Institute of Dentistry, University of Helsinki
Department of Oral and Maxillofacial Diseases, Helsinki University
Central Hospital, Finland

Arresting occlusal enamel caries lesions with pit and fissure sealants

Sari Kervanto-Seppälä

Academic Dissertation

To be publicly discussed by the permission of the Faculty of Medicine,
University of Helsinki, in Auditorium 2, Biomedicum, Helsinki,
on March 6th 2009, at 12 noon

Helsinki 2009

Supervised by

Professor Eero Kerosuo, DDS, PhD
Department of Clinical Odontology
Faculty of Medicine
University of Tromso, Norway

Professor Jukka H. Meurman, MD, DDS, PhD
Institute of Dentistry, University of Helsinki, and
Department of Oral and Maxillofacial Diseases
Helsinki University Central Hospital
Helsinki, Finland

Reviewed by

Professor Sven Poulsen, Dr. Odont, PhD
Department of Pediatric Dentistry
Faculty of Health Sciences
University of Aarhus, Denmark

Docent Kaisu Pienihäkkinen, DDS, PhD
Institute of Dentistry
University of Turku, Finland

Opponent

Docent Helena Forss, DDS, PhD
Oral and Dental Diseases Unit
Tampere University Hospital
Tampere, Finland

ISBN 978-952-92-5136-0 (paperback)
ISBN 978-952-10-5295-8 (PDF)

Helsinki 2009
Yliopistopaino

To Ari, Pyry and Aarni

CONTENTS

ABBREVIATIONS 6
LIST OF ORIGINAL PUBLICATIONS 7
ABSTRACT 8
INTRODUCTION 9
REVIEW OF LITERATURE 11

1. From sound enamel to caries lesion formation 11
Sound enamel 11
Lesion formation 11
Occlusal caries lesions 12
Detection and assessment of occlusal lesions 13
Active and inactive lesions 14
2. Treatment of occlusal caries lesions 16
Historical perspective 16
Preventing vs. managing caries lesions 18
Interceptive role of fluoride 18
3. Pit and fissure sealants in managing caries lesions 20
Sealant methods and materials 20
Recommendations and clinical guidelines for the sealant approach 21
4. Epidemiological considerations 26
Caries risk evaluation with the sealant approach 27
Economical aspects of sealant procedures 28

HYPOTHESES OF THE STUDY 31
AIMS OF THE STUDY 31
MATERIALS AND METHODS 32
Criteria for sealant application and the policies in practice in Varkaus (I, III, IV) 32

1. A prospective study on the retention and caries rate of two sealant methods used routinely in the dental public health clinic (I) 35

2. A prospective study comparing the duration of a sealant application procedure with two sealant methods (II) 35
3. A retrospective study to explore the coverage and outcome of a sealant program (III) 36
4. A questionnaire survey on pit and fissure sealants used in public dental health. The general application criteria for sealants and the nationwide policies used; exploring the attitudes of dentists towards sealants (IV) 37
5. Statistical methods 39

RESULTS 42
1. Dentin caries rate (I, III) and DMFT values (IV) 42
2. Retention rate of sealants (I, III) 43
3. Caries risk evaluation and examination policies (I, III, IV) 44
4. Duration of the sealant application procedure (II) 45
5. The role of dentists and dental auxiliaries in the sealant approach (I, IV) 45
6. Role of sealants in caries prevention and management (IV) 45
Systematic sealant approach and the criteria and policies for sealant application 45
Opinions on sealant use 46

DISCUSSION 47
1. Methodological aspects 47
Validity of material 47
Validity of methods 48
2. Results of the study 49
CONCLUSIONS 54
RECOMMENDATIONS 54
ACKNOWLEDGEMENTS 55
REFERENCES 57
APPENDICES 68

ABBREVIATIONS

AAPD	American Association of Pediatric Dentistry
ADA	American Dental Association
ART	atraumatic restorative treatment
BIS-GMA	bisphenol-A-glycidylmethacrylate
BPA	bisphenol A; a methacrylic resin
BSPD	British Society of Paediatric Dentistry
CDO	chief dental officer
CDC	center for disease control and prevention
DMFS	decayed, missing or filled surfaces - index number
DMFT	decayed, missing or filled teeth - index number
EAPD	European Association of Paediatric Dentistry
FPM	first permanent molar
FSPM	first and second premolar
GIC	glass-ionomer cement
GDP	general dental practitioner
HEMA	hydroxyethyl methacrylate
ICDAS	International Caries Detection and Assessment System
MS	Mutans streptococci
NIH	National Institute of Health
PRR	preventive resin restoration
RB	resin-based material
RR	relative risk ratio
SPM	second permanent molar
WHO	World Health Organization

LIST OF ORIGINAL PUBLICATIONS

I

Kervanto-Seppälä S, Lavonius E, Pietilä I, Pitkäniemi J, Meurman JH, Kerosuo E.
Comparing the caries-preventive effect of two fissure sealing modalities in public health care: a single application of glass ionomer and a routine resin-based sealant programme. A randomized split-mouth clinical trial. Int J Paediatr Dent. 2008 Jan;18(1):56-61.

II

Kervanto-Seppälä S, Lavonius E, Kerosuo E, Pietilä I.
Can Glass ionomer sealants be cost-effective? J Clin Dent. 2000;11(1):1-3.

III

Lavonius E, Kerosuo E, Kervanto-Seppälä S, Halttunen N, Vilkuna T, Pietilä I.
A 13-year follow-up of a comprehensive program of fissure sealing and resealing in Varkaus, Finland. Acta Odontol Scand. 2002 Jun;60(3):174-9.

IV

Kervanto-Seppälä S, Pietilä I, Meurman JH, Kerosuo E.
Pit and fissure sealants in public dental health care – Application criteria and general policy in Finland. BMC Oral Health 2009, in press.

ABSTRACT

Arresting occlusal enamel caries lesions with pit and fissure sealants

The aim of this study was to evaluate the feasibility of pit and fissure sealants and the effectiveness of the two sealant methods applied in every-day practice in public dental health care in Finland.

Two sealant methods were evaluated according to their effectiveness in preventing dentin caries at occlusal surfaces and sealant integrity and retention. Application time with these sealant methods was measured and compared. The survival rate of sealed first and second molars was followed for nine and 13 year periods, respectively. Caries risk evaluation and observed increased caries risk were the basis for considering sealant application.

A questionnaire, sent nationwide to all public dental health centers in Finland, monitored the attitudes of the dental profession towards sealant application and explored the current criteria and policies used as well as changes noted in the sealant application protocol. Mean DMFT index values collected from the health centers were evaluated.

The difference in caries rate between two methods investigated in this three year study was highly significant. When compared to the glass ionomer sealant method (GIC), the effectiveness of the resin-based method (RB) in preventing dentin caries was 74% and the rate difference 3%. The relative risk for RB-sealed surfaces vs. GIC-sealed surfaces of having detectable dentin caries was 0.3 (95% CI 0.12, 0.57). The retention rate of sealants was higher with RB than GIC ($P<0.001$). Application of RB sealant material was less time-consuming than application of GIC sealant. Occlusal dentin caries lesions were found in 4% and proximal caries in less than 2% of sealed teeth. The resealing rate with the second molars was 23%. The majority of respondents reported application of sealants on a systematic basis along with caries-risk evaluation. Those health centers sealing over suspected or detected enamel caries had lower average DMFT index values (1.0) when compared to DMFT values (1.2) of health centers applying sealants by alternative criteria.

It is concluded that the RB sealant method is more effective than the GIC sealant method in preventing dentin caries. Sealant maintenance may increase the costs of a sealant program. Occlusal caries management may be improved if the applied sealant policies are changed towards an interceptive approach i.e. applying the sealants over detected or suspected enamel caries lesions instead of sealing sound teeth in a preventive manner.

INTRODUCTION

Dental caries is a multifactorial disease that affects most populations throughout the world. It is the primary cause of oral pain and tooth loss (Fejerskov et al., 2008a).

Keyes (1954) was the first to explain the interplay between local cariogenic bacteria in plaque, fermentable carbohydrates, constitutional factors (related to species and strains) and tooth structure. Dental caries was shown to be an infectious process of teeth with the interplay of three principal factors: the host, microflora and diet (Keyes, 1960). Even though knowledge of the biological determinants and the interactions among the different factors has increased, this model is still valid today (Clarkson, 1999).

The dental hard tissues – enamel, dentin and cementum – form relevant solid surfaces which are coated by a pellicle to which microbial cells attach (Kidd and Fejerskov, 2004). Saliva modifies the complex interplay between the teeth and the surrounding biofilm: the secretion, flow-rate and composition of saliva are dynamic parameters that are controlled by the physiological and pathological conditions of the host (Bardow et al., 2008). The bacteria in the biofilm are metabolically active, causing fluctuations in the pH of saliva. These fluctuations may cause a loss of mineral from the tooth when the pH decreases or gain of mineral when the pH increases (Kleinberg, 1970; Manji et al., 1991). The localized destruction of the hard tissues, often referred to as the *lesion*, is the *sign* or the *symptom* of the disease (Fejerskov et al., 2008a).

Occlusal surfaces of posterior teeth are the most vulnerable sites for dental caries due to their anatomy favoring plaque maturation and retention (Black 1914; *in* Asbell, 1994; Ripa, 1993). Although the overall caries rate has fallen for populations in industrialized countries, the rate of caries lesions in pits and fissures has not decreased at the same time (Carvalho et al., 1989; Marthaler, 2004).

Once viable in the dentition, the bacteria causing dental decay – after the dentition has been affected by these cariogenic bacteria – will remain in the mouth as long as the teeth exist. However, progression of enamel caries lesions can be effectively arrested if the conditions at the tooth surface are changed to those less favorable to the cariogenic bacteria. The choice of professional treatment will depend on the accessibility for plaque removal. For the non-cavitated active lesions, non-operative interceptive interventions are preferred (Nyvad, 1993). Significant numbers of early lesions are likely to arrest or regress without professional intervention (Backer Dirks, 1966; 1971).
Sealant application as a solely non-invasive approach to the susceptible incipient enamel lesions of occlusal surfaces is suggested without no preceding enameloplasty (Welbury

et al., 2004; Feigal and Donly, 2006; Beauchamp et al., 2008). As restoration of the tooth starts a restorative cycle in which restorations will often be replaced several times (Elderton et al., 1990), interceptive sealant application postpones the need for invasive treatment. Watchful waiting and interceptive treatment should therefore always be the first options with initial occlusal lesions (van Amerogen et al., 2008).

The present series of investigations outlined in this thesis were performed to evaluate the effectiveness of two sealant methods (I, II) and to explore the feasibility of a routine sealant approach in public dental health (I, II, III, IV).

REVIEW OF THE LITERATURE

1. From sound enamel to caries lesion formation

Sound enamel

Sound enamel consists of hydroxyapatite crystals arranged in tight rods. Each crystal is separated from the other by intercrystalline spaces. The spaces are filled with water and organic material (Boyde, 1976). The intercrystalline spaces form diffusion pathways referred to as micropores. All spaces within the enamel, irrespective of their size, will contain protein of developmental origin, lipid and water. Once a tooth has erupted into the oral cavity, the enamel surface constantly undergoes modification. It is therefore to be regarded as being in dynamic transformation at all times (Fejerskov et al., 2008b).

Lesion formation

Mineral dissolution and redeposition occur constantly at the enamel-plaque interface. The dissolution of enamel takes place within the intercrystalline spaces as they are enlarged during caries lesion formation (Thylstrup and Fejerskov, 1979). The cumulative result of the de- and re-mineralization processes may be a net loss of mineral, leading to dissolution of the hard tissues and the formation of a caries lesion (Kidd and Fejerskov, 2004).

A lesion forms in three dimensions, guided by prism direction, and thus assumes the shape of a cone with its base toward the enamel-dentin junction (Kidd and Fejerskov, 2004). Dental caries develop where microbial deposits are allowed to form biofilms that are not frequently removed or disturbed by mechanical wear (mastication, attrition, abrasion from brushing, flossing or toothpicks) (Fejerskov et al., 2008b).

As teeth are erupting they are not in occlusion and do not participate in mastication. The entire process of eruption takes time. Such teeth offer more favorable conditions for bacterial accumulation than fully erupted teeth (Thylstrup and Fredebo, 1982; Carvalho et al., 1989; 1991; 1992). When completely in occlusion, functional chewing will modify microbial accumulation (Fejerskov et al., 2008b).

After eruption bacterial deposits are well protected against removal forces in the deeper parts of the occlusal groove – the fossa system (Thylstrup and Fredebo, 1982; Carvalho

et al., 1989; 1991; 1992). The thin fissures of the molar teeth are thus especially prone to develop caries lesions (Carvalho et al., 1989; Bohannan, 1983).

Occlusal caries lesions

The term *fissure caries* was earlier used to describe the caries lesions found in pits and fissures. This definition was based on the assumption that the high incidence of caries lesions in molar pits and fissures was directly related to the poor cleaning accessibility to these surfaces. Occlusal pits and fissures vary in shape but are generally narrow (about 0.1 mm wide) and tortuous, with invaginations or irregularities where bacteria and food are mechanically retained. Saliva does not readily reach the base of fissures, nor can those areas be mechanically cleaned. An explorer tip or toothbrush bristle, for example, is too large (diameter 0.2 mm) to penetrate most fissures. The thickness of enamel at the base of deep fissures is minimal and in many cases the fissures extend practically to the dentinal surface (Newbrun, 1989).

Present knowledge indicates that the narrow fissures at the posterior surfaces of teeth are not the focus for the caries initiation *per se* (Figure 1). Two factors have been considered of importance for plaque accumulation and caries initiation on occlusal surfaces: the stage of eruption or functional usage of teeth, and surface specific anatomy (Carvalho et al., 1989; 1991; 1992). A carious lesion initiates as a local process at the entrance along to deep fissures as plaque accumulates within the slopes of cusps at occlusal surfaces. These sites offer protection against physical wear and favor the formation of microcavities that further improve local conditions for oral bacteria whereas the deepest part of the fissure usually harbors non-vital bacteria or calculus (Theilade et al., 1976; Ekstrand and Bjørndal, 1997).

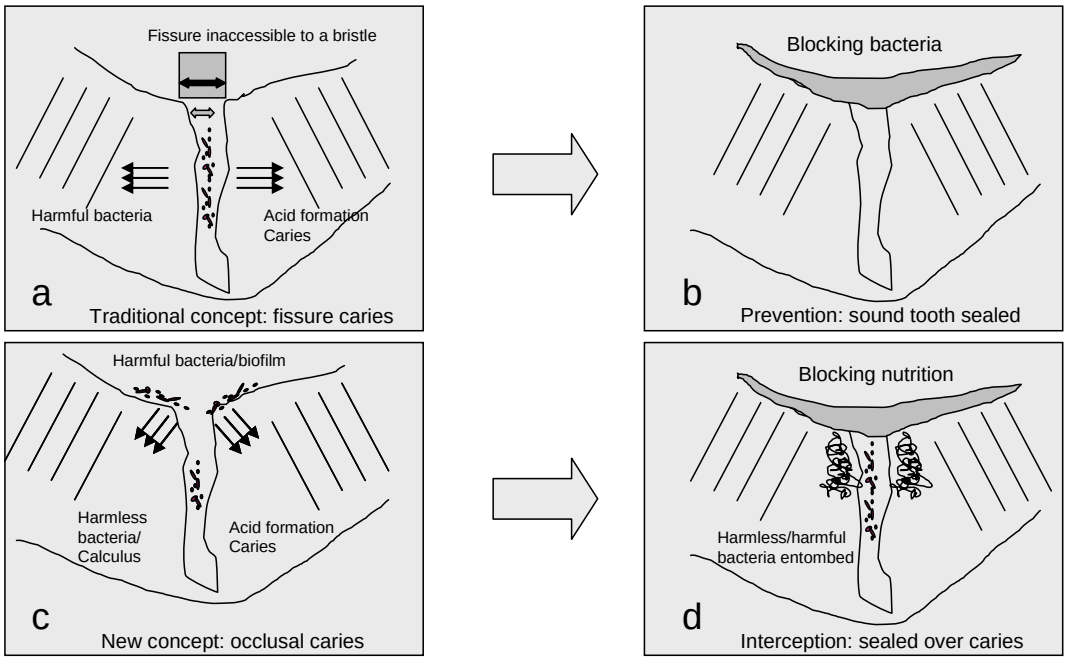


Figure 1. The traditional vs. modern concept in the pathogenesis of dental caries and consequences for the sealant approach.
Traditional concept (a), modified from Newbrun (1989) emphasizing the role of bacteria in the fissure and leading to preventive sealing of sound teeth only (b) to block the growth of bacteria. Modern concept (c) emphasizing the role of bacteria on the cuspal slope occlusally, leading to interceptive sealing (d), based on the findings of Theilade et al. (1976), Carvalho et al. (1989; 1991; 1992), and Ekstrand and Bjørndal (1997), see text above.

The growth and proliferation of bacteria accelerate demineralization and destruction of occlusal surfaces (Fejerskov et al., 2008a). These areas often become stagnated due to the demineralization/remineralization process and can also be clinically identified. Hence, instead of the conventional *pit and fissure caries*, the use of a more accurate term *occlusal caries* is suggested (Carvalho et al., 1989; 1991; 1992; Ekstrand et al., 1991b).

