centre dental offices is locally monitored by the chief dental officers on a regular basis. In the Finnish public oral health care system, the clinical examinations of the children are performed regularly, and patient records form systematic annual descriptions of clinical observations and accomplished treatment. The continuity and internal compatibility of a patient history reduces random errors.

All the data for the study were collected from the dental treatment histories of the children and entered into a computer file by the author. The collection and arrangement of data were conducted according to a predetermined scheme. Each treatment history was handled as a whole, one by one, which ensured general logic and reliability.

Kemi and Tornio were comparable, regarding, for instance, economic life and social structure, as described in the general background of the study. Major changes did not occur during the studied period. In the present study, the target population consisted of nearly all children in the two towns because almost all children and adolescents participate in the public oral health care system. Moving away from the area was the major reason for the incompleteness of the treatment histories, and consequently exclusion from the study. Even though some treatment histories did not meet the inclusion criteria and were excluded, the original numbers of patient treatment histories in the study cohorts were large enough to ensure sufficient numbers of records in almost all cohorts.

7.2 Study design and methods

In the design of the present study, a fairly large sample size was considered necessary to obtain useful information on the visits and costs of caries management from the viewpoint of the public provider. No previous studies were available to refer to on the cumulative costs of caries management, whereas the steady and relatively low level of

caries occurrence was known. It was possible to use the knowledge on caries occurrence to estimate the sample size. The quite large sample size made it possible to avoid any systematic error arising from individual variation in diagnosing and record keeping. Moreover, the sample size ensured large coverage of patient treatment histories, and thus reduced bias originating from differences, for example, in the social or educational background of subjects and their families.

In general, the possible bias caused by variation over a period of time is smaller in studies where longitudinal data instead of cross-sectional data are used for comparisons. This worked in favour of the present study. The cohort of children born in 1980 was selected as a basis for comparisons between the cohorts because it represented well the conventional operational model of dental care in both towns. The cohort born in 1992 represented the new model in Kemi, while no major operational changes had been made in Tornio for the respective 1992 birth cohort. The comparisons between Kemi and Tornio made it possible to weigh the changes observed in Kemi against an outside reference in the same time period. While the 1992 cohort enabled follow-up to 12 years of age, the 1980, 1983, 1986 and 1989 cohorts provided data for the estimation of cumulative costs up to 15 years of age, and thus gave a wider perspective to the monitoring of secular changes in Kemi. The 1995 cohort provided information on the most recent development of the new operational model in Kemi.

Ages 5, 9, 12 and 15 were selected for statistical analyses because they are clinically practical. Ages 5 and 12 are commonly used for comparisons of dmf and DMF indices, at both national and international levels. In Kemi, most of the 9-year-olds were examined because of the screenings for orthodontic treatment need. In Finland, 15 years is the last year the entire age cohort has to attend school; hence participation in dental examinations is high.

Oral health was described using two measures. The proportion of subjects having healthy dentitions depicts the overall success in achieving health goals and avoiding disease. The mean dmft/DMFT scores were used as measures of caries experience. The measures provide a means for expressing various elements of caries in distinct and comparable numbers fairly precisely. Using a measure for oral hygiene would have given a wider perspective to dental health in the present study. However, although oral hygiene status is assessed at dental visits, it may be reported unclearly in patient treatment histories. Consequently, collecting such information is rather time-consuming or even impossible. Regarding both measures used, certain problems arise at the stage of mixed dentition, where the status of deciduous teeth is to some extent overlooked. The limitations of the dmf/DMF index are well recognized. The dmf/DMF index does not indicate the severity of the disease, nor does it show the prognosis for remaining teeth. If a tooth is both carious and filled at the same time, it is counted only once in the index, and the real condition remains unrevealed. Teeth

may be lost through other causes than caries, but this is not necessarily taken into account in determining the index value. In the present study, the systematic clinical examinations registered on the patient records made it possible to check for errors in the determining of dmf or DMF indices, and to calculate the missing indices by interpolation. The use of longitudinal index values increases validity in this kind of study.

Caries treatment strategies shifted towards a more conservative approach in the Nordic countries during the 1980s and 1990s (Bryhni et al. 1985, Heidmann et al. 1988, Edward 1997, Gimmestad et al. 2003). Variation in diagnosing caries and making treatment decisions has occurred both annually and over time (Rytömaa et al. 1979, Kay et al. 1992, Lewis et al. 1996, Mejàre et al. 1999, Espelid et al. 2001). Bader and Shugars (1997) suggest that dentists use their individual caries scripts when making treatment decisions. The scripts are influenced by salient factors such as dentists' personal characteristic, preferences and beliefs called "biases", and practice characteristics. In the present study, a large number of dental professionals had taken part in the care of the subjects. In Kemi, 65 dentists and 11 dental hygienists had been employed in the health centre during the time period studied. The corresponding estimated figures for Tornio were 42 dentists and 7 dental hygienists. The core of the personnel in both towns consisted of experienced dental professionals who had been working at the same health centres for several years (range 10-40 years), and had taken part in regional continuing education and discussions on treatment strategies. There is no known evidence to show that the views of the professionals on diagnosing and controlling caries would have diverged. Thus, presumably their concepts of caries treatment were reasonably similar. On the other hand, a large number of visits conducted by a large number of dental professionals may level the effect of variation among the professionals. As regards the costs, the variation in diagnostics did not result in bias in the present study because the examinations and other caries treatment visits took place according to the decisions of the dental professionals; it is the treatment decisions that cause the costs, not the disease itself.

In the present study, the numbers of caries treatment visits and the costs related to caries treatment from early childhood to adolescence were analysed both annually and cumulatively. This method enables the description of the timing of the visits and the costs over time, both by the provider (dentist-assistant pair, dental hygienist) and in total in relation to the health status. It is also possible to demonstrate the relation between the provider and cost and visualize their relation and changes.

The cost-estimation was based on caries treatment visits, including examinations, preventive and restorative visits. The calculation of input use was based on the assumption that each visit represented a treatment time of 30 minutes, and not on the actual treatment time. For administrative and practical reasons the duration of treatment appointments has to be predetermined. The planning of timetables is based on clinical experience. Despite

the variation in the actual treatment time, the working time as a whole is mostly associated with the treatment of patients, and the 30 minute time estimate has proven to be useful and quite stable. The interviews with the chief dental officers and experienced personnel, as well as the administrative instructions, revealed that there were no significant differences between the operational models in the use of the working time. Customarily, the weekly working time had been 37 hours for dentists and 38 hours and 15 minutes for dental hygienists and nurses, all including 30 hours of clinical work. The cost estimation method of the present study has made the cost of a visit shorter than 30 minutes "too high" and the cost of a longer visit "too low". Certainly, there have been both shorter and longer visits, but most likely they have taken place in both towns and in each cohort.

Labour costs were considered the most important factor for the estimation of cumulative costs. In Finland, the average labour share of total cost in the public oral health care service in 2003 was 75% (Widström and Erkinantti 2004). Other costs such as material, services and capital borne by the provider each form a minor share, 5 to 10% of the overall costs (Widström and Erkinantti 2004), and are quite equally utilized by all dental professionals. Since labour costs have such a high impact on the overall costs, it is quite reasonable to use them on their own for the estimation of operating costs in the public dental care of children. The costs can be correlated to either visits conducted or treatment time used. In both towns, the labour costs constituted 80% of the total costs in 2004. Higher salaries paid for working in remote areas in Finland apply to Kemi and Tornio, and explain the higher than national average figure. In the present study, the total costs related to caries treatment would have increased if other costs had been included in the calculations. However, relatively, the results of cost calculations would have remained similar. Labour costs are in proportion to the working hours (input) of dental professionals as are material, capital and other costs. Any alteration in the input of dental professionals changes the proportion of costs by profession to total costs but the effect on unit costs is irrelevant. In the present study, the share of labour costs by the provider was different between the operational models, but there is no reason to assume that the ratio of labour costs to total costs was different. The labour costs of Kemi, including salaries and indirect employee costs, were used for cost estimation. The use of weighted labour costs of both towns would probably not have altered the results of cost calculations. The collective bargaining agreements were respected in both towns, and social insurance and pension payments were collected following a similar policy. Moreover, the employees had similar working experience. Therefore, the unit labour costs of dentists, dental hygienists and assistants and their relation were presumably comparable in these towns. The accuracy of the estimated savings is not as crucial in the present study where two operational models were compared in relation to costs and effectiveness as in the case where the costs of a dental health programme are estimated for decision makers.

The choice of the method of economic analysis was cost-effectiveness analysis (CEA) because the health outcome was evaluated with natural indicators and not in monetary terms. CEA allows implicit monetary valuation of the health outcome. Another reason for choosing CEA was that the present study did not aim to address whether the health outcomes were worth their costs. For that purpose a cost-benefit approach would have been appropriate. The municipalities in Finland are obliged by law to deliver public oral health care services, and the question is how they are delivered. Data on effectiveness and cost were brought together in a nine-cell matrix which makes it possible to combine potential impacts on effectiveness and cost resulting from a new operational model. The matrix illustrates the possible outcomes of CEA, but also highlights the importance of judgement in decision making.

Dealing with the divergence in obtaining costs and effects is a conventional problem in economic evaluation. Usually, costs incurred in different years are discounted to their present value by using an appropriate discount rate. In the present study, discounting was not necessary, because the costs were incurred already during the follow-up period. The different timing of costs was taken into account by using the labour costs of the year 2004, and the calculations on resource use in the study years.

Incremental cost-effectiveness ratios were calculated for the 1980 and 1992 cohorts at the ages of 5 and 12 years. An observation period of twelve years gave a good opportunity to gain information on the health and economic effects of the operational concepts. Health outcome and cumulative costs at the age of 5 years served as an additional point of reference in the CEA, because the long-term cost-effectiveness of early prevention had much weight in the present study. Restorative care of decayed teeth in young children is demanding for the children and their families, as well as for the dental personnel. Avoiding or at least postponing such treatment has considerable intrinsic utility. The relation between provider and costs was investigated in the sensitivity analysis using hypothetical costs. This gave valuable information on how critically the profession and salary of the provider affect the costs.

7.3 Statistical procedures

In the present study, the emphasis was on handling, analysing and describing the collected data with instruments suitable for the evaluation of practical operations. In the statistical management, the intention was to examine the effect of the operational model on the changes detected between both the cohorts and the towns. Some robustness was looked for in the selection of statistical methods, since caution was regarded as important when drawing conclusions. The use of multivariate methods, for example, logistic regression analysis and the two-way analysis of variance made it possible to compress the information contained in the complex and large data to obtain an overview

of the phenomenon observed. In this way, it was possible to study the effect of cohort and town on the dependent variables, i.e. dmf/DMF scores, the number of visits and the costs. Furthermore, the repeating of tests was thus avoided.

7.4 Clinical effectiveness and costs

7.4.1 Health outcome

The health of deciduous dentitions of the subjects improved in the 1992 cohort compared to the 1980 in both towns, but in Kemi, the health outcome at pre-school age was significantly better than in Tornio. The result indicates that the new operational model of caries treatment in Kemi was beneficial, with its emphasis on early prevention. The result is in line with earlier studies among young children (Holst et al. 1997, Wendt et al. 2001, Pienihäkkinen and Jokela 2002). At the age of 12 years, there were no differences in the DMFT scores between the 1980 and 1992 cohorts in either town. Furthermore, there was no difference between the towns in the 1992 cohort. It is noteworthy that both towns already had a relatively low level of caries occurrence during the period studied. The findings indicate that the long-term health outcome was not jeopardized by the new operational model. This is in accordance with other studies in the Nordic countries (Wang and Holst 1995, Hannerz and Westerberg 1996). On the other hand, the findings among school-aged children show that we may be getting close to the situation where fever visits no longer means better effectiveness. Inventively planned and performed prevention based on promotion of healthy lifestyles could probably help to achieve an even more favourable health outcome in this age group.

Good dental health in the early years of childhood certainly has value *per se*, but is also associated with values such as less discomfort experienced by the child and less time missed from school or work. The values of such factors are not easily quantifiable. Moreover, the postponement of the cavitation process resulting from early prevention can be advantageous if the restorative treatment is carried out more easily when the children are older.

7.4.2 Accumulation and distribution of caries treatment visits

Caries treatment visits formed 70–80% of all oral health care visits (Table A6 and Figure A2 in the Appendix). The no-show incidents were quite often related to caries treatment: forgotten appointments for examinations or for restorative treatment. The result indicates that caries treatment forms a significant cost factor in child dental care even at a relatively low level of caries.

In Kemi, regarding the care of pre-school-aged children, the change in the strategy of caries management from a conventional to an early risk-based one was seen in the

distribution of caries treatment visits. Altogether, the number of caries treatment visits did not change, but there was a remarkable difference in their allocation by provider between the operational models. In the cohorts representing the concept of early prevention, visits to dental hygienist increased while visits to dentist decreased. In the 1992 cohort, the visits consisted almost entirely of dental hygienist visits up to the age of 5 years. In Tornio, the decrease in the number of cumulative caries treatment visits at the age of 5 years in the 1992 cohort compared to the 1980 cohort probably reflects both the recall system of young children and the improved health of deciduous dentitions. Although the number of dental hygienist visits also increased in Tornio, it is noteworthy that in the 1992 cohort, at the age of 5 years, the number of dental hygienist visits in Kemi was more than double compared to Tornio. Moreover, in the 1992 cohort, the number of dental hygienist visits by the age of 5 years in Kemi was higher than by the age of 12 years in Tornio. The difference between the operational models in the distribution of the cumulative numbers of dentist and dental hygienist visits was also obvious at the age of 12 years. In the 1992 cohort in Tornio, dentist visits accounted for most visits from the age of six years onwards, whereas in the 1992 cohort in Kemi, dental hygienists visits still accounted for most visits at the age of 12 years. The observations indicate that with the adoption of the early risk-based concept of caries management in Kemi, intense effort was put into control of caries and a great-deal of time was spent on preventive care.

