# Paper III

Caries increment and prediction from 12 to 18 years of age: A follow-up study. European Archives of Paediatric Dentistry 2006; 7(1): 31-37.

# Caries increment and prediction from 12 to 18 years of age: A follow-up study

*J. David*,**, M. Raadal*, N. J. Wang***, G.V. Strand*****

** Department of Oral Sciences – Pedodontics, University of Brogen; Norway. ** Centre for International Health, Armauer Hansen Building, Bergen, Norway; *** Institute of Clinical Dentistry – Pedontics, University of Oslo, Norway; **** Department of Oral Sciences – Gerodontecs, University of Bergen, Norway.*

## Abstract

**Aim:** This was to determine the increment of caries from 12 to 18 years of age and to explore the possibility of predicting caries increment in this period based on the caries experience at age12 years. **Study design:** Prospective longitudinal survey. **Methods:** A sample of 12-year-old children (n =159) were examined in 1993 and 70% of them re-examined at 18 years of age. Bitewing radiographs were taken and a diagnostic system using five caries grades ($D_1$-$D_5$) was used at both ages. Children at risk were defined as those who developed manifest caries lesions ($D_{3-5}$FS) on approximal surfaces during the follow-up period. Possible predictors were analysed by calculation of sensitivity, specificity, and actual proportion of the population at risk. **Results:** The mean caries increment ($D_{1-5}$MFS) from 12 to 18 years of age was 4.2 (SD±9.1). The percentage of caries-free adolescents at 12 and 18 years of age was 10% and 1% respectively; 25% had either a reversal or no increment in caries experience while the $D_{1-5}$MFS increased in 65% of the adolescents. Of the increment of manifest lesions ($D_{3-5}$FS), 18% were located in incisors/canines, 40% in premolars, 26% in first molars and 16% in second molars. Premolars had the largest proportion of the approximal surfaces with manifest caries increment. The best predictors of children at risk of approximal caries increment ($D_{3-5}$FS) were caries experience ($D_{1-5}$FS) on the approximal surfaces of premolars and second molars at the age of 12 years. The individuals that developed four or more manifest lesions on approximal surfaces between 12 and 18 years were the easiest to predict (sensitivity + specificity = 175%). **Conclusions:** There was a considerable increment of manifest caries lesions from 12 to 18 years of age in all tooth groups. The best predictors for increment of manifest caries on approximal surfaces during the age period were approximal caries in premolars and second molars at the age of 12 years.

## Introduction

In developed countries the reduced prevalence of dental caries has changed the strategy of dental treatment [Hausen et al., 2000] which in Norway, through the Public Dental Service (PDS), is to base both the amount of preventive dental care and the length of recall intervals on an individual assessment of each child's caries risk [Wang and Holst, 1995; Statens Helsetilsyn, 1999]. Knowledge regarding the development of caries is important as a basis for this approach.

In Norway the PDS provides regular dental care for all children and adolescents up to the age of 18 years and reports dental caries using the DMFT index [Statens Helsetilsyn and Sosial- og Helsedirektoratet, 2003]. The diagnostic basis for this information is an individual dentist's decision to use restorative treatment, which usually does not include enamel caries. Treatment of enamel lesions by the use of non-invasive techniques (interceptive caries treatment) [Raadal, 2002] has been suggested as this treatment can stop progression of dental caries, reduce the need for restorations and decrease the cost of dental care. Based on this strategy, detailed diagnostic criteria is needed to evaluate caries prevalence and risks in order to plan for future dental care [Pitts, 1993]. The need to include enamel caries in the diagnostic criteria is also strengthened as it has been suggested that caries prevalence among Norwegian children is increasing [Haugejorden and Birkeland, 2002].

It is acknowledged that longitudinal studies provide suitable data to study the development of caries and offer valuable information for risk assessment and planning of dental health services. However, there is a scarcity in the number of longitudinal surveys on caries development in adolescents [Bjarnason et al., 1993; Mejàre et al., 1999]. Since the early 1990's caries prevalence in Scandinavian adolescents has been stable [Mejare et al., 1998] and studies in developed countries have demonstrated a skewed pattern of caries distribution [Glass, 1982]. Longitudinal studies from Scandinavia have reported mean caries increments of less than one surface per year from 12 to 18 years of age [Bjarnason et al., 1993; Mejare et al., 1998], and the first molars have been reported to be the most frequently affected teeth in adolescence [Eklund and Ismail, 1986; Mejare et al., 1998].

