Caries risks and appropriate intervals between bitewing x-ray examinations in schoolchildren

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Key words: bitewing X-ray examination, X-ray interval, approximal caries, caries risk, schoolchildren

Summary Short intervals between bitewing examinations favor the timely detection of lesions on approximal surfaces. Long intervals reduce the exposure to radiation. Thus, the question arises which intervals between bitewing examinations are appropriate.

The length of intervals between bitewing examinations should be adapted to the caries risk on approximal surfaces of molars and premolars. In order to estimate the caries risk in the Swiss school population, longitudinal data of 591 schoolchildren from the Canton (County) of Zurich were analyzed. These schoolchildren had been examined at 4-year intervals.

The proportion of 7-year-olds with caries increment on approximal surfaces within 4 years was 7.1%, i.e., the caries risk in the population was 7.1%. In the 11-year-olds, the caries risk was 17.6%.

Seven-year-olds without caries experience on selected approximal surfaces had a low caries risk of 2.2%. However, 7-year-olds with caries experience on selected approximal surfaces had a high risk of 24.2%.The same applied to 11-year-olds: those without caries experience had a low risk (7.5%), and those with caries experience had a high risk (38.5%).

For the 7-year-old schoolchildren without any caries experience, an X-ray interval of 8 years is proposed. For the 7-year-old schoolchildren with caries experience, an X-ray interval of 1 year is proposed.

Introduction

Bitewing X-ray images play an important role in the detection of approximal caries on molars and premolars. A review (Pitts & Kidd 1990) showed that around half of the lesions were detected only thanks to bitewing X-ray images. Two more recent studies (Machiulskiene et al. 1999, Machiulskiene et al. 2004) are of particular interest because, despite a meticulous clinical examination, 24–26% of enamel lesions and 38–44% of dentin lesions were detected only by radiological means. The percentages are based on the total number of lesions detected clinically and/or radiologically.

The use of ionizing radiation is associated with risks. The risk of death from cancer is estimated at 0.02–0.6 deaths per million intraoral dental X-ray images produced (European Commission 2004). The risk must be multiplied by a factor of 3 for children under 10 years, and by a factor of 2 for children and adolescents between 10 and 20 years (European Commission 2004). However, it should be noted that people are also exposed to natural ionizing radiation (background radiation). The exposure from two bitewing X-ray images is equivalent to the exposure from background radiation over a one-day period (European Commission 2004).

Short X-ray intervals (the time period between bitewing X-ray examinations) favor the timely detection of lesions on approximal surfaces. Long X-ray intervals reduce the exposure to radiation. Thus, the question arises as to which intervals between bitewing X-ray examinations are appropriate.

The dental literature offers various recommendations for the length of intervals between bitewing X-ray examinations (Pitts & Kidd 1992, Espelid et al. 2003, European Commission 2004, American Dental Association 2004, Schweizerische Zahnärzte-Gesellschaft [Swiss dental association] 2005). In each case, the length of the X-ray intervals was based on the caries risk.

A whole range of studies (Lith & Gröndahl 1992, Lith et al. 2002, Stenlund et al. 2002, Sköld et al. 2005, David et al. 2006) reported that the caries risk on approximal surfaces in adolescents depended on whether or not they had already had caries experience on approximal surfaces.

The present study had the following objectives:
1) To estimate the risk for approximal caries on permanent molars and premolars in the Swiss school population.
2) To estimate the risks for approximal caries in schoolchildren with and without caries experience on approximal surfaces.
3) To propose intervals between bitewing X-ray examinations based on these caries risks.

Materials and methods

Material

The data were obtained from schoolchildren from 16 rural communities of the Canton (County) of Zurich. In these communities, caries epidemiological studies were undertaken every 4 years (Menghini et al. 2003). The schoolchildren in each community were randomly selected. In order to obtain sufficient longitudinal data, the schoolchildren who had been selected were asked to return for another examination in 4 years' time. Schoolchildren with fixed appliances in both the maxilla and in the mandible were excluded. There were two longitudinal data sets: data set A (children examined in 1995/1996 and 2000), and data set B (children examined in 2000 and 2004/2005). It was possible to combine both data sets into a single data set, because there were no statistical differences between them (Steinegger 2008).