The differences in the timing of preventive visits and in the implementation of work division between the operational models are seen in the series of figures "mean annual number of caries treatment visits" (Figure 6a-d). The new model in Kemi (Figure 6b) included preventive visits carried out by dental hygienists and preventive dental nurses in the early years of childhood. The conventional operational model (Figures 6a, c, and d) was based much more on dentists' input, with preventive efforts taking place later.

Because the number of caries treatment visits decreased substantially, it can be assumed that also the number of examinations decreased, and examination intervals were extended. In Kemi, the recommended examination interval varied from 6 to 36 months. In the first phase, the recall intervals of children assessed as having a low risk of caries were extended, and over time the intervals became more individualized. This observation is in line with previous studies (Wang and Holst 1995, Helminen and Vehkalahti 2002). The decisions on examination intervals in a Finnish public health centre were to some extent dependent on factors such as the total number and general dental health of dentists' patients, rather than an individual patient's dental state (Helminen and Vehkalahti 2002). This may reflect the dentists' efforts to survive under increasing workloads. It should be remembered, however, that other than caries-related oral conditions may require frequent check-ups, and lead to diverse recall intervals.

Allocating resources for prevention at a young age and employing the skill mix of dental professionals gave favourable health results. The health advantage gained in early childhood compared to the conventional concept of caries treatment, however, could not be maintained into adolescence. One explanation may be that though parents in general are highly motivated to give the best possible care to their children, their influence on the oral health habits of their children decreases as the children grow older. Schoolchildren and adolescents may need another kind of support to maintain or adopt good habits. The concept of early prevention gives an opportunity to build contacts with families. A very early start is essential to ensure positive development in oral health.

7.4.3 Accumulation and distribution of costs related to caries treatment

In the present study, the decrease in the total costs of caries treatment over time in both towns reflected the decrease in the number of visits. The decrease in costs was due to a decrease in the number of more expensive dentist visits. At the age of 12 years in the 1992 cohorts, there was no difference in the total number of visits between the towns, but there was a 20% (59 €) difference in costs per treated subject in favour of Kemi. One explanation is that in Kemi one half of the visits were dentist visits and the other half were dental hygienist visits, whereas in Tornio, dentist visits dominated. In the new operational model in Kemi, the former dentist visits of early childhood were to a great extent replaced by dental hygienist visits. The increase in the number of dental hygienist visits had a minimal effect on costs.

The difference between dentist and dental hygienist salaries increased in the early 1990s. The salaries of dentists rose more than those of dental hygienists, as the salary system of public dentists was renewed. The numbers of clinical examinations and treatment procedures dentists carry out, as well as the procedures' degree of difficulty, have since then played an increasingly greater role in public dentists' salaries. The use of individual examination intervals has been promoted with economic incentives since 1995. Dentists are paid a bonus for every interval exceeding 12 months, presuming the examinations take place according to the planned treatment scheme. The change in the salary system aimed to increase productivity in the public oral health care service. On the other hand, the purpose was to encourage dentists to give regular and comprehensive dental care to their patients. The rationale was that eventually this approach would have positive health and economic effects for both the patient and the public provider. In the present study, the use of current salaries acted in favour of the hypothesis. The fact that the ratio of dentist to dental hygienist salaries changed over the study period, however, does not carry significant weight. Studies like the present one are made for today and tomorrow, and therefore the use of current salaries is justified. In the future, the work contents of dental professionals, and, consequently, the salaries and their ratios to each other may change, and this should be noted when the results of the present study are considered.

7.4.4 Evaluation of cost-effectiveness

The cost-effectiveness analysis of the two operational models of caries treatment revealed that, compared with the conventional model, the new operational model was less costly and resulted in better dental health at the age of 5 years and in at least as good dental health at the age of 12 years. The new operational model thus dominated over the conventional model in both towns. The profession of care provider was considered a central factor of cumulative costs. The findings of the sensitivity analysis indicate that the operational model had a major effect on the result of the CEA. Using the hypothetical dentist-assistant pair based costs in the CEA resulted in a situation where no differences were found in costs between Kemi and Tornio in the 1992 cohort. The finding is understandable because there was no difference between the towns in the total number of caries treatment visits at the age of 12 years in this cohort. Another indicator of the effect of the operational model on the result of the CEA is that in the 1980 cohort in Kemi the hypothetical costs were 25% higher than the actual costs, whereas in the 1992 cohort they were 52% higher. The explanation is that the conventional model was dentist-based, whereas in the new operational model, dental hygienists had a significant role.

The results indicate that the economic outcome was mainly based on the profession of the care provider and the differences in their salaries. Although the total number of visits at the age of 5 years in the 1992 cohort was higher in Kemi than in Tornio, they were mostly dental hygienist visits, and thus less costly. Also at the age of 12 years, the proportion of dentist and dental hygienist visits was different in these towns, and therefore a difference in costs in favour of Kemi was detected. Accordingly, the choice of the operational model had significant economic consequences. This observation is in line with studies by Jokela and Pienihäkkinen (2003) and Oscarson et al. (2003). The key explanation for the better cost-effectiveness of the new operational model was the allocation of dental hygienists' and preventive dental assistants' input for prevention and control of caries. Their salaries generated a lower accumulation of costs, and were therefore favourable for the positive economic outcome.

The findings of the present study suggest that, in addition to cost savings and positive health outcome, implicit benefits were achieved with the new operational model. The early preventive approach was favourable to work division. The saved dentist-assistant time could be used to provide services for other population groups. From a health economic viewpoint, the true health benefit gained was the alternate use of the saved resources.

The results of the present study enable comparison with the study by Pienihäkkinen et al. (2005) who reported on the long-term clinical and economic aspects of risk-based early prevention in comparison with routine prevention. The new operational model in Kemi is comparable with their risk-based prevention programme utilizing work division, while

the conventional model is comparable with their routine prevention programme described in Pienihäkkinen and Jokela (2002). They reported that both the level of caries experience in permanent teeth and the running costs were significantly lower in the group that had received risk-based prevention up to 5 years of age than in the former routine prevention group. The follow-up examination was conducted seven years after the cessation of the targeted prevention programme, i.e. when the subjects were 12 years of age. The present practice-based results are fully in line with their clinical and economic findings.

Some studies allow comparison on single aspects such as methodology, observation period and specific preventive measures. In their study on the cost-effectiveness of large amalgam and crown restorations, Kolker et al. (2006) used cumulative curves to visualize both the total and annual costs, as well as the health outcome. The curves were a valuable aid in monitoring the relation of cost and longevity of restorations in a long-term perspective, especially as neither restoration was an ideal treatment alternative with lower cost and higher effectiveness. Weintraub et al. (1993) examined the cost-effectiveness of placing fissure sealants from a long-term perspective. Either cost savings or improved cost-effectiveness over time were revealed in their retrospective cost-effectiveness analysis. The placing of fissure sealants became cost-effective after ten years. For children identified as having a high risk of caries, the procedure yielded cost savings already after 4 to 6 years. A theoretical cost estimation model predicted cost savings and enhanced oral health outcome from mutans streptococci screenings of toddlers and early management of dental caries (Zavras et al. 2000). A dental health education programme to prevent early childhood caries in infants, based on repeated home visits with mothers, and starting at 8 months of age, gave favourable cost-effectiveness and cost-benefit ratios compared to other preventive programmes (Kowash et al. 2006).

The above studies (Weintraub et al. 1993, Zavras et al. 2000, Pienihäkkinen et al. 2005, Kowash et al. 2006) suggest that preventive programmes are inevitably faced with costs that occur immediately and benefits which accrue later, whereas the costs of not undertaking prevention are postponed to a future period. This observation is in line with the findings of the present study.

7.4.5 Differences between the cohorts

In the present study, the total cost of caries treatment decreased over time in both towns. The difference between the birth cohorts was remarkable. However, this information was not known prior to the present study. A similar health outcome was achieved with less cost in both towns in the 1992 cohort compared with the 1980 cohort. The finding indicates that cost-effectiveness in the dental care of children improved in general in these two health centres. The public oral health care system has sometimes been criticized for concentrating too much on the care of children and adolescents and disregarding the needs of the adult population. But, in fact, the improved cost-effectiveness in the dental

care of children enabled the using of the saved dentist-assistant pairs' time for the care of other population groups. It is noteworthy that in the public health centre of Kemi, the number of dentist posts was reduced from 11 to 7 in the early 1990s as a consequence of the economic recession at the time, and has thus far remained on the same level. Contemporaneously, the number of dentist posts was reduced from 10 to 9 in Tornio. In Kemi, the adoption of the new operational model has most certainly made it possible that, in addition to treating practically all children and adolescents under 18 years of age, the proportion of adult patients has also continuously increased (annual statistics of Kemi). Similar trend could also be seen in Tornio (annual statistics of Tornio).

The productivity function is seldom rectilinear. Most often increasing the resources does not endlessly increase the health outcome (Figure 11). In the present study, the reduction in the total number of caries treatment visits between the 1980 and 1992 cohorts at the age of 12 years was more intense in Tornio than in Kemi. Moreover, the decrease in total costs related to caries treatment was greater in Tornio in absolute monetary terms. However, the decrease in total costs at the age of 12 years was comparable in these towns, and the total costs were significantly lower in Kemi also in the 1992 cohort. One possible explanation is that the numbers of caries treatment visits at baseline, and consequently the costs, were remarkably higher in Tornio than in Kemi. The reduction in the number of visits is easier to achieve when the starting point is high compared with an already lower starting point. In Kemi, from the early 1990s onwards, the emphasis was put on transferring the latest scientific knowledge, e.g. on issues like early control of caries and work division, into the processes and everyday practices. These reforms, also advocated in the national practice guidelines on caries management and the legislative amendments concerning the provision of oral health care (e.g. Guideline of National Board of Health 1985, The Primary Health Care Act 746/1992, Eerola et al. 1998), had already been incorporated and implemented in the new operational model in Kemi, whereas in Tornio the reforms took place more gradually. Therefore, the changes in the 1992 cohort compared to the 1980 cohort were probably even more noticeable in Tornio. The overall decrease in caries occurrence in the Nordic countries in the 1970s and 1980s should also be noted when the results of the present study are considered.

The changing operational environment and the new knowledge of caries management brought about modifications in the processes of caries treatment in both towns. In Kemi, the processes were up-dated in 1992, 1996, 2000 and 2004. In Tornio, the examination of patient treatment histories and the unstructured interviews of staff revealed some changes in the treatment processes in the 1992 cohort compared to the 1980 cohort. The design of the present study did not represent a controlled clinical trial or cohort study; instead, it represented a practice-based analysis of operational models of caries treatment. The benefits and feasibility of the operational models were evaluated in real-life conditions. The results of the present study must not be interpreted too narrowly as

a comparison between the 1980 and 1992 cohorts. The main emphasis of comparisons is on the examining of contemporaneous cohorts.

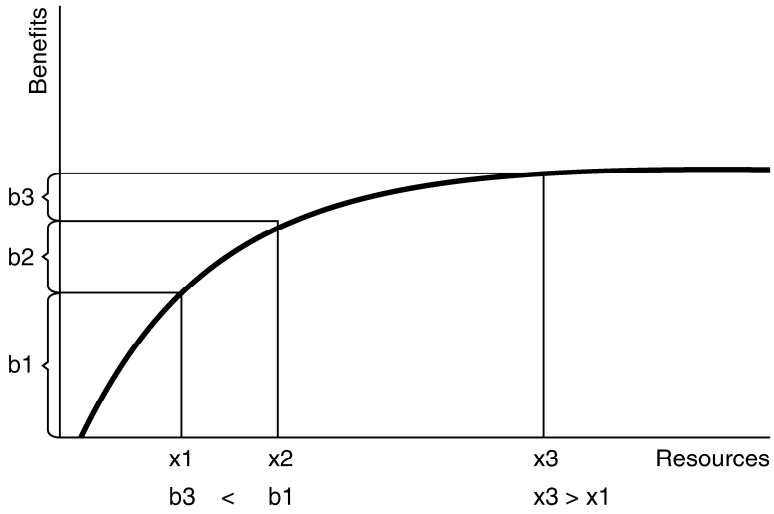

Figure 11 The productivity function

7.4.6 Implementation of work division

Some dental professionals may be hesitant to adopt new and effective research findings into clinical practice (Nakata 1990, Haines and Jones 1994, Fontana and Zero 2007). The implementation of scientific innovations has to be decisively planned and carried out. The series of figures "mean annual number of caries treatment visits" (Figure 7a-f) show that the new model of caries treatment was adopted well in Kemi. From its introduction in 1989 onward, the main responsibility for the care of pre-school children lay with dental hygienists. The unstructured interviews of the staff in Kemi revealed that at first the new model was met with scepticism and resistance but gradually was well accepted and appreciated. This observation is in line with experiences from Norway (Wang and Riordan 1995).

