

# Treatment decisions on approximal caries and longevity of Class II restorations



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2013

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*Series of dissertations submitted to the  
Faculty of Dentistry, University of Oslo*

ISBN 978-82-91757-87-2

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Printed in Norway: AIT Oslo AS

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# Acknowledgements

The work included in this thesis was carried out at the Department of Paediatric Dentistry and Behavioural Science, Faculty of Dentistry, University of Oslo, between 2006 and 2013. I want to express my gratitude to the Faculty of Dentistry for providing financial support and excellent work facilities, and to the Department of Paediatric Dentistry and Behavioural Science for the opportunity to do this work in an inspiring research environment.

The Kvit-project was developed and initiated by my two supervisors, professors Ivar Espelid and Anne Bjørg Tveit. I will always be indebted to them for allowing me to take part in the project. Without them, there would be no thesis. The office of Ivar Espelid was next to mine, and his door was always wide open; his desk was constantly occupied with piles of work, but he was never too busy to take time to supervise me whenever I entered. I am grateful for his willingness to share his extensive knowledge with me and for his confidence in me, giving me the freedom to work independently. Anne Bjørg's exceptional scientific guidance, combined with never-ending enthusiasm and support, has kept my spirits high throughout my years as a PhD student. My motivation and self-confidence was never better than after a pep talk in her office!

I gratefully extend my thanks to the personnel in the Public Dental Health Service in Hordaland, Norway, for their dedication to this study. Particular thanks are due to Dr Torunn Gaarden, who was always positive and supportive and was the *locomotive* of the study, and to Dr Inge Magnus Bruvik (Director of Public Dental Health Service, Hordaland), for his faith in the project and all his support.

I wish to thank Professor Leiv Sandvik for comprehensive statistical guidance, Ibrahimu Mdala for assisting with multi-level Cox regression analyses and Dr Paul Riordan (Write2Publish) for providing scientific and linguistic advice.

I am also grateful for the support from colleagues and friends at the Department of Paediatric Dentistry and Behavioural Science. I have had seven great years at the department and I will miss you all!

Finally, I would like to thank my family and friends, especially my loving wife, Ingebjørg and our beautiful daughter Kirsti, for their patience, encouragement and love.

Oslo, August 2013

Simen Eidhammer Kopperud



# List of papers

- Paper I Vidnes-Kopperud S, Tveit AB, Espelid I. **Changes in the treatment concept for approximal caries from 1983 to 2009 in Norway.** Caries Res 2011;45:113-20.
- Paper II Vidnes-Kopperud S, Tveit AB, Gaarden T, Sandvik L, Espelid I. **Factors influencing dentists' choice of amalgam and tooth-colored restorative materials for Class II preparations in younger patients.** Acta Odontol Scand 2009;67:74-9.
- Paper III Kopperud SE, Tveit AB, Gaarden T, Sandvik L, Espelid I. **Longevity of posterior dental restorations and reasons for failure.** Eur J Oral Sci. 2012;120:539-48.

Please note that my author's name is changed from *Vidnes-Kopperud S* to *Kopperud SE* in the last paper due to marriage.





# Introduction

## Approximal dental caries

Dental caries, also known as tooth decay, is a bacterial infection that causes demineralization and destruction of the dental hard tissues (enamel, dentine and cement) by production of acid by bacterial fermentation of food debris accumulated on the tooth surface [MedlinePlus Encyclopedia]. It was first scientifically described in texts by Hippocrates, “the father of Western medicine”, in ancient Greece [Clifton 1752]. For many years, tooth extraction was the most common treatment of dental caries [Ring 1985]. In the late nineteenth century, Black and Miller put forward an understanding the aetiology of dental caries and developed classifications and treatment techniques that have endured until recent times [Miller 1883; Black 1908]. Dental caries may develop at any tooth site in the oral cavity where a biofilm develops, but this occurs at a higher rate in protected sites where dental plaque may accumulate, e.g. difficult-to-access approximal surfaces. Black named lesions beginning in the approximal surfaces of premolars and molars *Class II lesions* [Black 1908], and this remains the professional term today.

## Treatment criteria for dental caries

Initial carious lesions can be treated non-operatively. It is well-known that dietary advice, effective oral hygiene and use of fluoride can retard the carious process [Kidd and Fejerskov 2008]. If the carious lesion progresses and reaches a certain size, operative treatment is indicated. Carious tooth substance must be removed and a dental restoration placed to restore the tooth. Unfortunately, all dental restorations have a limited lifespan and will eventually have to be replaced. Once a restoration

has been placed in a tooth, its limited longevity, leading to its replacement (and further tooth substance loss), during a lifetime may lead to a destruction of the tooth: a *death spiral* [Brantley et al. 1995]. Therefore, it is important that dentists do not initiate operative treatment of dental caries too soon.

In 1983, Elderton and Nuttall showed large variations among dentists in treatment decisions in a study where 18 patients were examined by 15 dentists [Elderton and Nuttall 1983]. Only 2.6% of all restorations that were suggested by the study dentists were a result of an unanimous agreement. One explanation could be that dentists use different criteria for initiating operative treatment. During recent decades, there has been a substantial shift in dentists' criteria for initiation of operative treatment of dental caries in Norway [Tveit et al. 1999; Gimmestad et al. 2003]. After fluoride-containing tooth pastes became available without prescription in Norway in 1971, the dental caries incidence and progression dropped dramatically [Løkken and Birkeland 1978], and there was less need of prompt operative treatment. It was shown that dental caries is a slowly progressing disease and that lesions could be arrested [Backer Dirks 1966]. Most dentists gradually changed their treatment criteria, postponing operative treatment until the lesion reached a certain severity [Tveit et al. 1999; Gimmestad et al. 2003]. The focus in teaching in most universities in Europe today is on a preventive approach, rather than operative intervention; "a dentist's aim should be to avoid operative treatment wherever possible" [Ricketts and Pitts 2009] and new concepts, such as *minimally invasive approaches*, have been introduced [Peters and McLean 2001]. Nevertheless, It has been shown that dentists still use different criteria for initiating operative treatment of dental caries [Tveit et al. 1999; Espelid et al. 2001; Doméjean-Orliaguet et al. 2004; Ghasemi et al. 2008; Gordan et al. 2009; Baraba et al. 2010]. According to Fejerskov et al. [Fejerskov et al.

2013], a more profound break with traditional thinking in dental education is necessary to implement a more preventive approach for control of dental caries.

## Preparation techniques

Located in the posterior regions of the dental arch, Class II restorations are exposed to high biting force and more challenging conditions, due to difficult access to the restored surfaces both for the patient and the dentist [Demarco et al. 2012]. Traditionally, preparations of Class II lesions were made with mechanical retention and *extension for prevention*, according to Black's principles [Black 1908]. The term *Extension for prevention* was postulated to avoid secondary caries by placing cavity margins at sites that were accessible for direct cleaning by food particle movement in mastication. The introduction of adhesive techniques made it less important to focus on cavity design for the retention of restorations. It was shown that the longevity of a tooth was better when the preparation was kept small [Walls et al. 1988], and Elderton re-named Black's term to *Extension for destruction* because he claimed too much healthy tooth substance was lost with the traditional preparation technique [Elderton 1994]. New techniques, such as saucer-shaped (box-only) and tunnel preparations, were developed to allow minimal substance removal [Peters and McLean 2001]. Unfortunately, the failure rate of tunnel preparations was considered too high [Strand et al. 1996; Hasselrot 1998; Pilebro et al. 1999; Nicolaisen et al. 2000; Strand et al. 2000]. The failure rate of saucer-shaped preparations has not hitherto been examined thoroughly. Thus, there is little available evidence on the survival of saucer-shaped preparations. Nevertheless, today's dental students are taught to use saucer-shaped restorations [Van Amerongen et al. 2008; Mejàre et al. 2009]. To what extent dentists who were educated to apply Black's principles actually use the new minimal preparation techniques would be interesting to explore.

## Restorative materials in Class II preparations

Dental amalgam and resin composite are both considered appropriate restorative materials for Class II restorations [Van Amerongen et al. 2008]. Compomer and glass ionomer cements are commonly used for Class II restorations in deciduous teeth, but are considered inappropriate in permanent teeth because of low wear resistance and high risk of fracture [Hickel and Manhart 2001; Van Amerongen et al. 2008]. Amalgam is an alloy that is formed by mixing mercury with silver, copper and tin, and which also may contain palladium, zinc and other elements to improve handling characteristics [Phillips and Anusavice 2013]. Amalgam was the main restorative material for posterior restorations for more than a century, but during recent decades, the use of amalgam has declined in many countries [Friedl et al. 1995; Forss and Widstrom 2001; Doméjean-Orliaguet et al. 2004; Lynch et al. 2007; Opdam et al. 2007a; Sunnegårdh-Grönberg et al. 2009; Baraba et al. 2010; Eklund 2010]. Possible detrimental effects of mercury on general health, as well as environmental concerns, are important reasons for the decline, but improved general dental health and advances in adhesive technology could be just as valid reasons. In Norway, the use of amalgam was banned in 2008 [Norwegian Ministry of the Environment 2008]. In the years preceding the ban, the national health authorities put pressure on dentists to limit the use of amalgam and advised that amalgam should never be the first choice when placing restorations [Norwegian Directorate of Health and Social Affairs 2003]. Nevertheless, amalgam continued to be used to some extent in Norway until the ban was definite.

Resin composite is a restorative material consisting of a matrix, reinforced by a dispersion of filler particles bound to the matrix by coupling agents [Phillips and Anusavice 2013]. The first resin composites were introduced in the 1960s. The restorative material was developed for anterior restorations that are not exposed to

occlusal stress, but gradual modification of materials and techniques now allow the use of resin composites to be extended to posterior teeth with occlusal loading [Craig 2002]. The effect of etching tooth substance with phosphoric acid to achieve better adhesion was discovered in 1955, when Buonocore performed clinical studies based on knowledge from general industry [Buonocore 1955]. This brought a new dimension to restorative dentistry, since acrylic – and later resin modified – dental materials could adhere to tooth substance, reducing the need for a retentive cavity preparation. Thus, sound tooth substance could be preserved. Compared with amalgam, the aesthetic properties of resin composite are favourable, as the colour of restorations can be made to match the natural appearance of teeth. Resin composite has been considered more technique sensitive compared with amalgam and greater plaque accumulation is claimed; the material may also be associated with the development of more secondary caries [Bollen et al. 1997; Eley 1997]. Placing resin composite restorations is more time consuming, leading to a higher cost of resin composite restorations compared with amalgams [Beazoglou et al. 2007]. Nevertheless, several studies show that resin composite has become the most commonly used restorative material for posterior restorations in many countries [Friedl et al. 1995; Forss and Widstrom 2001; Doméjean-Orliaguet et al. 2004; Opdam et al. 2007a; Sunnegårdh-Grönberg et al. 2009; Baraba et al. 2010; Eklund 2010; Seemann et al. 2011]. With the increasing use of resin composite worldwide, it is important for dentists to be aware of the probable restoration longevity and factors influencing this for these materials.