Two age groups were extracted, one group with the youngest possible age at the start (6.5–8.0 years) and one group with the highest possible age at the start (10.0–12.0 years). The 6.5- to 8.0-year-olds had an average age of 7.33 years; in the following, they will be referred to as 7-year-olds. The 10.0- to 12.0-year-olds had an average age of 10.78 years; in the following, they will be referred to as 11-year-olds.

A total of 296 7-year-olds and 295 11-year-olds were studied.

Method

The standardized method (Marthaler 1966) records the condition of 92 predilection sites. The approximal surfaces of the posterior teeth were analyzed using bitewing X-ray images. A maximum of 12 approximal surfaces of the primary molars (second primary molar distal to first primary molar distal), and a maximum of 24 approximal surfaces of the permanent molars and premolars (second molar mesial to first premolar distal) were assessed.

Digital bitewing X-ray images were produced (Digora, Orion Corporation Soredex, Helsinki, Finland). The images were produced using a 0.65-KV X-ray machine, HDX Intraoral X-ray (DentalEZ, Lancaster, PA, USA), with an exposure time of 0.12 seconds. The imaging plates were fixed in a support at a right angle to the radiation beam. The X-ray images were analyzed in a darkened room on a FlexScan L768-type screen (EIZO Nanao Corporation, Ishikawa, Japan) using Digora 2.5 software.

The approximal surfaces of the permanent molars and premolars were assessed as follows:
– No radiolucency = Healthy
– Radiolucency in the outer half of the enamel = D1
– Radiolucency in the inner half of the enamel = D2
– Radiolucency in the dentin = D3
– Radiolucency in the dentin at the margin of a filled approximal surface = D4
– Extracted = M
– Filled = F
– Unassessable = X

The approximal surfaces of the primary molars were assessed as follows:
– No radiolucency = Healthy
– Radiolucency in the enamel = d12
– Radiolucency in the dentin = d34
– Missing = m
– Filled = f
– Unassessable = x

All bitewing X-ray images were analyzed by one and the same employee of the Oral Epidemiology department (M.S.). To assess the reliability the X-ray images of a portion of the subjects (N = 242) were analyzed a second time.

Statistical evaluation

The *target variable* "caries increment" was generated for each schoolchild. This measures the quantity of new radiolucencies extending into the dentin and/or fillings (new D34FS) appearing on the approximal surfaces of the molars and premolars within 4 years (maximum = 24). So-called "reversals" (transitions from D3/D4/F to Sound/D1/D2) were subtracted (net increment). The target variable was dichotomized (new D34FS = 0/>0).

Predictor variables were generated for each child. They measure the caries experience at the first examination on selected approximal surfaces:
– D14F6mes = Number of carious (D1, D2, D3, D4) or filled mesial surfaces on the first permanent molars (max. = 4)
– D14FS = Number of carious (D1, D2, D3, D4) or filled approximal surfaces on the permanent molars and premolars (max. = 24)
– d14mf5dis = Number of carious (d12, d34), filled, or missing distal surfaces on the second primary molars (max. = 4)
– d14mfs = Number of carious (d12, d34), filled, or missing approximal surfaces on the primary molars (max. = 12)
– D34FS = Number of carious (D3, D4) or filled approximal surfaces on the permanent molars and premolars (max. = 24)

Predictors were generated by combining and dichotomizing the predictor variables. These predictors have two categories (without/with caries experience):
Predictor A
– D14F6mes = 0 and d14mf5dis = 0
– D14F6mes >0 and/or d14mf5dis >0

Predictor B
– D14F6mes = 0
– D14F6mes >0

Predictor C
– d14mf5dis = 0
– d14mf5dis >0

Predictor D
– d14mfs = 0
– d14mfs >0

Predictor E
– D14FS = 0
– D14FS >0

Predictor F
– D34FS = 0
– D34FS >0

The reliability of the measurements was assessed using kappa statistics. The predictive power of the predictors was assessed based on the measures of sensitivity, specificity, Youden's J, negative predictive value, and positive predictive value. The evaluations were carried out using the SPSS program.