Detection and assessment of occlusal lesions

Changes in disease presentation, particularly on occlusal surfaces (Kidd et al., 1993), provide an increasing challenge to the detection and assessment steps in the modern caries management process (Pitts, 2004a). Due to the deductive nature of the diagnostic process, the term diagnosis should not be used synonymously with the term detection (Nyvad, 2004). By definition *to diagnose is the act of identifying a disease from its signs and symptoms* (Merriam-Webster 2008). Since there are virtually no symptoms of caries

lesions at early stages, caries examination becomes primarily a question of detection (Pitts, 2004a). As a whole, caries diagnosis is a process which can be considered as a three-step procedure: detection of the lesion, followed by assessment of the severity of the lesion, followed by assessment of the lesion activeness (Ekstrand et al., 2001).

Lesion assessment aims to characterize or monitor a lesion once it has been detected. Accurate and reliable assessment of caries activity is important for determining appropriate treatment needs (Ekstrand et al., 2005). The caries process has been defined into stages in order to measure the lesion. *The diagnostic threshold* describes the cut-off level used in an arbitrary decision of what to classify as a diseased tooth and what to classify as sound. This has been represented with an iceberg-model (Figure 2), which demonstrates the large proportion of non-cavitated lesions among all detected caries lesions and suggests either interceptive or operative treatment modes for the lesion types (Pitts, 2008).

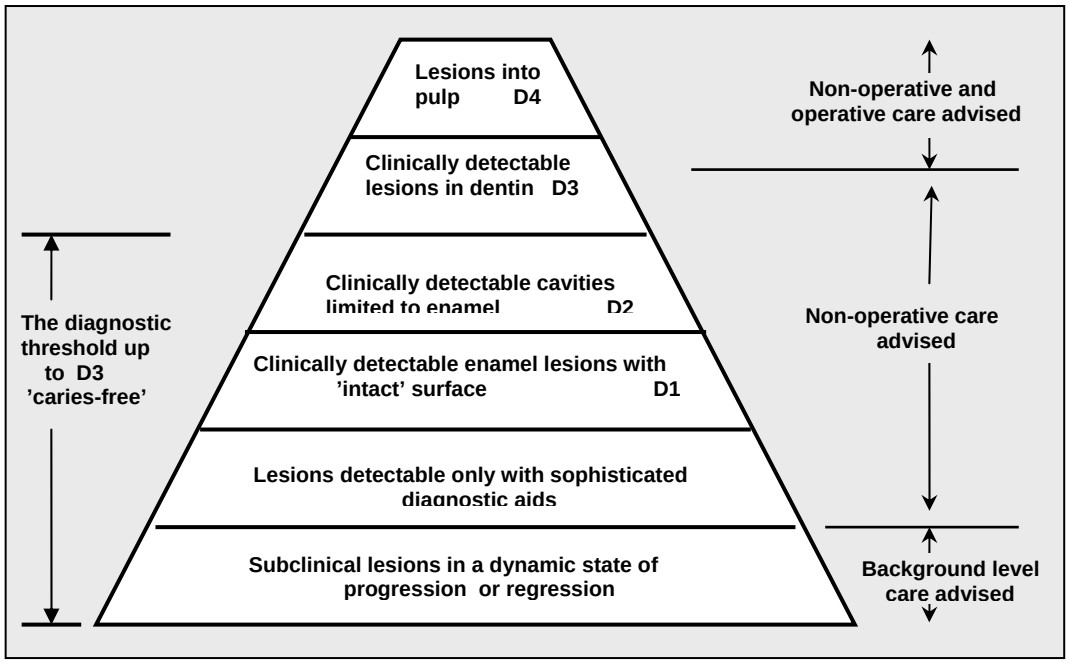


Figure 2. The iceberg model for dental caries: diagnostic thresholds for lesion extent related to advice given to patients and the treatment need for the lesions. Modified from Pitts (2008).

Active and inactive lesions

From a clinical point of view, carious lesions can be classified as *progressive* (active*)*, or as *non-progressive* (inactive). If progression of the lesion can be limited, the terms *arrested* or *chronic* are used.

Assessment of the activity of lesions was introduced in a set of clinical caries diagnostic criteria (Nyvad et al., 1999). These criteria, the '*Nyvad criteria',* are based on the physical properties of surface reflection and texture of early lesions with chalky and rough lesions being active, and smooth, shiny surfaces being inactive or arrested. The color of the lesion can also be used to make the distinction between arrested and active as the surface enamel of arrested lesions takes minerals from surrounding fluids, while active lesions retain their white appearance. The predictive validity of caries lesion activity assessments were estimated by means of their ability to reflect known effects of fluoride on caries lesions (Nyvad et al., 2003). It was concluded, that the criteria have construct as well as predictive validity (Nyvad et al., 2003) and that they can be used reliably (Nyvad et al., 1999). Active non-cavitated lesions have a higher risk of progressing to a cavity than do inactive non-cavitated lesions.

An International Caries Detection and Assessment System, ICDAS, and its updated modification ICDAS II (ICDAS II Rationale and evidence, 2005, updated; Ismail et al., 2007) was developed to create an integrated definition of dental caries and a uniform system to measure the caries process. The criteria for the ICDAS-classification were created by Pitts in 2004 (Pitts, 2004a; Pitts and Stamm, 2004) and have features associated with the '*Nyvad criteria'* (Nyvad et al., 1999). Key changes to the previously used categorization system were the idea to avoid the use of the misleading and widely misunderstood term "caries free" and to explicitly acknowledge whether or not initial lesions clinically confined to the enamel were included or excluded in examinations (Figure 2). In a study where the performance of fluorescence methods, radiographic examination and ICDAS II were compared on occlusal surfaces in an *in vitro* setting, ICDAS II combined with bite-wing radiography showed the best performance (Rodrigues et al., 2008).

A dentist's ability to identify active and inactive lesions by judging the appearance of a non-cavitated lesion (visual and tactile) was studied by Ekstrand et al. (1991a) and Ekstrand and Christiansen (2005). In their study lesions were inactivated by professional cleaning and activated by abstaining from cleaning. The accuracy and reliability of caries assessment in this study was relatively poor, which reflects the difficulties in defining the status of the lesion. Thus, this result suggests that a great proportion of lesions that require interceptive treatment are unlikely to receive it on the basis of a single examination by a dentist not specially trained or calibrated in caries diagnostics.

With occlusal surfaces the identification of lesion activity and the stage of cavitation can be even more difficult to identify. The term *hidden caries* refers to occlusal dentin caries lesions which are missed upon visual examination but can be detected radiographically

when the lesion is large enough and is demineralized enough (Ricketts et al., 1997). Hidden caries lesions are found more frequently in dentitions with low DMFT values (Weerheim et al., 1992; Ricketts et al. 1997). For those lesions which are not visible upon radiograph, sealing the occlusal surfaces will reduce the need to estimate and asses the depth of the lesion. Sealant application can be considered the treatment of choice in such cases (Ricketts et al. 1997).

2. Treatment of occlusal caries lesions

Historical perspective

Since the high incidence of occlusal caries lesions in pits and fissures has long been recognized, numerous varying procedures for decreasing the vulnerability of these surfaces have been proposed. Until the nineteenth century, dental treatment was based on the use of traditional remedies or extraction of teeth. Wilson used zinc-oxide to block fissures in 1895 (Wilson, 1985; *in* Feigal and Donly, 2006), which can be considered as one of the first non-invasive approaches in preventing dentin caries lesions at occlusal surfaces.

The first paper describing arrested caries lesions was published in 1880 by GV Black; Huxley and Fullerton published their studies some years later (Black, 1880; Huxley, 1885; Fullerton, 1913; *in* Newbrun, 1989). Recommendations to arrest or cure dental caries by cleaning to remove bacteria were published in 1909 (Brunson, 1909; *in* Newbrun, 1989).

Webb introduced the concept that cavity preparations on teeth to be treated for occlusal caries should be extended to remove noncarious fissures (Webb, in the beginning of 20th century; *in* Newbrun, 1989). The principle of this method was *extension for prevention*. Black concluded already in 1910 that '*caries in enamel, or early caries, appears in the teeth of patients…from day to day and these lesions are usually found in pits and fissures of occlusal surfaces, proximal and labial and buccal tooth surfaces'*. He contended that '*the whole subject of caries of the enamel is the most important one in its relation to everyday practice*' (Black 1910; *in* Asbell, 1994).

Prophylactic odontotomy, introduced by Hyatt in 1923, was based on a finding that the posterior teeth decayed soon after eruption. It was therefore suggested that small amalgam restorations should be placed in pits and fissures of newly erupted teeth before the appearance of clinical signs of decay. In treating pits and fissures mechanical fissure eradication was suggested by Bodecker in 1929. He recommended reshaping the

noncarious pits and fissures into wide nonretentive grooves rather than placing restorations. Prophylactic odontotomy and fissure eradication did not become commonly employed because there was a reluctance to perform operative procedures on teeth with no apparent lesions (Hyatt, 1923; Bodecker, 1929; *in* Newbrun, 1989).

Chemical treatment of caries lesions by silver nitrate solutions was proposed by several researchers (Howe, 1917; Kline, 1942; Younger, 1949; *in* Newbrun, 1989). Numerous dental materials, including zinc phosphate and copper cement, were used in attempts to physically block pits and fissures. These substances, however, had limited value due to their high solubility and poor retention on the tooth structure (Newbrun, 1989).

Acid etch bonding, introduced first by Buonocore in 1955, started a new era in preventive dentistry. He concluded that acid etching created minute channels and thus increased the surface area of the enamel into which the resin flowed. Upon hardening, microscopic mechanical bonds, also called tags, were formed between the material and the tooth surface. Etching the enamel and bonding of the sealant material by a resin marked an approach towards a more preventive mode in the caries treatment (Buonocore 1955; Handelman and Shey 1996).

Cueto and Buonocore (1967) used methyl cyanoacrylate as the bonding agent in the first clinical study of occlusal sealants. The purpose of this procedure was to establish a physical barrier between sound enamel and the potentially cariogenic bacteria in the most susceptible region of the dentition, the enamel fissure. However, the difficult handling characteristics of cyanoacrylates and their degradation by oral bacteria made this compound unsuitable for use in the oral cavity.

A viscous liquid resin, BIS-GMA, was first introduced by Buonocore (1970; 1971). It formed long-lasting bonds with enamel when used in conjunction with the acid-etch procedure. BIS-GMA is a hybrid-monomer formed by the reaction of *bis*-phenol A and glycidyl methacrylate (Buonocore, 1971; Bowen, 1982). The molecule combines the desirable properties of both methacrylate and epoxy molecules – it polymerizes rapidly and undergoes minimal polymerization shrinkage in oral conditions.

Robinson et al. (1976) conducted an experimental study on arresting and controlling of carious lesion with a resorcinol-formaldehyde resin. It was thought already then that due to the greater accessibility and reactivity of the porous carious tissue, the principal means of effect was by penetrating into and accumulating in the porous enamel of the lesion itself. Here the topical agents retard, arrest or even reverse the process of lesion formation.

Preventing vs. managing caries lesions

Prevention of dental caries lesions can take place when the lesion formation has not yet begun, for example in the erupting teeth. Bacterial colonialization occurs within hours in the mouth and the diversity of microbes increases as the formation of the biofilm begins. In the biofilm plaque, *mutans streptococci* (MS) pay a potential role in initiation of caries of smooth surfaces and fissures and mainly the species *Streptococci mutans* and *Streptococci sobrinus* can be implicated as the principal oral bacteria responsible for the initiation and development of early childhood caries (Tanzer, 2001). Children generally acquire MS organisms by transmission through their mother (Berkowitz, 2006). As the biofilm is ubiquitous, i.e. always forming, always present and always metabolically active, the process of caries lesion initiation cannot be prevented if streptococcal colonialization has occurred. However, it can be controlled so that a clinically visible lesion never develops (Manji et al., 1991; Kidd and Fejerskov, 2004) by interrupting or *intercepting* the lesion development so that the active caries process is delayed or arrested.

The caries process is defined (by evidence) as a continuum of disease states ranging from subclinical, subsurface changes through to more advanced, clinically detectable subsurface caries to various stages of more advanced lesions with microscopic and later macroscopic cavitation of enamel and significant involvement of dentin (Pitts, 2001; Kidd and Fejerskov, 2004; Featherstone, 2004). After detection assessment of the presence or absence of dental caries is dependent on the diagnostic cutoff points selected, which greatly affects clinical treatment decisions (Fejerskov, 1997). Managing caries lesions thus includes the treatment of the whole process of caries lesions beginning from the early invisible stages to the more advanced lesions.

The studies of Handelman (1972; 1973; 1976) and some later studies by Mertz-Fairhurst et al. (1979; 1986; 1998) and Elderton (1985a) have shown that when a dentin caries lesion is tightly sealed, the lesion does not progress. These findings led in the early 1980's to suggestions to seal over incipient non-cavitated enamel lesions and this approach is in line with many recent recommendations and guidelines (Table 1).

Interceptive role of fluoride

Fluorides play a key role in the control of dental caries (ten Cate, 2004). The effectiveness of fluoride is due to its presence in the aqueous phase during enamel dissolution. Fluoride acts in three ways: i) inhibition of demineralization, ii) enhancement of remineralization and iii) by effects on bacteria (ten Cate and Duijsters, 1983a; 1983b; Theuns et al., 1986; Shellis and Duckworth, 1994). The beneficial effects of fluoride on

dental caries are primarily due to the topical effect of fluoride after the teeth have erupted in the oral cavity (Fejerskov et al., 1981). The unfavorable effects of fluoride are due to its systemic absorption during tooth development, resulting frequently in dental fluorosis (Levy et al., 1995).

The effect of fluoridated water on caries lesions was evaluated in the Tiel-Culemborg experiment (Backer Dirks et al., 1961). Enamel and dentin caries lesions were registered from two groups of children at the age of seven from two nearby Dutch cities; Tiel having fluoridated (1 ppm F-) and Culemborg non-fluoridated (0.1 ppm F-) tap water. Both groups were followed until the age of 18 years. At age 18, both groups registered the same number of enamel lesions. A significant reducing effect of systemic, pre-eruptive fluoride could be seen in the number of dentinal lesions in the fluoridated area if fluoride was consumed in a topical manner post-eruptedly for a period of time. However, while smooth surfaces benefited the most from systemic fluoride ingestion (a reduction of 67% of cavities up to the dentin level), pits and fissures benefited the least (reduction of 12% at age 15). The systemic effect of fluoride was found to be lost in the studies of Marthaler (1967) if the use of topical fluoride was discontinued. The achieved effectiveness of fluoride was due probably more to the topical than the systemic, pre-eruptive fluoride consumption. Therefore, the effect of fluoride on caries lesions is considered interceptive rather than preventive.

The arresting effect of topical fluoride varnishes on enamel caries lesions in pits and fissures is questionable. Topical fluoride varnish applied to fissures did not markedly reduce the rate of caries (Holm et al., 1984). This is in line with the studies of Bravo et al. (2005) where fissure sealing and fluoride varnish application on sound first permanent molar fissures were compared, and with a meta-analysis (Hiiri et al., 2006) where pit and fissure sealants were found to be superior to topical fluoride.

3. Pit and fissure sealants in managing caries lesions

Sealant methods and materials

The two predominant sealant materials in use are the resin-based composite sealants (RB) and the glass ionomer cements (GIC). The sealant methods are traditionally classified according to the manner in which polymerization is initialized. Resin containing sealant materials can be polymerized by autopolymerization, photopolymerization using visible light, or a combination of the two processes (Ripa, 1993). GIC sealants are available in two forms: conventional (autopolymerized), and resin-modified (visible light activated or combination of autopolymerized-visible light activated material) (Pardi et al., 2003).

BIS-GMA, the main constituent of RB sealants, has properties well suited for a sealant material. Due to the adhesive properties it adheres well to enamel, adapts to the walls of fissures, forms a thin layer over the fissure and can well resist occlusal forces (Gwinnett and Buonocore 1965). The occlusal surface of the tooth is cleaned with pumice and etched by phosphoric acid before sealant application.

The effectiveness of RB sealants in preventing progression of enamel lesions is based on the establishment of a tight seal preventing leakage of nutrients to the microflora in the deeper parts of the fissure (Welbury et al., 2004). The fissure itself is very narrow contributing only a small surface area which undermines the sealant. Optimal adhesion is formed between the sealant and the sound enamel surrounding the fissure (van Amerogen et al., 2008). However, the RB sealant method is technique-sensitive. Saliva contamination after the acid etching restricts the sealant adherence to enamel and thus may lower the retentiveness of the sealant. This method therefore requires efficient moisture control which may limit its use in some working environments (Songpaisan et al., 1995).

Fluoroaluminiun silicate glass ionomer (GIC) was developed in the 1970's as an alternative sealant material to the RB composite (McLean and Wilson, 1974). GIC adheres to enamel with a chemical bond so the sealant application procedure does not require acid etching of the tooth surface or the use of an adhesive. GIC releases fluoride, which is considered the major advantage of the material. When applied, GIC is not as sensitive to humidity and fluids as is the RB material (McLean and Wilson, 1974). With the chemically curable GIC no allergic reactions have been reported, however, all resin-modified GIC sealants contain short chain oligomers (*e.g*. HEMA), which have been shown to be highly sensitising (Kanerva et al., 1991; 1997). A transient amount of BPA has been

detected in the saliva of some patients directly after sealant application; however, potential estrogenicity with such low levels of exposure has not been investigated (Fung et al., 2000; Söderholm and Mariotti, 1999).