## **Longevity of restorations**

The longevity of dental restorations is dependent upon factors related to the patient, the dentist and the restorative material [Hickel and Manhart 2001]. Traditionally,

amalgam restorations have had better longevity compared with resin composites [Mjör et al. 1990; Jokstad et al. 1994; Mjör and Moorhead 1998; Bogacki et al. 2002; Forss 2004]. With the passage of time, the longevity of resin composites has become increasingly better, and more recent studies have demonstrated comparable longevity of both materials [Manhart et al. 2004; Opdam et al. 2007a; Opdam et al. 2010]. It has been stated that operators who are skilled in placing both amalgam and resin composite can achieve comparable longevity [Opdam et al. 2007a]. The improved longevity of resin composites may not only be due to increasing skill among dentists in handling composites, but also to the development of better materials [Phillips and Anusavice 2013] and new methods of cavity preparation [McComb 2001]. In a systematic review, it was found that studies published prior to 1990 showed significantly poorer longevity of both amalgam and resin composite restorations compared with studies published later [Manhart et al. 2004]. Previous studies have shown that longevity of restorations is associated with patient-related factors like oral hygiene [Stecksen-Blicks and Gustafsson 1986; Bjertness 1991; Vehkalahti et al. 1997; Mascarenhas 1998], past caries experience [Powell 1998; Kidd et al. 2003; Fontana and Zero 2006; Zhang and van Palenstein Helderma 2006], caries activity [Opdam et al. 2010], tooth type [Pallesen 2003; Van Nieuwenhuysen et al. 2003; Opdam et al. 2007b; Da Rosa Rodolpho et al. 2011], cavity size [Van Nieuwenhuysen et al. 2003; Bernardo et al. 2007; Soncini et al. 2007; Simecek et al. 2009] and the number of surfaces involved [Van Nieuwenhuysen et al. 2003; Bernardo et al. 2007; Soncini et al. 2007; Simecek et al. 2009]. Though many studies have been performed on longevity of restorations in posterior teeth, only nineteen of fifty-one included in the review by Manhart *et al.* 2004 had separate results for Class II restorations [Manhart et al. 2004]. Of these, thirteen were prospective studies; six of them had an observation period of more than four years and only one included more than 1000 restorations (n=1100). Thus, there remains a need for long-term studies on

Class II composites placed in general clinical practice, where attention is given not only to the material used, but also to the preparation techniques, to the size of cavity and to patient-related factors.

## Study design

For comparing different treatments – such as restorative materials – randomised clinical trials (RCTs) are considered to be the best study design [Pandis 2011]. In the clinical situation, the clinician usually suggests what he or she thinks is the best alternative for the patient and the decision should be in accordance with the patient's preferences. That cannot be the case in an RCT, in which treatment decisions are made independently of the operator. Also, conducting RCTs is expensive and time-consuming, and the risk of drop-out is high. Many studies on longevity are therefore cross-sectional and retrospective. The weakness of these studies compared with prospective studies is that vital information on the restorations may be missing [Bayne 2007]. Normally there will be little or no information on preoperative variables and considerations during the observation time. It has been argued that cross-sectional studies give an underestimation of the average longevity of routine restorations [Downer et al. 1999]. Furthermore, in cross-sectional studies, longevity has often been estimated by 'the age of failed restorations'. This has been claimed to be a deceptive longevity parameter, compared with Kaplan-Meier statistics [Opdam et al. 2011]. Finally, cross-sectional studies do not necessarily reflect general dental practice because they are often based on restorations placed by a small number of selected operators who might have special interest or skills in operative dentistry. Practice-based research with a large number of practitioners and patients can be very valuable, as it sheds light on decisions made by practitioners in everyday clinical practice [Mjör 2007] and such

research may be performed without ethical dilemmas for the operators. At present, few prospective time-to-event studies have been reported in the dental literature [Opdam et al. 2011; Vähänikkilä et al. 2012], so a reasonable approach to strengthen evidence-based information on longevity of restorations in dental practice could be to perform a prospective practice-based study.



# Aims of the thesis

The overall aim of the thesis was to explore treatment decisions of practising dentists on approximal caries, and the longevity of approximal restorations in posterior teeth.

## Specific aims were:

- To investigate the present criteria for operative treatment of approximal carious lesions among dentists, and further to compare these with those reported in corresponding surveys performed in 1995 and 1983. The research hypothesis to be tested was that no change had occurred in the threshold for initiation of operative treatment, preparation technique and use of restorative materials for approximal caries, compared with a survey undertaken 14 years previously (Paper I).
- To explore dentists' actual choice of restorative materials for Class II restorations. The research hypothesis to be tested was that patient related variables might have influenced the choice of restorative material (Paper II).
- To assess the survival time of Class II restorations placed by dentists in "everyday" practice. The research hypothesis to be tested was that there was no difference in survival of restorations of different restorative materials and no single factor could be identified as a significant predictor of failure (Paper III).

# Materials and Methods

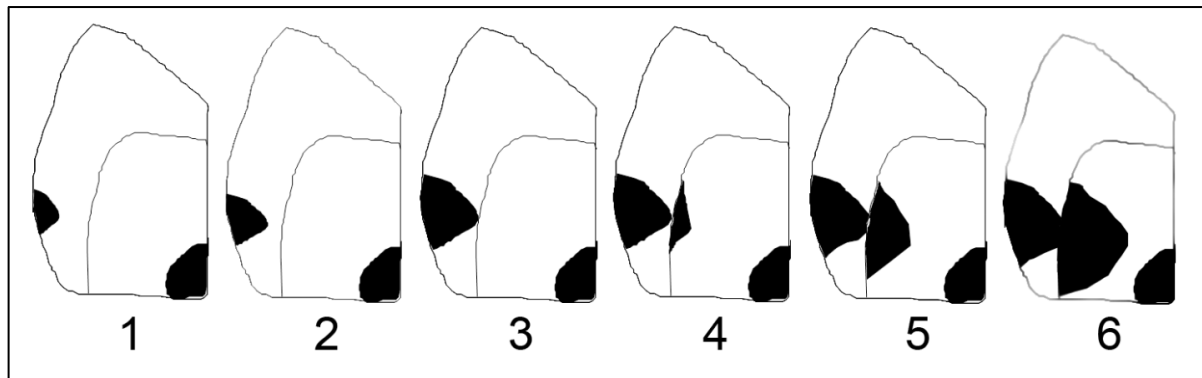
The thesis consists of three separate papers with different study designs. Paper I was a questionnaire study among dentists in Norway. Papers II and III were based on a prospective practice-based study (the Kvit-project). Paper II was cross-sectional, based on the baseline material. Paper III was prospective, based on the full study material.

## Questionnaire study (Paper I)

An electronic questionnaire form was created using the Norwegian-produced, web-based utility, QuestBack (QuestBack Norge, Oslo, Norway). E-mail addresses for the respondents were provided by the Norwegian Dental Association (Den norske tannlegeforening - NTF). Of the 4315 members of NTF, 3654 e-mail addresses were registered. The questionnaire was sent on 30 March 2009. Reminders were sent on 20 April and 5 May 2009. Participation was voluntary and respondents received no compensation. In the questionnaire, basic information was collected on the respondents' sex, age, home county, type of dental practice and to what extent the respondent was involved with caries diagnosis and treatment. Respondents who did not work with caries treatment, could indicate this on the first page and did not then need to answer more questions, without affecting the response rate.

Questions covered treatment strategies for caries, use of and attitudes to different restorative materials and estimated lifetime of restorations. In the part of the study presented in Paper I, questions covered treatment criteria for approximal caries, preferred type of preparation and restorative material of choice. The questions were copied from questionnaire studies conducted in Norway in 1983 and 1995 [Espelid et

al. 1985; Tveit et al. 1999] with identical case scenarios and questions. The results were compared.



**Fig.1:** A six-graded scale indicating stages of approximal caries used in the questionnaire study. Diagram 1 - not more than half enamel depth; 2 – between outer half and outer two thirds of enamel; 3 –to dentine-enamel junction; 4 – in outer third of dentine; 5 – not more than two thirds of dentine depth; 6 – in inner two thirds of dentine.

*The questions put to the respondents were:*

1. "Which lesion or lesions should be restored immediately (Fig.1)? We assume that the patient's caries activity is low and his/her oral hygiene is adequate.
2. "Which type of preparation would you prefer for the smallest of the lesions you decided to drill and fill? You should imagine that the approximal lesion is located distal on the second premolar in the upper jaw. The patient is twenty years of age, sees his/her dentist once a year, has adequate hygiene and uses fluoride toothpaste. Choose one of the following alternatives; 1) Traditional Class II preparation; 2) Tunnel preparation; 3) Saucer-shaped preparation.
3. "Which restorative material would you prefer? Choose one of the options; 1) Resin composite; 2) Compomer; 3) Conventional glass ionomer cement (GIC); 4) Resin modified GIC; 5) A combination of resin composite and GIC; 6) Other."

The QuestBack software was configured to send automatic reminders to all participants who did not reply within three and five weeks respectively. Anonymity was ensured by QuestBack. The study was approved by the Norwegian Social Science Data Services (NSD).

### **Prospective study - "The KVIT-project" (Papers II and III)**

The KVIT-project was started in Bergen in 2001 as a response to a request from the Norwegian government that "assessments of dental restorative materials, independent of manufacturers, should be made available." [Statens Helsetilsyn 1998]. The project was led by a group consisting of professors Ivar Espelid and Anne Bjørg Tveit (University of Bergen), Dr Torunn Gaarden (PDHS, Hordaland), Dr Inge Magnus Bruvik (Director of Public Dental Health Service, Hordaland), and Professor Vibeke Qvist (University of Copenhagen, Denmark). The study was carried out in clinics of the Public Dental Health Service (PDHS) in Bergen city and the surrounding area in western Norway, after being approved by the Regional Committee for Medical Research Ethics. A similar study was conducted in PDHS clinics in Denmark.