Results

Reliability

The reliability (reproducibility) of the measurements was checked for the dichotomized variables D14F6mes, D14FS, and d14mf5dis and for the variable D34FS (not dichotomized). The reliability was good (kappa values between 0.73 and 0.90).

Proportion of schoolchildren with caries increment, predictive power of the predictors

The proportion of 7-year-olds with caries increment was 7.1% (Tab. I). Using predictor A, schoolchildren were divided into those with and those without caries experience (at the first examination) on the mesial surfaces of the first permanent molars and the distal surfaces of the second primary molars. At baseline a total of 77.7% of the schoolchildren had no caries on any of the eight surfaces. In this group, 2.2% of the schoolchildren exhibited caries increment. A total of 22.3% of the schoolchildren had caries on at least one of the eight surfaces. In this group, 24.2% of the schoolchildren exhibited caries increment. The sensitivity of the predictor A was 0.76, the specificity was 0.82, Youden's J was 0.58; the negative predictive value was 0.98 and the positive predictive value was 0.24. The predictors B, C, and D were less powerful (Youden's J 0.48, 0.45, and 0.29).

The proportion of 11-year-olds with caries increment was 17.6% (Tab. II). Using predictor B, schoolchildren were divided into those with and those without caries experience (at the first examination) on the mesial surfaces of the first permanent molars. A total of 67.5% of the schoolchildren had no caries on any of the four surfaces at baseline. In this group, 7.5% of the schoolchildren exhibited caries increment. A total of 32.5% of the schoolchildren had caries on at least one of the four surfaces. In this group, 38.5% of the schoolchildren exhibited caries increment. The sensitivity of the predictor B was 0.71, the specificity was 0.76, Youden's J was 0.47; the negative predictive value was 0.92 and the positive predictive value was 0.39. The predictor E was similarly powerful (Youden's J 0.49); predictor F was less powerful (Youden's J 0.21).

Discussion

Generally low risk for approximal caries

In order to estimate the risk for approximal caries in Swiss schoolchildren, longitudinal data from 16 communities of the Canton of Zurich were analyzed. The caries risk of an individual in the population is equal to the percentage of schoolchildren with caries increment (new D34FS >0) in the sample. The caries risk of the schoolchildren in the 16 communities is most likely similar to that of the schoolchildren in the Canton of Zurich and in the rest of Switzerland.

The present study revealed a generally low risk for approximal caries. This assessment is based on comparisons with studies abroad. In the present study, caries increment within 4 years was observed in 7% of the 7-year-olds and in 18% of the

Tab. I Proportion of 7-year-olds with caries increment[1] within 4 years

	N children	% children	N children without caries increment	N children with caries increment	% children with caries increment	% children with caries increment 95% CI	SN	SP	YJ	NPV	PPV
All	296	100%	275	21	7.1%	4.7–10.6%					
Predictor A											
D14F6mes = 0 and d14mf5dis = 0	230	77.7%	225	5	2.2%	0.9–4.5%	0.76	0.82	0.58	0.98	0.24
D14F6mes > 0 and/or d14mf5dis > 0	66	22.3%	50	16	24.2%	15.5–35.8%					
Predictor B											
D14F6mes = 0	273	92.2%	263	10	3.7%	2.0–6.6%	0.52	0.96	0.48	0.96	0.48
D14F6mes > 0	23	7.8%	12	11	47.8%	29.2–67.0%					
Predictor C											
d14mf5dis = 0	236	79.7%	228	8	3.4%	1.7–6.6%	0.62	0.83	0.45	0.97	0.22
d14mf5dis > 0	60	20.3%	47	13	21.7%	13.1–33.9%					
Predictor D											
d14mfs = 0	107	36.1%	105	2	1.9%	0.5–6.6%	0.90	0.38	0.29	0.98	0.10
d14mfs > 0	189	63.9%	170	19	10.1%	6.5–15.2%					

[1] Appearance of new radiolucencies extending into the dentin or fillings on approximal surfaces of molars and premolars within 4 years (new D34FS > 0)
SN = sensitivity / SP = specificity / YJ = Youden's J (SN+SP–1) / NPV = negative predictive value / PPV = positive predictive value / 95% CI = 95% confidence interval