**Key words:** Adolescents, Dental caries, Increment, Prediction, Follow-up study

Postal address: Dr. J. David, Department of Oral Sciences – Pedodontics, University of Bergen, Bergen, Norway.
Email: jamil.david@rasmus.uib.no

Towards the end of the last decade there has been an increased interest in identifying individuals susceptible to dental caries. This strategy is considered to be valuable as it increases the cost-effectiveness of preventive programs. Various caries risk predictors have been studied and it is considered that past caries experience is the most significant predictor for future caries [Seppa et al., 1989; Newburn and Leverett, 1990]. This is reasonable, as caries is a chronic disease with lesions of a variety of severity grades. The validity in predictive studies is therefore reduced if initial lesions are excluded from the caries diagnosis [Skold et al., 1997; Amarante et al., 1998].

The aims of this follow-up study of adolescents were to describe in detail the development of dental caries in the young permanent dentition from 12 to 18 years of age, and to explore the possibilities for predicting the caries increment from 12 to 18 years of age based on the caries experience at 12 years.

## Materials and methods

*Study design and sample.* In 1993 all 12-year-old children receiving routine dental check-ups in three public dental clinics in the city of Bergen, participated in the study, and 159 children were examined. The adolescents were invited to be re-examined at the age of 18 years in 1999, and 112 (70%) of them were. The initial invitation provided information about the examination and a questionnaire to be completed by the parents when the children were 12 years of age and by the adolescents themselves at the age of 18 years. A written reminder followed by a phone call was made to adolescents who did not show up. Drop-out at the age of 18 years was probably due to having moved or unwillingness to participate. The 12-year-olds that participated in the study at the age of 18 years were included in the analysis.

*Caries examination.* Five dentists examined the adolescents clinically at the age of 12 years and one dentist performed the examinations at the age of 18. Prior to the examinations, calibration exercises were conducted. In 1993, twenty adolescents were randomly selected, examined twice and the intra-and inter-examiner reproducibility was calculated. All examinations were under standardised conditions in well-equipped dental clinics. The same criteria were used for examining 12- and 18-year-olds. The teeth were polished and dried before examination. A plane mouth mirror and probe were used for examination. Bitewing radiographs were taken at both ages.

A diagnostic system using five caries grades ($D_1$ to $D_5$) [Espelid et al., 1990; Tveit et al., 1990] was used both in 1993 and 1999. Caries grades $D_1$ and $D_2$ were enamel lesions and caries grades $D_3$, $D_4$ and $D_5$ were dentinal lesions. Teeth and surfaces were given a code according to status: sound, decayed ($D_{1-5}$), filled (F) or missing due to caries (M). In this study the caries grades are grouped and presented as enamel caries ($D_1 + D_2$) and dentine (=manifest) caries ($D_3 + D_4 + D_5$). Dental records were used to decide whether a tooth with filling material was a fissure sealant (coded sound) or a permanent restoration placed due to dental decay (coded filled). Extracted teeth and those indicated for extraction due to caries were counted as five missing surfaces. Teeth restored due to trauma were registered as sound.

*Questionnaire.* Socio-demographic characteristics assessed were gender and mother's education, which was assessed with two categories (less than or equal to 12 years, greater than 12 years). The questionnaire was completed during a visit to each dental clinic.

*Statistical analyses.* The analyses were performed by the Statistical Package Social Sciences (SPSS, Inc. Chicago IL), version 11.0. Independent two sample t-tests were used to compare caries experience between groups. To predict the probability of being at risk, sensitivity and specificity were calculated [Munro 2005].

*Caries prediction.* In order to predict those children at risk (risk groups) of developing manifest caries lesions ($D_{3-5}$ FS) on the approximal surfaces during the age period from 12 to 18 years, the predictive values of indicators available at 12 years of age were explored. Identification of the best possible predictors at 12 years of age was based on the values of sensitivity, specificity, and actual proportion of the population at risk. The predictors with the highest predictive values are presented. Different cut-off points of caries increment ($D_{3-5}FS > 0$, 1, 2, 3 and 4) on approximal surfaces were used for defining risk groups. The level of significance was set at $p < 0.05$.

## Results

*Examiner agreement.* Cohen's kappa values for intra- and inter-examiner reliability of the caries examination at baseline varied from 0.71 to 0.90 (Amarante et al., 1998). The Kappa value for test-retest at the follow-up examination, with only one examiner was 0.62.

*Caries experience among dropouts and follow-ups.* At the age of 12 the mean (±SD) caries experience was significantly higher among those adolescents who dropped out ($D_{1-5}MFS = 12.3 \pm 11.6$) than among those who participated ($D_{1-5}MFS = 8.9 \pm 7.8$) in the study at the age of 18 years ($t = 2.114$, $p = 0.04$).