Most adolescents in Norway up to the age of 20 years regularly attend the PDHS. To allow for a four year follow-up period, it was decided to admit to the study only patients aged <17 years at the beginning. All Class II restorations placed in permanent premolars and molars in a defined time period were to be included in the study. The restorations were to be followed for at least four years (Fig. 2). The dentists were to use their standard routines concerning operative techniques and choice of restorative material.

All clinicians working in a PDHS dental district (11 clinics) were invited to take part in the study. Of these dentists, about 60% responded positively. In addition, some

dentists from another district were included because they wanted to join the study. Altogether 27 dentists participated (3 male and 24 female) with a mean age of 46.5 (SD=8.9) years. The patients, belonging to the 11 different dental clinics, reflected patients living in both urban and rural areas and of different socio-economic status. To reach the planned number of restorations for the study (n=4000), 136 Class II restorations in 80 regular attenders older than 20 years were also included. They accounted for 3.3% of the restorations. The majority of these patients were younger than 25 years of age. The included restorations were closely examined clinically and radiographically at baseline and at the end point. Most patients followed standard recall intervals and were examined annually during the observation period.

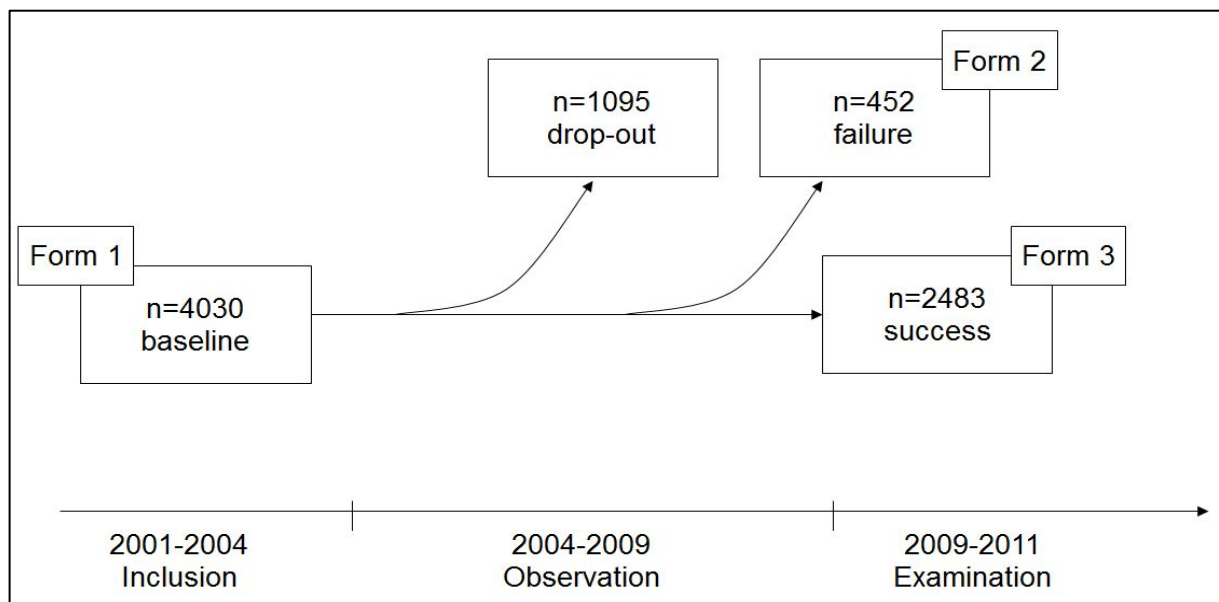
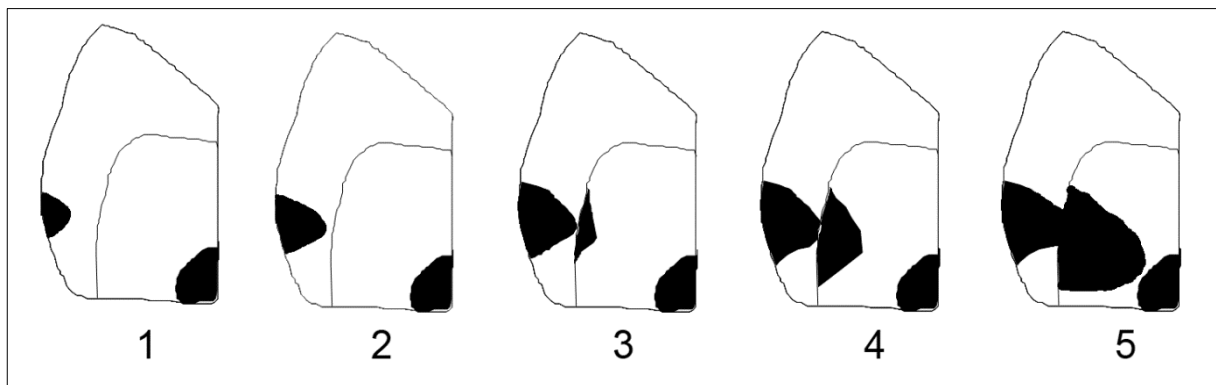


Fig. 2: Flow chart of the prospective study

For each restoration, a set of variables was collected on a Baseline form (Appendix; Prospective study - form 1). Information on the patient's age and sex, the reason for placement of the restoration, caries experience (DMFT), oral hygiene and the size and shape of the cavity were recorded at baseline. Oral hygiene at baseline was

defined as good, medium or poor according to the dentist's clinical judgment. The tooth number, occlusal extension and depth of cavity preparation were recorded. The latter was categorised in thirds of the estimated total dentine thickness. Occlusal extension was expressed in thirds of the inter-cuspal width. The restorative material was the dentist's own choice and was recorded on the form. Proposed reasons for placement were either primary caries or replacement of an old restoration. A five-point scale was used for evaluation of the depth of primary caries (Fig 3).



**Fig. 3:** A five-graded scale indicating stages of approximal caries used in the prospective study. Diagrams 1 and 2 represent lesions confined to the outer and inner half of enamel, and diagrams 3-5 represent lesions confined to the outer, middle and inner third of the dentine respectively.

The restorations were examined at each (normally annual) recall examination. After at least four years, they were thoroughly examined and classified as either successful or failed. The dentists had no instructions with respect to criteria for evaluation of the restorations. When diagnosing restorations as failed, a pre-coded form (Appendix; Prospective study - form 2) coupled to the baseline form was completed, and information on some characteristics and reasons for failure were noted. Each patient's DMFT and oral hygiene (good, medium or poor) were registered. The extent of the replacement (repair vs. full replacement) and whether the restoration had been examined by the dentist who placed the original restoration or another

clinician, were registered. Reasons for failure were registered. When diagnosing restorations still functional after at least four years of observation, a similar recording form was used (Appendix; Prospective study - form 3) to collect information about the status of the restoration and who performed the final examination. The status was categorised either as *restorations with no defects recorded* or *restorations with minor defect(s) recorded, without need for replacement or repair*. The minor defects in "acceptable" restorations were registered.

## **Statistical methods**

### **Questionnaire study (Paper I)**

To process the data, SPSS 16.0 (Statistical Package for the Social Sciences, SPSS, Chicago, Ill., USA) was used and statistical evaluation was carried out by means of descriptive statistics with chi-square tests and logistic regression analyses. The regression analyses were performed with *not restoring enamel lesions operatively* as the dependent variable and dentist's age (ref. group 60-69 years), sex (male vs. female), type of practice (PDHS vs. private practice), DMFT in the dentist's county of practice, dentist density in home county, preparation technique (ref. group tunnel preparation) and restorative material (compomer and GIC vs. resin composite) as independent variables.

### **Prospective study (Papers II and III)**

Specially designed software [Kjøsnes 2004] was used to ensure a standardized registration (input) and validation of all baseline data (Appendix; Prospective study - form 1). Standardized registration of Form 2 and Form 3 was ensured by designing a

user friendly form in Microsoft Access, coupled to the database (Appendix; Prospective study - form 2 and 3).

In Paper II, SPSS 14.0 (Statistical Package for the Social Sciences) was used to process the data. Statistical evaluation was carried out by means of descriptive statistics with chi-square tests and logistic regression analyses. The latter was performed with *amalgam as restorative material* as dependent variable and age, sex, oral hygiene, caries experience (DMFT), reason for placement, cavity width, cavity depth, tooth type and dentist (categorical variable) as independent variables.

In Paper III, IBM SPSS 19.0.0.1 (Statistical Package for the Social Sciences) and R version 2.10.1 (The R Foundation for Statistical Computing 2009-12-14) were used to analyse the data. Mean annual failure rate of the investigated restorations was calculated according to the formula  $(1-y)^5 = (1-x)$ , in which 'y' expresses the mean annual failure rate and 'x' the total failure rate at 4.5 years [Opdam et al. 2004]. Multi-level Cox regression models were fitted with gamma-distributed heterogeneity using the *coxph*-function in the software R. Two separate multi-level Cox regression analyses were performed: 1) Comparison of survival of amalgam vs. resin composite restorations, and 2) Unadjusted and adjusted analyses on factors related to failure of resin composite restorations with the following independent variables: patient's age, sex, caries experience (DMFT at time of placement of restoration), oral hygiene (medium/poor vs. good), tooth type (molar vs. premolar), caries severity (primary caries grade 4-5 and replacements vs. primary caries grade 3), preparation technique (traditional Class II preparations vs. saucer-shaped preparations), cavity width (medium/broad vs. narrow), cavity depth (medium/deep vs. shallow) and restorative material (Other resin composites vs. Filtek Z100). Collinearity was checked using the criterion  $VIF < 5$ , and no independent variables were found to invalidate the analysis. A significance level of 5% was used in all three papers.



# Results

## Questionnaire study (Paper I)

The research hypothesis to be tested was that no change had occurred in the threshold for initiation of operative treatment, choice of preparation technique and use of restorative material for approximal caries, compared with a survey undertaken 14 years previously.

### Threshold for initiation of operative treatment

Only 7.0% of the dentists would initiate operative treatment on carious lesions confined to the enamel in 2009, compared with 18.3% in 1995. In 1983 the corresponding amount was 65.6%. Younger dentists more often than older dentists, and PDHS-employees more often than private practitioners, would defer operative treatment until the approximal carious lesion appeared to have penetrated dentine on radiographs ( $p < 0.01$ ). This was in accordance with results from the 1995 study.

### Preparation technique

A saucer-shaped preparation technique was most favoured in 2009 (68.4%), followed by traditional Class II preparation (27.8%) and tunnel preparation (3.8%). Younger dentists chose saucer-shaped preparation more often than the older dentists ( $p = 0.04$ ), and likewise for dentists in the Public Dental Health Service vs. private practitioners ( $p < 0.01$ ). In 1995, 47.3% of the dentists preferred tunnel preparation, 28.2% traditional Class II preparation and 24.3% saucer-shaped preparation technique. Significantly more dentists in the PDHS preferred tunnel preparation compared with private practitioners in the 1995 study. This preference was unrelated to the dentist's age.