Recommendations and clinical guidelines for the sealant approach

Clinical guidelines can improve the quality of clinical decisions. Guidelines based on critical appraisal of scientific evidence (evidence-based guidelines) clarify which interventions are of proven benefit and document the quality of the supporting data (Woolf et al., 1999). It is important to detail areas of uncertainty (i.e. gaps in the current evidence base) in order that best practice recommendations can be made and future research needs may be identified and commissioned (Pitts, 2004b). The distribution of caries lesions within the dentition and the population and the costs associated with sealant use emphasize the importance of guidelines for sealants that can be used in both individual and community-organized programs (Rozier, 1995).

The first international consensus reports concerning sealants and suggesting interceptive arresting of occlusal enamel lesions were published in the beginning of the 1980's (Table 1). Yet, in the beginning of the 1990's many sealant studies mainly comprised of sealants applied in a solely preventive manner only to intact and unstained fissures (Meurman et al., 1978; Newbrun, 1989; Mejare and Mjör, 1990). Teeth with susceptive enamel caries lesions were excluded from these studies as they were restored after the susceptible caries lesion or all visible caries lesions were cleaned.

The risks of sealant use were assessed to be minimal and the effectiveness in preventing and arresting caries lesions good or excellent. The main concerns with sealants, the possibility of lesion progression under the sealed surface and the fear that the occlusal surface is prone to caries attack if the sealant is lost or defected, were found unjustified (NIH, 1983). The preventive approach was in line with the recommendations since the use of sealants to newly erupted first and second molars, especially for children with elevated caries risk, was suggested. Meiers and Jensen (1984) suggested that the use of sealants should be interceptive instead of strictly preventive. As the accurate assessment of the presence and activity of small pit and fissure lesions was often found to be difficult, it was concluded that suspicious occlusal surfaces should always be assumed to have small active lesions and should therefore be treated by sealants (Elderton 1985a). Patient recall and sealant maintenance was advised.

Over the past decades it has been a convention in Finland and in other Nordic countries to seal all sound molars however, there are no international recommendations supporting this protocol as most of the guidelines and recommendations suggest the sealant approach on the basis of caries risk evaluation (Table 1). It is probable that the risk evaluation and targeting of the subjects to be sealed have nevertheless been adapted in the public health care while the massive sealant application trend has declined (Nordblad et al., 2004). Even though arresting incipient lesions with conservative sealant application is broadly suggested, sealing sound occlusal surfaces and unstained fissures is also suggested in most recommendations (Table 1).

The changes in caries epidemiology in the beginning of the 1990's and the reporting of slower progression of caries lesions, led to suggestions that sealant use should be targeted to those teeth most prone to develop caries lesions. The first molars were thus priorized followed by the second molars. Arresting incipient lesions by sealants was recommended, and it was further suggested that sealant application procedures could be delayed until a point in time when it was suspected that a (dentin) caries lesion might develop (Brown and Selwitz, 1995; Söderholm, 1995). By this approach, fissure sealing became to be considered as a therapeutic or restorative rather than a preventive measure. This approach also indicated cost savings as the unnecessary use of sealants would decrease and as the treatment of a lesion with a sealant would reduce the time until 'restoration' when compared to the more traditional and more invasive treatment options (Söderholm, 1995).

Griffin et al. (2008) evalued the effectiveness of sealants in managing caries lesions in a meta-analysis, and found their effectiveness in preventing dentin caries (annualized probability of preventing progression) to be in the range of 62% to 100% (median 74% for all; 83% for non-cavitated and 65% for cavitated lesions). They recommended the placement of sealants to arrest lesions in the early carious stages and also to surfaces where caries status is uncertain. The progression of non-cavitated occlusal lesions was slow also for surfaces that were not sealed indicating that such surfaces could either be monitored or sealed. Invasive treatment methods were not recommended.

Sealant maintenance is an integrated part of the sealant approach – all sealed surfaces should be regularly monitored clinically and radiographically. Bitewing radiographs are suggested to be taken at a frequency consistent with the patient's risk status especially in cases where there has been doubt about the surface caries status prior to sealant application (Welbury et al., 2004). Defective or lost sealants should be reapplied in order to maintain the marginal integrity of sealants.

P*reventive resin restoration* (PRR), or *sealant restoration*, was first introduced by Simonsen and Stallard (1977). PRR is indicated for small cavitated lesions, i.e. for occlusal surfaces with small and discrete caries lesions in fissures extending up to the dentin level (Ripa and Wolff, 1992). In this method the susceptive fissures at molar occlusal surfaces are opened up with a narrow tapered fissure turbine drill. The cavity preparation is minimal and limited to the removal of the local caries lesion. The cavity is then restored with diluted composite before the sealant is applied over the edges of the filled cavity, covering also all of the other remaining pits and fissures at the occlusal surface.

Simonsen classified resin restorations into 3 categories: type 1 PRR does not penetrate enamel, and type 2 PRR involves a restorative procedure in which replacement of tooth structure and sealing of adjacent unprepared pits and fissures is accomplished using a flowable resin composite. Type 3 PRR is suggested if the lesion has emerged up to the dentin level. Two materials are used – one to restore and one to prevent future caries attack. Both materials are used in their primary roles as restorative and preventive materials therefore there is no compromise of function of the two materials (Simonsen, 2005). Additionally, GIC has been suggested as an underlying filling material (McLean and Wilson, 1974). Garcia-Godoy (1986) demonstrated *in vitro* that less micro-leakage occurred in these *preventive glass ionomer restorations* than in fissures sealed entirely with composite resin. GIC is applied to the cavity prior to the resin layer, which seals the restoration (McLean and Wilson, 1974).

Another method with the fluoride-releasing material, GIC, has been suggested for sealant application and managing incipient lesions in a minimally-invasive procedure called atraumatic restorative treatment (ART). ART has been successfully performed in areas where the application conditions are generally not optimal (Frencken et al., 2007).

Table 1. Recommendations and guidelines for the use of sealants. Prevention (P) indicates suggested sealing over sound fissures, arresting (A) indicates interceptive treatment with sealants. Targeting (T) indicates that the risk approach is considered, Seal-all-sound (S) indicates that sealing all sound surfaces of permanent molars is suggested.

Study / Year published / Organization	Type of recommendation or publication	Prevention (P) / Arresting (A)	Targeting (T) / Seal-all-sound (S)	Recommendation / comments
National Institutes of Health (1984)	Consensus Development Conference Statement: Dental sealants in the prevention of tooth decay (1983)	P + A	T	Besides prevention, sealants may also be used to arrest the progress of small or incipient pit and fissure lesions.
Rock (1984) NHS	Workshop - Potential use of Fissure sealants in the NHS	P + A	T	Case-selection/targeting is suggested.
Stamm (1984)	Conference on Declining Prevalence of Dental Caries (1982 Boston)	P	T	Pit and fissure lesions should be prevented by sealant application.
Meiers and Jensen (1984)	Review	A	T	Interceptive caries management of susceptible fissures is suggested.
Elderton (1985b)		P + A	T	Interceptive approach to caries management is recommended.
Dowell (1986)	Meeting report	P + A	T	Sealing over questionable fissure lesions is suggested.
Eccles (1989)	Review	P + A	T	Interceptive use of sealants is advocated.
Murray and Nunn (1993). BSPD	Policy document	P + A	T	Pits and fissures of permanent molars should be sealed if in caries risk.
Workshop on Guidelines for Sealant Use (1995)	Recommendations	P + A	T	The least invasive approach, using the simplest intervention for dental caries is preferred. Sealants arrest lesion progression.
Brown and Selwitz (1995) and Söderholm (1995). ADA	Guidelines for sealant use – Changes in caries epidemiology	P + A	T	Seal sound or questionable surfaces. Targeting for high caries prevalence is suggested.
Nunn et al. (2000). BSPD	A policy document on fissure sealants in paediatric dentistry	P + A	T	Application of sealants to all susceptible sites of permanent molars is recommended to children in caries risk. If there is doubt of a dentine lesion, radiograph or enamel biopsy is suggested.
Smallridge (2000).	National clinical guidelines (UK)	P	T	Predictive factors should be considered in risk evaluation.
Scottish Intercollegiate Guidelines Network (2001).	National clinical guidelines	P	T	Sealants should be applied and maintained in the tooth pits and fissures of high caries-risk children.
National Institutes of Health. (2001). NIH	Consensus Development Conference Statement. Diagnosis and Management of dental caries throughout life	A	T	The use of sealants is effective in arresting the progression of early dental caries. Caries-risk indicators are evalued and risk evaluation is suggested.

CDC-Task Force on Community Preventive Services (2001).	Recommendations and reports	-	T	School-linked and school-based sealant programs are recommended.
Rozier (2001).	Review	P + A	T	Arresting incipient lesions is suggested. Sites / surfaces / teeth at greatest caries risk should be sealed.
Bader et al. (2001).	Review	P + A	T	Occlusal sealants showed significant reduction in lesion progression (only one study concerning treatment with sealants).
Locker et al. (2003).	Review	P + A	S	The use of GIC is not advised.
Welbury et al. (2004). European Association of Paediatric Dentistry. EAPD	Guidelines	P + A	T	Caries risk evaluation at individual level is strongly recommended. Sealing over enamel caries lesions is suggested. Purposeful removal of enamel prior to sealing or enameloplasty is undesirable and unnecessary.
Ahovuo-Saloranta et al. (2004).	Meta-analysis	P	T	Sealing is recommended to prevent caries of the occlusal surfaces.
American Academy of Pediatric Dentistry Clinical Affairs Committee-Restorative Dentistry Subcommittee (2005). AAPD	Guideline on pediatric restorative dentistry (2004)	P + A	T	Sealants should be applied to teeth retaining plaque / in caries risk. Enameloplasty is not recommended.
Simonsen (2005).	Review	P + A	T	Sealants and minimally invasive PRRs are recommended
Feigal and Donly (2006). Symposium on the Prevention of Oral Disease in Children. AADP	Recommendations and a consensus statement	P + A	T	Risk evaluation is suggested.
Bader and Shugars (2006).	Review	P + A	T	Sealing both enamel caries and suspected occlusal dentin caries lesions is suggested.
American Academy of Pediatric Dentistry (2007). AAPD	Clinical guideline	-	T	Sealants should be applied to teeth retaining plaque / in caries risk. Enameloplasty is not recommended.
Jenson et al. (2007).	Clinical protocols for caries management by risk assessment	P + A	T	Caries risk assessment is the basis for subsequent treatment planning and it is strongly recommended. Sealants are considered optional if no tooth structure is moved to complete the procedure.
Griffin et al. (2008).	Meta-analysis	P + A	T	Sealing over incipient lesions was found efficient.
Beauchamp et al. (2008). ADA	Evidence-based clinical recommendations for the use of pit-and-fissure sealants	P + A	T	Sealants should be placed to prevent caries initiation and to arrest lesion progression. Enameloplasty is not recommended.
American Academy of Pediatric Dentistry Clinical Affairs Committee, Restorative Dentistry Subcommittee (2008). AADP	Guideline on Pediatric Restorative Dentistry	P + A	T	Sealants should be placed on surfaces judged to be at high risk or surfaces exhibiting incipient carious lesions to inhibit lesion progression. In general, enameloplasty is not indicated. Sealant maintenance is recommended.
Azarpazhooh (2008).	Review	P + A	-	Sealants should be placed on all permanent molar teeth without cavitation; sealant application based on assessment of caries risk is suggested.
Oong et al. (2008).	Review	A	(T)	Sealants prevented caries progression effectively. Practitioners should be encouraged to provide sealants.

4. Epidemiological considerations

As the overall caries trend in western countries has shown a favorable, decreasing tendency during the last decades, a definite shift towards a more non-invasive approach to treat caries lesions can be seen. The publicly funded dental health care system in Finland provides services free of charge to all age groups up to age 19. The scope of health care to these age groups has been comprehensive and preventively oriented.

Health centers have recorded data regarding the use of health-care services since the 1970's; the nationwide data has provided access to reliable figures when monitoring the volume of health-services provided. In the 1970's and 1980's particular attention was paid to the coverage of systematic health care and the health services were priorized to children and young adults. Due to the favorable trend in the dental health of children, a gradual change towards individually determined dental appointments took place in the 1990's (Nordblad et al., 2004). A change of legislation in 2001 extended the services to cover the whole population which limits the resources available for the younger age groups and increases noticeably the costs of the publicly funded oral health care.

The use of sealants was extensive in the 1980's in Finland and in the other Nordic countries, after that the sealant approach has shown a decreasing trend. The total number of sealants per treated child was highest in 1988: 1.2 per child in both the 6 and 12 year age groups. In 1994 the number of sealants per treated child was 1.0 in both age groups and in 2000 the number had decreased to 0.8 (for the age group 6) and to 0.7 (age group 12). The decrease in the whole age group from 6 up to 18 decreased was from 0.8 (1988) to 0.4 (2000). During the indexed years of 1997 and 2000 fillings far outnumbered sealant application as a treatment to all age groups up to 18 years (Nordblad et al. 2004).

Suni (1997) studied the survival rates of selected teeth and tooth surfaces in four age cohorts of Finnish children and young adolescents in the city of Lahti during 1972-1993, during which period the dentin caries increment decreased drastically. Sealants were applied routinely until 1989 after that a selective sealant approach was chosen. The younger age cohorts had higher cumulative survival rates of teeth than did older ones where the decrease in dentin caries figures was based mainly on the changes in the number of dentin caries lesions detected in molar fissures. Occlusal surfaces of first molars showed the lowest cumulative survival rates after 12 years post-eruption: the survival rate was about 13% (age-cohort 1965), 49% (age-cohort 1970) and 73% (age-cohort 1975). Between the age cohorts born in 1975 and 1980 no significant differences

was found in the survival which may indicate that the improvement in dental health had reached its limit.

Comparing the timing of the first dentin caries attack from three different age cohorts (age cohorts of 1960's, 1970's and 1980's) in the Finnish population showed that in the older age cohorts (1960 and 1970) both FPMs and SPMs developed dentin caries lesions soon after eruption (Korhonen et al., 2003). With the 1980 age cohort, a definite decline in the dentin caries rate was seen in all teeth groups. Despite the overall low dentin caries prevalence, an upward shift of caries increment with the SPMs and premolars was noted three to four years after eruption (Korhonen et al., 2003). Virtanen et al. (2003) compared molars of two samples of children from Finland and Sweden who were entitled to different sealant application strategies. Of first and second molars 80-90% of the Finnish sample and about 20% of the Swedish sample were sealed during the two post-eruptive years. At age 18 (follow-up of 10-12 years for first molars; children born in 1980-81) the Finnish subjects had fewer fillings. Sealants were concluded to be efficient for preventing dentin caries, however, an extensive sealant application strategy with the seal-all approach may not be relevant in a population where the caries risk is low.

Caries risk evaluation with the sealant approach

The continuing susceptibility of pit and fissure surfaces to caries has been studied by numerous investigators (Carvalho et al., 1989; Bohannan and Bader, 1984; Ripa et al., 1985; Chestnutt et al., 1996).

According to Ekstrand and Christiansen (2005a), pit and fissure sealants are indicated if i) active occlusal caries have been diagnosed in pits and fissures, ii) a high risk has been established and iii) fissures are deep and the patient or parent either cannot, or will not, remove plaque effectively. Caries risk assessment of the individual and the tooth are important in determining the need for sealants (Rethman, 2000). As caries risk on surfaces with pits and fissures may continue to adulthood the posteruptive age alone should not be used as a major criterion for sealant decisions. Sealants should be used both in a preventive manner for at-risk teeth, and in an interceptive manner to treat teeth with questionable caries or definite enamel caries lesions. Sealed teeth need to be evaluated periodically for sealant integrity and retention (Siegal, 1995; Feigal and Donly, 2006; Beauchamp et al., 2008).

Caries risk assessment determines the probability of caries incidence (the number of new cavities or incipient lesions) in a certain period (Reich et al., 1999). Due to the

multifactorial etiology of dental caries, predicting the onset of new caries lesions is difficult. A thorough dental examination with consideration of the medical and dental history best support the treatment decision. How to analyze the risk of caries in the process of decision-making for the need for sealants? Clinical studies indicate that an experienced dentist can make such a decision appropriately without expensive technology (Graves et al., 1991; Arrow, 1998). Alanen et al. (1994) studied clinicians' abilities to identify caries risk subjects in a public health setting and found remarkable variation between clinicians in their ability to identify the risk subjects and in the precise prediction of caries lesions. Some experienced clinicians were able to predict caries risk with high specifity and sensitivity.

Rethman (2000) identified the best predictors of caries risk to be the prior caries experience and fluoride history of the patient, fissure anatomy and the plaque load. Targeting preventive procedures on the basis of individual risk-assessment has been criticized as being impractical and thus inefficient in dental public health by Burt (2005) who concluded that, as the risk assessment methods are imprecise, persons at high risk cannot be adequately identified. The main goal of a recommendation for risk-based decision-making for sealants is to have dentists actually make a decision rather than to assume sealant application for every tooth (Feigal and Donly, 2006).

Economical aspects of sealant procedures

The two principal characteristics of economic evaluation are the comparison of alternatives, and the costs and consequences of alternatives (Drummond, 1980). The differences in the identification and measurement of consequences for full economic evaluation are defined as follows according to Lewis and Morgan (1994):

- *cost-effectiveness analysis* considers costs related to a single, common effect, i.e. means of achieving the same outcome. The results may be stated either in terms of cost per unit of effect, or effects per unit of cost.