In the present study, the hourly salary of a dental hygienist was approximately 30% of the combined hourly salary of a dentist-assistant pair, which is in line with the results of some Scandinavian studies (Jokela and Pienihäkkinen 2003, Oscarson et al. 2003). The difference in salaries suggests that the costs of caries treatment could be reduced and cost-effectiveness improved by work division. The concept of an "efficiency wage" which would relate the costs of dentists and dental auxiliaries to their productivity has been brought up (e.g. Harris and Haycox 2001). The idea suggests that no savings will arise from substituting a dentist with a dental auxiliary if the dentist can make up the higher salary by treating patients more quickly. If work division is implemented rationally, the personnel is considered as a team and their roles and tasks carefully

planned. Therefore, the question of an efficiency wage as presented above is not of great importance. Improvement in cost-effectiveness is not necessarily achieved if dentists' duties are merely delegated to dental hygienist but no attention is paid to either the effectiveness and timing of treatment measures or the coordination of care delivery. It is more beneficial to develop practices in which the timing and targeting of prevention are correct and the work is carried out on an appropriate competence level. Preventive care decreases the need for more expensive restorative treatment, and therefore it is sensible to apply work division in providing prevention. Rational work division does not mean that the same procedures are carried out at less cost. Instead, it means that the dental professionals use their competencies in a way that provides maximum benefit for the whole system. The input of dental hygienists and preventive dental assistants has to be correctly distributed if it is also to be economically profitable. Dental hygienists are highly trained in health education, community dentistry and behavioural sciences, and they are motivated towards preventive dental care. Therefore, it is sensible to locate their contribution in early childhood, the time period known to affect later caries experience (Poulsen and Holm 1980, Seppä et al. 1989, O'Sullivan and Tinanoff 1996, Kowash et al. 2000, Li and Wang 2002, Skeie et al. 2006). Success in preventive care guarantees good quality, whereas restorative intervention is not necessarily treatment of good quality.

In the implementation of work division, it should be noted that performing high quality precise work continuously is very tiring both physically and mentally, especially when combined with the challenges of patient and staff interaction and strict timetables. To ensure wellbeing at work, the degree of difficulty of tasks should be varied for all dental professionals.

The public oral health care of children under 18 years of age is free-of-charge in Finland. Since no fees are collected, the costs incurred by families are closely related to the number of visits. To make the best use of each visit, work division should be applied flexibly. If a child has a dentist appointment it is sensible to carry out all necessary treatment during the same appointment rather than rigidly executing work division and possibly causing extra visits. Fluent coordination in care delivery is patient- and family-friendly good service, but it also saves a lot of time in the change-over of patients and in instrument maintenance.

A possible future development in the implementation of work division could be that specially trained preventive dental nurses would have an increased role in the treatment of pre-school children. Check-ups for small children and preventive treatment for all children and adolescents could be given by them. Preventive dental nurses could also serve as intermediaries between the oral health service and other actors in the every-day life of children. Their role could be that of a public relations person, and on the other hand, of an instructor in oral health care matters. A considerable part of the treatment

of school-aged children could be carried out by dental hygienists. In the 1995 cohort in Kemi, some indication of this kind of development could be seen. In Finland, the difference in the salaries of dental assistants and dental hygienists is currently quite small, but there is a substantial difference in their education. Therefore, attention should also be paid to how the skills of dental hygienists and assistants can be utilized most rationally. The role of the dentist in the treatment of children and adolescents could be more that of consultant and team manager. However, diagnosis and treatment planning should be based on the patient's clinical examination by a dentist.

7.4.7 Reaching out from the dental office

For success in oral health promotion, healthy habits should be adopted as early as possible. One of the main goals of the early risk-based concept was to create a positive attitude to oral health in families. This included establishing an active relationship already with parents-to-be: the importance of self-care and model learning were highlighted during the appointments.

In the present study, the patient treatment histories revealed that although the frequent preventive appointments gave the families extra support in taking care of dental health, the preventive programme was often disturbed or even terminated due to recurrent no-show incidents. The author has the feeling that the families who probably would have benefited the most from extra support, were the most difficult to reach. This is in accordance with the finding of Lahti et al. (2005) who studied the area-based variation of factors related to oral health among 6-year-olds in Kemi. Even though no association between areal socio-economic variables and oral health was found, areas were identified where oral health was poor according to measures such as percentage of caries-free (dmft=0) children, missed appointments, and uncooperative behaviour. The observation indicates the importance of interventions being sensitive to the capacity of the person and his/her social and economic circumstances (Kinnby et al. 1991, Wendt et al. 1995, Adair et al. 2004). Innovatively planned and performed prevention based on promotion of healthy lifestyles is needed to ensure positive development of dental health among schoolchildren and adolescents. Because of the complex nature of dental caries, opportunities to overcome such challenges may well lie outside the dental office. Co-operation between public oral health care and mother and child health care services could easily be enhanced in Finland. The systems are well established and virtually all families participate. It would be possible to intensify the integration of services provided by the parties for the benefit of both general and oral health. Moreover, there is a lot of potential in the school environment, and therefore the active part played by schools in the health care of children should be re-established. The goals and the messages of these and all other actors in the every-day life of children have to be uniform to support families in adopting favourable health-related lifestyles.

7.5 General discussion

The present study provides a first report on the cost-effectiveness of caries treatment of children and adolescents during the past decades in Finland. The evaluation of the operational models adds to the knowledge required in the planning and decision making of public oral health care services.

In Finland, most children and adolescents attend the public oral health services regularly; this also held true in Kemi and Tornio. Practically the whole birth cohorts were included in the study in both towns, and the subjects who fulfilled the inclusion criteria represented the vast majority of the cohorts. According to national statistics, the dental health of children in Kemi and Tornio was comparable to other Finns of their age. Thus, the present results can be generally used to benefit the Finnish public oral health care.

In Finland, the oral health records of patients in the public oral health care system provide a large data bank for studies. The present study indicates that the records offer an excellent opportunity for gaining longitudinal information on individual subjects, which in turn may be analyzed to obtain useful clinical and economic information. Although the patient treatment histories enable the acquiring of data from a long time period within a reasonable time, the manual collection of data is time-consuming, as in the case of the present study. Nowadays, the patient records in public oral health care are almost entirely in electronic form, but the data they provide are not analyzed to their full potential. One possible reason for this is that several different kinds of databases and programmes are used in dental care in Finland. Thus far, bringing together and analysing data from different sources has not been possible without laborious manoeuvres. The data-mining system appears to be one feasible methodology. Online determination of health parameters in two Finnish health centres has recently been reported (Korhonen et al. 2007). The usability of electronic patient information for various purposes would be greatly enhanced if the data could be transferred directly into statistical programmes. Information gained in this way would be helpful in the assessment and development of operations in public oral health care. The national archive which is currently being established may solve some of the difficulties in this field.

Recently, two major changes affecting the oral health care services took place in Finland: in December 2002, the age limits applied in Finnish dental care until then were disallowed, and in March 2005, a new Guaranteed Access to Treatment Act was implemented. The new laws are intended to allow the citizens more equal access to publicly funded oral health services, and emphasize the assessment of need for non-emergency treatment in patient admittance. The new regulations are likely to increase the demand for oral health care among adults. The first reports indicate that the assumption is valid (Suominen-Taipale and Widström 2006, Niiranen et al. 2008). The municipal resources have not, however, been increased along with the new requirements. Therefore, serious attention

should be paid to ensuring that preventive dental care is not overlooked in the pressure of more acute care needs. The significance of health promotion is accentuated in recent health care legislation (Primary Health Care Act 2005).

The current issues in health care; the insufficiency of public funding, the increase of health needs, differences in health status between population groups, and the changing population structure, also apply to oral health care. Both national and local health policy objectives call for innovative thinking in the provision of health services. Creating operational models and care processes which, instead of concentrating on single treatment measures, focus on promoting healthy lifestyles necessitates a multi-professional approach. Flexible work division within the health care sector is essential to execute such processes. However, addressing the great challenges of health care will require team work with commitment from all health care providers.

Expanding the concept of work division to team work leaves room for discussion and provides firmer ground for co-operation. One of the reasons why work division in dentistry has been debated quite vigorously in Finland in recent years may be that the meaning of "work division" has been understood in many ways, and the debate has often concentrated on the threats envisaged by the dental professionals. It might be beneficial if the discussion were based rather on the quality of dental service. Then, the focus would be on the ability of the public oral health care system to meet the requirements and expectations placed upon it. For successful team work, it is essential that the team members recognize the basic assignment of their organization and share the commitment to the values, visions and strategies of the organization. This calls for competence and determination in management. Regarding the work community as a team with the same goals would most certainly improve the overall quality of services, including increased work satisfaction.

When new strategies for delivering health care services are to be put into practice, the first consideration should be given to how they can be integrated into the care processes. The involvement of the personnel in the planning of the processes facilitates their adoption. One important aspect is that the facilities support the strategy. The processes should be well documented and the personnel, including new employees, fully familiarized with them. Continuing education with dialogue and encouragement are also essential. The goal is that the personnel are confident and self-conductive in applying the processes flexibly. Resistance to change is very human; the personnel should be allowed time to adopt the new strategies and processes. However, it is not merely the personnel who may be slow in applying the new strategies. It may be even more of a challenge to chief administrators to convince the public decision makers of the benefits and cost-effectiveness of a new strategy, however well demonstrated it may be. This may be the case especially if capital investments or new personnel resources are required. It

should be ensured that the facilities and the structure and competencies of the personnel support the operational model and the implementation of processes. It should not be the case that the processes are planned on the basis of the available personnel and facilities. The optimal personnel structure enables good economic and health results, but there is no general advice on its best possible composition. Factors such as the care needs of patients, the focus of field of treatment, the knowledge and abilities of the personnel, as well as their personal qualities, have an effect on designing practical and well-functioning operational models. On the other hand, if the competencies of all personnel are not used in a cost-effective manner, even the finest resources can be wasted. It is likely that also the patients and their families need both time and information to learn to appreciate individual examination intervals and treatment plans instead of annual check-up visits to the dentist. As tax-payers, they fund the service, and therefore matters related to the cost-effective delivery of services should be in their interest as well.

In public decision making, the cost-effectiveness of services will carry increasing weight. The resources are inevitably limited and making choices about their distribution is challenging. The decision makers and administrators need information on the new approaches to providing services. Rational use of resources requires economic evaluation of operational models. The results of evaluations make it possible to recognize ineffective practices and promote cost-effective approaches. Work division among dental professionals has been suggested as a mean to adjust public oral health service to the new operational environment, including the improved but skewed distribution of dental health of children and the care needs of the adult population, as well as economic requirements. The findings of the present study strongly indicate that adoption of the new operational model is to be recommended. The opinion of the author is that the result of the cost-effectiveness analysis in favour of the new operational model in Kemi was based on the early preventive approach utilizing work division. Early risk-based prevention and control of dental caries enables successful work division, and consequently, cost-effectiveness.

8. SUMMARY AND CONCLUSIONS

Aims of the study

The aims of the present study were to compare two models in the management of caries in children and adolescents in the public health centres of Kemi and Tornio in order to calculate and compare the cumulative costs of caries treatment of children, to investigate the association between the operational models and the cost-effectiveness, and to explore possible changes in cost-effectiveness between birth cohorts.

Material and methods

Data for the historic cohort study were collected from the files of the Public Health Centres. In Tornio, the cohorts born in 1980 or 1992 (n = 400), and in Kemi, the cohorts born in 1980, 1983 or 1986 (n = 600) represented the conventional operational model, whereas the cohorts 1989, 1992 and 1995 (n = 600) in Kemi represented the new model. The conventional model was based on high dentist input and annual examinations, whereas the new model was based on utilising the skill-mix of dental professionals and the early risk-based approach for control of dental caries, including screening for high caries risk. The cohorts and towns were compared in relation to dental health and resources used; the dental health by using the mean dmft or DMFT figures and the percentages of subjects having healthy dentitions at the ages 5 and 12 years, and the use of resources by using the mean cumulative numbers of caries treatment visits by providers and total cumulative costs related to caries treatment. Cumulative costs in relation to caries experience were assessed in cost-effectiveness analysis. The effect of cohort and town and their interaction term on dmft and DMFT were analyzed using logistic regression analysis for ordinal data. The effect of cohort and town and their interaction term on the number of visits and cumulative costs at ages 5 and 12 years were tested in the 1980 and 1992 cohorts using analysis of variance.

Results

The health of the subjects' deciduous dentitions improved in the younger cohorts compared with the 1980 cohorts in both towns, but in Kemi, the health outcome at pre-school age was significantly better than in Tornio. In permanent teeth, the DMFT scores developed in a similar way in Kemi and Tornio and remained on a stable and low level. In all cohorts, approximately half of the 12-year-olds and one third of the 15-year-olds had healthy teeth in these towns.