## **Use of restorative materials**

In 2009, resin composite was preferred by a majority of the respondents (94.9%). Preferences for other materials were few and evenly distributed: Compomer (1.1%), conventional glass ionomer cement (1.1%), resin modified glass ionomer cement (0.5%) and a combination of resin composite and glass ionomer cement (1.8%). Because of the amalgam ban in Norway, amalgam was not an option in 2009. In 1995, the values were more equal: 15.5% amalgam, 15.8% resin composite, 22.3% conventional glass ionomer cement, 7.2% resin modified glass ionomer cement and 22.4% a combination of resin composite and glass ionomer cement. Compomer was not an option in 1995. Almost all dentists aged 20-29 years (98.9%) would use resin composite as restorative material, compared with 89.5% of the dentists aged 60-68 years ( $p < 0.01$ ). In 1995, there was no significant difference in the use of restorative materials by age group, but resin composite was used significantly more by private practitioners compared with dentists in the PDHS. In 2009, no significant difference was found in use of resin composite by type of practice (PDHS: 94.8%; private practice: 94.9%,  $p = 0.11$ ).

## **Factors relevant for initiation of operative treatment**

Logistic regression analyses were performed to identify factors relevant for threshold for initiation of operative treatment. In the adjusted regression analyses, high age of the dentists and working in private practice was found to be significantly related to the risk of restoring enamel lesions operatively. Accordingly, dentist's sex, caries prevalence (DMFT) and dentist density in the dentist's home county, preparation technique and filling material were not significantly related to whether dentists would treat enamel lesions operatively or defer treatment until the lesion was radiographically visible in dentine.

## Prospective study (Papers II and III)

The research hypotheses to be tested were that: 1) Among dentists who chose to use amalgam as one of the alternative materials for Class II restorations in the years preceding the amalgam ban in Norway, patient related variables might have the choice of restorative material (Paper II). 2) There was no difference in survival of restorations of different restorative materials and no single factor could be identified as a significant predictor of failure (Paper III).

## Use of amalgam in the years preceding the amalgam ban (Paper II)

The age of the patient was associated with the choice of restorative material. The mean age of patients receiving tooth-coloured restorations was 14.5 years, compared with 15.4 years for patients receiving amalgam restorations ( $p < 0.01$ ). The frequency of amalgam restorations was 8.2% in the highest age quartile ( $\geq 16.3$  years), compared with 2.1% in the lowest quartile ( $\leq 12.8$  years) ( $p = 0.02$ ). Fewer female than male patients received amalgam restorations ( $p < 0.01$ ). In patients rated as having poor oral hygiene, the proportion receiving amalgam fillings was not significantly higher than in those with medium and good oral hygiene ( $p = 0.2$ ). When patients were grouped in quartiles according to DMFT values, more frequent use of amalgam was found in patients with high DMFT ( $p < 0.01$ ). Amalgam was more commonly used in treatment of caries grade 4 than grade 3 ( $p = 0.02$ ). Amalgam was more frequently used in deep than in shallow cavities ( $p < 0.01$ ), but there was no significantly greater use of amalgam in wide cavities compared with narrow ( $p = 0.80$ ). The proportion of molars receiving amalgam restorations was 8.1%, compared with 1.5% in premolars ( $p < 0.01$ ). Use of amalgam did not differ significantly between upper and lower teeth, neither in premolars ( $p = 0.42$ ), nor molars ( $p = 0.67$ ). For each participating dentist, the proportion of amalgam restorations placed was calculated. This proportion was not significantly related to the age of the dentist ( $r = 0.30$ ,  $p = 0.22$ ).

## **Influence of patient related factors on use of amalgam (Paper II)**

Regression analyses were performed to identify factors related to using amalgam as restorative material. In the adjusted analyses, the following factors were found to be significantly related to the dentist's choice of amalgam: male patients, high caries experience, severe caries and restorations in molars. Accordingly, patient's age, oral hygiene, and cavity size were not significantly related to the dentist's choice of restorative material.

## **Longevity of dental restorations (Paper III)**

In our prospective practice-based study, amalgam showed significantly better survival compared with resin composite ( $p=0.02$ ). The mean annual failure rate was calculated to be 1.6% for amalgam, compared with 2.9% for resin composite restorations. Secondary caries was the most common reason for replacement of resin composite restorations (73.9%), followed by lost restorations (8.0%), fracture of restorations (5.3%) and marginal defects (2.4%). Of amalgam, nine restorations out of 184 were replaced due to secondary caries, two due to fracture of tooth and two due to lost restorations.

## **Factors related to failure of resin composite restorations (Paper III)**

Multi-level Cox-regression analyses were performed to identify factors related to failure of the resin composite restorations. In the analyses, low age of the patient, caries experience, saucer-shaped preparation technique, deep cavities and use of the resin composite brand *Filtek Z100* remained statistically significant. Thus, the patients' sex, oral hygiene, tooth type, caries severity, cavity width, brand of adhesive, operator and evaluator were not significantly related to failure of resin composite Class II restorations.

The two strongest variables in the multi-level Cox regression analyses were *type of preparation* and *restorative material*. Resin composite restorations performed significantly better in terms of longevity when placed in traditional Class II cavities compared with saucer-shaped preparations ( $p < 0.01$ ). The amount of traditional Class II preparations and saucer-shaped preparations was 24.4% and 74.6% respectively ( $n = 3286$ ). Four different brands of resin composites were used by the study dentists: Tetric ceram (30.7%), Filtek Z100 (26.3%), Herculite XRV (24.3%) and Filtek Z250 (18.7%). Filtek Z100 restorations failed significantly more often compared with the other resin composites ( $p < 0.01$ ). Filtek Z100 was used by nine of the 27 participating dentists, and all of them also used other resin composites. The main reason for replacement of resin composites was secondary caries. In patients in whom restorations had failed ( $n = 194$ ), the oral hygiene was measured both at baseline and when the restoration was replaced. In more than half of the patients, there was no difference in estimated oral hygiene (60%), while 20% had worse oral hygiene and in 20% it had improved. Changes in oral hygiene were not measured in patients whose restorations had not failed. More than half of the restorations (52.4%) available for final evaluation were examined by a dentist other than the one who placed the restoration at baseline, but there was no significant effect of evaluator in multilevel Cox-regression analyses.

# Discussion

## Methodological considerations

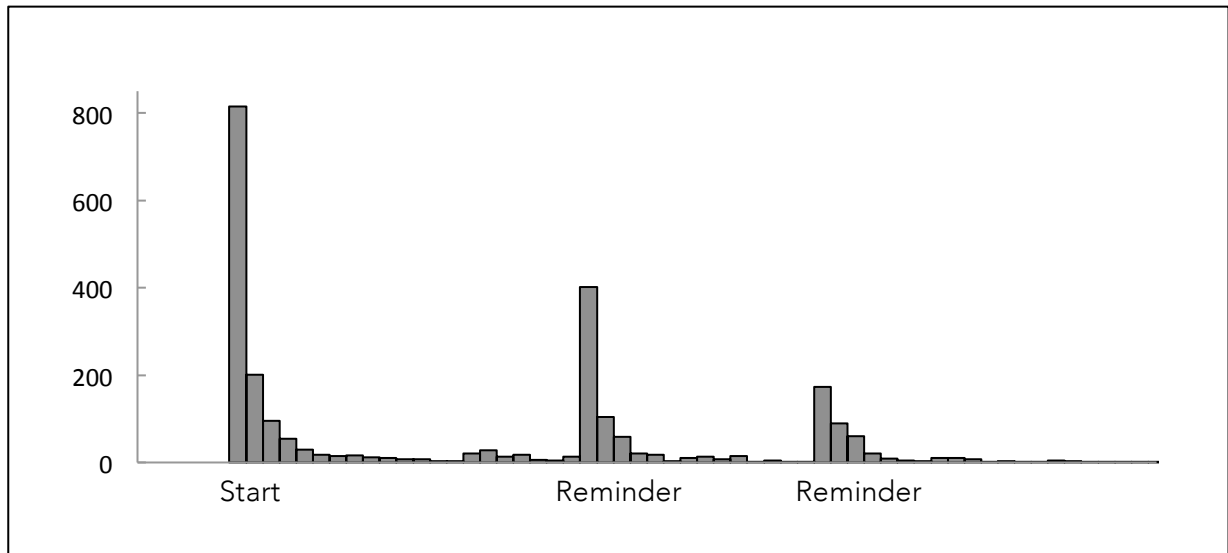
### Questionnaire study

Conducting an electronic questionnaire study had many advantages over conventional questionnaire forms. The cost of the software was actually much lower than the cost of just distributing a conventional questionnaire by ordinary post. All biases related to input of the data were eliminated as the software produced files ready to use with SPSS. Anonymity of the participants was ensured by the software, and the Norwegian Social Science Data Services (NSD) was familiar with the system, so approval for the study was given without reservations.

The software automatically sent reminders only to the participants who had not replied by a pre-set date, while respecting anonymity. Thus, respondents that had already replied were spared reminders. Although not significant in previous studies [Edwards et al. 2009], both the questionnaire and reminders were sent on Mondays or Tuesdays, because the producers of the software claimed that respondents were more likely to reply early rather than later in the week. Most replies came on the day that the questionnaire or reminders were received (Fig 4).

The Norwegian Dental Association (NTF) estimates that 90-95% of all practising dentists in Norway are members of the association. The relatively high response proportion (61.3%) and the matching age distribution of the respondents with the original sample are consistent with our sample being representative of the members of NTF and all authorized dentists in Norway. Measures taken to ensure a high response proportion in accordance with a systematic review on questionnaires [Edwards et al. 2009] proved successful, e. g. the questionnaire was styled as a

personal approach with simple header, pictures were used as illustrations in the questionnaire and placed early in the document to interest the respondents. In the reminder communication, respondents were informed of the response proportion so far, to emphasise the importance of a reply.



**Fig. 4:** Response log for the questionnaire (Paper I). Most replies came on the day that the questionnaire was received. Peaks in number replies were obtained on the days that reminders were sent.