- *cost-benefit analyses* can be used when the consequences of the alternatives are different

Cost-effectiveness and cost-benefit analysis have been used in relation to fissure sealant programs (Lewis and Morgan, 1994). Hunter (1988) investigated the cost-effectiveness of

a sealant program by comparing the time taken to place either sealants or amalgam restorations. If caries later occurred, the time taken to place sealants and subsequent amalgams were compared to placing amalgam restorations alone. Using time as a measure of cost-effectiveness, he concluded that fissure sealants were less cost-effective than amalgam restorations.

Another study (Niessen and Douglass, 1984) comparing cost-effectiveness of four preventive programs found sealant programs less cost-effective. Burt (1989) argued that the choice of comparison group can influence the economic outcome. If sealants are compared with lower cost fluorides, the comparison will not favor sealants. However, if sealants are compared with restorative procedures, the comparison is likely to favor sealants (Lewis and Morgan, 1994). Leverett et al. (1983) measured cost-benefit by the cost of implementation of a preventive program divided by the savings in the cost of treatment for carious surfaces saved. They concluded that at-risk patients do benefit from the use of sealants when sealants were compared with amalgam restorations. Comparisons that evaluate different outcomes, such as sound unfilled teeth with sound filled teeth, have been made without regard for the markedly distinct quality of these outcomes (Lewis and Morgan, 1994).

Griffin et al. (2002) compared the costs of three sealant delivery strategies in a hypothetical model in a nine year perspective. The incremental cost, incremental effectiveness and incremental cost-effectiveness were calculated in three groups: seal-all, target and seal-none. The sealant application in the seal-all and target delivery groups became less costly when compared to the seal-none group with the assumed annual first molar occlusal caries increment and the rate of costs from restorations. As the annual caries prevalence varies by populations and communities, the sealant delivery strategy should be determined at the community level. It was pointed out, that depending on the individual patient's evaluation of their oral health, the increased delivery of sealants with associated increase in effectiveness and costs may still be worth the investment if the other alternative is a restored occlusal surface (Griffin et al., 2002).

As pits and fissures are highly susceptible to caries lesions and least likely to benefit from topical fluorides, sealants are considered cost-effective (Mertz-Fairhurst, 1984; Simonsen, 1991; Welbury et al., 2004; Feigal and Donly, 2006). However, the cost-effectiveness depends upon a number of factors that are related to sealant use, e.g. the caries prevalence in the population, the different tooth types sealed, whether all teeth and fissures are routinely sealed or sealed based on specific indications, retention of the sealant and to what extent other caries preventive methods are used (Raadal et al., 2001). If the retention rate of sealants is low the need for resealing and restorative

treatment of carious fissures may increase thus reducing the cost-effectiveness of the sealant approach (Welbury et al., 2004). Interceptive use of sealants is less time-consuming and personnel-demanding than the method where the fissure is opened prior to sealing.

HYPOTHESES OF THE STUDY

1. GIC sealants are at least as effective as RB sealants in preventing and arresting caries lesions.
2. GIC sealants are effective in preventing and in arresting lesion progression in fissures even after the sealant is found to be defective or totally lost.
3. Since no re-application procedures are needed for teeth with defective or lost GIC sealants, sealing with GIC is more economical than sealing with RB.
4. If FPMs and SPMs are sealed according to a 'seal-all' fissure policy and only the teeth with dentin caries lesions are left unsealed, both teeth groups can be managed equally effectively against occlusal caries.
5. A uniform sealant protocol based on international clinical guidelines exists throughout the Finnish public dental health care

AIMS OF THE STUDY

The purpose of this study was to compare the effectiveness of two pit and fissure sealant methods and evaluate the routine treatment mode in the public dental health care of Finland. The specific aims were:

1. To compare the caries preventive effect and the retention rate of two sealant methods used routinely.
2. To assess the time needed to apply GIC and RB sealants as part of a routine procedure, factors affecting the length of the procedure, and further, to evaluate the plausible costs of the GIG sealant method in public dental health.
3. To explore the coverage of the sealing program and the rate and outcome of the sealing/resealing approach in a health center applying the 'seal-all-sound' policy.
4. To evaluate the sealant application criteria and policies in practice as well as the profession's attitudes towards sealants.
5. To assess whether the applied local sealant protocol could be associated with the mean DMFT-values of the 12 year old children examined.

MATERIALS AND METHODS

The field trial (I-II) was carried out in the public health center clinics of Varkaus by local dentists, dental hygienists and dental assistants. Varkaus is a city of 25 000 inhabitants located in eastern Finland and the local dental health center represents an average public health center. Sealants have been applied systematically in Varkaus since the late 1970s up until 1990 (Figure 3). The subjects of the study were all children living in Varkaus and attending dental check-up examinations routinely at the public dental health center.

Children aged between 12 and 16 (I) and between 10 and 17 (II) years were examined and the caries risk of each second permanent molar was evaluated. Visual inspection and fiber-optic transillumination were used routinely at the examinations. All second molars assessed and considered to be at caries risk, or having a suspected or detected enamel caries lesion on the occlusal surface, were sealed in a split mouth setting with either of the two sealant methods. Second molars that had not erupted or were only partially erupted at baseline were re-examined every 6 months and included in the study if considered to be at caries risk.

The teeth considered to be at risk for caries were sealed randomly with either RB or GIC sealant material. A split-mouth randomization was carried out as follows: the sealant material for the first tooth to be sealed per mouth was chosen according to the child's birth date. Odd numbers indicated RB, and even numbers GIC. For the following tooth (starting from the upper right quadrant, followed by the upper left, lower left, and finally lower right quadrant), the opposite material was chosen. In case the second upper molar on the right side had not erupted at the time of examination and the others had, the molar from the left side determined the sealant material used. Based on this randomization, both molars in either the upper or lower jaws were sealed by a different material. The opposing second molars on different jaws had different sealant materials applied as well.

Criteria for sealant application and the policies in practice in Varkaus (I, III, IV)

From the start of the sealant program in 1975 up until 1990 the dentists in Varkaus were advised to seal all first and second permanent molars suitable for sealing (III). From 1993, at the onset of this study, specific attention was paid to sealant application criteria and to the actual application procedure due to the study protocol.

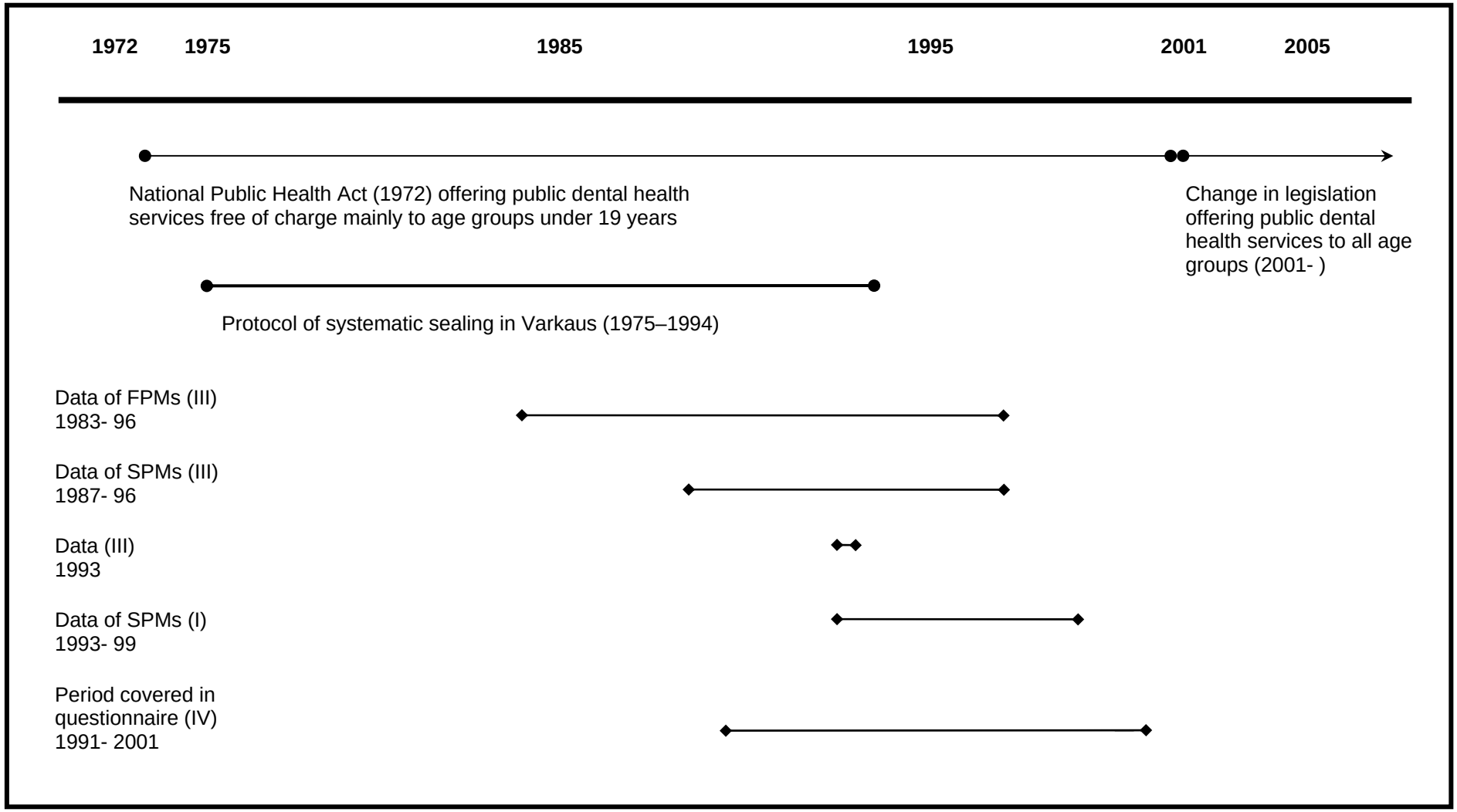


Figure 3. Study periods and their relation to the national oral health care legislation in Finland (1972-) as well as the onset and duration of the systematic fissure sealant program in the city of Varkaus, Finland.

The initial examinations as well as the caries risk assessments were performed at the health center by the local dentist on duty at the time of examination. All dentists involved in the study (N=10) had participated in calibration and their inter- and intra-examiner variables in occlusal caries diagnostics were calculated before starting the clinical trial (Lavonius et al., 1997). For the 10 dentists the mean interexaminer reproducibility showed fair agreement (kappa value 0.42, SD= 0.19).

According to the clinical assessment by the local dentist, the second molars were divided into three categories. Caries risk-evaluation of each tooth was based on the case history and on the clinical status of each child as follows with the suggested procedures indicated:

1. No risk for dentin caries - no clinical procedures.

a. essential requirement:

- no dentin caries (by inspection) or restorations in any permanent tooth

b. in addition clinicians were encouraged to consider the following points:

- tooth morphology: shallow fissure pattern
- good oral hygiene: no visible plaque in the fissures
- diet not indicating elevated caries risk
- low caries prevalence among the siblings

2. Elevated risk for dentin caries and/or initial enamel caries detected – sealant

a. essential requirements

- initial caries lesions/'questionable' fissures by inspection (including hypoplasia of the tooth)
- no visible cavitation
- and/or caries or fillings in other permanent teeth

b. in addition clinicians were encouraged to consider the following points:

- deep fissures
- visible plaque in the fissures
- diet indicating elevated caries risk
- high caries prevalence among the siblings

3. Indication of dentin caries – teeth excluded from the sealant study

- visible cavitation up to dentin level
- changes in tooth color indicating undermining dentin caries
- anamnestic information indicating pulpal symptoms

The sealant materials of the two methods in use were the chemically curable glass ionomer Fuji III® (GC Corporation, Tokyo, Japan), and the light-curable resin-based composite Delton® (Dentsply, York, PA, USA). Both materials were applied according to the manufacturer's instructions with one modification: a standard probe was used instead of the

applicator provided by the manufacturer (Dentsply). Teeth with re-exposed fissures or defective RB sealants were resealed with RB. Defective or lost GIC sealants were not replaced.

Sealants were applied by dentists working with chair-side assistants, or by dental hygienists working alone. The operators, dentists and dental hygienists were experienced with both sealant methods and were further instructed before the study. The evaluation was made by comparing tooth pairs on contra-lateral sides in both the upper and lower jaws.

1. A prospective study on the retention and caries rate of two sealant methods used routinely in the dental public health clinic (I).

During 1993 to 1996 a total of 599 children with 2356 second molars participated in the baseline examination. Each tooth was examined at baseline and re-examined at 6, 12, 24, and 36 months after sealant application. The conditions of the molars were registered according to WHO criteria (1997) as sound if no dentin caries were detected or carious if dentin caries could be detected. Sealants were classified as intact or defective. The retention of sealants and the caries rate of sealed teeth were recorded from paired RB-GIC observations for a three-year period until the end of 1999. The 36 months retention rate was evaluated from 559 pairs and the cumulative caries rate from 657 pairs of teeth. Once carious, no further treatments for that specified tooth were recorded. No other exclusion criteria were applied.

The initial examination, the caries risk assessment and the choice of the intended treatment mode was performed at the health center by the local dentist on duty at the time of the examination. Sealants were applied either by one of the 10 dentists or by one of the five dental hygienists, all of whom were experienced with both methods. The operator effect between dental hygienists and dentists was analyzed.

2. A prospective study evaluating the duration of sealant application with two sealant methods (II)

This study evaluated the factors influencing the time needed to apply a sealant, and thus the estimated costs of the RB and GIC sealants. Children aged between 10 and 18 years and attending a dental check-up routinely at the dental public health center were randomly chosen to participate in the study. The subsample comprised of all the sealants applied by

seven operators: three dentists and four dental hygienists during the chosen calendar week. A total of 140 sealants were applied, 24 by a dentist and 116 by a dental hygienist. 86 second molars were sealed with RB and 54 with GIC. The time spent for sealant application was recorded with a stop watch by the assistant without the operator knowing it.

3. A retrospective study to explore the coverage and outcome of a sealant program (III).

A retrospective study of a comprehensive pit and fissure sealing program was carried out with the oral health records from the Varkaus public dental health center. The participants were 245 children born in 1977 who were examined in the health center during 1994-1996. The data from the dental records were collected in 1996 (Fig.3). All participants in this study had attended a dental examination at 1-3 year intervals depending on the caries-risk evaluation.

The examination, caries risk assessment and the choice of the intended treatment had been performed by a local dentist on duty at the health center at the time of the examination. Sealants were applied either by a dentist working with a chairside assistant or by a dental hygienist working alone, each being experienced with the RB sealant method. The 10 dentists whose occlusal restorative decisions had been calibrated in 1993 were solely responsible for the dental examinations in 1993-1996. Prior to 1993, the examinations of the children, the risk evaluation and the treatment given were performed in a pragmatic mode with the instructions below.

The general instructions of the sealing protocol were as follows. Bite-wing radiographs at the examination were advised to be used only for the proximal caries diagnostics. The dentists were advised to seal all first (FPM) and second (SPM) permanent molars with the 'seal-all' approach and leave the premolars (FSPM) and the primary molars unsealed.

Sealant materials were applied according to the manufacturer's instructions with one modification: a standard probe instead of the applicator provided by the manufacturer was used with the RB sealant. No rubber-dam was used but it was emphasized to the operators to keep the operating area dry. No instructions were given to open the fissures with rotating instruments but occasionally this was done by some dentists. This procedure was not recorded and was thus not included in the analysis. Other routinely used caries preventive measures received by the participants were dietary and home-care instructions, professional cleaning with prophy-paste and the application of topical fluorides.

At baseline a tooth was recorded as occlusally filled even if a partial sealant was present. If proximal dentin caries existed or had existed (proximal filling), a tooth was considered proximally decayed despite occlusally placed sealants or fillings. DMFT indexes were recorded.

The total sample of FPMs and SPMs examined at least once every three years was 664 and 720, respectively. A sample of 336 unerupted FPMs at age 6, and 666 unerupted SPMs at age 10 were identified. The sample of FPMs sealed at age 6 (N= 238) and SPMs sealed at age 11 (N= 127) were followed for 13 (1983-1996) and 9 (1987-1996) years, respectively.

4. A questionnaire survey on pit and fissure sealants used in public dental health. The general application criteria for sealants and the nationwide policies used; exploring the attitudes of dentists towards sealants (IV)

A postal questionnaire was sent to each of the 257 public dental health centers in Finland in 2001. As the population densities greatly vary regionally the health centers were categorized into subgroups of ‘large’ and ‘small’ in order to get representative cluster samples among the dentists applying sealants within public health. Public dental health centers with less than seven dentists were classified as ‘small’, all other health centers were classified as ‘large’. The questionnaires with a cover letter were mailed to the chief dental officer (CDO). Additional questionnaires were mailed to the large health centers for every seventh general dental practitioner (GDP). The additional questionnaires were sent to the CDO of each health center and asked to be forwarded to local GDPs of that health center applying sealants thus excluding those who did not apply sealants (Table 2). The questionnaire was simultaneously sent by e-mail, by which it could be responded to as well. It was re-mailed by post and e-mail once to those who did not reply the first time. The response rate to the questionnaire was 79% after one re-issue (Table 2).

Table 2. Distribution of the questionnaires sent and the response rate according to the respondent's occupation and size of the health center.