In general, the number of all caries treatment visits decreased substantially towards the younger birth cohorts. The decline was seen especially in the number of visits to dentists. The number of visits to dental hygienists rose slightly in both towns. In the comparison between the towns, no difference was found in the total number of visits at the age of five

years in the 1980 cohort, whereas in the 1992 cohort, pre-school children had paid more visits in Kemi than in Tornio. In the new operational model in Kemi, the former dentist visits of early childhood were to a great extent replaced by dental hygienist visits.The number of school-aged children's visits dropped in both towns. In the 1980 cohort, visits to dentists dominated, but in the 1992 cohort, dental hygienist visits accounted for half of the visits in Kemi and one third in Tornio by the age of 12 years.

The total cost of caries treatment by the age of 12 years decreased over time in both towns. In the 1992 cohort, costs related to caries treatment fell by 40% (176 €) in Kemi, and by 45% (259 €) in Tornio compared to the 1980 cohort. At the age of 12 years in the 1992 cohort, there was a 20% (59 €) difference in costs per treated subject in favour of Kemi. The operational model had a major effect on the cumulative costs of caries treatment in children.

The cost-effectiveness analysis of the two operational models of caries treatment revealed that, compared with the conventional model, the new operational model of early prevention and control of caries carried out by dental hygienists was less costly and resulted in better dental health at the age of 5 years and in at least as good dental health at the age of 12 years. The cost-effectiveness in caries treatment of children in the Public Health Centres had significantly improved during the study years.

Conclusions

A long-term follow-up setting and cumulative calculations indicate the timing of treatment and costs and enable evaluation of operational models.

The early risk-based approach to prevention and control of caries utilizing team work in the public oral health care of children can be both clinically effective and economically profitable.

The cost-effectiveness in caries treatment of children has improved considerably in the studied towns during the study years.

Computer software has to be generated to enable the efficient collection and analysis of longitudinal data to be used for economic studies in oral health care in Finland. Due to variations among health centres, the best operational models could then be identified and benchmarked to be applied elsewhere.

The findings of the present study support work division between dental professionals by applying the principles of team work.

REFERENCES

Act on Guaranteed Access to Treatment. DNo 1019/2004. Helsinki 2004.

Act on the Status and Rights of Patients. DNo 785/1992. Helsinki 1992.

Adair PM, Pine CM, Burnside G, Nicoll AD, Gillett A, Anwar S, Broukal Z, Chestnutt IG, Declerck D, Ping FX, Ferro R, Freeman R, Grant-Mills D, Gugushe T, Hunsrisakhun J, Irigoyen-Camacho M, Lo EC, Moola MH, Naidoo S, Nyandindi U, Poulsen VJ, Ramos-Gomez F, Razanamihaja N, Shahid S, Skeie MS, Skur OP, Splieth C, Soo TC, Whelton H, Young DW. Familial and cultural perceptions and beliefs of oral hygiene and dietary practices among ethnically and socio-economicall diverse groups. Community Dent Health 2004; 21: 102-111.

Alaluusua S, Renkonen OV. Streptococcus mutans establishment and dental caries experience in children from 2 to 4 years old. Scand J Dent Res 1983; 91: 453-457.

Alaluusua S. Transmission of mutans streptococci. Proc Finn Dent Soc 1991; 87: 443-447.

Alaluusua S, Malmivirta R. Early plaque accumulation - a sign for caries risk in young children. Community Dent Oral Epidemiol 1994; 22: 273-276.

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

Alanen P, Isokangas P, Gutmann K. Xylitol candies in caries prevention: results of a field study in Estonian children. Community Dent Oral Epidemiol 2000; 28: 218-224.

Alm A, Wendt LK, Koch G, Birkhed D. Oral hygiene and parent-related factors during early childhood in relation to approximal caries at 15 years of age. Caries Res 2008; 42: 28-36.

American Academy of Pediatric Dentistry. Clinical guideline on periodicity of examination, preventive dental services, anticipatory guidance/ counselling, and oral treatment for infants, children, and adolescents. American Academy of Pediatric Dentistry 2007. Available at: http:// www.aapd.org.

Antczak-Bouckoms AA, Tulloch JF, White BA, Capilouto EI. Methodological considerations in the analysis of cost effectiveness in dentistry. J Public Health Dent 1989; 49: 215-222.

Arrow P. Cost minimisation analysis of two occlusal caries preventive programmes. Community Dent Health 2000; 17: 85-91.

Bader JD, Shugars DA. What do we know about how dentists make caries-related treatment decisions? Community Dent Oral Epidemiol 1997; 25: 97-103.

Baltutis L, Morgan M. The changing role of dental auxiliaries: a literature review. Austr Dent J 1998; 43: 354-358.

Batalden P, Davidoff F. Teaching quality improvement: the devil is in the details. JAMA 2007; 298: 1059-1061.

Berkowitz RJ, Turner J, Green P. Maternal salivary levels of Streptococcus mutans and primary oral infection of infants. Arch Oral Biol 1981; 26: 147-149.

Birch S. The relative cost effectiveness of water fluoridation across communities: analysis of variations according to underlying caries levels. Community Dent Health 1990; 7: 3-10.

Birch S, Leake JL, Lewis DW. Economic issues in the development and use of practice guidelines: an application to resource allocation in dentistry. Community Dent Health 1996; 13: 70-75.

Bjarnason S, Finnbogason SY, Holbrook P, Köhler B. Caries experience in Icelandic 12-year-old urban children between 1984 and 1991. Community Dent Oral Epidemiol 1993; 21: 195-197.

Blair Y, Macpherson L, McCall D, McMahon A. Dental health of 5-year-olds following community-based oral health promotion in Glasgow, UK. Int J Paediatr Dent 2006; 16: 388-398.

Blinkhorn AS, Downer MC, Mackie IC, Bleasdale RS. Evaluation of a practice based preventive programme for adolescents. Community Dent Oral Epidemiol 1981; 9: 275-279.

Briggs AH, O'Brien BJ. The death of cost-minimization analysis? Health Econ 2001; 10: 179-184.

Brouwer WB, Niessen LW, Postma MJ, Rutten FF. Need for differential discounting of costs and health effects in cost effectiveness analyses. BMJ 2005; 331: 446-448.

Bryhni I, Ellingsen S, Naas S, Rolstad M, Sellaeg J, Wikstrand K, Överaas E. Behandlingskriterier for karies. Endringer over tid. En undersökelse blant offentlig ansatte tannleger i fem fylker i 1978 og 1983. Den Norske Tannlegeforenings Tidende 1985; 95: 693-698.

Buck D. Economic evaluation and dentistry. Dent Update 2000; 27: 66-73.

Caufield PW, Cutter GR, Dasanayake AP. Initial acquisition of mutans streptococci by infants: evidence for a discrete window of infectivity. J Dent Res 1993; 72: 37-45.

Chassin MR, Galvin RW. The urgent need to improve health care quality. Institute of Medicine National Roundtable on Health Care Quality. JAMA 1998; 280: 1000-1005.

Claxton K, Sculpher M, Culyer A, McCabe C, Briggs A, Akehurst R, Buxton M, Brazier J. Discounting and cost-effectiveness in NICE - stepping back to sort out a confusion. Health Econ 2006; 15: 1-4.

Crowley SJ, Campain AC, Morgan MV. An economic evaluation of a publicly funded dental prevention programme in regional and rural Victoria: an extrapolated analysis. Community Dent Health 2000; 17: 145-151.

Cunningham SJ. Economic evaluation of healthcare - is it important to us? Br Dent J 2000; 188: 250-254.

Demers M, Brodeur JM, Mouton C, Simard PL, Trahan L, Veilleux G. A multivariate model to predict caries increment in Montreal children aged 5 years. Community Dent Health 1992; 9: 273-281.

Deshpande A, Jadad AR. The impact of polyol-containing chewing gums on dental caries: A systematic review of original randomized controlled trials and observational studies. J Am Dent Assoc 2008; 139: 1602-1614.

Doessel DP. Cost-benefit analysis of water fluoridation in Townsville, Australia. Community Dent Oral Epidemiol 1985; 13: 19-22.

Doherty NJ, Crakes GM. Economic specification of cost estimates in dental programs. J Dent Res 1985; 64: 922-924.

Donabedian A. The quality of care. How can it be assessed? JAMA 1988; 260: 1743-1748.

Donabedian A. Quality and cost: choices and responsibilities. J Occup Med 1990; 32: 1167-1172.

Donaldson C, Forbes JF, Smalls M, Boddy FA, Stephen KW, McCall D. Preventive dentistry in a health centre: effectiveness and cost. Soc Sci Med 1986; 23: 861-868.

Donaldson C. Economic evaluation in dentistry: an ethical imperative? Dent Update 1998; 25: 260-264.

Downer MC, Blinkhorn AS, Attwood D. Effect of fluoridation on the cost of dental treatment among urban Scottish schoolchildren. Community Dent Oral Epidemiol 1981; 9: 112-116.

Downer MC. Caries prevalence in the United Kingdom. Int Dent J 1994; 44: 365-370.

Drummond MF, Stoddart GL, Torrance GW. Methods for the economic evaluation of health care programmes. Oxford: Oxford University Press,1997.

Dyer TA, Robinson PG. Exploring the social acceptability of skill-mix in dentistry. Int Dent J; 58: 173-180.

Edward S. Changes in caries diagnostic criteria over time related to the insertion of fillings. A comparative study. Acta Odontol Scand 1997; 55: 23-26.

Eerola A, Hausen H, Lahti S, Widström E (Eds.). Tutkimus- ja tarkastusvälit lasten ja nuorten suun terveydenhuollossa. Asiantuntijatyöryhmän raportti. Oral health examination intervals among Finnish children and adolescents. Report of an expert group. Abstract in English. National Research and Development Centre for Welfare and Health (STAKES), Report 225. Saarijärvi: Gummerus Kirjapaino Oy; 1998.

Espelid I, Tveit AB, Mejàre I, Sundberg H, Hallonsten AL. Restorative treatment decisions on occlusal caries in Scandinavia. Acta Odontol Scand 2001; 59: 21-27.

von der Fehr FR. Caries prevalence in the Nordic countries. Int Dent J 1994; 44: 371-378.

Fejerskov O. Strategies in the design of preventive programs. Adv Dent Res 1995; 9: 82-88.

Fejerskov O, Nyvad B. Is dental caries an infectious disease? Diagnostic and treatment consequences for the practitioner. In Schou L (Ed). Nordic Dentistry 2003 Yearbook. Copenhagen: Quintessence Publishing Co Ltd; 2003: 141-152.

Fontana M, Zero D. Bridging the gap in caries management between research and practice through education: the Indiana University experience. J Dent Educ 2007; 71: 579-591.

Forbes JF, Donaldson C. Economic appraisal of preventive dental techniques. Community Dent Oral Epidemiol 1987; 15: 63-66.

Gimmestad AL, Holst D, Fylkesnes K. Changes in restorative caries treatment in 15-year-olds in Oslo, Norway, 1979-1996. Community Dent Oral Epidemiol 2003; 31: 246-251.

Gisselsson H, Birkhed D, Björn AL. Effect of a 3-year professional flossing program with chlorhexidine gel on approximal caries and cost of treatment in preschool children. Caries Res 1994; 28: 394-399.

Goggin G, O'Mullane DM, Welton H. The effectiveness of a combined fluoride mouthrinse and fissure sealant programme. J Ir Dent Assoc 1991; 37: 38-40.

Gomez SS, Weber AA. Effectiveness of a caries preventive program in pregnant women and new mothers on their offspring. Int J Paediatr Dent 2001; 11: 117-122.

Gomez SS, Emilson CG, Weber AA, Uribe S. Prolonged effect of a mother-child caries preventive program on dental caries in the permanent 1st molars in 9 to 10-year-old children. Acta Odontol Scand 2007; 65: 271-274.

Griffin SO, Jones K, Tomar SL. An economic evaluation of community water fluoridation. J Public Health Dent 2001; 61: 78-86.

Grindefjord M, Dahllof G, Modeer T. Caries development in children from 2.5 to 3.5 years of age: a longitudinal study. Caries Res 1995; 29: 449-454.

Grytten J, Rongen G. Efficiency in provision of public dental services in Norway. Community Dent Oral Epidemiol 2000; 28: 170-176.

Haines R, Jones R. Implementing findings of research. BMJ 1994; 308: 1488-1492.

Hannerz H, Westerberg I. Economic assessment of a six-year project with extensive use of dental hygienists in the dental care of children: a pilot study. Community Dent Health 1996; 13: 40-43.

Harris RV, Haycox A. The role of team dentistry in improving access to dental care in the UK. Br Dent J 2001; 190: 353-356.

Haugejorden O, Birkeland JM. Analysis of the ups and downs of caries experience among Norwegian children aged five years between 1997 and 2003. Acta Odontol Scand 2005; 63: 115-122.

Haugejorden O, Magne Birkeland J. Ecological time-trend analysis of caries experience at 12 years of age and caries incidence from age 12 to 18 years: Norway 1985-2004. Acta Odontol Scand 2006; 64: 368-375.

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

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

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

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

Hausen H. Caries prediction. In: Fejerskov O, Kidd E (Eds.). Dental Caries. The disease and its clinical management. Oxford: Blackwell-Munksgaard; 2003: 393-411.