### Prospective study

Traditional power analyses were not performed to calculate the desirable size of the study sample. The dentists participating in our study were asked to estimate how many Class II restorations they would normally place during a 12 - 18 months period. Based on their estimates and a review of previous studies on longevity of posterior restorations [Hickel and Manhart 2001], the inclusion of 4000 restorations was considered to be a realistic goal and a sufficiently high number in the current study. The participating dentists were not selected at random, as motivation and interest in practice-based studies were judged as a prerequisite for participating. This is in accordance with experiences from practice-based studies in the USA [Mjör 2007].

The patient age limit less than 17 years was chosen mainly because we wanted to investigate the longevity of restorations in adolescents, but also to try to keep drop-out as low as possible. All cohorts in Norway up to the age of 20 regularly attend the PDHS and are enrolled in a recall program [Statistics Norway 2008]. Once the patients leave home at early adulthood, they may be more difficult to reach and the risk of drop-out increases. The inclusion criteria were patients younger than 17 years old who, at the regular recall examination, needed one or more Class II restorations. The probability that they would remain in the recall system during the planned study period of four years was high.

Practice-based research networks are essential in order to study the impact of the collective knowledge and skill among clinicians [Green and Dovey 2001; Mjör 2007]. Involvement of general dental practitioners in clinical research is a valuable adjunct to traditional research trials [Randall and Wilson 1999]. For the clinicians who volunteered to participate in the present study, it was a prerequisite that they could decide what sort of preparation technique and restorative material they would use, in collaboration with the patient. Thus, our study reflects everyday clinical practice and is categorized as a practice-based study [Hickel 2007; Mjör 2007].

Motivation of the participating dentists during annual meetings was a crucial step for a successful study. In addition to social activities, professional lectures were held by the Kvit project leadership. This was not regarded as calibration of the clinicians, but rather a general update on various professional topics in pedodontics and cariology, to enhance the motivation of the dentists.



## Statistical considerations

Descriptive and multivariable statistical analyses were used to process the data. A multivariable analysis may be used to determine the relative contribution of different variables to a single event, e.g. *not restoring enamel lesions operatively* (Paper I) or *use of amalgam as restorative material* (Paper II). Because these outcome variables were dichotomous in Papers I and II, logistic regression analyses was chosen as statistical method to explore the effect of different variables on the outcome variable. The outcome of logistic regression analyses may be expressed as odds ratios (ORs) with (in this case) 95% confidence intervals and p-values. In Paper III, Cox-regression analyses was used to evaluate the influence of selected variables on survival of the restorations. The outcome of Cox-regression analyses is expressed as hazard ratios (HRs) with (in this case) 95% confidence intervals and p-values. The main assumptions in all three papers were checked and found to have been adequately satisfied, namely that the numbers of independent variables were less than ten per cent of the numbers of cases with outcome and Spearman's Rank Correlation Coefficient values were  $<0.7$  (Papers I and II). In Paper III, collinearity was checked using the criterion  $VIF < 5$ , and no independent variables were found to invalidate the analysis.

In the prospective study, the restorations were grouped by patient. The performance of multiple restorations placed in one subject cannot be considered to be independent as the influence of the subject may play a crucial role [Hickel et al. 2010]. That means that statistical methods of analysis that treat the outcome event (failure of restoration) as independent, may not be appropriate. Failure to account for this lack of independence could lead to wrongly estimated model parameters, which may indicate that the parameters are significantly contributing to the model when in fact they are not. Two different approaches were taken to overcome this problem. In

Paper II, we used only data related to the first restoration placed in each patient to obtain independent units of analysis. This was a reasonable choice, because in that part of the study, the outcome was most likely to be patient related. In Paper III, longevity of restorations was the main interest, and *frailty models* were used. By including a frailty term in the Cox model, any dependence of the recurrent restorations in the patients is taken into account. Since it was reasonable to assume some correlation between two or more restorations for any given patient, we modelled this as a shared frailty model where the sharing took place at patient level.

## Discussion of results

### Treatment criteria

Seven per cent of the responding dentists in our questionnaire study (2009) would intervene with operative therapy while the caries lesion was still confined to enamel, compared with 18.3% in 1995 and 65.6% in 1983 (Paper I). In our prospective study, only five of the 4030 restorations placed in the time period 2001-2004 (0.1%), were placed to restore lesions confined enamel (Papers II and III). Thus, the trend to postpone treatment of lesions until they reach dentine was consistent already five to eight years before our questionnaire study was conducted. Actually, fewer dentists participating in the prospective study (Papers II and III) chose to restore enamel lesions compared with the respondents in the questionnaire study (Paper I). The reluctance to restore enamel lesions is in line with new minimally invasive concepts in dentistry, which have been promoted in dental education during recent decades [Van Amerongen et al. 2008; Mejàre et al. 2009]. The difference between the questionnaire (Paper I: 7.0% restoring enamel lesions in 2009) and the prospective study (Paper II: 0.1% restoring enamel lesions in 2001-2004) may be explained by two factors: 1) While the questionnaire was sent to all dentists in Norway and the

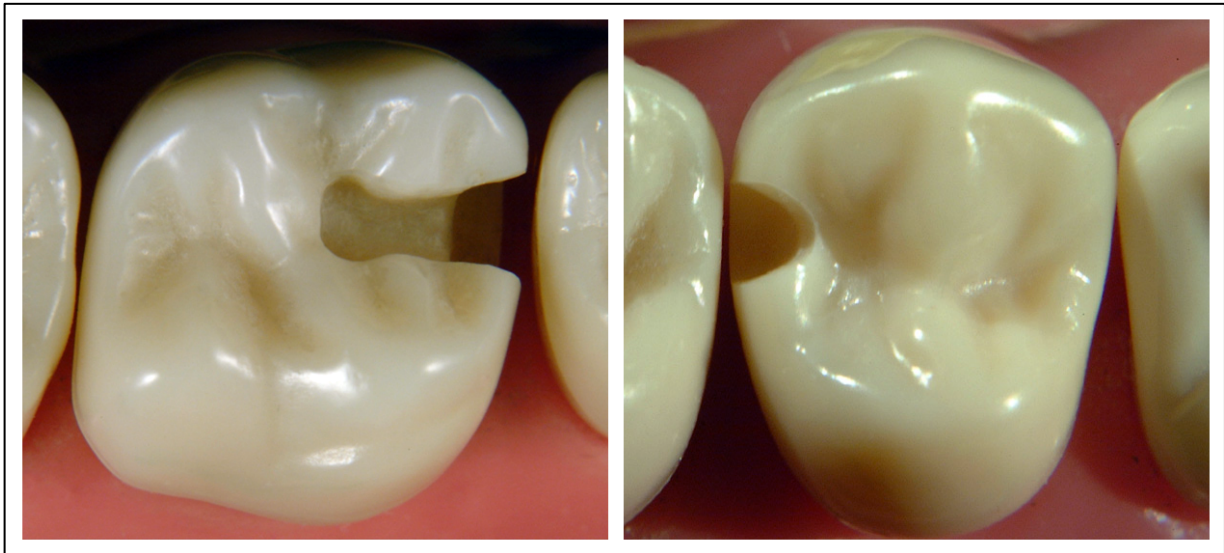
responding participants were considered representative of all dentists in Norway, the 27 dentists who volunteered to participate in the prospective study were not necessarily representative for all other dentists in Norway. Although practice-based research should reflect everyday clinical practice, the dentists were likely to have special interest in dentistry and were possibly more up-to-date on recommended treatment criteria. 2) The scale of caries severity used in our questionnaire had six categories (Fig. 1). Most dentists in Norway today use a five-graded scale to describe the severity of a carious lesion (Fig.3). Thus, a possible bias could be that respondents ticked the box of what they thought was caries grade 3 in a five-graded scale (lesions confined to the outer third of the dentine), while it was actually *lesions confined to the dentine-enamel junction* on the six-graded scale, and thus defined as enamel lesions. If we exclude the respondents who chose to intervene at that stage, the proportion of dentists who would restore enamel lesions in 2009 is reduced from 7.0% to 0.9%. Still, since a six-graded scale was used in the questionnaires both in 1983 and 1995, it was considered important to use the same scale in 2009 to get comparable results.

Nevertheless, Norwegian dentists seem reluctant to initiate operative treatment of early carious lesions, compared with dentists elsewhere [Doméjean-Orliaguet et al. 2004; Ghasemi et al. 2008; Gordan et al. 2009; Baraba et al. 2010]. In a recent questionnaire study among dentists in a practice-based research network (PBRN) in the USA and Scandinavia, 41% (n=202) of respondents reported they would treat operatively an approximal lesion confined to the enamel in a patient with low risk of developing caries. None of the Scandinavian respondents in the PBRN would intervene before the lesion was apparent in dentine [Gordan et al. 2009].

## Preparation technique

In 1995, the tunnel preparation was a favoured technique [Forsten 1993; Tveit et al. 1999]. In 2009, the saucer-shaped preparation technique was preferred by more than two-thirds of the respondents (Paper I). Fewer than 4 % of dentists preferred tunnel preparation in 2009 compared with 47 % in 1995. This shift is probably due to clinicians' experience of the short durability of these restorations. Several clinical studies have confirmed this view [Strand et al. 1996; Hasselrot 1998; Pilebro et al. 1999; Nicolaisen et al. 2000; Strand et al. 2000]. The longevity of saucer-shaped restorations compared with tunnel preparations has been found to be greater [Hörsted-Bindslev et al. 2005], but in general, the number of clinical studies on saucer-shaped restorations is limited. In a systematic review, McComb has claimed that proximal slot preparations without any occlusal dovetail provide similar or greater longevity compared with traditional Class II preparations [McComb 2001], but this conclusion was based on just three studies [Lumley and Fisher 1995; Kreulen 1998; Nordbø et al. 1998] and none was designed to compare longevity of restorations in different types of Class II preparations. The number of restorations was low in all three studies, ranging from 14 to 68 restorations and only one had a follow-up time of more than five years [Nordbø et al. 1998]. For resin composites in our prospective study, traditional Class II preparations demonstrated significantly better longevity compared with saucer-shaped restorations (Paper III). Thus, even though the intention of saucer-shaped preparations is to preserve tooth substance, the preparation technique may lead to the opposite result, if restorations will need to be replaced more often and consequently the tooth continues in the *death spiral* [Elderton 1977; Brantley et al. 1995]. This shows the importance of conducting clinical studies to monitor the fate of restorations and to study factors which are important for the longevity [Bayne 2007]. Because of its small size and the use of adhesive techniques, the saucer-shaped preparation is today considered minimally invasive

dentistry [Peters and McLean 2001]. This supports the idea that new materials and techniques have changed dentistry in Norway. From an educational point of view, this change is an example of successful adaptation to new knowledge. It remains to be shown whether the saucer-shaped preparation technique is the best choice to preserve tooth substance when taking into account the longevity of the restorations.