	Large Health Centers		Small Health Centers		Total number of	
	Question-naires Sent (N)	**Responses Received (N)**	**Question-naires Sent (N)**	**Responses Received (N)**	**Question-naires Sent (N)**	**Responses Received (N)**
Public Health Centers	77	70	187	153	**257**	**219**
CDO	87	60	180	139	**267**	**199**
GDP	167	129	-	14	**167**	**143**
Total	**254**	**189**	**180**	**153**	**434**	**342**

The structured questions were categorized as follows:

- Demographic data: occupation/status (CDO or GDP); location and size of the health center where each respondent was working
- Examination policy: annual or individual check-up periods
- Sealant application protocol: local agreements on sealant application criteria, sealant application criteria and protocol, sealant materials in use, caries-risk evaluation
- Changes in protocols (examination policies, sealant application, attitudes) between the years 1991 and 2001
- Attitudes towards sealant use, opinions on the effectiveness and cost-effectiveness of sealants
- Local DMFT index values (mean) for each health center (years 1991 and 2000)

Public health centers collect data from the patients examined; the local DMFT index values, records of years 1991 and 2000, reflect the actual practice that took place at each health center. The questionnaire was initially piloted by three CDOs and was amended according to their suggestions before the study began.

The change (decrease or increase) in the mean DMFT index values between 1991 and 2000 for each dental health center were evaluated as well as the relation between the systematic sealing and the mean DMFT value in 2000. The association between caries experience and the sealant policy was estimated by comparing the DMFT levels of the health centers following the interceptive approach with those following alternative policies.

5. Statistical methods

In a split mouth study design the unit of analysis can be a quadrant, a tooth surface, or a tooth as was the case in the present study (I). For a tooth pair one site is designated as the *test* site and the homologous contralateral site functions as the *control.* The result for each tooth pair can be classified as *positive* or *negative* depending on the status of the *test* and *control* teeth (Table 3a and 3b) (Riordan and Fitzgerald, 1994).

Table 3a. The possible outcomes for each participant in split mouth caries trials.

Dentin caries detected		**Outcome**
Test tooth	**Control tooth**	
No	No	**No difference**
No	Yes	**Positive**
Yes	No	**Negative**
Yes	Yes	**No difference**

Table 3b. Data summary for split mouth caries trials.

	Test		
Control	Dentin caries detected	No dentin caries detected	**Total**
Dentin caries detected	a	b	**a+b**
No dentin caries detected	c	d	**c+d**
Total	**a+c**	**b+d**	**n**

The RB-GIC sealant pair was treated as a matched pair. The data (I) were analyzed by a modified McNemar's test according to Durkalski et al. (2003). The rate difference or net gain, the relative risk and the effectiveness to prevent dentin caries and the sealant retention rate with both methods was reported, as well as the 95% confidence interval (Vaeth and Poulsen 1998).

The effectiveness, rate difference and relative risk are defined as follows (Riordan and Fitzgerald 1994):

Effectiveness = difference between the number of tooth pairs where both the control tooth and the test tooth develop dentin caries divided by the number of pairs where the control tooth develops dentin caries during the studied period and defined by the notation

$$\frac{(a + b) - (a + c)}{(a + b)} = \frac{b - c}{a + b}$$

Rate difference indicates the number of teeth 'saved' from dentin caries *per* 100 teeth treated and can be defined using the notation

$$\frac{(a + b) - (a + c)}{n}$$

Relative risk (RR) is defined as the ratio between *the cumulative incidence of caries in test teeth* and *the cumulative incidence of caries in control teeth* (Vaeth and Poulsen, 1998).

Relative risk measures the effect in epidemiology and permits the association to be estimated (Riordan and Fitzgerald, 1994).

- RR that lies in the range of $0 < RR < 1$ indicates an agent preventing disease
- RR that is > 1 indicates a risk factor for disease

In analyzing the caries rate of the sealed teeth and the operator effect between dental hygienists and dentists the Huber-White-method was used. The data (II) were analyzed by

Student's t-tests. The DMFT-index values (the arithmetical mean) were analyzed by t-tests (IV) to monitor if an association could be found in the effectiveness of the sealant policy and the local DMFT values: those health centers that had chosen the protocol to seal over incipient enamel lesions were evaluated against the health centers that used an alternative protocol.

RESULTS

1. Dentin caries rate (I, III) and DMFT values (IV)

The second molars sealed with GIC had more dentin caries lesions than teeth sealed with RB, the difference was statistically significant, P<0.001 (I). The cumulative dentin caries rate of the sealed tooth pairs is shown in Table 2 of the original publication (I).

The values for the RB sealant method compared to the GIC sealant method were:

- effectiveness in caries management 74.1% (95% CI 43.40%, 88.13%)
- net gain (rate difference) 3.2% (95% CI 1.44%, 4.98%)
- relative risk for dentin caries 0.26 (95% CI 0.12, 0.57)

Among the FPMs sealed at age 6 and followed up to age 19, 16% developed dentin caries. During the nine-year follow-up 5% of the SPMs sealed at age 11 developed dentin caries at the occlusal surface (III). A definite decrease in the DMFT values was found during the study period in Varkaus shifting the population from a high-risk to a low-risk population (I, III, IV). The DMFT index values of Varkaus and of Finland in general are shown in Table 4.

Table 4. DMFT index values from Varkaus and from Finland in general, data compiled from (I,III,IV).

	DMFT Varkaus	DMFT Finland	Age of subjects (years)	Data obtained from study
1975	8.9[1]	6.9[2]	12	(III)
1985	2.3	2.8	12	(III)
1990	0.8	1.2	12	(III)
1991	0.45	1.5[3]	12	(IV)
1993	0.57	N.A.	13	(I)
1997	N.A.	1.1[4]	12	(I)
2000	0.67	1.2[5]	12	(IV)

N.A.; DMFT values not available from the original publications (I,III,IV)

[1] Nordblad et al. 1993

[2] Marthaler et al. 1996

[3] Local DMFT-values 1991 (mean)

[4] Nordblad et al. 2004

[5] Local DMFT-values in 2000 (mean)

The health centers (N=28) where sealants were applied systematically over suspected or detected enamel caries lesions on the occlusal surfaces in 1991 had in 2000 a mean DMFT value of 1.0 when compared to a mean value of 1.2 for the health centers applying sealants by any alternative criteria; the difference was statistically significant, P<0.001 (IV).

2. Retention rate of sealants (I, III, IV)

The retention rate of the RB sealants applied to the second molars was high, while GIC sealants showed lower retention, P<0.001 (I). The status of the sealed tooth pairs after the three-year period is shown in Table 3 of the original publication (I).

The retention values for RB sealants compared to GIC sealants were:

- effectiveness 94.8% (95% CI 92.46%, 96.41%)
- net gain (rate difference) 87.2% (95% CI 83.86%, 90.50%)
- relative risk for a defective or lost sealant 0.052 (95% CI 0.036, 0.075)

The resealing rate of second molars was 15.2% in the clinical trial (I) and 23% in the nine-year follow-up study (III). For the FPMs the resealing rate was 23% (III). During the nine year and 13 year follow-up, respectively, both the FPMs and SPMs had a mean of 1.2 sealant procedures per tooth (III). Among the health centers resealing decreased in general from 26% in 1991 to 8% in 2001 (IV).

According to the study protocol the teeth initially sealed with GIC were not resealed even if the sealant was found to be defective or lost at examination. Teeth where the GIC sealant was totally lost were more prone to having detectable dentin caries than those teeth where the sealant was only partially lost or defected, P< 0.039, adjusted (I). Caries status of the GIC-sealed teeth at the end of the study compared to the sealant status (defective or totally lost) at the previous examination is shown in Table 4 of the original publication (I).

The rate difference and relative risk of teeth with defective GIC sealants compared to teeth with total absence of GIC sealants to develop dentin caries lesions were:

- rate difference -1.5 % (95% CI -1.53%, 4.54%)
- relative risk 0.60 (95% CI 0.21, 1.52)

3. Caries risk evaluation and examination policies (I, II, III, IV)

Caries risk was evaluated from all children examined in the Varkaus health center since the beginning of the 1990's. Patients at high caries risk were called for examination at fixed individual intervals, the shortest interval being 6 months; the children considered to be in the low caries risk group were called for examination every other year. Caries risk evaluation and observed increased caries risk were the basis for considering sealant application since the beginning of the 1990's in Varkaus (I, II, III) and in the public dental health of Finland in general through to 2001 (IV). In 1991, 91% of all health centers in Finland reported to have examined children annually; in 2001 individually fixed intervals were reported by 78% of the respondents.

The determinants reported to indicate low risk for dentin caries at fissures were as follows (the percentage after the determinant indicates the rate among respondents):

- Intact dentition of a child (52%)
- Good level of dental hygiene (44%)
- Gently sloping cusps of molar teeth (41%)
- Absence of initial (enamel) caries lesions, absence of visible plaque or gingival bleeding

The reported indicators of least importance for determining low risk were:

- Gender
- Lack of visible calculus, lack of use of dental floss
- Overall caries decline among the children

4. Duration of the sealant application procedure (II)

It took almost twice the time to apply a GIC sealant as an RB sealant, the ratio being 1.7 for dentists and dental hygienists, P<0.001. Dentists working with a chair-side assistant took 20% less time to apply an RB sealant than did the hygienists working alone, P<0.001 (II).

5. The role of dentists and dental auxiliaries in the sealant approach (I, IV)

The role of dental hygienists increased both in independent decision making and in the actual procedure of sealant application during the decade from 1991 to 2001. In 1991 the majority of sealants (63%) in dental public health were applied by dentists, while in 2001 55% of the sealants were applied by dental hygienists.

In health centers where sealants were applied by dental auxiliaries, the dentist examined and set the initial diagnosis in 69% of cases in 1991 and in 47% of cases in 2001. A small minority of health centers reported dental assistants as the main group applying sealants (IV). In most health centers where dental auxiliaries applied sealants, the dental hygienists and the dental assistants had the opportunity to consult the dentist if necessary. The difference in the caries rate of the sealed second molars was not statistically significant between the two sealant methods regardless of whether the sealants were applied by a hygienist or a dentist-assistant pair. The caries rate with the RB method for hygienists and dentists was 0.42% and 1.48% (P=0.21), and for the GIC method 3.38% and 4.89% (P=0.40) respectively (I).

6. Role of sealants in caries prevention and management (IV)

Systematic sealant approach and the criteria and policies for sealant application

Sealants were applied on a systematic basis by the majority of respondents but only half of these respondents had a local agreement on the criteria for when to apply sealants. The criteria for applying sealants and the actual strategies seemed to vary between the dentists within the health centers and between the health centers nationwide. During the 10 year period a distinct shift towards sealing over enamel caries lesions had taken place: the proportion of respondents using this approach increased from 30% in 1991 to 37% in 2001, yet 44% preferred to seal only the sound fissures in 2001. The most common choice of treatment for permanent molars with suspected or detected enamel caries

lesions at the occlusal surface was to open the fissure up at the enamel level and to apply a sealant. The preceding eradication of enamel caries before applying a sealant (PRR2) was done almost as often as the application of topical fluoride to suspect occlusal surfaces. Only 10% of the respondents applied sealants without a preceding opening of the fissure.

Opinions on sealant use

Most of the respondents estimated that sealants had both long- and short-term effects on dentin caries development. When asked the hypothetical question of what should be done if the treatment would concern their own child, one-third of the respondents (N=98) were willing to pay whatever was needed to cover the costs to ensure intact teeth rather than receiving a filling free of charge.

Of all the appointments for children up to age 19, the estimated proportion of appointments where sealants were applied decreased from 16% in 1991 to 10% in 2001. The majority (76%) of the respondents estimated that they had applied fewer sealants towards the end of the 10-year period of 1991-2001. Most respondents (96% in 1991; 97% in 2001) reported the use of other methods in addition to sealant application for the prevention and management of pit and fissure caries. The prevailing method of choice was fluoride therapy, either in topical form or as fluoride tablets.

Ten percent of the respondents refrained totally from applying sealants. The reasons given for this were:

- sealants are thought to have low cost-effectiveness (30%)
- there is no further need to seal fissures since the DMFT values have decreased to the low levels they were in 2001 (26%)
- sealants are ineffective, or other methods are more effective than sealants in arresting enamel caries lesions at occlusal surfaces (17%)

DISCUSSION

The results of the present series of studies strongly suggest that sealing the occlusal surfaces appropriately will effectively prevent the progression of initial enamel lesions when the sealants are applied as a routine procedure in the public dental health care.

.

1. Methodological aspects

Validity of material

Studies I-III took place during the years 1986 to 1999 in the health center of Varkaus, representing a public health center with a systematic sealing program. Two sealant methods were applied as a routine procedure for children attending public dental health care after examination and risk-evaluation (I, II). During the study period the public health care in Varkaus as well as elsewhere in Finland was comprehensive for the age cohorts up to 19 years. Since the studied cohorts were followed for three (I), nine, and 13 years (III) and since the dental personnel as well as the population in Finland are homogeous, the results can be taken to represent the whole country.

The sample of teeth in the retrospective study comprised all FPMs and SPMs that were examined in Varkaus at least once in three years or that had not erupted yet at the baseline, so the coverage of the sealant program was 68% for FPMs and 73% for SPMs for the whole sample. The teeth not relevant for this approach were either erupted but receiving a sealant that year, already sealed, carious, filled or extracted (III). The drop-out of patients was 20% (I) in the clinical trial. The drop-out rate can be considered low (I) to moderate (III). There can be various reasons for these drop-outs, one being the fact that some of the participants were not examined at the 36 month-examination because each child had personally scheduled dental check-up periods (I). Other participants might have moved away which is more probable with the long follow-up periods of the retrospective study (III). As most children under the age of 19 attended the community organized health care, it is not probable that these drop-out children had a different social status that could have altered the results of the study (I, III).

The questionnaire study (IV) covered the entire country, a health center being a cluster for the sample. Thus the respondents and their responses are considered as a representative sample of the dental health personnel in Finland. A high total response

rate of the dentists (79%) and of the dental health centers (cluster, 85%) render the study representative of the whole country.

Validity of methods

The study design in the prospective study (I) was a randomized split mouth clinical trial where sealants were placed by two methods. One of the advantages of the split mouth study design is that both modalities of sealant application are compared in the same environment equivocally. In the present study (I) the fluoride released from the GIC sealant could have favored the RB sealant had the different sealant methods been equally effective in arresting caries lesions. However, it does not seem possible that the GIC sealants would have had a positive effect on the RB sealants since the GIC sealant was far more ineffective than the RB sealant in the fissures where it was intentionally applied.

The split mouth design can also cause a bias since the teeth/teeth pairs in the same mouth are never independent 'units'. In our study (I) one or two matched pairs were obtained *per* child. The advantage of this study design was that a reasonably large number of all second molars from the specified age-cohorts in the city of Varkaus could be included in the study. The modified McNemar's test (Durkalski et al., 2003) used in the statistical analysis takes into account the problem of dependent pairs in a split mouth design. The RB-GIC sealant pair was treated as a matched pair and either one or two tooth pairs were observed per mouth.

Even though the sealant material choice was randomized by the birth date (odd/even birth date indicating a different material for the molar to be sealed first), the two different sealant methods cannot be applied as blinded due to the difference of the materials. Another possible bias can be caused by the fact that there were many participating operators (I, II, III). The GDPs from Varkaus had attended a calibration study in occlusal caries diagnostics resulting in fair agreement of the mean interexaminer variables in terms of reproducibility; all personnel participating in the study were experienced with both sealant methods and received additional instructions before the study began. No significant difference between dental hygienists and dentist-assistant pairs could be found in the dentin caries rate of the sealed teeth (I). Since the conditions of this split mouth study reflect the conditions in real life with a large patient series, we assume that the results can be adapted to early caries management and to a public health setting elsewhere.

The duration of all sealant application procedures to second molars was recorded during a one-week period (II): the study was done as part of routine work in the Varkaus health center and the operator (dentist or dental hygienist) was not aware of being monitored (II, III). As all sealant procedures from that calendar week were included, it is unlikely that a single operator would have biased the results (II).

A retrospective study design monitors the real-life situation; in our study the coverage of a comprehensive sealant program was examined in Varkaus, an average Finnish city including all the children that were examined at least every three years (III). Neither the dental hygienists nor the dentist-assistant pairs applying sealants were aware that they would be monitored subsequently. The long follow-up periods of 13 (FPMs) and nine (SPMs) years add reliability to the figures since the development of a caries process can take time. Proximal and occlusal dentin caries lesions were monitored separately. However, if a proximal lesion was detected at the same (or earlier) examination as an occlusal lesion in a certain tooth, the tooth was recorded as proximally decayed. This can lead to a bias where some occlusal lesions are considered as proximal and the rate of occlusal lesions is thus underestimated.

Our questionnaire had limitations since the answers given are self-reported and do not necessarily correspond to the real-life situation of treatment choices (IV). As some of the questions go back to the situation over ten years ago, the information may not be accurate and should be interpreted with caution. It can be assumed, though, that the trends of the earlier attempted sealant approach will stay in mind even if the details are forgotten. The questions were also formulated to enable explicit answers. Before starting the study, the questionnaire was piloted by three CDOs. This study is beneficial in reflecting the attitudes towards sealant application and describing the sealant policies in practice as well as reporting the changes that have taken place in the dental public health of Finland during the 10-year period.

2. Results of the study

In the beginning of the 1990s when the Varkaus sealant study was designed it was considered unethical in Finland to leave any permanent molars of a child in the caries risk group unsealed despite the fact that the interceptive approach had already been suggested internationally (Meiers and Jensen, 1984; Rock, 1984; Elderton, 1985a). As no caries risk group was intentionally left without sealing that could be used as controls, the actual dentin caries preventive effect with either of the materials or treatment modalities

used cannot be estimated, which is a weakness in this study (I, III). Most children were classified as having a high caries risk even though the inclusion criteria applied were not specified or recorded. However, it has later become evident that by limiting the choice of sealant application to those children and teeth at high risk the cost-effectiveness of sealants is increased (Locker et al., 2003; Beauchamp et al., 2008).