Tab. II Proportion of 11-year-olds with caries increment[1] within 4 years

	N children	% children	N children without caries increment	N children with caries increment	% children with caries increment	% children with caries increment 95% CI	SN	SP	YJ	NPV	PPV
All	295	100%	243	52	17.6%	13.7–22.4%					
Predictor B											
D14F6mes = 0	199	67.5%	184	15	7.5%	4.6–12.1%	0.71	0.76	0.47	0.92	0.39
D14F6mes > 0	96	32.5%	59	37	38.5%	29.4–48.5%					
Predictor E											
D14FS = 0	193	65.4%	180	13	6.7%	4.0–11.1%	0.75	0.74	0.49	0.93	0.38
D14FS > 0	102	34.6%	63	39	38.2%	29.4–47.9%					
Predictor F											
D34FS = 0	277	93.9%	237	40	14.4%	10.8–19.1%	0.23	0.98	0.21	0.86	0.67
D34FS > 0	18	6.1%	6	12	66.7%	43.8–83.7%					

[1] Appearance of new radiolucencies extending into the dentin or fillings on approximal surfaces of molars and premolars within 4 years (new D34FS > 0)
SN = sensitivity / SP = specificity / YJ = Youden's J (SN+SP–1) / NPV = negative predictive value / PPV = positive predictive value / 95% CI = 95% confidence interval

11-year-olds. In a Norwegian study, 47% of 12-year-olds developed new lesions on the approximal surfaces within 6 years (David et al. 2006). In a Swedish study of 13-year-olds, 39% (with fluoridated drinking water) and 64% (without fluoridated drinking water) developed new lesions on approximal surfaces within 5 years (Lith & Gröndahl 1992). In another Swedish study, 82% of 11- to 13-year-olds developed new lesions within 4 years (Stenlund et al. 2002). However, the latter study included newly developed D2 lesions (radiolucencies in the inner half of the enamel).

The generally low risk for approximal caries at the present time is also evident from cross-sectional data from the Canton of Zurich. The examinations, which have been undertaken every 4 years since 1964, show a steady decline in caries on the approximal surfaces of molars and premolars up until the 1990s (Menghini & Steiner 2007). The decline in caries is depicted in Fig. 1 with respect to 15-year-olds.

Predictors for differentiating between schoolchildren with a high risk and schoolchildren with a low risk

In order to differentiate between schoolchildren with a high risk and those with a low risk for approximal caries, powerful predictors (discriminators) are necessary. One important predictor is caries experience on approximal surfaces (Lith & Gröndahl 1992, Lith et al. 2002, Stenlund et al. 2002, Sköld et al. 2005, David et al. 2006). The schoolchildren in the present study were therefore divided into those with and those without caries experience on selected approximal surfaces.

In the case of the 7-year-olds, predictor A (see Tab. I) proved to be the best discriminator for differentiating between schoolchildren with a low risk and schoolchildren with a high caries risk (Youden's J = 0.58). Schoolchildren without caries experience had a caries risk of 2.2%. This caries risk was classified as low. Schoolchildren with caries experience had a caries risk of 24.2%. This risk was classified as high.

In the case of the 11-year-olds, the predictors B and E (see Tab. II) proved to be powerful predictors (Youden's J = 0.47 and 0.49, respectively). Schoolchildren without caries experience had a caries risk of 7.5% (predictor B) and 6.7% (predictor E). This caries risk was classified as low. Schoolchildren with caries experience had a high caries risk of 38.5% (predictor B) and 38.2% (predictor E).

High negative predictive values and moderate positive predictive values

The negative predictive values of the predictors A and B were 0.98 and 0.92, respectively. This means that over 90% of the schoolchildren who were classified as having a low caries risk did not develop any caries on approximal surfaces.

The positive predictive values of the predictors A and B were only 0.24 and 0.39, respectively. This means that only 24% and 39%, respectively, of the schoolchildren who were classified as having a high caries risk actually developed caries on approximal surfaces.