*Caries experience at the age of 12 and 18 years.* Table 1 depicts caries experience at 12 and 18 years of age at tooth (DMFT) and surface (DMFS) level. At 12 years of age, the major part of the DMFS was decayed surfaces, while at 18 years of age, filled surfaces constituted the major part of the caries experience. Of the decayed surfaces at the age of 12, more surfaces had initial caries than dentine caries.

**Table 1** Mean (SD) caries experience at tooth and surface level at the age of 12 and 18 years in a group of Norwegian adolescents (N = 112).

| | Age | $D_{1-2}$ | $D_{3-5}$ | M | F | $D_{3-5}MF$ | $D_{1-5}MF$ |
|---|---|---|---|---|---|---|---|
| Teeth | 12 yr | 3.4 (2.9) | 0.6 (0.9) | 0.0 (0.1) | 1.3 (1.7) | 1.9 (2.2) | 5.3 (3.9) |
| | 18 yr | 2.8 (3.1) | 0.8 (1.7) | 0.0 (0.2) | 5.2 (3.7) | 6.1 (4.4) | 8.9 (5.1) |
| Surfaces | 12 yr | 6.3 (5.9) | 0.6 (1.1) | 0.0 (0.5) | 2.0 (2.8) | 2.7 (3.5) | 8.9 (7.8) |
| | 18 yr | 4.4 (4.5) | 0.9 (2.2) | 0.2 (1.1) | 7.6 (8.0) | 8.7 (9.4) | 13.1 (11.4) |

**Table 2** Total number and percent of surfaces with caries experience ($D_{1-5}FS$) according to tooth and surface type at 12 and 18 years of age.

| | Incisors and canines | | Premolars | | First molars | | Second molars | | All tooth types (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 12 yr | 18 yr | 12 yr | 18 yr | 12 yr | 18 yr | 12 yr | 18 yr | 12 yr | 18 yr |
| Approximal | 28 | 93 | 70 | 94 | 188 | 112 | 22 | 37 | 308 (30.9) | 336 (23.2) |
| Buccal | 13 | 49 | 4 | 51 | 133 | 107 | 31 | 67 | 181 (18.2) | 274 (18.9) |
| Lingual | 17 | 10 | 3 | 0 | 108 | 25 | 18 | 24 | 146 (14.6) | 59 (4.0) |
| Occlusal | | | 43 | 125 | 187 | 344 | 129 | 308 | 359 (36.1) | 777 (53.7) |
| All surfaces (%) | 58 (5.8) | 152 (10.5) | 120 (12.0) | 270 (18.6) | 616 (61.9) | 588 (40.6) | 200 (20.1) | 436 (30.1) | 994 (100) | 1446 (100) |

Figure 1 shows the distribution of the adolescents according to their caries experience ($D_{1-5}MFT$) at the ages of 12 and 18 years. The percentages of adolescents who were caries-free ($D_{1-5}MFT = 0$) at the ages of 12 and 18 was 10% and 1%, respectively. When excluding enamel caries ($D_{3-5}MFT = 0$), the percentages of adolescents who were caries free at the ages of 12 and 18 increased to 37% and 8%, respectively.

Figure 2 shows the adolescents grouped according to caries status at 12 and 18 years of age. Among those adolescents who were caries-free at 12 years of age (10%), only 1% remained caries-free at 18 years of age. However, 25% had either a reversal or no increments in caries level from 12 to the age of 18 years, while the $D_{1-5}MFS$ increased in 65% of the adolescents.

**FIG. 1** Frequency distribution of the adolescents according to $D_{1-5}MFT$ at 12 and 18 years of age in a Norwegian population.

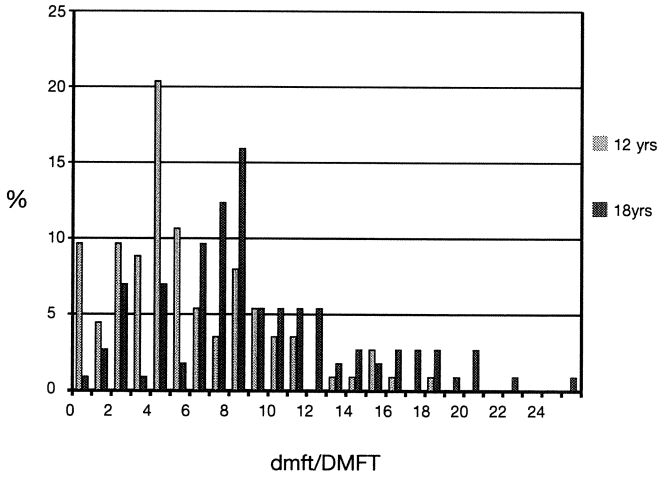


**FIG. 2** Norwegian adolescents grouped according to their caries experience ($D_{1-5}MFS$) at the age of 12 and 18 years (N = 112).