A comparison of sealant effectiveness in different age groups in three European countries showed that the caries prevalence of the population affected the sealant effectiveness markedly (Leskinen et al., 2008). Sealing was very effective among the age cohorts of 1970-72 in Finland and Sweden and in the 1980 cohort of Greece; the dentin caries preventive effect being 40-50% with about the same caries prevalence in all three countries at the given periods. In the younger age cohorts of Finland and Sweden the dentin caries prevention with a selective sealant approach was as effective as the approach where the teeth were intentionally left unsealed (Leskinen et al., 2008). Even though the caries trends in Finland have been decreasing since the 1970's (Nordblad et al., 2004) the current trend may have reached the lower limit as the DMFT-scores tend to rise when compared to the levels in other European countries (Marthaler et al., 1996; Downer et al., 2008). Therefore, when the effectiveness of a sealant approach is evaluated, the present caries prevalence should also be considered.

With RB sealants protection against dentin caries is assumed to be directly related to the degree of retention. In our field study, RB sealants showed a higher retention rate than did GIC sealants. This is consistent with several other studies that have found high retention rates with RB sealants (Mertz-Fairhurst et al., 1986; Romcke et al., 1990; Simonsen, 1991; Poulsen et al., 2006).

Romcke et al. (1990) used an autopolymerized RB sealant in a field trial where incipient occlusal lesions of FPMs were sealed in children with moderately high caries susceptibility. The complete retention rate after one year was 89%, after two years 81% and 60% after seven to nine years; only about two to four % of the sealed surfaces required maintenance sealing each year. The overall success rate with sealants, which takes into account the teeth with completely retained sealants, with partial sealant retention not requiring resealing and the teeth requiring and receiving maintenance resealing, was 85% after four to 10 years from insertion (Romcke et al., 1990). Approximately one % of the sealed occlusal surfaces developed dentin caries in each of the first four years and essentially none thereafter.

Forss and Halme (1998) compared RB and GIC sealants in a seven year follow-up study and found a highly significant difference in the retention rate favoring RB sealants. The

relative risk of a GIC sealed tooth of having dentin caries was 1.44 when compared to an RB sealed tooth. Poulsen et al. (2001) compared the retention and the dentin caries preventive effect of RB and GIC sealant methods in FPMs in a three-year follow-up study and found consistently lower retention with GIC than with RB sealants. The relative risk of having dentin caries in a GIC sealed tooth was 3.4 when compared to a RB sealed tooth. This is well in line with the 3.9 found in our study with SPMs, suggesting similar results with the sealed FPMs and SPMs.

Studies with longer follow-up periods of 15 (Simonsen, 1991) and 10 years (Wendt et al., 2001), have also reported high retention rates with RB sealants. Simonsen reported complete sealant retention with a single application of RB sealants in 82%, 57% and 28% of sealed teeth after five, 10 and 15 years, respectively. Only 17% of the surfaces were found to be sound in the control group, while the rate was 69% in the FPM-sealed group. The rate of occlusal dentin caries lesions found in our study 16% for FPMs (follow-up 13 years) and 5% (follow-up nine years) for SPMs is in line with the study of Wendt et al. (2001), who reported retention rates of 65% in both FPMs (after 20 years) and SPMs (after 15 years) and dentin caries rates of 13% (FPMs; 20 years) and five% (SPMs; 15 years) of the sealed teeth. The maintenance resealing rates in our study were 28% for FPMs and 23% for SPMs, indicating lower overall retention rates.

In the study of Wendt et al. (2001) only the ‘caries-free’ surfaces were sealed and observed unlike in our study (I), where the instructions were to seal molars on the basis of risk evaluation. Thus the susceptive fissures or detected enamel caries lesions were sealed as well as any other molar fissures considered to have a high risk for dentin caries lesions. The relative risk of having a defective RB sealant was low and maintenance resealing was applied in 15% of the initially RB sealed teeth (Wendt et al., 2001). These findings (Wendt et al., 2001) suggest the long-term effectiveness of sealants. These results are also in line with the clinicians responses from the questionnaire study (IV): the majority of the respondents thought that sealants have both short- and long-term effectiveness.

A defective RB sealant, even if the sealant is only partially lost, can lead to a lesion growth under the sealant, a situation not always easily detected – the *hidden caries* phenomenon (Weerheijm, 1997). The defected sealant can also create an environment favorable to bacteria, thus leading to plaque accumulation. Periodical re-evaluation of the sealed teeth and resealing of the defected sealants have therefore been suggested (Welbury et al., 2004; Feigal and Donly, 2006; Beauchamp et al., 2008), which is in line with our studies.

GIC sealants have been assumed to offer permanent protection against caries with a single application. Mejare and Mjör found (1990) that in pits and fissures which at clinical observation showed total loss of sealant, remnants of GIC could be detected when their replicas were observed with a microscope. In their clinical trial, none of the 44 GIC sealed teeth developed dentin caries lesions (Mejare and Mjör, 1990). Torppa-Saarinen and Seppä (1990) reported 75% retention rates with GIC sealants in a four month follow-up study; significantly low retention rates (26%) have been reported by Forss et al. (1994) in a two year trial, and in two four year follow-up studies (35%, 20%) (Williams and Winter, 1981; Arrow and Riordan, 1995), respectively.

Despite the lower retention and the macroscopic absence of the sealant, GIC sealants have been shown to retain some level of cariostatic effect on the occlusal surface (Raadal et al., 2001; Gilpin, 1997). The use of GIC has been suggested to be limited to those cases where application of RB sealants is contradictory or compromised, for example to erupting teeth where isolation is a problem (Raadal et al., 2001; Gilpin, 1997). The present study (I) shows that when the erupting teeth were evaluated after a six month period (in order to allow the tooth to erupt properly), the six month period was not so long as to compromise the sealant program as none of the erupting teeth had developed dentin caries and thus could be sealed in an interceptive manner.

Systematic sealant application to molar fissures was the treatment of choice in the majority of the health centers even though defined general guidelines for sealant application criteria or policies used were rare among the health centers (IV). The larger the health center the more inconsistency was found in the sealant policies applied. Even though most respondents replied as having applied sealants on susceptive or carious occlusal surfaces, they in fact did not use sealants in arresting enamel lesions but rather applied a PRR. In this method, described by Simonsen (1982; 1988) as type 2 PRR, a prophylactic opening is prepared when cleaning the fissure before the sealant is applied to the fissure and the surrounding sound enamel.

As the profession is used to meticulously clearing all plausible visible ‘abnormalities’ from the tooth surfaces and from the prepared cavities, it may be difficult to adapt to sealing over stained noncavitated enamel lesions. Had the profession been more familiar with the methodology, the earlier studies and the international guidelines published earlier, the frequent use of sealants in a more interceptive way could have been encouraged (IV). Local agreements on the sealant approach (‘the clinical guidelines’) would probably further aid the dentists in getting the evidence into practice.

Caries risk assessment of the teeth and of the individual are important determinants when the sealant approach is considered (Welbury et al., 2004; Feigal and Donly, 2006). As the detection and grading of occlusal caries lesions is often inaccurate and shows great variance among clinicians (Alanen et al., 1994; Ekstrand and Christiansen, 2005; Bader et al., 2006) and since the accurate assessment of caries risk is not always possible, it is concluded that sealing over initial enamel lesions reduces the need for assessment of whether the lesion is active or inactive.

The health centers that used the interceptive sealant policy of sealing over initial enamel lesions profited most from the systematic sealing as their DMFT values showed a decreasing trend, while the other health centers the trend was for increasing values. Even though sealing over initial enamel caries lesions has been suggested in many consensus reports since the 1980's (Table 1), the present questionnaire study revealed that in the year 2001 this was not the prevailing protocol in Finland. Hence, it is suggested that that dentists should be encouraged to seal over initial, non-cavitated enamel lesions in order to arrest the progression of the lesion into the dentin.

CONCLUSIONS

Sealing permanent molars at caries risk with the RB sealant method prevents dentin caries more effectively than a single application of GIC sealant in a routine public health setting (I). Teeth with defective or totally lost GIC sealants were more prone to develop dentin caries than teeth with intact sealants; it is therefore concluded that the positive effect of the fluoride-releasing GIC will not last on the occlusal surface if the sealant is lost (I). As sealant integrity and thus the regular maintenance of sealants and sealed teeth is necessary to the successful outcome with the sealant approach, a method having low retention rates and time-consuming application procedures may add to the final costs of a sealant program (I, II, III). As targeting both the teeth and the individuals was found effective (I), it is concluded that caries-risk evaluation may improve the effectiveness of a sealant program and may render the sealant approach more economically attractive.

Even though sealants were broadly applied within Finnish public health care during the study period, the profession did not seem to be familiar with the effectiveness of sealing over incipient caries lesions (IV). An association could be found between the practiced sealant application protocol and the local DMFT figures, favoring those health centers that applied sealants in an interceptive manner (IV).

RECOMMENDATIONS

As the integrity and retention of a sealant is considered crucial to the success of sealants in the long-term, RB is the material of choice. Sealing over incipient caries lesions is both effective and practical – the dental profession should be encouraged to use sealants more in an interceptive manner rather than in a preventive or operative manner. Distinct national guidelines on sealant application criteria and protocols, based on evidence, would aid the GDP in the appropriate sealant approach.

ACKNOWLEDGEMENTS

This study was carried out at the Institute of Dentistry, University of Helsinki, during the years 1999-2008. The clinical part of the study has been carried out in the Health Center of Varkaus during 1993-1999.

I wish to express my thanks to Professor Jarkko Hietanen, MD, DDS, PhD, the Dean of the Institute of Dentistry, for placing the research facilities at my disposal.

I express my deepest gratitude for my supervisor, Professor Eero Kerosuo, DDS, PhD, for introducing me to the world of dental research. I have been priviledged to benefit from his expertise in this field. His inspiring attitude and interest in this work as well as his guidance, including the numerous discussions, have been leading me through these years of research.

I am profoundly grateful for my other supervisor and the former Dean of the Institute of Dentistry Professor Jukka H. Meurman, MD, DDS, PhD, for his guidance and support during the study. He has taught me skills in scientific writing and with his vast experience, has encouraged me in bringing this project to conclusion.

I am grateful to the official reviewers, Professor Sven Poulsen, Dr.Odont, PhD, University of Aarhus, Denmark, and Docent Kaisu Pienihäkkinen, DDS, PhD, University of Turku, for their valuable comments and constructive criticism in improving the manuscript.

I express my sincere thanks to all the collaborators and co-authors of this study, especially Ilpo Pietilä, DDS, the former head of Varkaus Health Center and the present head of Pori Health Center, and Eeva Lavonius, DDS, for their contributions in this study. I am grateful to Janne Pitkäniemi, PhD, co-author, and Professor Seppo Sarna, PhD, for their expertise in the epidemiological and statistical methods especially with study I. I thank the other co-authors Noora Halttunen, DDS, and Tiina Vilkuna-Rautiainen, DDS, for their participation.

I thank Jodie Painter, PhD, for editing the English language of the manuscript, and Mrs. Marjo Kostia for helping me with the many practical matters.

This study has been supported by The Finnish Dental Society Apollonia, The Helsinki University Research Funds and the Finnish Woman Dentists' Association, which are all gratefully acknowledged.

My warm thanks go to the whole personnel of the Health Center of Varkaus for participation in the study, as well as to all participating patients for making this work possible.

I owe my thanks to the whole personnel of the Institute of Dentistry. Special thanks go to my teacher colleagues Anja Kotiranta, DDS, PhD, Päivi Mäntylä, DDS, PhD, Eva Siren, DDS, and Marja Ekholm, DDS, PhD, for their friendship and encouragement during these years. I also wish to thank all my colleagues, dental hygienists and assistants at Viherlaakson Hammaslääkärit for creating a pleasant and supportive athmospere at work. All my friends, thank you for being there.

I warmly thank my mother Eila, and my sister Anja, for their encouragement and interest in this work throughout these years. I also wish to thank my in-law parents Seija and Elja for their support during these years.

I thank my sons Pyry and Aarni for keeping me up with the realities and reminding me of what is really important in life. Finally, my heartfelt thanks go to my husband Ari for his love and support throughout these years. I am priviledged to have you all in my life.

Espoo January 20th, 2009

Sari Kervanto-Seppälä

REFERENCES

Ahovuo-Saloranta A, Hiiri A, Nordblad A, Worthington H, Makela M. (2004). Pit and fissure sealants for preventing dental decay in the permanent teeth of children and adolescents. *Cochrane Database Syst Rev* (3)(3):CD001830.

Alanen P, Hurskainen K, Isokangas P, Pietilä I, Levänen J, Saarni UM*, et al*. (1994). Clinician's ability to identify caries risk subjects. *Community Dent Oral Epidemiol* 22(2):86-89.

American Academy of Pediatric Dentistry Clinical Affairs Committee-Restorative Dentistry Subcommittee, American Academy of Pediatric Dentistry Council on Clinical Affairs. (2005). Guideline on pediatric restorative dentistry. *Pediatr Dent* 27(7 Suppl):122-9.

American Academy of Pediatric Dentistry Clinical Affairs Committee, Clinical Affairs Committee. (2008). Guideline on periodicity of examination, preventive dental services, anticipatory guidance counselling and oral treatment for infants, children and adolescents. Reference manual V29(7):102-7.

Arrow P. (1998). Oral hygiene in the control of occlusal caries. *Community Dent Oral Epidemiol* 26(5):324-30.

Arrow P, Riordan PJ. (1995). Retention and caries preventive effects of a GIC and a resin-based fissure sealant. *Community Dent Oral Epidemiol* 23(5): 282-5.

Asbell MB. (1994). Research in dental caries in the United States: 1820-1920. *Compendium*15(6):792,794,796 passim.

Azarpazhooh A, Main PA. (2008). Pit and fissure sealants in the prevention of dental caries in children and adolescents: a systematic review. *J Can Dent Assoc* 74(2):171-7.

Backer Dirks O. (1966). The clinical testing of agents for the prevention of dental caries. *Adv Fluorine Res* 4:1-2.

Backer Dirks O. (1971). Cariostatic effects observed at Tiel after 15 years of fluoridation. *Med Hyg (Geneve)* 29(980): 1550-1.

Backer Dirks O, Houwink B, Kwant GW. (1961). The results of 6 1/2 years of artificial fluoridation of drinking water in the Netherlands. The Tiel-Culemborg experiment. *Arch Oral Biol* 5:284-300.

Bader JD, Shugars DA, Bonito AJ. (2001). A systematic review of selected caries prevention and management methods. *Community Dent Oral Epidemiol* 29(6):399-411.

Bader JD, Shugars DA. (2006). The evidence supporting alternative management strategies for early occlusal caries and suspected occlusal dentinal caries. *J Evid Based Dent Pract* 6(1):91-100.

Bardow A, Lagerlöf B, Nauntofte B, Tenovuo J. (2008) The role of saliva. In: Dental Caries The Disease and its Clinical Management. Fejerskov O, Kidd EAM, editors. Second ed. Oxford: Blackwell Munksgaard, pp. 189-207.

Beauchamp J, Caufield PW, Crall JJ, Donly K, Feigal R, Gooch B*, et al*. (2008). Evidence-based clinical recommendations for the use of pit-and-fissure sealants: a report of the American Dental Association Council on Scientific Affairs. *J Am Dent Assoc* 139 (3):257-68.

Berkowitz R. (2006). Mutans strepto-cocci: Acquisition and transmission. *Pediatr Dent* 28:106-9.

Bohannan HM. (1983). Caries distribution and the case for sealants. *J Public Health Dent* 43(3):200-4.

Bohannan HM, Bader JD. (1984). Future impact of public health and preventive methods on the incidence of dental caries. *J Can Dent Assoc* 50(3):229-33.

Bowen RL. (1982). Composite and sealant resins--past, present, and future. *Pediatr Dent* 4(1):10-15.

Boyde A (1976) Amelogenesis and the structure of enamel. In: Scientific foundations of dentistry. Cohen B, Kramer I, editors. London: Heinemann Medical Books, pp. 335-52.

Bravo M, Montero J, Bravo JJ, Baca P, Llodra JC. (2005). Sealant and fluoride varnish in caries: a randomized trial. *J Dent Res* 84(12):1138-43.

Brown LJ, Selwitz RH. (1995). The impact of recent changes in the epidemiology of dental caries on guidelines for the use of dental sealants. *J Public Health Dent* 55(5 Spec No):274-91.

Buonocore MG. (1955). A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. *J Dent Res* 34(6):849-53.

Buonocore M. (1970). Adhesive sealing of pits and fissures for caries prevention, with use of ultraviolet light. *J Am Dent Assoc* 80(2):324-30.

Buonocore MG. (1971). Caries prevention in pits and fissures sealed with an adhesive resin polymerized by ultraviolet light: a two-year study of a single adhesive application. *J Am Dent Assoc* 82(5):1090-3.

Burt BA. (1989). Cost effectiveness of preventive dental programs: Results of the workshop. *Journal of Public Health Dentistry* 49(Special issue):331-7.

Burt BA. (2005). Concepts of risk in dental public health. *Community Dent Oral Epidemiol* 33: 240-7.

Carvalho JC, Ekstrand KR, Thylstrup A. (1989). Dental plaque and caries on occlusal surfaces of first permanent molars in relation to stage of eruption. *J Dent Res* 68(5):773-9.