**Fig. 5:** Clinical images of a traditional Class II preparation (to the left), compared with a saucer-shaped preparation (to the right). The images are taken from an internet-based teaching program of the propaedeutic course at the Department of Cariology, Faculty of Dentistry, University of Oslo.

### **Use of restorative materials**

In our prospective study, the participating dentists were allowed to choose the restorative material they preferred during the inclusion period from 2001-2004. Although resin composite was the dominating material of choice (82%), the number of amalgam restorations placed made it possible to compare the two restorative materials. Unfortunately, too few restorations in compomer and glass ionomer cement were placed to allow for statistical analysis. In the questionnaire study in 2009, resin composite was preferred by the vast majority of the respondents (94.9%).

The choice of restorative material was more evenly balanced between the different options in the questionnaire study in 1995 [Tveit et al. 1999] compared with 2009, and the distribution of restorative materials used in our prospective study in the time period 2001-2004 seems to lie somewhere in the middle. Thus, it appears that use of other restorative materials than resin composite has gradually been phased out from 1995 to 2009. After the Norwegian government banned use of amalgam in 2008, dentists were forced to find other filling materials. International reactions to the ban were not always positive. In the USA, it has been named a "Scandinavian tragedy" [Jones 2008a, b] and it has been estimated that more than 15 million fewer restorations would be placed in the USA due to patients' inability to pay if amalgam were banned, and thus untreated caries would be a consequence [Beazoglou et al. 2007]. The American Dental Association Council on Scientific Affairs claims that scientific evidence supports the position that amalgam is a valuable and safe choice for dental patients, based on a review of literature on amalgam safety that summarizes the state of the evidence for amalgam safety from 2004 to 2009 [American Dental Association 2009]. Nevertheless, a study on trends in dental treatment in the USA showed that patients received approximately 50% fewer amalgam fillings in 2007 compared with 1992, while there was a corresponding rise in use of resin-based composite restorations [Eklund 2010]. In other countries, the use of amalgam has also decreased rapidly [Friedl et al. 1995; Forss and Widstrom 2001; Doméjean-Orliaguet et al. 2004; Lynch et al. 2007; Opdam et al. 2007a; Sunnegårdh-Grönberg et al. 2009; Baraba et al. 2010; Eklund 2010]. Our results indicate that resin composite, which is preferred by 95% of the respondents (Paper I), has replaced not only amalgam, but also compomer and glass ionomer cement as restorative material of choice in Norway. This is in accordance with a recent practice-based study showing that amalgam was used in only 6% of the restorations reported by Scandinavian dentists, and the overall use of materials other than amalgam and resin

composite in the practice-based network was only 5% for both US and Scandinavian dentists when placing restorations in premolars and molars [Nascimento et al. 2010].

In Paper II, we conclude that dentists found amalgam to be the material of choice in specific situations, based on clinical considerations. Amalgam was more frequently used in male patients with higher caries experience (measured in DMFT) and more severe caries, and more often in molars compared with premolars. Still, the success rate of the amalgam restorations was significantly better than that of resin composites (Paper III). Thus, it could seem that even though amalgam is used in what could be considered more challenging cases, its longevity is after all better compared with resin composite.

Many clinicians have experienced that use of tooth-coloured, direct restorations presents a number of clinical problems related to the handling properties and physical properties of the materials [Roulet 1997; Mackert and Wahl 2004]. Having a high DMFT was one of the factors related to high risk of failure of resin composites in our prospective study (Paper III). It can be speculated that longevity of resin composite could be overestimated because some patients with high DMFT may have received amalgam restorations rather than resin composites. Caries experience (DMFT) has been named the single best clinical predictor of dental caries [Kidd et al. 2003]. Associations between caries experience and new carious lesions are also found in other studies [Powell 1998; Fontana and Zero 2006; Zhang and van Palenstein Helderma 2006]. The fact that, in patients with high DMFT, the use of amalgam was more frequent could possibly indicate a perception that amalgam is associated with a lower rate of secondary caries and has better durability than the tooth-coloured alternatives. This is in accordance with findings in a questionnaire study on Finnish dentists' perceptions on reasons for replacement of restorations [Palotie and Vehkalahti 2012]. A recent randomized clinical trial showed that the

overall risk of secondary caries was 3.5 times greater in resin composite restorations (n=892) than in amalgam restorations (n=856) in a follow-up period of up to seven years [Haj-Ali et al. 2005]. Similar results were also found in two RCT studies in 2007 [Bernardo et al. 2007; Soncini et al. 2007].

Few amalgam restorations were placed in premolars in our prospective study (Paper II). This could reflect a belief that, in teeth exposed to higher biting force, amalgam is superior to resin composite, or that satisfactory resin composite restorations are more difficult to place in molars because of limited visual access. It has been shown that restorations in premolars perform better than those in molars [Pallesen 2003; Van Nieuwenhuysen et al. 2003; Opdam et al. 2007b; Da Rosa Rodolpho et al. 2011; Pallesen et al. 2013a]. In our study, no significant impact of tooth type on survival of resin composite restorations was found in the Cox-regression analyses on survival of resin composites (Paper III). Aesthetics could offer an alternative explanation why few amalgam restorations were placed in premolars, suggesting that tooth-coloured materials were preferred in more visible areas of the oral cavity. Adolescents often tend to choose aesthetics before longevity [Espelid 2006]. The fact that amalgam was used less in female patients than in males could indicate that female adolescents are more concerned about aesthetics than male, or perhaps that the dentists regarded aesthetics as more important for females than males. These findings are in accordance with a similar study by Hawthorne et al. [Hawthorne and Smales 1996].

In the unadjusted logistic regression analyses, significantly higher odds of receiving amalgam restorations were found in medium or deep cavities compared with shallow ones (Paper II). This did not remain statistically significant when adjusting for all other variables, but still it raises a clinical consideration. Longevity of resin composites was found to be poorer in medium or deep cavities compared with shallow (Paper III). Previous studies have shown that the effectiveness of light curing resin composites



decreases with increasing cavity depth [Hansen and Asmussen 1997; Soh et al. 2003] and it has been found that deep Class II resin composite restorations with the restoration margin extended below the cemento-enamel junction, had a significantly lower fracture strength than more shallow restorations [Lægneid et al. 2011]. Thus, in deep Class II restorations, amalgam could be a reasonable choice, if available for use. Even though not statistically significant, some of our participating dentists could have had that in mind when choosing restorative material.

### **Longevity of restorations**

In the present study, resin composite restorations failed more often than amalgam restorations. Better longevity of amalgam has also recently been found in two RCT studies; Bernardo *et al.* found a survival rate of amalgam restorations of 94% compared with 86% for resin composite after seven years [Bernardo et al. 2007], while Soncini *et al.* found the survival rates to be 89% and 85% respectively after five years [Soncini et al. 2007]. In a review by Hickel *et al.* on studies conducted in the 1990s focusing on longevity on posterior restorations [Hickel and Manhart 2001], annual failure rates were found to be 3.3% for amalgam, compared with 2.2% for resin composite. The results presented on the low failure rate of resin composite are criticized for being based on short-term results [Mackert and Wahl 2004], which could under-estimate the longevity of the restorations [Downer et al. 1999; Opdam et al. 2011].

The annual failure rate of resin composite restorations in our study was calculated to be 2.6%. This is at the high end of what has previously been reported in prospective studies, with annual failure rates ranging from 1.1% to 2.8% [Manhart et al. 2004; Opdam et al. 2004; Van Dijken and Sunnegardh-Gronberg 2005; Lindberg et al. 2007;

Pallesen et al. 2013a]. As 93% of our restorations were placed due to primary caries in adolescents, all our included patients could be considered as having a risk of caries. Restorations placed in caries active patient groups have previously shown a 2.5 times higher chance of failure due to secondary caries compared with restorations placed in low caries activity groups [Opdam et al. 2010].

Secondary caries was the main reason for failure of the resin composite restorations in our study (73.9%). A review of studies conducted in the 1990s on the longevity of dental restorations reported that secondary caries was the reason for replacement in 33–65% of failed resin composite restorations [Hickel et al. 2000]. Studies published later have reported similar rates: 25% [Da Rosa Rodolpho et al. 2011], 38% [Opdam et al. 2007a], 52% [Soncini et al. 2007], 57% [Pallesen et al. 2013b] 58% [Kuper et al. 2012], and 88% [Bernardo et al. 2007]. In a recent review on the longevity of posterior resin composite restorations, secondary caries and fracture of restoration are considered the main reasons for failure [Demarco et al. 2012]. In our study, fracture of resin composite restorations was registered as main reason for failure in only 5.3% of the cases. Nevertheless, the lack of standardized diagnostic criteria for marginal failure could cause over-registration of secondary caries [Kidd 2001; Mjör 2005]. Crevices and ditched margins in which the explorer sticks, and marginal colour changes, could be wrongly diagnosed as secondary caries [Kidd and Beighton 1996; Mjör 2005; Magalhaes et al. 2009].

Filtek Z100 performed less well than the other resin composites. Filtek Z100 was introduced by 3M in 1992, promoting very good aesthetics, strength and wear resistance for use in posterior and anterior teeth. Filtek Z100 was compared with newer brands of resin composite (Filtek Z250, Herculite XRV and Tetric Ceram) in our study. In Paper III, we propose that its high elastic modulus compared with newer resin composites [Chung et al. 2005] could explain the difference in survival rate.

There is a rapid development of new restorative materials on the market, and even the three latest composites resin in our studies have today been succeeded by new versions of resin composites. To be able to publish results on new restorative materials within a reasonable time, relatively short-term clinical studies with limited numbers of restorations have often been used as scientific evidence of good longevity. In such studies, differences in performance are seldom found, as most materials perform well on a short-term basis [Demarco et al. 2012]. Long-term studies are needed to identify modes of failure and possible reasons for failure. If a restorative material showing mainly late failures is compared with a material showing mainly early failures, the latter restorative material will get disproportionately bad results [Opdam et al. 2011]. Thus, the observation time for clinical studies should be as long as possible. This corresponds well with results presented by Opdam *et al.*; comparable annual failure rates for resin composite and amalgam were reported after five years of follow-up, but after 12 years the annual failure rate of resin composite was superior to that of amalgam [Opdam et al. 2010].