Hausen H, Seppä L, Poutanen R, Niinimaa A, Lahti S, Kärkkäinen S, Pietilä I. Noninvasive control of dental caries in children with active initial lesions. A randomized clinical trial. Caries Res 2007; 41: 384-391.

Heidmann J, Helm S, Helm T, Poulsen S. Changes in prevalence of approximal caries in 17-year-olds and related restorative treatment strategies over a 6-year period. Community Dent Oral Epidemiol 1988; 16: 167-170.

Helminen SE, Vehkalahti M, Murtomaa H, Kekki P, Ketomäki TM. Quality evaluation of oral health record-keeping for Finnish young adults. Acta Odontol Scand 1998; 56: 288-292.

Helminen SE, Vehkalahti M, Lammi R, Ketomäki TM, Murtomaa H. Dentists' decisions as to mode of preventive treatment in adolescents and young adults in Finland. Community Dent Health 1999; 16: 250-255.

Helminen SE, Vehkalahti M, Murtomaa H. Dentists' perception of their treatment practices versus documented evidence. Int Dent J 2002; 52: 71-74.

Helminen SK, Vehkalahti MM. Do check-up intervals correspond to caries indices in the free public dental service in Helsinki, Finland? Community Dent Health 2002; 19: 166-172.

Holbrook WP, de Soet JJ, de Graaff J. Prediction of dental caries in pre-school children. Caries Res 1993; 27: 424-430.

Holst A, Mårtensson I, Laurin M. Identification of caries risk children and prevention of caries in pre-school children. Swed Dent J 1997; 21: 185-191.

Honkala S, Honkala E, Tynjälä J, Kannas L. Use of xylitol chewing gum among Finnish schoolchildren. Acta Odontol Scand 1999; 57: 306-309.

Honkala S, Honkala E, Rimpelä A, Vikat A. Oral hygiene instructions and dietary sugar advice received by adolescents in 1989 and 1997. Community Dent Oral Epidemiol 2002; 30: 124-132.

Horowitz HS, Heifetz SB. Methods of assessing the cost-effectiveness of caries preventive agents and procedures. Int Dent J 1979; 29: 106-117.

Hugoson A, Koch G, Helkimo AN, Lundin SA. Caries prevalence and distribution in individuals aged 3-20 years in Jonkoping, Sweden, over a 30-year period (1973-2003). Int J Paediatr Dent 2008; 18: 18-26.

Isokangas P, Alanen P, Tiekso J, Mäkinen KK. Xylitol chewing gum in caries prevention: a field

study in children. J Am Dent Assoc 1988; 117: 315-320.

Isokangas P, Tiekso J, Alanen P, Mäkinen KK. Long-term effect of xylitol chewing gum on dental caries. Community Dent Oral Epidemiol 1989; 17: 200-203.

Jokela J. Kariesriskin arviointi ja prevention kohdentaminen alle kouluikäisillä. Assessment of caries risk and targeting of caries prevention among pre-school children. Summary in English. Thesis. Turun yliopiston julkaisuja, sarja C, osa 130. Turun yliopisto 1997.

Jokela J, Pienihäkkinen K. Economic evaluation of a risk-based caries prevention program in preschool children. Acta Odontol Scand 2003; 61: 110-114.

Kandelman D, Bär A, Hefti A. Collaborative WHO xylitol field study in French Polynesia. Caries Res 1988; 22: 55-62.

Kay EJ, Nuttall NM, Knill-Jones R. Restorative treatment thresholds and agreement in treatment decision-making. Community Dent Oral Epidemiol 1992; 20: 265-268.

Ketomäki TM, Luoma AR. Järjestelmällisen hammashuollon yksilöllisen tutkimusvälin yhteys kariekseen ja voimavarojen käyttöön. National Research and Development Centre for Welfare and Health (STAKES), Themes, 49. Vantaa 1993.

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

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

Klock B. Economic aspects of a caries preventive program. Community Dent Oral Epidemiol 1980; 8: 97-102.

Kolker JL, Damiano PC, Flach SD, Bentler SE, Armstrong SR, Caplan DJ, Kuthy RA, Warren JJ, Jones MP, Dawson DV. The cost-effectiveness of large amalgam and crown restorations over a 10-year period. J Public Health Dent 2006; 66: 57-63.

Komarov YuM, Korotkova AV, Massoud MRF, McGlynn E, Meyer GS, Notzon S. Health care quality glossary. Russian Federation – United States of America. 1999. Available at: http://www.ahrq.gov/qual/hcqgloss.pdf.

Korhonen M, Larmas M. Dental age and dental health determined longitudinally from patient records in three towns in Finland. Acta Odontol Scand 2003; 61: 105-109.

Korhonen M, Salo S, Suni J, Larmas M. Computed online determination of life-long mean index values for carious, extracted, and/or filled permanent teeth. Acta Odontol Scand 2007; 65: 214-218.

Kovari H. Ksylitolipurukumin käyttö päiväkodissa. The use of xylitol gum at day-care centres. Experimental follow-up study. Abstract in English. Thesis. Turun yliopiston julkaisuja, sarja C, osa 186. Turun yliopisto 2002.

Kowash MB, Pinfield A, Smith J, Curzon ME. Effectiveness on oral health of a long-term health education programme for mothers with young children. Br Dent J 2000; 188: 201-205.

Kowash MB, Toumba KJ, Curzon ME. Cost-effectiveness of a long-term dental health education program for the prevention of early childhood caries. Eur Arch Paediatr Dent 2006; 7: 130-135.

Källestål C, Norlund A, Söder B, Nordenram G, Dahlgren H, Petersson LG, Lagerlöf F, Axelsson S, Lingström P, Mejàre I, Holm AK, Twetman S. Economic evaluation of dental caries prevention: a systematic review. Acta Odontol Scand 2003; 61: 341-346.

Källestål C. The effect of five years' implementation of caries-preventive methods in Swedish high-risk adolescents. Caries Res 2005; 39: 20-26.

Kärkkäinen S, Seppä L, Hausen H. Dental check-up intervals and caries preventive measures received by adolescents in Finland. Community Dent Health 2001; 18: 157-161.

Köhler B, Bratthall D. Intrafamilial levels of Streptococcus mutans and some aspects of the bacterial transmission. Scand J Dent Res 1978; 86: 35-42.

Köhler B, Bratthall D, Krasse B. Preventive measures in mothers influence the establishment of the bacterium Streptococcus mutans in their infants. Arch Oral Biol 1983; 28: 225-231.

Köhler B, Andréen I, Jonsson B. The effect of caries-preventive measures in mothers on dental caries and the oral presence of the bacteria Streptococcus mutans and lactobacilli in their children. Arch Oral Biol 1984; 29: 879-883.

Köhler B, Andréen I, Jonsson B. The earlier the colonization by mutans streptococci, the higher the caries prevalence at 4 years of age. Oral Microbiol Immunol 1988; 3: 14-17.

Köhler B, Andréen I. Influence of caries-preventive measures in mothers on cariogenic bacteria and caries experience in their children. Arch Oral Biol 1994; 39: 907-911.

Lahti S, Hausen H. Yksilölliset tarkastusvälit tutkimusten valossa: katsaus kirjallisuuteen. Intervals for oral health examinations: review of the literature. In: Eerola A, Hausen H, Lahti S, Widström E (Eds.). Oral health examination intervals among Finnish children and adolescents. Report of an expert group. National Research and Development Centre for Welfare and Health (STAKES), Report 225. Saarijärvi: Gummerus Kirjapaino Oy; 1998: 35-49.

Lahti SM, Hausen HW, Widström E, Eerola A. Intervals for oral health examinations among Finnish children and adolescents: recommendations for the future. Int Dent J 2001; 51: 57-61.

Lahti S, Rusanen J, Kärkkäinen S, Kortelainen S, Hausen H. GIS and areal variation in dental caries - contribution of socio-economic factors among 6-year-olds in Kemi, Finland. Nordia geographical publications 2005; 33: 1-8.

Leskinen K, Salo S, Suni J, Larmas M. A practice-based study of the sealant treatment effectiveness in Finns. J Dent 2007; 35: 338-342.

Leverett DH, Handelman SL, Brenner CM, Iker HP. Use of sealants in the prevention and early treatment of carious lesions: cost analysis. J Am Dent Assoc 1983; 106: 39-42.

Lewis DW, Kay EJ, Main PA, Pharoah MG, Csima A. Dentists' stated restorative treatment thresholds and their restorative and caries depth decisions. J Public Health Dent 1996; 56: 176-181.

Li Y, Wang W. Predicting caries in permanent teeth from caries in primary teeth: an eight-year cohort study. J Dent Res 2002; 81: 561-566.

Linna M, Nordblad A, Koivu M. Technical and cost efficiency of oral health care provision in Finnish health centres. Soc Sci Med 2003; 56: 343-353.

Luoma H, Murtomaa H, Nuuja T, Nyman A, Nummikoski P, Ainamo J, Luoma AR. A simultaneous reduction of caries and gingivitis in a group of schoolchildren receiving chlorhexidine-fluoride applications. Results after 2 years. Caries Res 1978; 12: 290-298.

Läärä M, Widström E, Mattelmäki U, Meriläinen T. Hoitotoimenpiteet terveyskeskusten hammashuollossa. Dental treatments in municipal health centres in Finland. Summary in English. Stencils of the Ministry of Social Affairs and Health, 2000:17. Helsinki 2000.

Marthaler TM, O'Mullane DM, Vrbič V. The prevalence of dental caries in Europe 1990-1995. ORCA Saturday afternoon symposium 1995. Caries Res 1996; 30: 237-255.

Mattelmäki Ulla (Ed). Suun terveydenhuollon kehittämisprojekti 1998-2000. Loppuraportti. Final report on the oral health care development project. Summary in English. Stencils of the Ministry of Social Affairs and Health, 2001:13. Helsinki 2001.

Mattila ML, Rautava P, Sillanpää M, Paunio P. Caries in five-year-old children and associations with family-related factors. J Dent Res 2000; 79: 875-881.

Mattila ML, Rautava P, Paunio P, Ojanlatva A, Hyssälä L, Helenius H, Sillanpää M. Caries experience and caries increments at 10 years of age. Caries Res 2001; 35: 435-441.

Mattila ML, Rautava P, Ojanlatva A, Paunio P, Hyssälä L, Helenius H, Sillanpää M. Will the role of family influence dental caries among seven-year-old children? Acta Odontol Scand 2005a; 63: 73-84.

Mattila ML, Rautava P, Aromaa M, Ojanlatva A, Paunio P, Hyssälä L, Helenius H, Sillanpää M. Behavioural and demographic factors during early childhood and poor dental health at 10 years of age. Caries Res 2005b; 39: 85-91.

Mejàre I, Sundberg H, Espelid I, Tveit B. Caries assessment and restorative treatment thresholds reported by Swedish dentists. Acta Odontol Scand 1999; 57: 149-154.

Meriläinen T. Occurrence, polarisation and progression rate of dental decay. Thesis. Turun yliopiston julkaisuja, sarja D, osa 624. Turun yliopisto 2004.

Milén A, Laaksonen T, Halonen P. Coverage of public oral health services for young children in Finland. Proc Finn Dent Soc 1990; 86: 127-135.

Ministry of Social Affairs and Health. Health for All 2000, Revised strategy for cooperation. Publications of the Ministry of Social Affairs and Health 1993:9. Helsinki 1993.

Mooney GH, Drummond MF. Essentials of health economics: Part I - What is economics? Br Med J (Clin.Res.Ed) 1982; 285: 949-950.

Morgan MV, Crowley SJ, Wright C. Economic evaluation of a pit and fissure dental sealant and fluoride mouthrinsing program in two nonfluoridated regions of Victoria, Australia. J Public Health Dent 1998; 58: 19-27.

Mäkinen KK, Bennett CA, Hujoel PP, Isokangas PJ, Isotupa KP, Pape HR, Jr, Mäkinen PL. Xylitol chewing gums and caries rates: a 40-month cohort study. J Dent Res 1995; 74: 1904-1913.

Nakata M. Guest editorial: Transfer of innovations for advancement in dentistry. J Dent Res 1990; 69: 1543.

National Board of Health. Instructions about oral health promotion based on the Primary Health Care Act. DNo 7634/62/72. Helsinki 1972.

National Board of Health. Instructions for public oral health services in patients born after the year 1960. DNo 5200/02/85. Helsinki 1985.

National Institute for Clinical Excellence. Dental recall. Recall interval between routine dental examinations. Clinical guideline 19. National Institute for Clinical Excellence 2004. Available at: http://www.nice.org.uk/CG019NICEguideline.

Niessen LC, Douglass CW. Theoretical considerations in applying benefit-cost and cost-effectiveness analyses to preventive dental programs. J Public Health Dent 1984; 44: 156-168.

Niiranen T, Widström E, Niskanen T. Oral Health Care Reform in Finland - aiming to reduce inequity in care provision. BMC Oral Health 2008; 8: 3.

Nordblad A. Changes in epidemiologic pattern of dental caries in cohorts of schoolchildren in Espoo, Finland, during a 3-year period. Community Dent Oral Epidemiol 1986; 14: 126-127.

Nordblad A, Linna M, Luoma K, Niskanen T. Suun terveydenhuollon tuottavuuseroja terveyskeskuksissa 1992 tehokkuusluvuilla mitattuina. Differencies between cost efficiency scores in oral dental health care centres in Finland in 1992. Summary in English. J Soc Med 1996; 33: 307-314.