Carvalho JC, Ekstrand KR, Thylstrup A. (1991). Results after 1 year of non-operative occlusal caries treatment of erupting permanent first molars. *Community Dent Oral Epidemiol* 19(1): 23-8.

Carvalho JC, Thylstrup A, Ekstrand KR. (1992). Results after 3 years of non-operative occlusal caries treatment of erupting permanent first molars. *Community Dent Oral Epidemiol* 20(4):187-92.

CDC.(2001).Promoting Oral Health: Interventions for Preventing Dental Caries, Oral and Pharyngeal Cancers, and Sports-Related Craniofacial Injuries. A Report on Recommendations of the Task Force on Community Preventive Services. Report No.: 50(RR21).

Chestnutt IG, Schafer F, Jacobson AP, Stephen KW. (1996). Incremental susceptibility of individual tooth surfaces to dental caries in Scottish adolescents. *Community Dent Oral Epidemiol* 24(1): 11-16.

Clarkson BH. (1999). Introduction to cariology. *Dent Clin North Am* 43(4):569-78.

Cueto EI, Buonocore MG. (1967). Sealing of pits and fissures with an adhesive resin: its use in caries prevention. *J Am Dent Assoc* 75(1):121-8.

Dowell T. (1986). The Diagnosis and Management of the Early Carious Lesion. *Br Dent J* 16C:347.

Downer MC, Drugan CS, Blinkhorn AS. (2008). Correlates of dental caries in 12-year old children in Europe: a cross-sectional analysis. *Community Dent Health* 24:70-8.

Drummond MF. (1980). Principles of Economic Appraisal in Health Care. Oxford: Oxford University Press.

Durkalski VL, Palesch YY, Lipsitz SR, Rust PF. (2003). Analysis of clustered matched-pair data. *Stat Med* 22(15): 2417-28.

Eccles MFW. (1989). The problem of occlusal caries and its current management. *New Zealand Dent J* 85: 50-5.

Ekstrand KR, Westergaard J, Thylstrup A. (1991a). Organic content in occlusal groove-fossa-system in unerupted 3rd mandibular molars: a light and electron microscopic study. *Scand J Dent Res* 99(4):270-80.

Ekstrand KR, Carlsen O, Thylstrup A. (1991b). Morphometric analysis of occlusal groove-fossa-system in mandibular third molar. *Scand J Dent Res* 99(3):196-204.

Ekstrand KR, Bjørndal L. (1997). Structural analyses of plaque and caries in relation to the morphology of the groove-fossa system on erupting mandibular third molars. *Caries Res* 31(5):336-48.

Ekstrand KR, Ricketts DN, Kidd EA. (2001). Occlusal caries: pathology, diagnosis and logical management. Dent Update.28:380-7.

Ekstrand KR, Christiansen ME. (2005a). Outcomes of a non-operative caries treatment programme for children and adolescents. *Caries Res* 39(6):455-67.

Ekstrand KR, Ricketts DN, Longbottom C, Pitts NB. (2005b). Visual and tactile assessment of arrested initial enamel carious lesions: an in vivo pilot study. *Caries Res* 39(3):173-7.

Elderton RJ. (1985a). Management of early dental caries in fissures with fissure sealant. *Br Dent J* 158(7):254-8.

Elderton RJ. (1985b). Diagnosis and treatment of dental caries: the clinicians' dilemma. Scope for change in clinical practice. *J R Soc Med* 78 Suppl 7:27-32.

Elderton RJ, Jenkins CB, Marshall KJ, Hooper SM, Foster LV, Hooper GR*, et al*. (1990). Changing perceptions of the requirements of cavity preparations. *Br Dent J* 168(1):30-2.

Featherstone JD. (2004). The continuum of dental caries--evidence for a dynamic disease process. *J Dent Res* 83 Spec No C:C39-42.

Feigal RJ, Donly KJ. (2006). The use of pit and fissure sealants. *Pediatr Dent* 28(2):143-50.

Fejerskov O. (1997). Concepts of dental caries and their consequences for understanding the disease. *Community Dent Oral Epidemiol* 25(1):5-12.

Fejerskov O. (2004). Changing paradigms in concepts on dental caries: Consequences for oral health care. *Caries Research* 38:182-91.

Fejerskov O, Thylstrup A, Larsen MJ. (1981). Rational use of fluorides in caries prevention. A concept based on possible cariostatic mechanisms. *Acta Odont Scand* 39:241-9.

Fejerskov O, Kidd EAM, Nyvad B, Baelum V. (2008a) Defining the disease: an introduction. In: Dental Caries The Disease and its Clinical Management. Fejerskov O, Kidd EAM, editors. Second ed. Oxford: Blackwell Munksgaard Ltd, pp. 3-6.

Fejerskov O, Nyvad B, Kidd EAM. (2008b). Pathology of dental caries. In: Dental Caries The Disease and its Clinical Management. Fejerskov O, Kidd EAM, editors. Second ed. Oxford: Blackwell Munksgaard, pp. 19-48.

Forss H, Saarni UM, Seppä L. (1994). Comparison of glass-ionomer and resin-based fissure sealants: a 2-year clinical trial. *Community Dent Oral Epidemiol* 22(1):21-4.

Forss H, Halme E. (1998). Retention of a glass ionomer cement and a resin-based fissure sealant and effect on carious outcome after 7 years. *Community Dent Oral Epidemiol* 26(1):21-5.

Frencken JE, van't Hof MA, Taifour D, Al-Zaher I. (2007). Effectiveness of ART and traditional amalgam approach in restoring single-surface cavities in posterior teeth of permanent dentitions in school children after 6.3 years. *Community Dent Oral Epidemiol* 35(3):207-14.

Fung EY, Ewoldsen NO, St Germain HA, Jr, Marx DB, Miaw CL, Siew C*, et al*. (2000). Pharmacokinetics of bisphenol A released from a dental sealant. *J Am Dent Assoc* 131(1):51-8.

Garcia-Godoy F. (1986). The preventive glass ionomer restoration. *Quintessence Int* 17(10):617-19.

Gilpin JL. (1997). Pit and fissure sealants: a review of the literature. *J Dent Hyg* 71(4):150-8.

Graves RC, Abernathy JR, Disney JA, Stamm JW, Bohannan HM. (1991). University of North Carolina caries risk assessment study. III. Multiple factors in caries prevalence. *J Public Health Dent* 51(3):134-43.

Griffin SO, Griffin PM, Gooch BF, Barker LK. (2002). Comparing the costs of three sealant delivery strategies. *J Dent Res* 81(9):641-5.

Griffin SO, Oong E, Kohn W, Vidakovic B, Gooch BF, CDC Dental Sealant Systematic Review Work Group*, et al*. (2008). The effectiveness of sealants in managing caries lesions. *J Dent Res* 87(2):169-74.

Gwinnett AJ, Buonocore MG. (1965). Adhesives and caries prevention. *Br Dent J* 119;77-80.

Handelman SL, Buonocore MG, Heseck DJ. (1972). A preliminary report on the effect of fissure sealant on bacteria in dental caries. *J Prosthet Dent* 27(4):390-2.

Handleman SL, Buonocore MG, Schoute PC. (1973). Progress report on the effect of a fissure sealant on bacteria in dental caries. *J Am Dent Assoc* 87(6):1189-91.

Handelman SL, Washburn F, Wopperer P. (1976). Two-year report of sealant effect on bacteria in dental caries. *J Am Dent Assoc* 93(5):967-70.

Handelman SL, Shey Z. (1996) Michael Buonocore and the Eastman Dental Center: A Historic Perspective on Sealants. Mandel ID, (ed). *J Dent Res* 75(1):529-34.

Hiiri A, Ahovuo-Saloranta A, Nordblad A, Makela M. (2006). Pit and fissure sealants versus fluoride varnishes for preventing dental decay in children and adolescents. *Cochrane Database Syst Rev* (4)(4):CD003067.

Holm GB, Holst K, Mejare I. (1984). The caries-preventive effect of a fluoride varnish in the fissures of the first permanent molar. *Acta Odontol Scand* 42(4):193-7.

Hunter PB. (1988). A study of pit and fissure sealing in the School Dental Service. *N Z Dent J* 84(375):10-12.

International Caries Detection and Assessment System (IDCAS) Coordinating Committee (2005) Rationale and Evidence for the International Caries Detection and Assessment System (ICDAS II), pp. 1-44. *www.icdas.org*

Ismail AI, Sohn W, Tellez M, Amaya A, Sen A, Hasson H*, et al*. (2007). The International Caries Detection and Assessment System (ICDAS): an integrated system for measuring dental caries. *Community Dent Oral Epidemiol* 35(3):170-8.

Jenson L, Budenz AW, Featherstone JDB, Ramos-Gomez FJ, Spolsky VW, Young DA. (2007). Clinical protocols for caries management by risk assessment. *J Calif Dent Assoc* 35(10):714-23.

Kanerva L, Jolanki R, Estlander T. (1991). Allergic contact dermatitis from non-diglycidyl-ether-of-bisphenol-A epoxy resins. *Contact Dermatitis* 24(4): 293-300.

Kanerva L, Estlander T, Jolanki R. (1997). Occupational allergic contact dermatitis caused by acrylic tri-cure glass ionomer. *Contact Dermatitis* 37(1):49-50.

Keyes PH. (1954). Dental caries in the Syrian hamster. VI. Minimal dental caries activity in animals fed presumably cariogenic rations. *J Dent Res* 33(6):830-41.

Keyes PH. (1960). The infectious and transmissible nature of experimental dental caries. Findings and implications. *Arch Oral Biol* 1:304-20.

Kidd EA, Ricketts DN, Pitts NB. (1993). Occlusal caries diagnosis: a changing challenge for clinicians and epidemiologists. *J Dent* 21(6):323-31.

Kidd EA, Fejerskov O. (2004). What constitutes dental caries? Histopathology of carious enamel and dentin related to the action of cariogenic biofilms. *J Dent Res* 83 Spec No C:C35-8.

Kleinberg I (1970). Formation and accumulation of acid on the tooth surface. *J Dent Res* 49:1300-18.

Korhonen M, Käkilehto T, Larmas M. (2003). Tooth-by-tooth survival analysis of the first caries attack in different age cohorts and health centers in Finland. *Acta Odont Scand* 61:1-5.

Lavonius E, Kerosuo E, Kallio P, Pietilä I, Mjör IA. (1997). Occlusal restorative decisions based on visual inspection--calibration and comparison of different methods. *Community Dent Oral Epidemiol* 25(2):156-9.

Leverett DH, Handelman SL, Brenner CM, Iker HP. (1983). Use of sealants in the prevention and early treatment of carious lesions: cost analysis. *J Am Dent Assoc* 106(1):39-42.

Leskinen K, Ekman A, Oulis C, Forsberg H, Vadiakas G, Larmas M. (2008). Comparison of the effectiveness of fissure sealants in Finland, Sweden and Greece. *Acta Odont Scand* 66:65-72.

Levy SM, Kiritsy MC, Warren JJ. (1995). Sources of fluoride intake in children. *J Public Health Dent* 55:39-52.

Lewis JM, Morgan MV. (1994). A critical review of methods for the economic evaluation of fissure sealants. *Community Dent Health* 11(2):79-82.

Locker D, Jokovic A, Kay EJ. (2003). Prevention. Part 8: The use of pit and fissure sealants in preventing caries in the permanent dentition of children. *Br Dent J* 195(7):375-8.

Manji F, Fejerskov O, Nagelkerke NJ, Baelum V. (1991). A random effects model for some epidemiological features of dental caries. *Community Dent Oral Epidemiol* 19(6):324-8.

Marthaler TM. (1967). The value in caries prevention of other methods of increasing fluoride ingestion, apart from fluoridated water. *Int Dent J* 17(3):606-18.

Marthaler TM, O'Mullane DM, Vrbic V. (1996). The prevalence of dental caries in Europe 1990 – 1995. *Caries Res* 30; 327-55.

Marthaler TM. (2004) Changes in dental caries 1953-2003. *Caries Res* 38: 173-81.

McLean JW, Wilson AD. (1974). Fissure sealing and filling with an adhesive glass-ionomer cement. *Br Dent J* 136(7):269-76.

Meiers JC, Jensen ME. (1984). Management of the questionable carious fissure: invasive vs noninvasive techniques. *J Am Dent Assoc* 108(1):64-8.

Mejare I, Mjör IA. (1990). Glass ionomer and resin-based fissure sealants: a clinical study. *Scand J Dent Res* 98(4):345-50.

Merriam-Webster online dictionary (2008)..*http://www.merriam-webster.com/dictionary*

Mertz-Fairhurst EJ. (1984). Current status of sealant retention and caries prevention. *J Dent Educ* 48(2 Suppl):18-26.

Mertz-Fairhurst EJ, Schuster GS, Williams JE, Fairhurst CW. (1979). Clinical progress of sealed and unsealed caries. Part I: Depth changes and bacterial counts. *J Prosthet Dent* 42(5):521-6.

Mertz-Fairhurst EJ, Schuster GS, Fairhurst CW. (1986). Arresting caries by sealants: results of a clinical study. *J Am Dent Assoc* 112(2):194-7.

Mertz-Fairhurst EJ, Curtis JW,Jr, Ergle JW, Rueggeberg FA, Adair SM. (1998). Ultraconservative and cariostatic sealed restorations: results at year 10. *J Am Dent Assoc* 129(1):55-66.

Meurman JH, Helminen SK, Luoma H. (1978). Caries reduction over 5 years from a single application of a fissure sealant. *Scand J Dent Res* 86(3):153-6.

Murray JJ, Nunn JH. (1993). BSPD. A policy document on fissure sealants. *Int J Paed Dent* 3;99-100.

Newbrun E (1989) Cariology. 3rd ed. Chicago, Illinois: Quintessence Publishing Co, Inc.

Niessen LC, Douglass CW. (1984). Theoretical considerations in applying benefit-cost and cost-effectiveness analyses to preventive dental programs. *J Public Health Dent* 44(4):156-68.

National Institutes of Health Consensus Development Conference summary. Dental sealants in the prevention of tooth decay. (1984). *Br Dent J* 156(8):295-8.

National Institutes of Health Consensus Development Conference statement, March 26-28, 2001. Diagnosis and management of dental caries throughout life. (2001). *J Dent Educ* 65(10):1162-8.

Nordblad A, Suominen-Taipale L, Rasilainen J. (1993). Oral health care in health centres 1991. National Research and Development Centre for Welfare and Health (STAKES), *Reports 115.* Jyväskylä: Gummerus Kirjapaino Oy.

Nordblad A, Suominen-Taipale L, Rasilainen J, Karhunen T. (2004) Oral health care at health centres from the 1970s to the year 2000. National Research and Development Centre for Welfare and Health (STAKES), *Reports 278*.; 51.

Nunn JH, Murray JJ, Smallridge J, BSPD. British Society of Paediatric Dentistry. (2000). British Society of Paediatric Dentistry: a policy document on fissure sealants in paediatric dentistry. *Int J Paediatr Dent* 10(2):174-7.

Nyvad B. (1993). Microbial colonization of human tooth surfaces. *APMIS Suppl* 32:1-45.

Nyvad B. (2004). Diagnosis versus detection of caries. *Caries Res* 38(3): 192-8.

Nyvad B, Machiulskiene V, Baelum V. (1999). Reliability of a new caries diagnostic system differentiating between active and inactive caries lesions. *Caries Res* 33(4):252-60.

Nyvad B, Machiulskiene V, Baelum V. (2003). Construct and predictive validity of clinical caries diagnostic criteria assessing lesion activity. *J Dent Res* 82(2):117-22.

Oong EM, Griffin SO, Kohn WG, Gooch BF, Caufield PW (2008). The effect of dental sealants on bacteria levels in caries lesions. *J Am Dent Assoc* 139:271-8.

Pardi V, Pereira AC, Mialhe FL, Meneghim Mde C, Ambrosano GM. (2003). A 5-year evaluation of two glass-ionomer cements used as fissure sealants. *Community Dent Oral Epidemiol* 31(5):386-91.

Pitts NB (2008) The impact of diagnostic criteria on estimates of prevalence, extent and severity of dental caries. In: Dental Caries The Disease and its Clinical Management. Fejerskov O, Kidd EAM, editors. Second ed. Oxford: Blackwell Munksgaard Ltd, pp. 147-59.

Pitts NB. (2004a). Modern concepts of caries measurement. *J Dent Res* 83 Spec No C:C43-7.

Pitts NB. (2004b). Oral health Assessment in clinical practice. *BMJ* 196: 505.

Pitts NB. (2001). Clinical diagnosis of dental caries. An European perspective. *J Dent Educ* 65:973-80.

Pitts NB, Stamm J. (2004). International Consensus Workshop on Caries Clinical Trials (ICW-CCT) Final Consensus Statements: Agreeing Where the Evidence Leads. *J Dent Res* 83,125–8.

Poulsen S, Beiruti N, Sadat N. (2001). A comparison of retention and the effect on caries of fissure sealing with a glass-ionomer and a resin-based sealant. *Community Dent Oral Epidemiol* 29(4):298-301.

Poulsen S, Laurberg L, Vaeth M, Jensen U, Haubek D. (2006). A field trial of resin-based and glass-ionomer fissure sealants: clinical and radiographic assessment of caries. *Community Dent Oral Epidemiol* 34(1):36-40.

Raadal M, Espelid I, Mejare I. (2001) The caries lesion and its management in children and adolescents. In: Pediatric Dentistry: a clinical approach. Koch G, Poulsen S, (editors). Copenhagen: Munksgaard, pp. 173-212.