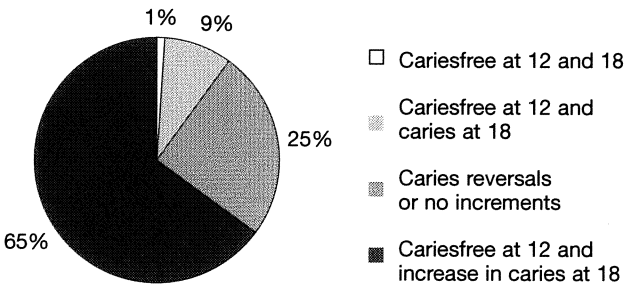

Table 3 Caries experience in Norwegian adolescents ($D_{1-5}$MFS) at 12 and 18 years according to mother's education and gender.

| | | n | Total % | $D_{1-5}$MFS 12 yr Mean (SD) | p | $D_{1-5}$MFS 18 yr Mean (SD) | p-value |
|---|---|---|---|---|---|---|---|
| Mother's education | ≤ 12 yr | 56 | 53 | 10.0 (8.4) | 0.03 | 15.4 (14.1) | 0.01 |
| | > 12 yr | 50 | 47 | 7.0 (6.1) | | 9.7 (6.3) | |
| Gender | Girl | 56 | 50 | 9.1 (8.6) | 0.86 | 13.1 (8.6) | 0.99 |
| | Boy | 56 | 50 | 8.8 (7.0) | | 13.1 (13.6) | |

At 12 years of age, 62% of the surfaces with caries experience ($D_{1-5}$FS) were in the first molars (Table 2). At 18 years of age, the first molars were still the tooth type that most frequently had caries experience (41%). The surfaces most commonly carious at 12 years of age were the occlusal (36%) and approximal (31%). At 18 years of age, the proportion of surfaces with caries on occlusal surfaces had increased from 36% to 54%, while, the proportion of approximal surfaces decreased from 31% to 23%.

The caries experience ($D_{1-5}$MFS) was similar in boys and girls, but adolescents whose mothers had 12 years or longer of education had statistically significant lower caries experience than those whose mothers had less than 12 years of education both at the age of 12 and 18 years (Table 3).

*Caries increment from 12 to 18 years of age.* The mean caries increment from 12 to 18 years of age was $D_{1-5}$MFS 4.2±9.1 and $D_{3-5}$MFS 6.0±7.5. Table 4 shows surfaces with caries increment in incisors, canines, premolars, first molars and second molars according to type of surface and tooth group. Some 75% of the caries increment from 12 to 18 years of age was on the occlusal surfaces of the first (35%) and second molars (40%). Premolars had the highest num-

Table 4 Number and per cent of surfaces with $D_{1-5}$FS increment according to tooth group and surface type from 12 to 18 years in Norwegian adolescents.

| Teeth/surfaces | $D_{1-2}$S (n) | $D_{3-5}$S (n) | FS (n) | $D_{1-5}$FS (n) | % |
|---|---|---|---|---|---|
| Incisors and canines | 52 | 17 | 25 | 94 | 20.8 |
| Approximal | 28 | 15 | 22 | 65 | 14.3 |
| Buccal | 33 | 04 | -1 | 36 | 8.0 |
| Lingual | -9 | -2 | 04 | -7 | -1.5 |
| Premolars | -1 | 08 | 143 | 150 | 33.2 |
| Approximal | -61 | 06 | 79 | 24 | 5.3 |
| Buccal | 44 | 01 | 02 | 47 | 10.3 |
| Lingual | -3 | 00 | 00 | -3 | -0.6 |
| Occlusa | 19 | 01 | 62 | 82 | 18.1 |
| First molars | -248 | -9 | 229 | -28 | -6.2 |
| Approximal | -131 | -7 | 62 | -76 | -16.8 |
| Buccal | -45 | 00 | 19 | -26 | -5.7 |
| Lingual | -68 | 01 | -16 | -83 | -18.3 |
| Occlusal | -4 | -3 | 164 | 157 | 34.7 |
| Second molars | -12 | 19 | 229 | 236 | 52.2 |
| Approximal | -20 | 08 | 27 | 15 | 3.3 |
| Buccal | 13 | 08 | 15 | 36 | 8.0 |
| Lingual | -5 | 02 | 09 | 06 | 1.3 |
| Occlusal | 00 | 01 | 178 | 179 | 39.6 |
| Total sum | -209 | 35 | 626 | 452 | 100 |

*Missing teeth are not included. Negative numbers indicate either reversals, inter-observer variation or progression of lesion to more severe grades*