### **Assessment of drop-outs**

In our prospective study, 27% of the restorations (n=1,095) could not be evaluated because the patients (n=537) did not attend despite several reminders. The mean annual drop-out rate was calculated to be 6.6%. This is well within the inclusion criteria (<10% annual drop-out) published in a large systematic review on prevention of caries in Sweden [Swedish Council on Technology Assessment in Health Care 2002]. In a survey on Norwegian children that did not attend for dental appointments, 15% of all children aged 3 to 18 years in a prosperous suburban area had missed at least one appointment during a two year period [Wang and Aspelund 2009]. The proportion of missed appointments in regular dental practice has

previously been found to increase with rising age from 12-18 years [Skaret et al. 1998] and the drop-out rate of Norwegian 17-18-year-olds was found to be 26% during two weeks where all dentists and dental hygienists in a county registered non-attendance [Wang and Schiøth 2000]. Consequently, our drop-out rate was considered satisfactory in a 4-5 year study period perspective. Efforts that were made to minimize the drop-out rate were fairly successful; patients who moved to another PDHS clinic in the county were marked in the electronic patient charts so that other dentists could report the requested variables related to the restorations. For patients moving to another county, letters were sent to the new dentist with information on the study and requesting information about the included restorations. Patients who did not attend for recall examination were contacted by mail and telephone to explain their importance for the study, and received new individual appointments, even after working hours, to be as flexible as possible. The patients that still did not show up despite these efforts were contacted by the author. Addresses of 80 patients living in or close to Bergen city centre were collected from the National Population Register and the patients were offered a free examination in an easily located dental clinic in Bergen city centre with a flexible time schedule. This effort was unsuccessful; only four patients attended (5%). The same procedure was repeated on 20 patients living in or close to Oslo city centre, but none attended. Thus, the remaining drop-out patients were considered impossible to reach.

The mean age of our patients was 15.3 years at baseline. During the study period, many patients probably left home to get education and were difficult to contact. Non-attenders have been found to have higher DMFT and more new carious lesions than regular attenders [Skaret et al. 1998; Wang and Aspelund 2009]. Those who dropped-out of our prospective study were significantly older and had higher DMFT, more traditional Class II preparations than saucer-shaped preparations and deeper cavities compared with the patients included in the study. It is difficult to speculate

on the influence of these drop-out restorations on the results. According to our findings, higher age and more traditional Class II preparations could indicate better restoration survival, while higher DMFT and deeper cavities could indicate increased risk of restoration failure.

# Conclusions

The overall aim of the thesis was to explore treatment decisions of practising dentists and the longevity of approximal restorations in posterior teeth.

*Our studies showed that:*

- Treatment criteria for approximal carious lesions had changed. Few Norwegian dentists treated approximal enamel lesions operatively in the period 2001-2009 compared with surveys performed in 1995 and 1983. The saucer-shaped preparation technique was preferred by more than two-thirds of the dentists in 2009. Tunnel preparation technique was the most preferred by the respondents in 1995, but was used by fewer than 4 % of dentists in 2009. Resin composite was the dominating restorative material of choice in Norway in 2009 and seems to have replaced the use of compomer, glass ionomer cement and amalgam. Use of the different materials was more evenly distributed in 1995 (Paper I).
- In the years preceding the amalgam ban, the use of amalgam for Class II restorations was higher in male patients with high caries experience, severe caries and restorations in molars rather than premolars (Paper II).
- Amalgam restorations performed better than resin composites when restoring approximal lesions in premolars and molars (Paper III). Predictors of failure of resin composite restorations were identified: patients' low age, high DMFT score, deep cavities, saucer-shaped preparation technique and the use of the resin composite brand Filtek Z100 (Paper III).

*Hypotheses to be tested:*

- The first research hypothesis to be tested was that no change had occurred in the threshold for initiation of operative treatment, choice of preparation technique and use of restorative material for approximal caries, compared with a survey undertaken 14 years previously (Paper I). This hypothesis was rejected.
- The second hypothesis to be tested was that patient related variables might have influenced the choice of restorative material (Paper II). This hypothesis was accepted.
- The third research hypothesis to be tested was that there was no difference in survival of restorations of different restorative materials and no single factor could be identified as a significant predictor of failure (Paper III). This hypothesis was rejected.

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*\* The reference list is formatted according to guidelines from the journal **Caries Research**.*

# Appendix

## 1) Questionnaire – first page:

### Fylke \*

### Fødselsår \*

### Kjønn \*

- Kvinne     Mann

### Klinisk yrkesaktiv? \*

- Ja             Nei

### Hovedbeskjeftigelse \*

- Privat praksis  
 Den offentlige tannhelsetjenesten  
 Annet, spesifiser her: \_\_\_\_\_

### Er kariesdiagnostikk og fyllingsterapi aktuelt i din praksis? \*

Dersom du ikke arbeider med kariesdiagnostikk og fyllingsterapi trenger du ikke å svare på de resterende spørsmålene. Klikk i så fall på det aktuelle svaralternativet, og du vil bli videreført til avslutningssiden i spørreskjemaet når du klikker på **Neste>>**

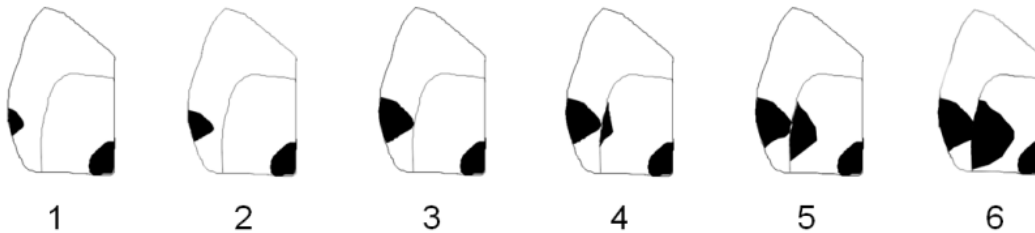
- Ja, jeg arbeider med kariesdiagnostikk og fyllingsterapi  
 Nei, jeg arbeider ikke med kariesdiagnostikk og fyllingsterapi og vil gå til avslutningssiden  
 Nei, jeg arbeider ikke med kariesdiagnostikk og fyllingsterapi, men vil likevel delta i spørreundersøkelsen

\* Obligatoriske spørsmål. Må besvares for å kunne gå videre.

## 2) Questionnaire –second page:

**Figurene illustrerer ulike røntgenologiske avtegninger av approximalkaries. Hvilken eller hvilke lesjoner mener du krever fyllingsterapi omgående?**

Det siktes til kariesangrep som du ikke under noen omstendigheter vil utsette behandlingen av til neste tannhelsekontroll, selv om pasientens kariesaktivitet er lav og hygienen god (kryss av for ett eller flere alternativ).



**Hvilken prepareringsmåte vil du foretrekke for den minste av de lesjoner som du vil fylle (klasse II fylling), dersom lesjonen ligger distalt på 15?**

Tenk deg at pasienten er 20 år, har tilfredsstillende hygiene og bruker fluortannkrem. Pasienten går regelmessig til kontroll én gang i året

- Tradisjonell kl.II
- Tunnelpreparering
- Skålformet preparering

**I tilfellet over, hvilket fyllingsmateriale vil du foretrekke for den minste av de lesjoner som du vil fylle?**

- Kompositt
- Kompomer
- Konvensjonell glassionomersement
- Lysherdende glassionomersement
- En kombinasjon av kompositt og glassionomersement
- Annet, spesifiser her: \_\_\_\_\_

### 3) Prospective study - form 1:

## KVIT-prosjektet: Skjema for nye fyllinger

IE 11.2.2002

1. Tannlegenr: \_\_\_\_\_

2. Fyllingsnr: \_\_\_\_\_

3. Tann: \_\_\_\_\_

4. Flate(r)-MODBL : \_\_\_\_\_

5-6. Kontakttann - mesialt: \_\_\_\_\_

distalt: \_\_\_\_\_

#### Basisopplysninger

7. Pasientens navn: \_\_\_\_\_

10. DMFT (etter at fyllingen er lagt): \_\_\_\_\_

8. Fødselsdato: / 19 \_\_\_\_\_

11. DMFT (sett ring: 11 - 12 - 13 år): \_\_\_\_\_

9. Klinik: \_\_\_\_\_

12. Munnhygiene:  G  M  D

#### Registreringer ved behandling

13. Fyllingsdato: / 200 \_\_\_\_\_

14. Hvorfor ble fyllingen lagt?  Primærkaries (ring rundt kariesgrad)

1 2 3 4 5

Omlegging av tidligere fylling

Annet (beskriv): \_\_\_\_\_

#### Pulpa

15. Symptomer før behandlingen?  Ja

Art, varighet: \_\_\_\_\_

16. Perforasjon under preparering?  Ja

17. Eventuell pulpabehandling?

Trinnsvis ekskavering

Teksjon (overkapping)

Pulpektomi/rotfylling

Annet (beskriv): \_\_\_\_\_

18. Symptomer etter behandlingen  Ja (0-4 uker etter behandlingen)

Art, varighet evt. behandling: \_\_\_\_\_

#### Kavitetsutformingen

19. Kl. I  borer opp deler av fissuren

borer opp hele fissuren

20. Kl. II mesialt:  emaljebegrensning

tradisjonell kl.II

skålpreparering

distalt:  emaljebegrensning

tradisjonell kl.II

skålpreparering

21. Bredde  liten ( $\leq 1/3$  kuspebredde)

middels ( $1/3 - 2/3$  kuspebredde)

stor ( $> 2/3$  kuspebredde)

22. Dybde

grunn (ytre 1/3 av dentin)

middels (midtre 1/3 av dentin)

dyp (indre 1/3 av dentin)

#### Kontaktflater

23. Beskyttelse av nabotann under preparering  Ja

24. Status mesialt:

Fylling

Klinisk kariesregistrering

Røntgenologisk kariesregistrering

0 1 2 3 4 5

0 1 2 3 4 5 (sett ring)

25. Status distalt:

0 1 2 3 4 5

0 1 2 3 4 5 (sett ring)

26. Behandling mesialt: \_\_\_\_\_

27. Behandling distalt: \_\_\_\_\_

#### Isolering, forbehandling, fyllingsmateriale

28. Isolering/foring  Ja

Produktnavn: \_\_\_\_\_

29. Etsing emalje  Ja

30. Etsing dentin  Ja

31. Annen forbehandling emalje  Ja

Produktnavn: \_\_\_\_\_

32. Annen forbehandling dentin  Ja

Produktnavn: \_\_\_\_\_

33. Fyllingsmateriale - Produktnavn: \_\_\_\_\_

34. Gjenetsing/resinbehandling  Ja

Produktnavn: \_\_\_\_\_

35.  Sett et kryss dersom du har skrevet bemerkninger om pasient, tann, behandling på baksiden av dette arket.

#### 4) Prospective study – form 2:

IE 1.11..2004

### **KVIT-prosjektet:** *Når fyllingen revideres eller repareres*

101. Tannlegenr (den som la fyllingen):

102. Fyllingsnr (fra tidligere registrering)

103. Tann:

104. Flate(r)-MODBL :

105-6. Kontakttann - mesialt:

distalt:

#### Basisopplysninger

107. Pasientens navn:

110. DMFT (ved revisjon/reparasjon)

108. Fødselsdato: / 19

109. Klinikkk:

111. Munnhygiene:

G

M

D

#### Registrering ved fyllingsrevisjon/reparasjon

112. Dato ved fyllingsrevisjon/reparasjon: / 200

113.  Hele fyllingen legges om

Fyllingen repareres

114. Hovedårsak til behandling (kun **ett kryss** for den avgjørende årsak til behandlingen):

*Fyllingsfeil/karies o.a. som har oppstått etter at fyllingen ble lagt.*

*Fyllingsfeil som sannsynligvis også var til stede da fyllingen var ny.*

*Forhold som ikke er knyttet til fyllingen.*

Sekundærkaries

Overheng

Primærkaries annet sted på tannen

Slitasje

Underskudd

Annet (skriv årsak):

Fraktur av fylling

Porøsiteter

Fraktur av tann/kusp

Manglende kontakt

Tapt fylling

Annet (skriv årsak):

Kantdefekt

Ikke akseptabel farge/estetikk

Kantmisfarging

Utilfredsstillende kontaktforhold

Infraksjon med smerter/ising

Smerter/ising/ubehag

Annet (skriv årsak):

#### Kontaktflater til den aktuelle KVIT-fylling

Kontakt- flatens status	Dersom flaten er fylt i perioden etter at KVIT-fyllingen er lagt så skriv fyllingsdato dag-mnd-år	Flaten kan ikke inspiseres direkte (kun via røntgen)	Klinisk kariesregistrering (sett ring for kariesgrad). Kun aktuelt å fylle ut når området kan inspiseres direkte.	Røntgen ikke tatt	Røntgenologisk kariesregistrering (sett ring for kariesgrad)
mesialt:	115 / /	116 <input type="checkbox"/>	0 1 2 3 4 5	117 <input type="checkbox"/>	0 1 2 3 4 5
distalt:	118 / /	119 <input type="checkbox"/>	0 1 2 3 4 5	120 <input type="checkbox"/>	0 1 2 3 4 5

121. Hvem bestemte at fyllingen skulle revideres eller repareres?

Samme tannlege som la fyllingen opprinnelig

En annen tannlege

123. Eventuelle bemerkninger om pasient, tann, behandling:

## 5) Prospective study – form 3:

IE 1.3.2006

### **KVIT-prosjektet-AVSLUTNINGSSKJEMA:**

*Dette skjemaet fylles ut når fyllingen observeres for siste gang dvs:  
a) fyllingen er minst 4 år og b) fyllingen skal ikke revideres eller repareres.*

SKJEMANO: \_\_\_\_\_

Dato fylling lagt: \_\_\_\_\_

101. Tannlegen som la fyllingen: \_\_\_\_\_

102. Fyllingsnr (fra tidligere registrering) \_\_\_\_\_

103. Tann: \_\_\_\_\_

104. Flate(r)-MODBL : \_\_\_\_\_

105-6. Kontakttann - mesialt: \_\_\_\_\_

distalt: \_\_\_\_\_

#### Basisopplysninger

107. Pasientens navn: \_\_\_\_\_

108. Fødselsdato: \_\_\_\_\_

109. Klinik: \_\_\_\_\_

#### Status ved avslutning (kryss av)

112. Dato ved avslutningskontroll (etter minst 4 år): \_\_\_\_\_ / \_\_\_\_\_ 200

STATUS fylling. Kryss av alle feil og mangler og sett ring rundt den største feil eller mangel ved flere kryss.  Feilfri

Akseptabel – fyllingsfeil, men ingen behandling nødvendig

Revisjon/reparasjon Dersom fyllingen skal repareres eller revideres brukes skjemaet "Når fyllingen revideres eller repareres" Skjemaet heftes på baksiden av dette arket etter utfylling. Rubrikkene nedenfor fylles ikke ut når det skjemaet brukes.

*Fyllingsfeil/karies o.a. som har oppstått etter at fyllingen ble lagt.*

*Fyllingsfeil som sannsynligvis også var til stede da fyllingen var ny.*

<sub>1</sub> Sekundærkaries

<sub>13</sub> Overheng

<sub>2</sub> Slitasje

<sub>14</sub> Underskudd

<sub>3</sub> Fraktur av fylling

<sub>15</sub> Porøsiteter

<sub>4</sub> Fraktur av tann/kusp

<sub>16</sub> Manglende kontakt

<sub>5</sub>

<sub>17</sub> Annet (skriv årsak):

<sub>6</sub> Kantdefekt

<sub>7</sub> Fargefeil/mangelfull estetikk

<sub>8</sub> Kantmisfarging

<sub>9</sub> Utilfredsstillende kontakt

<sub>10</sub> Infraksjon med smerter/ising

<sub>11</sub> Pulpasymptomer

<sub>12</sub> Annet (skriv årsak):

#### Kontaktflater til den aktuelle KVIT-fylling

**Kontakt-  
flatens status**

Dersom flaten er fylt i perioden etter at KVIT-fyllingen er lagt så skriv fyllingsdato dag-mnd-år

Flaten kan ikke inspiseres direkte (kun via røntgen)

Klinisk kariesregistrering (sett ring for kariesgrad). Kun aktuelt å fylle ut når området kan inspiseres direkte.

Røntgen ikke tatt

Røntgenologisk kariesregistrering (sett ring for kariesgrad)

mesialt: \_\_\_\_\_

115a / /

116a

0 1 2 3 4 5

117a

0 1 2 3 4 5

distalt: \_\_\_\_\_

118a / /

119a

0 1 2 3 4 5

120a

0 1 2 3 4 5

123a. Evt. merknader om pasient, tann, behandling (bruk evt. baksiden, men noter "se bakside")

121a. Hvem fylte ut dette skjemaet?

<sub>1</sub> Samme tannlege som la fyllingen opprinnelig

<sub>2</sub> En annen tannlege/tannpleier

## 6) Prospective study – informed consent:

Klinikkens stempel

Tannlegnr (den som la fyllingen): \_\_\_\_\_

### SAMTYKKE TIL DELTAKELSE I KVIT-PROSJEKTET

Den offentlige tannhelsetjenesten er opptatt av at fyllingene som legges på våre tannklinikker blir så gode og holdbare som mulig. Du har én eller flere fyllinger i tennene dine som er lagt i en bestemt periode, og som vi ønsker å ha med i et kvalitetssikringsprosjekt (KVIT-prosjektet). Vi vil analysere faktorer som har betydning for fyllingers holdbarhet. For at vi skal kunne bruke opplysninger om dine fyllinger må du være enig i dette og underskrive dette samtykkeskjemaet.

Dersom du ikke ønsker å delta i undersøkelsen, vil dette ikke ha noen betydning for den behandling eller oppfølging du får ved tannklinikken. Tannbehandlingen du mottar vil være nøyaktig den samme enten du vil være med i prosjektet eller ikke; den eneste forskjellen er at tannlegen noterer seg noen opplysninger om de aktuelle fyllingene i etterkant av dagens seanse. Disse opplysningene blir deretter bearbeidet og analysert i samarbeid med Universitetet i Oslo.

Du kan når som helst trekke deg fra studien uten å oppgi noen forklaring, og uten at dette påvirker videre tannbehandling. Data som er innsamlet i prosjektet vil slettes straks det ikke lenger er behov for dem, og senest 31. desember 2013. Dette gjelder også dersom du velger å trekke deg ut av prosjektet. Prosjektet er godkjent av Regional komité for medisinsk forskningsetikk. Alle opplysninger vil bli behandlet konfidensielt, på linje med kravene fra Datatilsynet.

Etter informasjon fra din tannlege og når du har fått svar på dine spørsmål kan du velge å delta i prosjektet ved å fylle ut skjemaet nedenfor.

#### Samtykkeerklæring

Jeg har lest informasjonen og forstår at deltakelsen er frivillig, og at jeg kan trekke meg når som helst uten å oppgi noen grunn. Jeg tillater at tannhelsesdata kan hentes fra journalen min

Navn: \_\_\_\_\_  
(bruk blokkbokstaver)

Dato: \_\_\_\_ / \_\_\_\_ - 20\_\_\_\_      Signatur: \_\_\_\_\_  
(foresatte må signere dersom pas er under 16 år)

#### Informasjon til tannhelsepersonellet:

Dette skjemaet skal fylles ut og signeres av samtlige pasienter når KVIT-fyllinger avsluttes eller revideres. Dersom pasienten er under 16 år må skjemaet signeres av foresatte.

Skjemaet merkes med tannlegnr og fyllingsnr. øverst til høyre og stiftes fast til avslutnings-/revideringsskjemaet før dette leveres til overtannlegen.

# Errata

- Thesis p. 22, ln. 13-15. Correct sentence should be: "Mean annual failure rate of the investigated restorations was calculated according to the formula  $(1-y)^z = (1-x)$ , in which 'y' expresses the mean annual failure rate and 'x' the total failure rate at z=4.5 years."
- Paper I Table 1, p.117. Table legend should be: "Associations between selected variables and the risk of not restoring enamel lesions operatively".
- Paper II Table 1, p.77. The independent variable Gender should be noted "female vs. male".



# Papers I-III

- Paper I      Vidnes-Kopperud S, Tveit AB, Espelid I. **Changes in the treatment concept for approximal caries from 1983 to 2009 in Norway.** Caries Res 2011;45:113-20.  
*Submitted: 4 September 2010 – Accepted for publication: 1 February 2011*
- Paper II     Vidnes-Kopperud S, Tveit AB, Gaarden T, Sandvik L, Espelid I. **Factors influencing dentists' choice of amalgam and tooth-colored restorative materials for Class II preparations in younger patients.** Acta Odontol Scand 2009;67:74-9.  
*Submitted: 10 July 2008 – Accepted for publication: 24 October 2008*
- Paper III    Kopperud SE, Tveit AB, Gaarden T, Sandvik L, Espelid I. **Longevity of posterior dental restorations and reasons for failure.** Eur J Oral Sci. 2012;120:539-48.  
*Submitted: 24 May 2012 – Accepted for publication: 15 September 2012*