Reich E, Lussi A, Newbrun E. (1999). Caries-risk assessment. *Int Dent J* 49(1):15-26.

Rethman J. (2000). Trends in preventive care: caries risk assessment and indications for sealants. *J Am Dent Assoc* 131 Suppl:8S-12S.

Ricketts D, Kidd E, Weerheijm K, de Soet H. (1997). Hidden caries: What is it? Does it exist? Does it matter? *Int Dent J* 47:259-65.

Riordan PJ, FitzGerald PEB. (1994). Outcome measures in split mouth caries trials and their statistical evaluation. *Community Dent Oral Epidemiol* 22:192-7.

Ripa LW. (1983). Occlusal Sealants: An Overview of Clinical Studies. Proceedings of a forum on the use of fissure sealants in public health programs. *J Public Health Dent* 43(3):216-25.

Ripa LW, Leske GS, Sposato A. (1985). The surface-specific caries pattern of participants in a school-based fluoride mouthrinsing program with implications for the use of sealants. *J Public Health Dent* 45(2):90-94.

Ripa LW. (1993). Sealants revisited: an update of the effectiveness of pit-and-fissure sealants. *Caries Res* 27 Suppl 1:77-82.

Ripa LW, Wolff MS. (1992). Preventive resin restorations: indications, technique, and success. *Quintessence Int* 23(5):307-15.

Robinson C, Hallsworth AS, Weatherell JA, Kunzel W. (1976). Arrest and control of carious lesions: a study based on preliminary experiments with resorcinol-formaldehyde resin. *J Dent Res* 55(5):812-18.

Rock WP. (1984). Potential use of fissure sealants in the NHS. *Br Dent J* 157(12):445-8.

Rodrigues JA, Hug I, Diniz MB, Lussi A. (2008). Performance of fluorescence methods, radiographic examination and ICDAS II on occlusal surfaces in vitro. *Caries Res* 42(4):297-304.

Romcke RG, Lewis DW, Maze BD, Vickerson RA. (1990). Retention and maintenance of fissure sealants over 10 years. *J Can Dent Assoc* 56(3):235-7.

Rozier RG. (1995). The impact of recent changes in the epidemiology of dental caries on guidelines for the use of dental sealants: epidemiologic perspectives. *J Publ Health D* 55(5):292-301.

Rozier RG. (2001). Effectiveness of methods used by dental professionals for the primary prevention of dental caries. *J Dent Educ* 65(10):1063-72.

Shellis RP, Duckworth RM. (1994). Studies on the cariostatic mechanisms of fluoride. *Int Dent J* 44(3 Suppl 1):263-73.

Siegal M. (1995). Promotion and use of pit and fissure sealants: an introduction to the special issue. *J Public Health Dent* 55(5 Spec No):259-260.

Scottish Intercollegiate Guidelines Network. (2000). Preventing dental caries in chidren at high caries risk: Targeted prevention of dental caries in the permanent teeth of 6-16 year olds presenting for dental care. *National clinical guideline* no 47. Edinburgh.

Simonsen RJ. (1982). Preventive resin restoration. Innovative use of sealants in restorative dentistry. *Clin Prev Dent* 4(4):27-9.

Simonsen RJ. (1988). Fissure sealants and the preventive resin restoration on the NHS. *Br Dent J* 165(7):238-9.

Simonsen RJ. (1991). Retention and effectiveness of dental sealant after 15 years. *J Am Dent Assoc* 122(10):34-42.

Simonsen RJ. (2005). Preventive resin restorations and sealants in light of current evidence. *Dent Clin North Am* 49(4):815-23, vii.

Simonsen RJ, Stallard RE. (1977). Sealant-restorations utilizing a diluted filled composite resin: one year results. *Quintessence Int Dent Dig* 8(6):77-84.

Smallridge J. (2000). UK National Clinical Guidelines in Paediatric Dentistry. Management of the stained fissure in the first permanent molar. *Int J Paediatr Dent* 10(1):79-83.

Songpaisan Y, Bratthall D, Phantumvanit P, Somridhivej Y. (1995). Effects of glass ionomer cement, resin-based pit and fissure sealant and HF applications on occlusal caries in a developing country field trial. *Community Dent Oral Epidemiol* 23(1):25-9.

Stamm JW. (1984). Is there a need for dental sealants? Epidemiological indications in the 1980s. *J Dent Educ* 48(2 Suppl):9-17.

Suni J. (1997). Changes in the cumulative tooth and surface specific survival rates between four age cohorts. *Thesis.* Turun yliopiston julkaisuja, ser. D 260., University of Turku.

Söderholm KJ. (1995). The impact of recent changes in the epidemiology of dental caries on guidelines for the use of dental sealants: clinical perspectives. *J Public Health Dent* 55(5 Spec No):302-11.

Söderholm KJ, Mariotti A. (1999). BIS-GMA--based resins in dentistry: are they safe? *J Am Dent Assoc* 130(2):201-9.

Tanzer JM. (2001).The microbiology of primary dental caries in humans. J Dent Educ 65(10):1028-37.

ten Cate JM. (2004). Fluorides in caries prevention and control: empiricism or science. *Caries Res* 38(3):254-7.

ten Cate JM, Duijsters PP. (1983a). Influence of fluoride in solution on tooth demineralization. II. Microradiographic data. *Caries Res* 17(6):513-19.

ten Cate JM, Duijsters PP. (1983b). Influence of fluoride in solution on tooth demineralization. I. Chemical data. *Caries Res* 17(3):193-9.

Theilade J, Fejerskov O, Horsted M. (1976). A transmission electron microscopic study of 7-day old bacterial plaque in human tooth fissures. *Arch Oral Biol* 21(10):587-98.

Theuns HM, Driessens FC, van Dijk JW, Groeneveld A. (1986). Experimental evidence for a gradient in the solubility and in the rate of dissolution of human enamel. *Caries Res* 20(1):24-31.

Thylstrup A, Fejerskov O. (1979). A scanning electron microscopic and microradiographic study of pits in fluorosed human enamel. *Scand J Dent Res* 87(2):105-14.

Thylstrup A, Fredebo L. (1982) Method for studying surface coatings and the underlying enamel features in the scanning electron microscope. In: Surface colloid phenomena in the oral cavity: methodological aspects. Frank L, Leach S, editors. London: IRL Press, pp. 169-84.

Torppa-Saarinen E, Seppä L. (1990). Short-term retention of glass-ionomer fissure sealants. *Proc Finn Dent Soc* 86(2):83-8.

Vaeth M, Poulsen S. (1998). Comments on a commentary: statistical evaluation of split mouth caries trials. *Community Dentistry and Oral Epidemiology* 26**:** 80-3.

van Amerogen JP, van Amerogen WE, Watson TF, Opdam NJM, Roeters D, Bitterman D*, et al.* (2008) Restoring the tooth: the seal is the deal. In: Dental Caries The Disease and its Clinical Management. Fejerskov O, Kidd EAM, editors. Second ed. Oxford: Blackwell Munksgaard Ltd, pp. 385-426.

Walker J, Floyd K, Jakobsen J. (1996) The effectiveness of sealants in pediatric patients. *Journal of Dentistry for Children* 63: 268-70.

Weerheijm KL. (1997). Occlusal 'hidden caries'. *Dent Update* 24(5):182-184.

Weerheim KL, Gruythuysen RJM, van Amerogen WE. (1992). Prevalence of hidden caries. *J Dent Child* 59:408-12.

Welbury R, Raadal M, Lygidakis NA, European Academy of Paediatric Dentistry. (2004). EAPD guidelines for the use of pit and fissure sealants. *Eur J Paediatr Dent* 5(3):179-84.

Wendt LK, Koch G, Birkhed D. (2001). On the retention and effectiveness of fissure sealant in permanent molars after 15-20 years: a cohort study. *Community Dent Oral Epidemiol* 29(4):302-7.

WHO Oral Health Country / Area Profile Programme (1997). Method of assessing dental caries. In: Oral Health Surveys - Basic Methods, 1997,Geneva.

Williams B, Winter GB. (1981). Fissure sealants. Further results at 4 years. *Br Dent J* 150(7):183-7.

Virtanen JI, Forsberg H, Ekman A. (2003). Timing and effect of fissure sealants on permanent molars: a study in Finland and Sweden. *Swed Dent J* 27(4):159-65.

Woolf SH, Grol R, Hutchinson A, Eccles M, Grimshaw J. (1999). Clinical guidelines: Potential benefits, limitations, and harms of clinical guidelines. *BMJ* 318:527-30.

Workshop on guidelines for sealant use: recommendations. (1995). *J Public Health Dent* 55(5 Spec Issue):263-73.

A QUESTIONNAIRE SURVEY ON SEALANTS

Demographic information
Name / Occupation:
Health center / City or Community:
Address and telephone:

1. Do you apply sealants systematically in your health center? If YES, since when has this been the applied protocol?

☐ YES, since _____

☐ NO

☐ NO, I have abstained completely from the sealant approach since _____

If you answered NO to the preceding question, please move straight to question 12.

2. Have you agreed on a specified policy concerning the sealant approach in your health center?

Please choose the alternative that best describes the current policy

☐ NO, each GP makes the decision according to his own views and knowledge

Please move straight to question 9.

☐ YES, the criteria for sealant application and the guidelines have been discussed and a verbal agreement exists over the current protocol

Please reply to questions 3–8 as you know has been the policy in your health center in 2001 and in 1991

3. On which criteria do you base the decision to apply sealants (currently/10 years earlier); in other words, when do you choose to apply a sealant to molar occlusal surfaces?

Please choose only one alternative at each period of time which best describes the policy at your health center.

	in 1991	**in 2001**
- only the unstained and visibly intact fissures are sealed		
- as above + - stained fissures are sealed		
- as above + - suspected or detected enamel caries lesions in fissures are sealed		
- as above + - suspected or detected dentin caries lesions in fissures are sealed		
- no specific policy exists		
- alternative or unknown policy		

4. When have the guidelines been agreed on (which year)?

In _____

Has the content of the agreement been changed afterwards?

☐ NO, it has not been changed

☐ YES, it has been changed during _____

5. How do you treat the susceptible fissures with plausible enamel caries lesions?
Please choose your treatment of choice.

	in 1991	**in 2001**
- no procedures, wait and see until the next routine examination		
- no treatment, re-examination after a shorter period		
- topical fluoride application to the fissure, wait and see until the next routine examination		
- topical fluoride application to the fissure, re-examination after a shorter period		
- sealant application		
- sealant application, re-examination after a shorter period		
- sealant application after opening the fissure up to enamel level		
- sealant application after opening the fissure up to dentin level (preventive resin restoration)		
- restore the fissure with filling		
- unknown treatment		
-alternative treatment mode, which is?		

6. How do you treat the partially erupted molars that would be sealed if it was possible?	**in 1991**	**in 2001**
- no procedures		
- no procedures, re-examination after a shorter period		
- topical fluoride application to the fissure, wait and see until the next routine examination		
- topical fluoride application to the fissure, re-examination after a shorter period		
- sealant application		
- sealant application, re-examination after a shorter period		
- sealant application after opening the fissure up to enamel level		
- sealant application after opening the fissure up to dentin level		
- restore the fissure with filling		
- unknown treatment mode		
- alternative treatment mode, which is?		

7. What do you choose to do/what is the applied policy in your health center if a sealant is found totally or partially lost at an examination and no visible caries lesion can be detected?	**in 1991**	**in 2001**
- no procedures		
- topical fluoride application to the occlusal surface		
- reseal the tooth		
- alternative treatment mode, which is?		
- no specific policy is applied – the policies vary according to the operator		

8. Which teeth groups do you consider to seal in general?		
	in 1991	**in 2001**
- the first molars		
- the second molars		
- some other teeth groups, which are?		
- no teeth groups are sealed in general		

9. Are the examination intervals in your health center scheduled		
	in 1991	**in 2001**
- annually		
- individually		

10. What is the rate (estimation) of examined teeth that are intentionally left without sealing because the predicted possibility for developing dentin caries is low?		
	in 1991	**in 2001**
- the first molars		
- the second molars		
- the other groups of teeth, which are?		

11. Continued from the preceding question, how do you predict that caries increment is improbable for a certain child?

Please score the four alternatives that in your opinion best describe this statement (the scoring from number one to four: 1 = the best choice, 2 = the second best choice and so on). The same number can be used more than once if the different alternatives are equal in your opinion.

	score (1-4)
- the level of oral hygiene is good	
- the diet is ok	
- no initial caries lesions in the dentition	
- no active caries lesion found for a year/low caries activity	
- no visible plaque / no bleeding from the gums	
- regular use of fluoride dentrifice	
- regular use of dental floss	
- professional instruction on teeth cleaning and on other preventive information has been shown and explained to the child and the child understands this information	
- regular use of xylitol products	
- intact dentition with no visible caries lesions or fillings	
- gently sloping cusps of molars	
- unstained fissures of molars	
- some teeth have already been sealed	
- only a few small fillings in the dentition	
- the decreasing trend of dentin caries in younger age groups	
- age	
- gender	
- social class	
- another alternative, which is?	
- no opinion	

12. Besides sealant application, do you consider/have you considered applying any alternative methods in managing occlusal caries lesions?		
Which alternative method?	**in 1991**	**in 2001**
	YES ☐	YES ☐
- teaching the children to clean their teeth/pointing out the importance of good oral hygiene		
- topical fluoride varnish/fluoride tablets/other topical fluoride methods		
- professional tooth cleaning regularly at separate appointments		
- an alternative method, which is?		
	NO ☐	NO ☐

13. If you have completely refrained from sealant application in your health center, what is this decision based on?
Please choose one or more of the choices:

- since the DMFT-values of the children have decreased, sealant application is no longer necessary in Finland - I doubt the effectiveness of sealants - sealant application procedures are expensive when compared to their effectiveness in preventing dentin caries - I find other methods more effective in preventing dentin caries lesions - the personnel doesn't have time to apply sealants - there is no personnel available for the sealant application procedures - most of the patients are in need of restorative rather than preventive or interceptive treatment - some other reason, which is?	

14. Which materials do you use/have been using for sealant application procedures? What is/was the proportion of the material

	in 1991	**in 2001**
- light-curing resin-based material: name of product?	%	%
- chemically curing resin-based material:	%	%
- glass-ionomer cement	%	%
- alternative material, which is?	%	%

15. What is the estimated rate of sealants applied by	**in 1991**	**in 2001**
- dentists	%	%
- dental hygienists	%	%
- dental assistants	%	%

16. If the dental auxiliary are responsible for the sealant application procedure, is the preceding initial caries assessment always set by the dentist?	**in 1991**	**in 2001**
YES		
NO		

If your answered NO for the preceding question, please clarify how you proceed in such situations

- the dental hygienist sets the diagnosis by himself	☐
- the dental hygienist sets the diagnosis by himself but has the possibility to consult a dentist if necessary	☐
- the dental nurse sets the diagnosis by himself	☐
- the dental assistant sets the diagnosis by himself but has the possibility to consult a dentist if necessary	☐
- alternative policy	☐

17. Please estimate the rate of appointments (of children up to 18 years of age) when sealants are applied in you health center (for example, an average of 4 appointment of which sealants are applied at one appointment = 25%)	
%	**in 1991**
%	**in 2001**

18. How has the volume of sealant application procedures changed in your health center	
a) during the previous ten-year period? Compared to the earlier ten-year period, there have been	
more sealant procedures	☐
fewer sealant procedures	☐
the number of sealant application procedures has stayed the same	☐
b) during the previous five-year period? Compared to the earlier five-year period, there have been	
more sealant procedures	☐
fewer sealant procedures	☐
the amount of sealant application procedures has stayed the same	☐

19. What is your opinion on the short- and long-term effectiveness of the sealant approach?
Please choose one or more of the choices below:

- sealants do not have **long-term** effects on preventing dentin caries lesions at the occlusal surfaces	☐
- sealants have **more short-term than long-term** effects on preventing dentin caries lesions at the occlusal surfaces	☐
- in **some** cases, sealants can postpone the development of dentin caries lesions for **a few years**	☐
- in **most** cases, sealants can postpone the development of dentin caries lesions for **a few years**	☐
- sealants do not have **short-term** effects on preventing dentin caries lesions at the occlusal surfaces	☐
- sealants have **more long-term than short-term** effects on preventing dentin caries lesions at the occlusal surfaces	☐
- in **some** cases, sealants can postpone the development of dentin caries lesions for **a lifetime**	☐
- in **most** cases, sealants can postpone the development of dentin caries lesions for a **lifetime**	☐
- another opinion	☐
- no opinion	☐

20. Suppose that all children in your area having dentin caries lesions are treated free of charge at the local health center by filling the dentin caries lesions.

Alternatively, the teeth can be treated by applying sealants before the dentin caries lesions develop.

In a hypothetical situation, how much would you be willing to pay for your own child's sealant program or other preventive program which would guarantee that no dentin caries lesions would develop during a period of time?

- I'm not willing to pay anything	☐
- 50€ (the estimated cost of sealing a molar at the health center)	☐
- 170€ (the estimated cost of a few appointments where sealants are applied)	☐
- 500€ (the estimated cost of sealing the teeth and of sealant maintenance and necessary resealing during a few-year period)	☐
- all the necessary costs even if the actual costs are difficult to estimate beforehand; including the costs of sealant application, sealant maintenance and necessary resealing procedures	☐
- no opinion	

21. What was the mean DMFT-index values (at age 12) of your health center in

1991 _____

2000 _____

22. Is there something else concerning sealants you would like to express here?

THANK YOU FOR YOUR REPLY!