Table 5 Mean caries increment in Norwegian adolescents ($D_{1-5}$MFS) from 12 to 18 years of age according to mother's education and gender

| | | n | Total % | $D_{1-5}$MFS Mean (SD) | p-value |
|---|---|---|---|---|---|
| Mother's education | ≤ 12 yr | 56 | 53 | 5.3 (11.7) | 0.14 |
| | > 12 yr | 50 | 47 | 2.8 (5.2) | |
| Gender | Girl | 56 | 50 | 4.0 (6.7) | 0.86 |
| | Boy | 56 | 50 | 4.3 (11.1) | |

Table 6 Number and percentage of adolescents and surfaces with manifest caries increment ($D_{3-5}$FS) from 12 to 18 years on approximal surfaces according to tooth type.

| Tooth | Adolescents n (%) | Surfaces n (%) |
|---|---|---|
| Incisors and canines | 12 (10.7) | 37 (17.5) |
| Premolars | 31 (27.7) | 85 (40.1) |
| First molars | 36 (32.1) | 55 (25.9) |
| Second molars | 16 (14.3) | 35 (16.5) |
| All/Total | 52 (46.6) | 212 (100) |

Table 7 Predictive values. Prediction of approximal caries increment ($D_{3-5}FS$) from 12 to 18 years of age. Predictors: caries experience on approximal surfaces of premolars and second molars at the age of 12 years. Five levels of caries increment.

| Predictor at 12 yrs | Adolescents with $D_{3-5}FS_{approx}$ increment | TP | TN | FP | FN | Sen % | Spec % | PPV % | NPV % | OR | 95% CI | PHR % | AHR % | EFF % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $D_{1-5}FS_{approx} > 0$ premolars | $D_{3-5}FS > 0$ | 18 | 57 | 03 | 34 | 35 | 95 | 86 | 63 | 10.1 | 2.7-36.6 | 19 | 46 | 67 |
| | $D_{3-5}FS > 1$ | 17 | 72 | 04 | 19 | 47 | 95 | 81 | 79 | 16.1 | 4.8-53.5 | 19 | 32 | 79 |
| | $D_{3-5}FS > 2$ | 14 | 79 | 07 | 12 | 54 | 92 | 67 | 87 | 13.1 | 4.4-39.2 | 19 | 23 | 83 |
| | $D_{3-5}FS > 3$ | 12 | 83 | 09 | 08 | 60 | 91 | 57 | 91 | 13.8 | 4.4-42.7 | 19 | 18 | 85 |
| | $D_{3-5}FS > 4$ | 11 | 89 | 10 | 02 | 85 | 90 | 52 | 98 | 48.9 | 9.4-252.9 | 19 | 12 | 89 |
| $D_{1-5}FS_{approx} > 0$ second molars | $D_{3-5}FS > 0$ | 11 | 59 | 01 | 41 | 21 | 98 | 92 | 59 | 15.8 | 1.9-127.4 | 11 | 46 | 63 |
| | $D_{3-5}FS > 1$ | 11 | 75 | 01 | 25 | 31 | 99 | 92 | 75 | 33.0 | 4.1-268.5 | 11 | 32 | 77 |
| | $D_{3-5}FS > 2$ | 10 | 84 | 02 | 16 | 38 | 98 | 83 | 84 | 26.2 | 5.2-131.2 | 11 | 23 | 84 |
| | $D_{3-5}FS > 3$ | 10 | 90 | 02 | 10 | 50 | 98 | 83 | 90 | 45.0 | 8.6-234.9 | 11 | 18 | 89 |
| | $D_{3-5}FS > 4$ | 08 | 95 | 04 | 05 | 62 | 96 | 67 | 95 | 38.0 | 8.4-170.2 | 11 | 12 | 92 |

*Approx = approximal, TP = true positive, TN = true negative, FP = false positive, FN = false negative, Se = sensitivity, Sp = specificity, PPV = positive predictive value, NPV = negative predictive value, OR = odds ratio, PHR = proportion of adolescents that tested positive, AHR = actual proportion of adolescents in risk group, EFF = efficiency. Predictors at 12 yrs are dichotomised (No caries experience and caries experience).*

ber of new approximal surfaces with dentine caries or restorations during this period, and also the increment of such lesions was considerable in the incisors. The highest number of surfaces with negative increment (reversals, inter-observer variation or progression of lesion to more severe grades) was registered in the first molars.

The $D_{1-5}MFS$ increment from 12 to 18 years of age was not statistically significantly different in boys and girls (Table 5). There was a higher caries increment ($D_{1-5}MFS$) among adolescents whose mothers had less than or equal to 12 years education than those with longer than 12 years of education, but this difference was not statistically significant (Table 5).