Nordblad A, Suominen-Taipale L, Rasilainen J, Karhunen T. Suun terveydenhuoltoa terveyskeskuksissa 1970-luvulta vuoteen 2000. Oral health care at health centres from the 1970s to the year 2000. Summary in English. National Research and Development Centre for Welfare and Health (STAKES), Report 278. Saarijärvi: Gummerus Kirjapaino Oy; 2004.

O'Rourke CA, Attrill M, Holloway PJ. Cost appraisal of a fluoride tablet programme to Manchester primary schoolchildren. Community Dent Oral Epidemiol 1988; 16: 341-344.

Oscarson N, Källestål C, Karlsson G. Methods of evaluating dental care costs in the Swedish public dental health care sector. Community Dent Oral Epidemiol 1998; 26: 160-165.

Oscarson N, Källestål C, Fjelddahl A, Lindholm L. Cost-effectiveness of different caries preventive measures in a high-risk population of Swedish adolescents. Community Dent Oral Epidemiol 2003; 31: 169-178.

O'Sullivan DM, Tinanoff N. The association of early dental caries patterns with caries incidence in preschool children. J Public Health Dent 1996; 56: 81-83.

Personal Data Act. DNo 523/1999. Helsinki 1999.

Petersen PE. The World Oral Health Report 2003: continuous improvement of oral health in the 21st century - the approach of the WHO Global Oral Health Programme. Community Dent Oral Epidemiol 2003; 31 Suppl 1: 3-23.

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

Pienihäkkinen K, Jokela J. Clinical outcomes of risk-based caries prevention in preschool-aged children. Community Dent Oral Epidemiol 2002; 30: 143-150.

Pienihäkkinen K, Jokela J, Alanen P. Risk-based early prevention in comparison with routine prevention of dental caries: a 7-year follow-up of a controlled clinical trial; clinical and economic aspects. BMC Oral Health 2005; 5: 2.

Pine CM, Curnow MM, Burnside G, Nicholson JA, Roberts AJ. Caries prevalence four years after the end of a randomised controlled trial. Caries Res 2007; 41: 431-436.

Pitts NB, Boyles J, Nugent ZJ, Thomas N, Pine CM. The dental caries experience of 5-year-old children in England and Wales. Surveys co-ordinated by the British Association for the Study of Community Dentistry in 2001/2002. Community Dent Health 2003; 20: 45-54.

Poulsen S, Holm AK. The relation between dental caries in the primary and permament dentition of the same individual. J Public Health Dent 1980; 40: 17-25.

Poutanen R, Lahti S, Seppä L, Tolvanen M, Hausen H. Oral health-related knowledge, attitudes, behavior, and family characteristics among Finnish schoolchildren with and without active initial caries lesions. Acta Odontol Scand 2007; 65: 87-96.

Powell LV. Caries prediction: a review of the literature. Community Dent Oral Epidemiol 1998; 26: 361-371.

Primary Health Care Act. DNo 66/1972. Helsinki 1972.

Primary Health Care Act. DNo 746/1992. Helsinki 1992.

Primary Health Care Act. DNo 928/2005. Helsinki 2005.

Quiñonez RB, Downs SM, Shugars D, Christensen J, Vann WF,Jr. Assessing cost-effectiveness of sealant placement in children. J Public Health Dent 2005; 65: 82-89.

Riordan PJ. Secular changes in treatment in a school dental service. Community Dent Health 1995; 12: 221-225.

Riordan PJ. Can organised dental care for children be both good and cheap? Community Dent Oral Epidemiol 1997; 25: 119-125.

Rolland E. Should dental hygienists replace dental directors in screening high-needs children? J Dent Hyg 2005; 79: 11.

Rose G. Sick individuals and sick populations. Int J Epidemiol 1985; 14: 32-38.

Rytömaa I, Järvinen V, Järvinen J. Variation in caries recording and restorative treatment plan among university teachers. Community Dent Oral Epidemiol 1979; 7: 335-339.

Savage MF, Lee JY, Kotch JB, Vann WF, Jr. Early preventive dental visits: effects on subsequent utilization and costs. Pediatrics 2004; 114: e418-e423.

Scheinin A, Mäkinen KK (Eds). Turku sugar studies I-XXI. Acta Odontol Scand 1975;33 Suppl 70:1-349.

Scheinin A, Banóczy J, Szöke J, Esztári I, Pienihäkkinen K, Scheinin U, Tiekso J, Zimmermann P, Hadas E. Collaborative WHO xylitol field studies in Hungary. I. Three-year caries activity in institutionalized children. Acta Odontol Scand 1985; 43: 327-347.

Sendi P, Gafni A, Birch S. Opportunity costs and uncertainty in the economic evaluation of health care interventions. Health Econ 2002; 11: 23-31.

Seppä L, Hausen H, Pöllänen L, Helasharju K, Kärkkäinen S. Past caries recordings made in Public Dental Clinics as predictors of caries prevalence in early adolescence. Community Dent Oral Epidemiol 1989; 17: 277-281.

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

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

Shaw CD, Kalo I. A background for national quality policies in health systems. World Health Organization. Regional Office for Europe. Copenhagen 2002.

Shiell A, Donaldson C, Mitton C, Currie G. Health economic evaluation. J Epidemiol Community Health 2002; 56: 85-88.

Simonsen RJ. Cost effectiveness of pit and fissure sealant at 10 years. Quintessence Int 1989; 20: 75-82.

Sintonen H. Terveystaloustieteen hammaslääketieteellisiä sovellutuksia. Summary in English. Applications of health economics in dental care. Proc Finn Dent Soc 1986; 82: 82-88.

Sintonen H, Pekurinen M, Linnakko E. Terveystaloustiede. Porvoo: WSOY; 1997.

Skeie MS, Raadal M, Strand GV, Espelid I. The relationship between caries in the primary dentition at 5 years of age and permanent dentition at 10 years of age – a longitudinal study. Int J Paediatr.Dent 2006; 16: 152-160.

Sköld L, Sundquist B, Eriksson B, Edeland C. Four-year study of caries inhibition of intensive Duraphat application in 11-15-year-old children. Community Dent Oral Epidemiol 1994; 22: 8-12.

Smith DH, Gravelle H. The practice of discounting in economic evaluations of healthcare interventions. Int J Technol Assess Health Care 2001; 17: 236-243.

Socialstyrelsen. Delegering inom barn och ungdomstandvården. Brev till landstingsförbundet och samtliga tandvårdschefer/tandvårdsdirektörer. Dnr 52-4134/1998. Stockholm 1998.

Sosialdepartementet. Helsepolitikken mot år 2000. National helseplan. St. meld. nr. 41 (1987-1988). Oslo 1988.

Spencer AJ, Davies M, Slade G, Brennan D. Caries prevalence in Australasia. Int Dent J 1994; 44: 415-423.

Splieth CH, Nourallah AW, König KG. Caries prevention programs for groups: out of fashion or up to date? Clin Oral Investig 2004; 8: 6-10.

Splieth CH, Flessa S. Modelling lifelong costs of caries with and without fluoride use. Eur J Oral Sci 2008; 116: 164-169.

Stephen KW, Campbell D. Caries reduction and cost benefit after 3 years of sucking fluoride tablets daily at school. A double-blind trial. Br Dent J 1978; 144: 202-206.

Suni J, Helenius H, Alanen P. Tooth and tooth surface survival rates in birth cohorts from 1965, 1970, 1975, and 1980 in Lahti, Finland. Community Dent Oral Epidemiol 1998; 26: 101-106.

Suominen-Taipale L, Widström E. Hammashoitouudistus ja hoitopalvelujen käyttö ja sisältö terveyskeskuksissa. Treatments provided in the Public Dental Service before and after a major health political reform. Summary in English. J Soc Med 2006; 43: 134-145.

Suonsivu K. Suun terveydenhuollon henkilöstörakenne ja toiminnan kehittäminen. Tehyn julkai-

susarja B: Selvityksiä 3/2001. Helsinki: Suun terveydenhoidon ammattiliitto ry, Tehy ry; 2000.

Takahashi N, Nyvad B. Caries ecology revisited: microbial dynamics and the caries process. Caries Res 2008; 42: 409-418.

Tenovuo J, Lehtonen OP, Aaltonen AS. Caries development in children in relation to the presence of mutans streptococci in dental plaque and of serum antibodies against whole cells and protein antigen I/II of Streptococcus mutans. Caries Res 1990; 24: 59-64.

Tenovuo J, Häkkinen P, Paunio P, Emilson CG. Effects of chlorhexidine-fluoride gel treatments in mothers on the establishment of mutans streptococci in primary teeth and the development of dental caries in children. Caries Res 1992; 26: 275-280.

Thenisch NL, Bachmann LM, Imfeld T, Leisebach Minder T, Steurer J. Are mutans streptococci detected in preschool children a reliable predictive factor for dental caries risk? A systematic review. Caries Res 2006; 40: 366-374.

Twetman S. Antimicrobials in future caries control? A review with special reference to chlorhexidine treatment. Caries Res 2004; 38: 223-229.

Utriainen P, Widström E. Economic aspects of dental care in Finnish health centers. Community Dent Oral Epidemiol 1990; 18: 235-238.

Utriainen P. Hammashuollon tuottavuus terveyskeskuksissa. Productivity in dental care provided by Finnish health centres. Summary in English. Thesis. University of Kuopio. Helsinki: Kuntaliiton painatuskeskus; 1994.

Varsio S, Vehkalahti M. Evaluation of preventive treatment by risk of caries among 13-year-olds. Community Dent Oral Epidemiol 1996; 24: 277-281.

Vehkalahti M, Helminen S. Suun terveydenhuollon tuottavuus terveyskeskuksessa. Productivity of public oral health care. Summary in English. J Soc Med 1992; 29: 173-180.

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

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

Vehmanen R. An economic evaluation of two caries preventive methods. Thesis. Turun yliopisto 1993.

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

Wang N, Marstrander P, Holst D, Övrum L, Dahle T. Extending recall intervals - effect on resource consumption and dental health. Community Dent Oral Epidemiol 1992; 20: 122-124.

Wang NJ. Efficiency in the public dental service for children in Norway. Change in use of dental hygienists and recall intervals. Thesis. University of Oslo 1994a.

Wang NJ. Productivity in dental care for children. Factors influencing the time spent delivering dental care. Community Dent Health 1994b; 11: 227-232.

Wang NJ. Use of dental hygienists and returns to scale in child dental care in Norway. Community Dent Oral Epidemiol.1994c; 22: 409-414.

Wang NJ. Variation in clinical time spent by dentist and dental hygienist in child dental care. Acta Odontol Scand 1994d; 52: 280-289.

Wang NJ, Holst D. Individualizing recall intervals in child dental care. Community Dent Oral Epidemiol 1995; 23: 1-7.

Wang NJ, Riordan PJ. Recall intervals, dental hygienists and quality in child dental care. Community Dent Oral Epidemiol 1995; 23: 8-14.

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

Wang NJ. Caries preventive methods in child dental care reported by dental hygienists, Norway, 1995 and 2004. Acta Odontol Scand 2005; 63: 330-334.

Weinstein MC. Economic assessments of medical practices and technologies. Med Decis Making 1981; 1: 309-330.

Weintraub JA, Stearns SC, Burt BA, Beltran E, Eklund SA. A retrospective analysis of the cost-effectiveness of dental sealants in a children's health center. Soc Sci Med 1993; 36: 1483-1493.

Wendt LK, Svedin CG, Hallonsten AL, Larsson IB. Infants and toddlers with caries. Mental health, family interaction, and life events in infants and toddlers with caries. Swed Dent J 1995; 19: 17-27.

Wendt LK, Hallonsten AL, Koch G, Birkhed D. Analysis of caries-related factors in infants and toddlers living in Sweden. Acta Odontol Scand 1996; 54: 131-137.

Wendt LK, Carlsson E, Hallonsten AL, Birkhed D. Early dental caries risk assessment and prevention in pre-school children: evaluation of a new strategy for dental care in a field study. Acta Odontol Scand 2001; 59: 261-266.

Werner CW, Pereira AC, Eklund SA. Cost-effectiveness study of a school-based sealant program. ASDC J Dent Child 2000; 67: 93-7, 82.

Westerberg I. Produktion, produktivitet och kostnader i svensk tandvård. Production, productivity and cost in Swedish dental care. Summary in English. Thesis. Linköping Studies in Art and Science. Rapport 15. Linköping 1987.

Widström E, Erkinantti J. Erillisselvitys suun terveydenhuollon kustannuksista ja tuotoksista terveyskeskuksissa vuonna 2003. Statistical information on costs and output of dental care in the Finnish Public Dental Service in 2003. National Research and Development Centre for Welfare and Health (STAKES), Themes 30. Helsinki 2004.

Widström E, Linna M, Niskanen T. Productive efficiency and its determinants in the Finnish Public Dental Service. Community Dent Oral Epidemiol 2004; 32: 31-40.

Widström E, Ekman A, Aandahl LS, Pedersen MM, Agustsdottir H, Eaton KA. Developments in oral health policy in the Nordic countries since 1990. Oral Health Prev Dent 2005; 3: 225-235.