The quality of prediction can be affected by various factors, such as insufficient validity and reliability of the measured variables, as well as by changes in caries activity. Hintze et al. (1994) established insufficient validity of radiological diagnosis of approximal carious lesions in enamel.

Bitewing X-ray examinations in the first and last school year

In Switzerland, in the first school year, X-ray images have to date been proposed according to individual requirements. In the final school year, bitewing X-ray images are proposed for every young person (SSO [Swiss Dental Association] 1997). In light of the findings of this study, a bitewing X-ray examination is also recommended for all schoolchildren in the first school year.

There are good grounds for a bitewing X-ray examination in the first school year (for 7-year-olds):

1) As this paper shows, the 7-year-olds can be easily divided into those with a low risk and those with a high risk for approximal caries. Ideally, the schoolchildren should be at least 7.0 years old at the time of the risk assessment. At this age, the mesial surfaces of the first permanent molars and the distal surfaces of the second primary molars have been in contact with one another for approximately one year, and there has thus been a sufficient exposure period for caries to develop.
2) In around half of the 7-year-olds (16 communities in the Canton of Zurich, 2000), lesions on approximal surfaces of primary molars that extended into the dentin were observed. In a quarter of the 7-year-olds, such lesions could be detected only on the X-ray images (unpublished data from the Oral Epidemiology department).