*Caries increment ($D_{3-5}FS$) on approximal surfaces.* Nearly half of the adolescents (47%) had at least one approximal surface with dentine caries or restoration during the age period from 12 to 18 years, and 32% of the adolescents had this kind of increment in the first molars (Table 6). Of the surfaces with approximal caries increment, 40% were in the premolars and 26% in the first molars.

*Prediction of approximal caries increment from 12 to 18 years of age.* The percentages of adolescents that had approximal $D_{3-5}FS$ increment larger than 0, 1, 2, 3 and 4 was 46, 32, 23, 18 and 12 respectively. The two predictors of approximal caries increment with the highest predictive power were caries experience on approximal surfaces ($D_{1-5}FS_{approx} > 0$) of premolars and second molars at 12 years. In Table 7 the predictive values of these two predictors are given for adolescents developing more than 0, 1, 2, 3 and 4 approximal surfaces with dentine caries or restorations ($D_{3-5}FS$) during the period from 12 to 18 years. The sensitivities of the predictors were highest for adolescents developing more than 4 $D_{3-5}FS$ on the approximal surfaces (85% and 62%). The specificities of the predictors were high for both predictors at all levels. Table 7 shows that the higher the approximal caries increment from 12 to 18 years of age the higher was the proportion of adolescents correctly predicted. The 12% of the adolescents that developed four or more approximal surfaces with caries between 12 and 18 years of age had the highest predictive values and were the easiest to predict (sensitivity + specificity = 175 and 158). Adolescents (12%) experienced 62% of the total manifest caries increment on premolar and second molar approximal surfaces.

## Discussion

The present study population was not representative of the general Norwegian population, but the skewed caries distribution in the study population has a similar pattern as previously reported studies with representative samples [von der Fehr, 1994; Macek et al., 2004]. Based on this, it seems reasonable to suggest that the caries increment in this study is similar to the general pattern in this age group. The drop-out rate of 30% was within the range of 20 to 50% when reported in other longitudinal studies [Dummer et al., 1988; Mejare et al., 1999]. The reliability of caries data in the current study was within an acceptable range [Landis and Koch, 1977] and better than in another study [Mejare et al., 1998] using similar radiographic recording criteria.

The baseline prevalence of caries at 12 years of age in the drop-out group was significantly higher than in the follow-up group suggesting that the caries prevalence at 18 years, as well as the size of the risk groups, might be underestimated. This is in accordance with a previous study among adolescents which reported that drop-outs had higher caries experience than others [Skaret et al., 1999]. The parents of children living in the study area had a high level of education compared with the general population in Norway [Amarante, 1995] and the caries prevalence in 18-year-olds in this study was lower than that in adolescents living in other areas in Norway. There is increasing evidence that the children of adults with higher level of education have low caries prevalence [Verrips et al., 1993].

Caries increment. According to our findings a mother's level of education has greater impact on the child's caries experience up to 12 years of age (Table 3) than from 12 to 18 years (Table 5). Following the philosophy of interceptive treatment of dental caries and the need to detect initial caries before cavitation [Raadal 2002], inclusion of enamel caries in the diagnostic criteria is important [Ismail et al., 1992; Ismail 1997]. With the inclusion of enamel caries, the mean $D_{1-5}$MFS more than tripled that of the $D_{3-5}$MFS for 12 years olds, while this difference was smaller at the age of 18 years. The fact that the caries increment was lower for $D_{1-5}$MFS than for $D_{3-5}$MFS (4.2 vs 6.0) clearly indicates that the main reason for the high number of filled surfaces in 18-year-olds was the progression of initial caries lesions from 12 to 18 years of age.

The highest number of caries increments was on the occlusal surfaces (Table 4). This is not in concordance with the findings reported by Dummer et al. [1988] in adolescents between 11 and 15 years of age, where the highest number of caries increments was found on approximal surfaces. Even Bjarnason et al. [1993], who studied adolescents from 16 to 19 years of age, found that the increase in number of surfaces was higher on approximal than on occlusal surfaces. In these studies it was suggested that preventive measures used during that period were sufficient for reducing caries on the free smooth surfaces, but techniques used to control approximal caries were inappropriate. One explanation for our finding was probably that the increment of approximal restorations led to restoration of occlusal surfaces in addition to the approximal surfaces (Class-II). Such restorations were recorded as occlusal and approximal filled surfaces in this study. A meticulous preventive care program has been shown to reduce the progression of approximal lesions [Axelsson et al., 1987]. In our study group, the prevention given has not been sufficient to restrict caries progression in the approximal surfaces. These findings illustrate the need for implementing more efficient methods for arresting incipient caries lesions (interceptive treatment) on approximal surfaces, as restorations result in large loss of healthy tooth substance.