World Health Organization. Oral Health Profiles for Countries Listed According to WHO Regions. Region Europe. Available at: http://www.whocollab.od.mah.se/ euro.html. (read February 22, 2007).

Yule BF, Van Amerongen BM, Van Schaik MC. The economics and evaluation of dental care and treatment. Soc Sci Med 1986; 22: 1131-1139.

Zavras AI, Edelstein BL, Vamvakidis A. Health care savings from microbiological caries risk screening of toddlers: a cost estimation model. J Public Health Dent 2000; 60: 182-188.

Zero D, Fontana M, Lennon AM. Clinical applications and outcomes of using indicators of risk in caries management. J Dent Educ 2001; 65: 1126-1132.

Zickert I, Emilson CG, Krasse B. Effect of caries preventive measures in children highly infected with the bacterium Streptococcus mutans. Arch Oral Biol 1982; 27: 861-868.

Öhrn K, Crossner CG, Börgesson I, Taube A. Accuracy of dental hygienists in diagnosing dental decay. Community Dent Oral Epidemiol 1996; 24: 182-186.

APPENDIX

Table A1 Percentage of subjects having healthy dentitions (dmft or DMFT = 0) at the age of 5, 9, 12 and 15 years by cohort and town

Age 5	**Kemi**	**dmft=0**	**Tornio**	
Cohort	N	**%**	N	**%**
1980	198	55.6	200	37.0
1983	198	63.1		
1986	199	65.8		
1989	191	68.6		
1992	194	80.4	200	67.0
1995	194	81.4		

Age 9	**Kemi**	**DMFT=0**	**Tornio**	
Cohort	N	**%**	N	**%**
1980	200	67.0	200	65.5
1983	200	62.5		
1986	200	80.5		
1989	200	71.5		
1992	200	77.0	200	75.0
1995	178	75.3		

Age 12	**Kemi**	**DMFT=0**	**Tornio**	
Cohort	N	**%**	N	**%**
1980	200	52.0	200	45.0
1983	200	47.5		
1986	200	64.5		
1989	200	54.0		
1992	139	55.4	200	47.5

Age 15	**Kemi**	**DMFT=0**	**Tornio**	
Cohort	N	**%**	N	**%**
1980	200	34.0	200	25.0
1983	200	29.0		
1986	200	36.0		
1989	200	27.5		

Table A2 The number of dmf or DMF teeth (Mean, standard deviation (SD) at the age of 5, 9, 12 and 15 years by cohort and town

Age 5	**Kemi**	**dmft**		**Tornio**	**dmft**	
Cohort	N	Mean	(SD)	N	Mean	(SD)
1980	198	2.2	(3.4)	200	2.9	(3.5)
1983	198	1.5	(2.8)			
1986	199	1.3	(2.5)			
1989	191	1.4	(2.8)			
1992	194	0.8	(1.9)	200	1.4	(2.8)
1995	194	0.6	(1.6)			

Age 9	**Kemi**	**DMFT**		**Tornio**	**DMFT**	
Cohort	N	Mean	SD	N	Mean	SD
1980	200	0.6	(1.1)	200	0.7	(1.2)
1983	200	0.8	(1.2)			
1986	200	0.4	(1.0)			
1989	200	0.5	(1.0)			
1992	200	0.4	(0.8)	200	0.5	(0.9)
1995	178	0.5	(1.0)			

Age 12	**Kemi**	**DMFT**		**Tornio**	**DMFT**	
Cohort	N	Mean	(SD)	N	Mean	SD
1980	200	1.2	(1.7)	200	1.7	(2.3)
1983	200	1.3	(1.6)			
1986	200	1.1	(2.2)			
1989	200	1.1	(1.7)			
1992	191	1.0	(1.6)	200	1.3	(1.6)

Age 15	**Kemi**	**DMFT**		**Tornio**	**DMFT**	
Cohort	N	Mean	(SD)	N	Mean	(SD)
1980	198	2.2	(2.7)	200	2.9	(3.1)
1983	197	2.4	(2.5)			
1986	196	2.4	(3.5)			
1989	160	2.5	(2.9)			

Table A3 Cumulative number of caries treatment visits per subject by provider, cohort and town. Mean, standard deviation (SD) and statistical significance (p) (analysis of variance: town and cohort effect and interaction term town*cohort (t*c) and Student's t-test)

Visits to dentists							**Kemi vs.**		**ANOVA**	
Age 5	**Kemi**			**Tornio**			**Tornio**		Significance	
Cohort	N	Mean	(SD)	N	Mean	(SD)	t-test	Town	Cohort	t*c
1980	200	2.3	(2.7)	200	5.2	(3.7)	< 0.001			
1983	200	1.9	(2.0)							
1986	200	1.8	(2.4)							
1989	200	1.1	(2.1)							
1992	200	0.7	(1.7)	200	2.0	(2.5)	< 0.001			0.027
1995	200	1.2	(1.9)							
Age 9	**Kemi**			**Tornio**			**Kemi vs. Tornio**			
Cohort	N	Mean	(SD)	N	Mean	(SD)	t-test			
1980	200	10.3	(6.8)	200	15.3	(7.5)	< 0.001			
1983	200	10.2	(5.9)							
1986	200	8.1	(5.5)							
1989	200	6.5	(4.7)							
1992	200	5.4	(4.0)	200	7.6	(4.7)	< 0.001			
1995	200	4.5	(3.8)							
Age 12	**Kemi**			**Tornio**			**Kemi vs. Tornio**		**ANOVA** Significance	
Cohort	N	Mean	(SD)	N	Mean	(SD)	t-test	Town	Cohort	t*c
1980	200	15.0	(8.3)	200	21.4	(9.7)	< 0.001			
1983	200	13.4	(7.0)							
1986	200	11.5	(7.1)							
1989	200	9.4	(5.9)							
1992	200	7.6	(5.1)	200	11.0	(5.9)	< 0.001	< 0.001	< 0.001	0.642
Age 15	**Kemi**			**Tornio**			**Kemi vs. Tornio**			
Cohort	N	Mean	(SD)	N	Mean	(SD)	t-test			
1980	200	18.9	(9.8)	200	26.1	(10.8)	< 0.001			
1983	200	16.8	(8.1)							
1986	200	14.6	(9.1)							
1989	200	12.1	(7.2)							

Table A4 Cumulative number of caries treatment visits per subject by provider, cohort and town. Mean, standard deviation (SD) and statistical significance (p) (analysis of variance: town and cohort effect and interaction term town*cohort (t*c) and Student's t-test)

Visits to dental hygienists							**Kemi vs.**	**ANOVA**		
Age 5	**Kemi**			**Tornio**			**Tornio**	Significance		
Cohort	N	Mean	(SD)	N	Mean	(SD)	t-test	Town	Cohort	t*c
1980	200	3.8	(1.6)	200	1.4	(0.8)	< 0.001			
1983	200	3.8	(1.5)							
1986	200	4.4	(1.6)							
1989	200	5.1	(1.7)							
1992	200	5.5	(1.4)	200	2.5	(1.1)	< 0.001	< 0.001	< 0.001	0.272
1995	200	4.8	(1.6)							
							Kemi vs.			
Age 9	**Kemi**			**Tornio**			**Tornio**			
Cohort	N	Mean	(SD)	N	Mean	(SD)	t-test			
1980	200	5.0	(2.7)	200	2.5	(1.4)	< 0.001			
1983	200	4.4	(1.8)							
1986	200	6.0	(2.1)							
1989	200	6.7	(2.4)							
1992	200	6.8	(2.2)	200	3.8	(1.5)	< 0.001			
1995	200	6.7	(2.6)							
							Kemi vs.	**ANOVA**		
Age 12	**Kemi**			**Tornio**			**Tornio**	Significance		
Cohort	N	Mean	(SD)	N	Mean	(SD)	t-test	Town	Cohort	t*c
1980	200	6.2	(3.4)	200	3.9	(2.1)	< 0.001			
1983	200	5.2	(2.0)							
1986	200	7.0	(2.6)							
1989	200	7.5	(2.8)							
1992	200	7.8	(2.8)	200	4.7	(2.2)	< 0.001	< 0.001	< 0.001	0.459
							Kemi vs.			
Age 15	**Kemi**			**Tornio**			**Tornio**			
Cohort	N	Mean	(SD)	N	Mean	(SD)	t-test			
1980	200	7.6	(3.8)	200	4.7	(2.2)	< 0.001			
1983	200	6.3	(2.5)							
1986	200	8.0	(3.3)							
1989	200	8.7	(3.3)							

Table A5 Total number of caries treatment visits per subject by cohort and town. Mean, standard deviation (SD) and statistical significance (p) (analysis of variance: town and cohort effect and interaction term town*cohort (t*c) and Student's t-test)

Total number of visits												
Age 5	**Kemi**			1980 vs. cohort	**Tornio**			1980 vs. 1992	**Kemi vs. Tornio**		**ANOVA** Significance	
Cohort	N	Mean	(SD)	t-test	N	Mean	(SD)	t-test	t-test	Town	Cohort	t*c
1980	200	6.1	(3.1)		200	6.6	(3.6)		0.104			
1983	200	5.7	(2.4)									
1986	200	6.2	(3.0)									
1989	200	6.2	(2.8)									
1992	200	6.2	(2.5)	0.106	200	4.6	(2.5)	< 0.001	< 0.001			< 0.001
1995	200	6.0	(2.8)									
Age 9	**Kemi**			1980 vs. cohort	**Tornio**			1980 vs. 1992	**Kemi vs. Tornio**			
Cohort	N	Mean	(SD)	t-test	N	Mean	(SD)	t-test	t-test			
1980	200	15.3	(7.2)		200	17.8	(7.4)		< 0.001			
1983	200	14.6	(6.2)									
1986	200	14.1	(6.2)									
1989	200	13.1	(6.0)									
1992	200	12.2	(5.3)	< 0.001	200	11.4	(4.9)	< 0.001	0.117			
1995	200	11.2	(5.6)									
Age 12	**Kemi**			1980 vs. cohort	**Tornio**			1980 vs. 1992	**Kemi vs. Tornio**		**ANOVA** Significance	
Cohort	N	Mean	(SD)	t-test	N	Mean	(SD)	t-test	t-test	Town	Cohort	t*c
1980	200	21.2	(9.6)		200	25.3	(9.6)		< 0.001			
1983	200	18.6	(7.7)									
1986	200	18.5	(8.4)									
1989	200	16.9	(7.5)									
1992	200	15.4	(6.8)	< 0.001	200	15.7	(6.5)	< 0.001	0.467			< 0.001
Age 15	**Kemi**			1980 vs. cohort	**Tornio**			1980 vs. 1992	**Kemi vs. Tornio**			
Cohort	N	Mean	(SD)	t-test	N	Mean	(SD)	t-test	t-test			
1980	200	26.5	(11.4)		200	30.3	(10.7)		< 0.001			
1983	200	23.1	(9.1)									
1986	200	22.6	(11.0)									
1989	200	20.7	(9.3)	< 0.001								

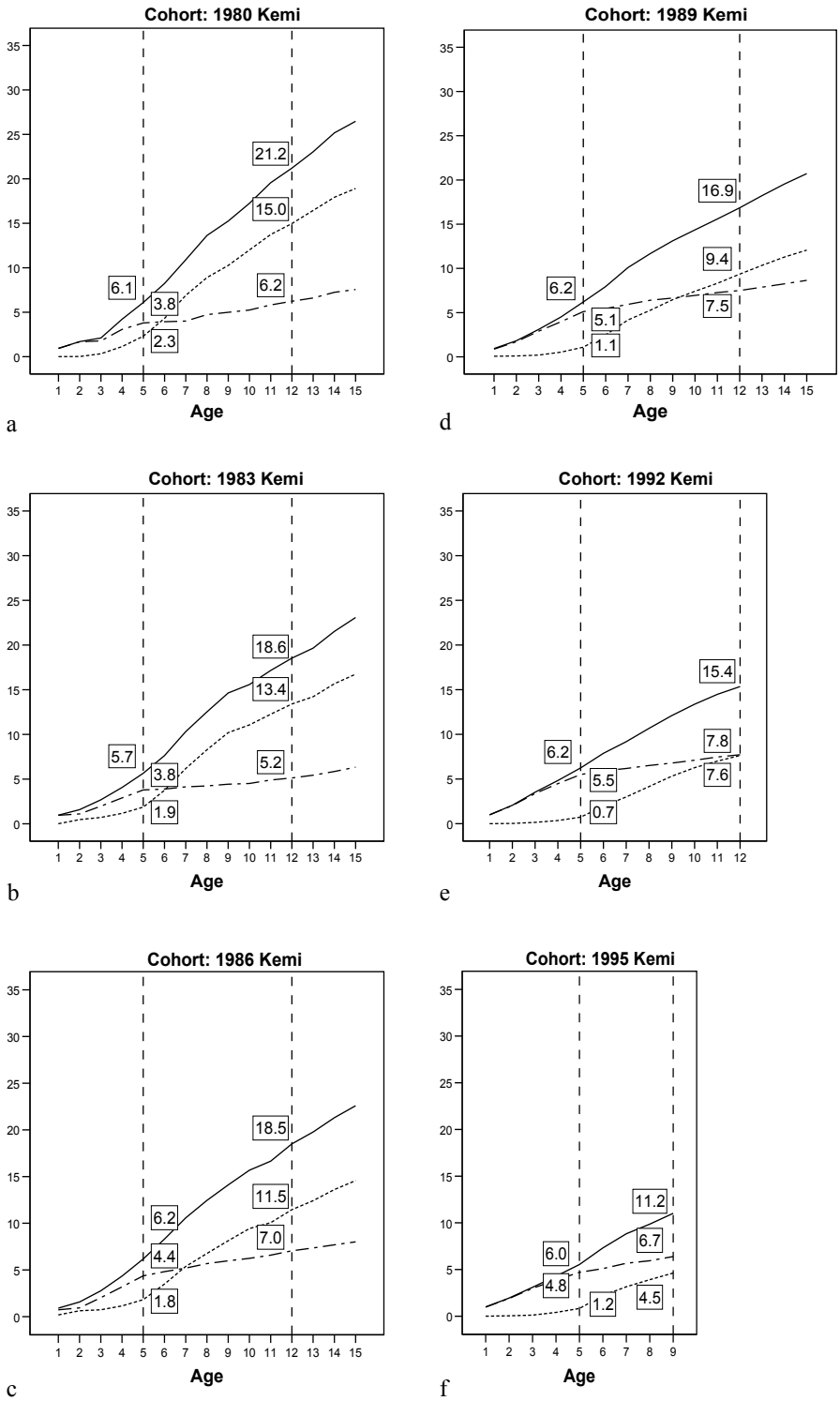

Figure A1a-f Cumulative mean numbers of caries treatment visits by provider and cohort in Kemi (in all figures: solid line = total visits, dotted line= visits to dentist and solid-dot-solid line= visits to dental hygienist)

Table A6 Cumulative number of all oral health care visits per subject including no-show incidents by cohort in Kemi. Range, mean and standard deviation (SD)

Age 5

Cohort	N	Range	Mean	(SD)
1980	200	20.0	6.8	(3.3)
1983	200	16.3	6.9	(3.0)
1986	200	19.0	7.0	(3.4)
1989	200	20.0	7.2	(3.0)
1992	200	20.0	7.1	(2.8)
1995	200	19.0	6.8	(3.2)

Age 9

Cohort	N	Range	Mean	(SD)
1980	200	62.0	18.9	(9.4)
1983	200	42.0	19.4	(8.5)
1986	200	43.0	18.4	(8.4)
1989	200	38.0	16.8	(7.5)
1992	200	40.0	16.5	(8.0)
1995	200	49.7	15.7	(8.5)

Age 12

Cohort	N	Range	Mean	(SD)
1980	200	92.7	30.2	(16.5)
1983	200	81.3	28.8	(14.2)
1986	200	67.0	28.9	(14.8)
1989	200	70.0	26.3	(12.5)
1992	200	72.7	25.5	(13.4)

Age 15

Cohort	N	Range	Mean	(SD)
1980	200	110.7	37.5	(19.0)
1983	200	99.3	37.7	(18.6)
1986	200	89.0	37.1	(19.9)
1989	200	91.0	34.6	(16.6)

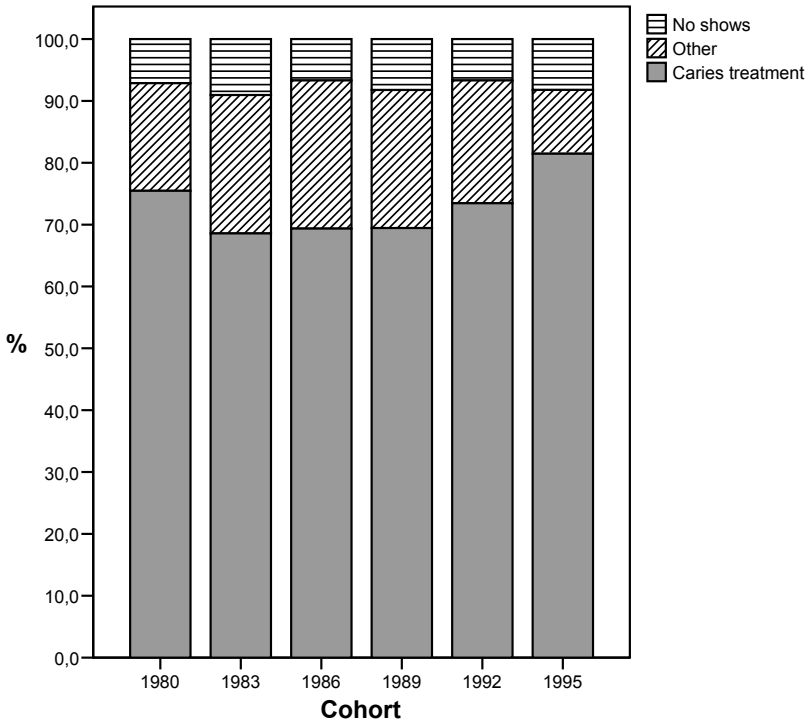

Figure A2 Proportion of caries treatment, other (e.g. orthodontic, surgery, trauma) and no-show visits of all oral health care visits by cohort in Kemi (in the 1980, 1983, 1986 and 1989 cohorts up to 15 years of age, in the 1992 up to 12 years of age and in the 1995 cohort up to 9 years of age)

Table A7 Total cumulative costs related to caries treatment visits per subject by cohort and town. Mean, standard deviation (SD) and statistical significance (p) (at age 12: analysis of variance: town and cohort effect and interaction term town*cohort (t*c), at age 15: Student's t-test)

Total costs

Age 5	**Kemi**			**Tornio**		
Cohort	N	Mean	(SD)	N	Mean	(SD)
1980	200	90	(70)	200	145	(94)
1983	200	78	(53)			
1986	200	82	(64)			
1989	200	69	(57)			
1992	200	64	(47)	200	72	(64)
1995	200	63	(54)			

Age 9	**Kemi**			**Tornio**		
Cohort	N	Mean	(SD)	N	Mean	(SD)
1980	200	304	(175)	200	414	(192)
1983	200	298	(152)			
1986	200	257	(145)			
1989	200	220	(130)			
1992	200	192	(110)	200	225	(121)
1995	200	174	(110)			

							ANOVA		
Age 12	**Kemi**			**Tornio**			Significance		
Cohort	N	Mean	(SD)	N	Mean	(SD)	Town	Cohort	t*c
1980	200	435	(221)	200	577	(247)			
1983	200	386	(184)						
1986	200	351	(191)						
1989	200	301	(161)						
1992	200	259	(143)	200	318	(154)	<0.001	<0.001	0.118

Age 15	**Kemi**			1980 vs. cohort
Cohort	N	Mean	(SD)	t-test
1980	200	547	(261)	
1983	200	482	(214)	0.011
1986	200	439	(247)	<0.001
1989	200	380	(200)	<0.001

Table A8 Dentist-assistant pair -based cumulative costs related to caries treatment visits per subject by cohort and town. Mean, standard deviation (SD) and statistical significance (p) (at age 15: Student's t-test)

Costs of dentist-assistant pair						
Age 5	**Kemi**			**Tornio**		
Cohort	N	Mean	(SD)	N	Mean	(SD)
1980	200	59	(70)	200	134	(95)
1983	200	48	(52)			
1986	200	47	(62)			
1989	200	28	(55)			
1992	200	19	(43)	200	52	(65)
1995	200	22	(49)			

Age 9	**Kemi**			**Tornio**		
Cohort	N	Mean	(SD)	N	Mean	(SD)
1980	200	264	(175)	200	394	(193)
1983	200	262	(151)			
1986	200	209	(141)			
1989	200	166	(122)			
1992	200	137	(103)	200	194	(121)
1995	200	119	(98)			

Age 12	**Kemi**			**Tornio**		
Cohort	N	Mean	(SD)	N	Mean	(SD)
1980	200	385	(213)	200	550	(249)
1983	200	345	(181)			
1986	200	294	(182)			
1989	200	240	(150)			
1992	200	196	(132)	200	281	(151)

Age 15				1980 vs. cohort
Cohort	N	Mean	(SD)	t-test
1980	200	487	(252)	
1983	200	431	(207)	0.036
1986	200	375	(233)	<0.001
1989	200	310	(186)	<0.001

Table A9 Dental hygienist -based cumulative costs related to caries treatment visits per subject by cohort and town. Mean, standard deviation (SD) and statistical significance (p) (at age 15: Student's t-test)

Costs of dental hygienists						
Age 5	**Kemi**			**Tornio**		
Cohort	N	Mean	(SD)	N	Mean	(SD)
1980	200	31	(13)	200	11	(6)
1983	200	30	(12)			
1986	200	35	(12)			
1989	200	41	(13)			
1992	200	45	(12)	200	20	(8)
1995	200	41	(13)			
Age 9	**Kemi**			**Tornio**		
Cohort	N	Mean	(SD)	N	Mean	(SD)
1980	200	40	(22)	200	20	(11)
1983	200	36	(15)			
1986	200	48	(17)			
1989	200	54	(19)			
1992	200	55	(18)	200	31	(12)
1995	200	55	(21)			
Age 12	**Kemi**			**Tornio**		
Cohort	N	Mean	(SD)	N	Mean	(SD)
1980	200	50	(28)	200	27	(15)
1983	200	41	(16)			
1986	200	57	(21)			
1989	200	60	(23)			
1992	200	63	(23)	200	37	(16)

Age 15				1980 vs. cohort
Cohort	N	Mean	(SD)	t-test
1980	200	61	(30)	
1983	200	51	(20)	0.190
1986	200	64	(27)	0.054
1989	200	70	(26)	0.003

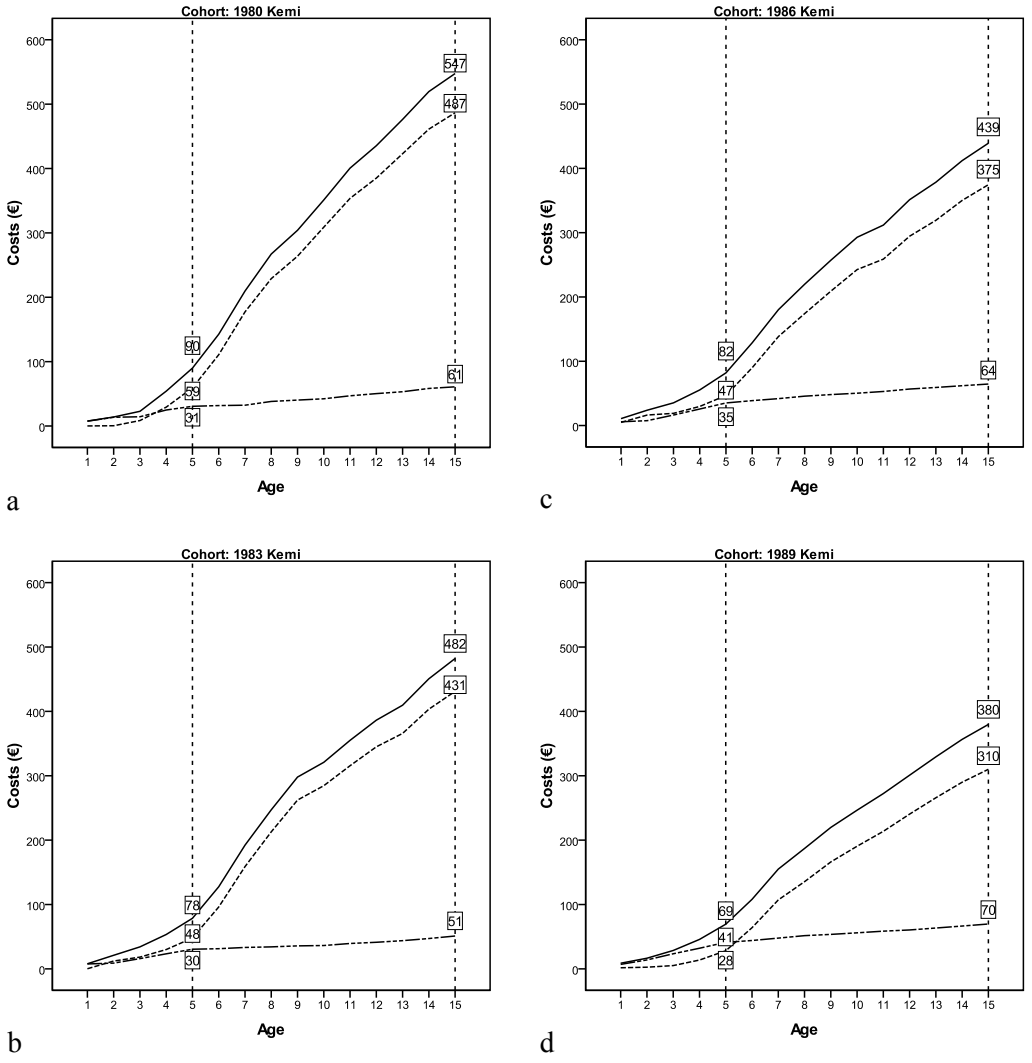

Figure A3a-d Cumulative costs related to caries treatment visits (total and provider-based) by cohort in Kemi (in all figures: solid line= total costs, dotted line= costs based on dentist-assistant pair and solid-dot-solid line = costs based on dental hygienist)