Premolars were the tooth group with highest number of approximal surface caries in need of restorative care. It is, therefore, of concern that occlusal-approximal restorations may weaken these teeth considerably with risk for cusp fractures.

The anterior teeth were, in this study, the tooth groups least affected by manifest lesions on the approximal surfaces. When compared with previous findings [Dummer et al., 1988; Batchelor and Sheiham, 2004], the need for a considerable number of restorations in anterior teeth in our study is worthy of concern as such restorations usually are in need of frequent review in order to be aesthetically acceptable.

Caries prediction. Caries lesions with a potential need of restorative treatment ($D_{3-5}$FS) on the approximal surfaces of the tooth were considered as the most serious development for the dentition in the period from 12 to 18 years of age. The reasons are that two surface lesions lead to considerable loss of sound tooth substance; such restorations may result in need for repeated replacements thereby leading to further tooth damage and finally loss of the tooth [Qvist et al., 1986; Mjor et al., 2002]; the concern of initiating dental anxiety due to painful and unpleasant restorative treatment [Locker et al., 1999; Raadal, 2002]. Taking these factors into account there is a need to predict an individual's risk of developing approximal lesions in order to prevent progression.

Based on the present approach, we found that the best caries predictors at the age of 12 years were the presence of approximal lesion on premolars and second molars. This seems reasonable as these teeth are recently erupted at that age and caries development early after eruption is an indicator of risk [Mejare et al., 1999]. The adolescents who developed more than four new caries lesions between the age of 12 and 18 years were the easiest individuals to predict, as the sum of the sensitivity and specificity was high (close to or above 160%). The percentage of adolescents who developed more than four lesions was 12%. In addition, 62% of the affected approximal surfaces were found in this group.

This, from a cost-efficiency point of view, may be a reasonable proportion of the population to offer intensive preventive care. The sums of the sensitivity and specificity for identifying children with less than four approximal lesions were below the level suggested as suitable for prediction [Stamm et al., 1988; Kingman, 1990].

It was found in the present study that a considerable proportion of the caries increment during the age period from 12 to 18 years was due to progression of initial lesions, which lead to a large amount of restorative treatment and consequently loss of dental tissues. The importance of early detection of caries lesions, particularly on occlusal and approximal surfaces needs to be stressed in order to motivate both patients and dental staff to provide interceptive treatment and prevent need for restorative care. Fissure sealing techniques are effective in arresting initial lesions in pits and fissures [Raadal et al., 2001] but there is an urgent need for more effective techniques for arresting approximal enamel caries before cavitation.

## Conclusion

There was a high increment of manifest caries lesions from 12 to 18 years of age in all tooth groups and a major portion of this was progression of initial lesions present at the age of 12 years. The best predictors for increment of manifest lesions on approximal surfaces were approximal lesions in premolars and second molars at the age of 12 years.

### Acknowledgements

Ethical approval and permission from the Regional Committee for Medical Research Ethics and the Norwegian Data Inspectorate was obtained. All adolescents at the age of 12 and 18 years in addition to their parents gave a written consent to participate in the study.

### References

Amarante E, Raadal M, Espelid I. Impact of diagnostic criteria on the prevalence of dental caries in Norwegian children aged 5, 12 and 18 years. Community Dent Oral Epidemiol 1998;Apr; 26(2):87-94.

Amarante E. Prevalence of dental caries and periodontal disease in 5-, 12-, and 18-year-old children in Bergen, Norway (M.Sc. thesis). Bergen, University of Bergen, 1995.

Axelsson P, Paulander J, Nordkvist K, Karlsson R. Effect of fluoride containing dentifrice, mouthrinsing, and varnish on approximal dental caries in a 3-year clinical trial. Community Dent Oral Epidemiol 1987;Aug;15(4):177-180.

Batchelor PA, Sheiham A. Grouping of tooth surfaces by susceptibility to caries: a study in 5-16 year-old children. BMC Oral Health 2004 Oct 28; 4(1):2.

Bjarnason S, Kohler B, Wagner K. A longitudinal study of dental caries and cariogenic microflora in a group of young adults from Goteborg. Swed Dent J 1993;17(5):191-199.

Dummer PMH, Addy M, Oliver SJ, et al. Changes in the distribution of decayed and filled tooth surfaces and the progression of approximal caries in children between the ages of 11-12 years and 15-16 years. Br Dent J 1988;May;164(9):277-282.

Eklund SA, Ismail AI. Time of development of occlusal and proximal lesions: implications for fissure sealants. J Public Health Dent 1986 Spring; 46(2):114-121.

Espelid I, Tveit AB, Mjor IA, et al. [Systems for grading occlusal and approximal carious lesions]. Nor Tannlaegeforen Tid 1990 Oct; 100(16):658-663.

Glass RL. The first international conference on the declining prevalence of dental caries. J Dent Res 1982;61:1304-1383.

Haugejorden O, Birkeland JM. Evidence for reversal of the caries decline among Norwegian children. Int J Paediatr Dent 2002;Sep;12(5):306-315.

Hausen H, Karkkainen S, Seppa L. Application of the high-risk strategy to control dental caries. Community Dent Oral Epidemiol 2000;Feb; 28(1):26-34.

Ismail AI. Clinical diagnosis of precavitated carious lesions. Community Dent Oral Epidemiol 1997;Feb; 25(1):13-23.

Ismail AI, Brodeur JM, Gagnon P, et al.Prevalence of non-cavitated and cavitated carious lesions in a random sample of 7-9-year-old schoolchildren in Montreal, Quebec. Community Dent Oral Epidemiol 1992;Oct;20(5):250-255.

Kingman A. Statistical issues in risk assessment in dentistry. In: Bader Jd (eds). Risk assessment in dentistry. Chapel Hill: University of North Carolina Dental Ecology; 1990. pp 193-200.

Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;Mar; 33(1):159-174.

Locker D, Liddell A, Dempster L, Shapiro D. Age of onset of dental anxiety. J Dent Res 1999 Mar; 78(3):790-796.

Macek MD, Heller KE, Selwitz RH, Manz MC. Is 75 percent of dental caries really found in 25 percent of the population? J Public Health Dent 2004;Winter;64(1):20-25.

Mejare I, Kallestål C, Stenlund H, Johansson H. Caries development from 11 to 22 years of age: a prospective radiographic study. Prevalence and distribution. Caries Res 1998;32(1):10-16.

Mejare I, Kallestål C, Stenlund H. Incidence and progression of approximal caries from 11 to 22 years of age in Sweden: A prospective radiographic study. Caries Res 1999;33(2):93-100.

Mjor IA, Dahl JE, Moorhead JE. Placement and replacement of restorations in primary teeth. Acta Odontol Scand 2002;Jan;60(1):25-28.

Munro BH. Statistical Methods for Health Care Research Philadelphia, Lippincott Williams & Wilkins.2005.

Newburn E, Leverett D. Risk assessment dental caries working group summary statement. In: Bader Jd (eds). Risk assessment in dentistry. Chapel Hill: University of North Carolina Dental Ecology; 1990. pp 304-305.

Pitts NB. Current methods and criteria for caries diagnosis in Europe. J Dent Educ 1993; 57(6):409-414.

Qvist V, Thylstrup A, Mjor IA. Restorative treatment pattern and longevity of resin restorations in Denmark. Acta Odontol Scand1986;Dec;44(6): 351 356.

Raadal M. Management of early carious lesions in primary teeth. In: Hugoson A ,Falk M, Johansson S. (eds). Management of early carious lesions in primary teeth. Stockholm: Forlagshuset Gothia; 2002. pp 48-56.

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

Seppa L, Hausen H, Pollanen L, Helasharju K, Karkkainen S. Past caries recordings made in Public Dental Clinics as predictors of caries prevalence in early adolescence. Community Dent Oral Epidemiol 1989;Dec;17(6):277-281.

Skaret E, Raadal M, Berg E, Kvale G. Dental anxiety and dental avoidance among 12 to 18 year olds in Norway. Eur J Oral Sci 1999;Dec;107(6): 422-428.

Skold UM, Klock B, Lindvall AM. Differences in caries recording with and without bitewing radiographs. A study on 5-year old children in the County of Bohuslan, Sweden. Swed Dent J 1997; 21(3):69-75.

Stamm JW, Disney JA, Graves RC, Bohannan HM, Abernathy JR. The University of North Carolina Caries Risk Assessment Study. I: Rationale and content. J Public Health Dent 1988 Fall; 48(4):225-232.

Statens helsetilsyn. Tenner for livet. Helsefremmende og forebyggende arbeid. IK-2659 Oslo, Statens helsetilsyn.1999.

Statens helsetilsyn, Sosial- og helsedirektoratet. Årsmelding for Den offentlige tannhelsetjenesten 2001 Oslo, Statens helsetilsyn. 2003.

Tveit AB, Espelid I, Mjor IA, et al. [New criteria for secondary decay and marginal defects]. Nor Tannlaegeforen Tid 1990 Oct; 100(16):652-656.

Verrips GH, Kalsbeek H, Eijkman MA. Ethnicity and maternal education as risk indicators for dental caries, and the role of dental behavior. Community Dent Oral Epidemiol 1993 Aug; 21(4):209-214.

von der Fehr FR. Caries prevalence in the Nordic countries. Int Dent J 1994 Aug; 44(4 Suppl 1):371-378.

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