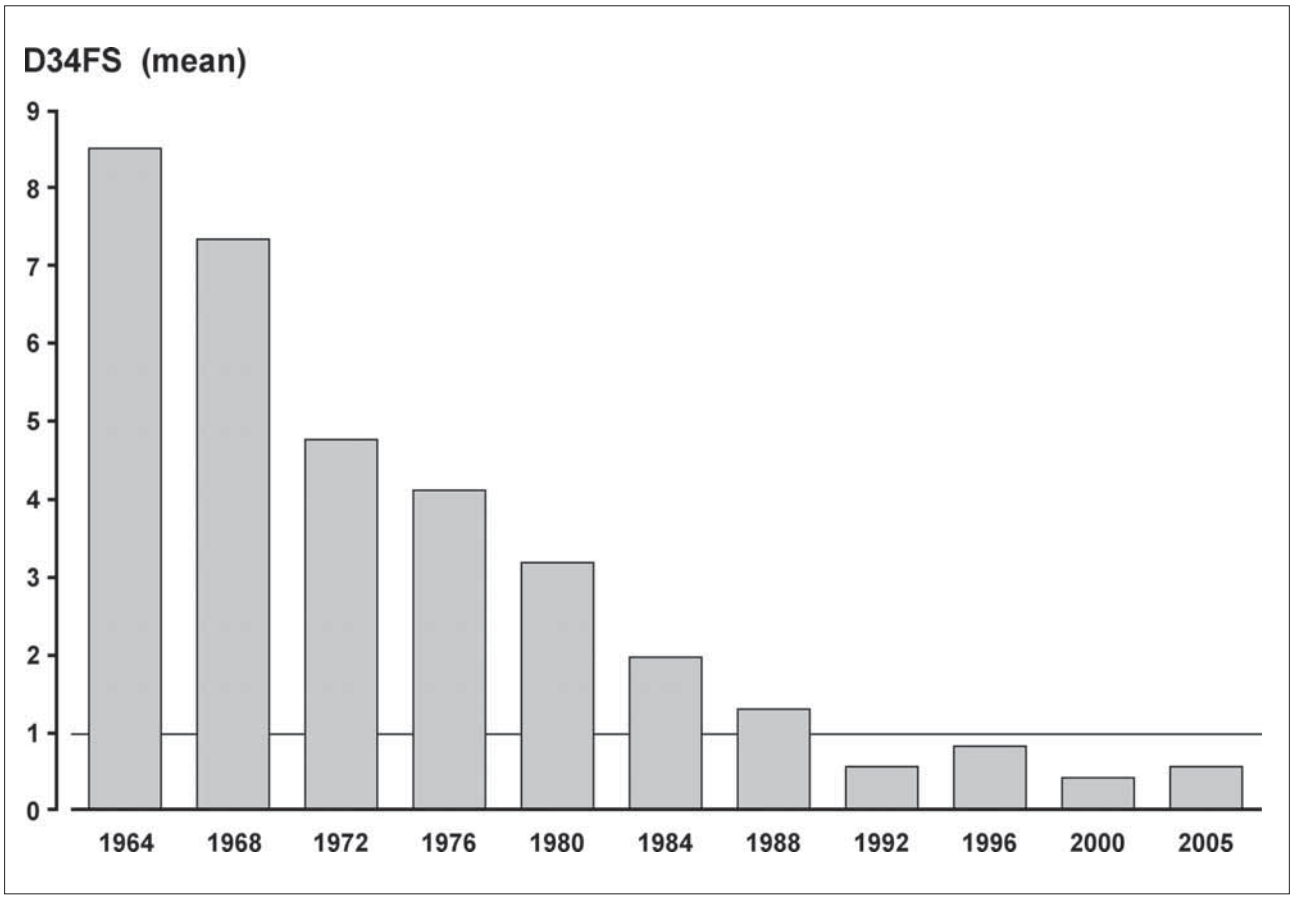

Fig. 1 Caries experience on approximal surfaces of molars and premolars in 15-year-old schoolchildren from 16 communities of the Canton (County) of Zurich

There are also good grounds for a bitewing X-ray examination in the last school year (for 15-year-olds):

1) In just over 10% of 15-year-olds (16 communities in the Canton of Zurich, 2000), lesions extending into the dentin were discovered on approximal surfaces of molars and premolars. In just over 10% of the 15-year-olds, lesions extending into the dentin were also detected under clinically intact fissures of molars and premolars (so-called "hidden caries") (unpublished data from the Oral Epidemiology department). Such lesions should be detected before the child is released from the school dental service.
2) In just over one-third of the 15-year-olds, advanced lesions were detected in the enamel (D2) on approximal surfaces of molars and premolars (unpublished data from the Oral Epidemiology department). Schoolchildren and their parents should receive appropriate advice on the matter upon release from the school dental service.
3) The X-ray images serve as an important reference document for dentists who subsequently assume responsibility for young persons' dental care.

Bitewing X-ray examinations between the first and the last school year

The question arises whether additional bitewing X-ray examinations are required between the first and the last school year, and if so, at what intervals these should take place. In order to answer this question, it is necessary to make an essential decision, namely, to determine the level of caries risk that warrants a bitewing X-ray examination. A threshold of 20% was adopted in the present study. This means that 20% of the schoolchildren benefit from the bitewing X-ray examination, since caries increment can be expected in 20% of cases; however, it also means that 80% do not benefit.

For the 7-year-olds without caries experience, the caries risk up to the age of 11 years was just 2.2%; the risk was well below the threshold of 20%. Producing X-rays after just 4 years would thus be premature. It is therefore recommended that 7-year-olds without caries experience undergo further X-rays only in the last school year (after 8 years).

The caries risk over 8 years can be estimated as follows: of the 7-year-olds without caries experience, around 98% remain "healthy" after 4 years (see predictor A/7-year-olds). Of these schoolchildren, who are now 11 years old, around 86% remain healthy (see predictor F/11-year-olds). Over the full time period of 8 years, 84% (98×0.86) remain healthy, or, to put it another way, 16% develop approximal caries. The caries risk thus remains below 20%.

For the 7-year-olds with caries experience, the caries risk up to the age of 11 years was 24.2%; the risk was higher than the threshold of 20%. Producing further X-rays after only 4 years would thus be too late. An initial interval of 1 year is recommended. If, after 1 or 2 years, no development of the lesions can be detected, a prolongation of the interval is recommended.

Recommendations based on this study

For the 7-year-old schoolchildren without caries experience, an X-ray interval of 8 years is proposed. For the 7-year-old schoolchildren with caries experience, an X-ray interval of 1 year is proposed.

Exceptions to these recommendations

Caution must be exercised in schoolchildren for whom an X-ray interval of 8 years is scheduled. Living conditions and health behavior may change over the years, meaning that caries risk may also change. Approximal surfaces must therefore be carefully inspected during the yearly clinical examinations. At the first suspicion of approximal caries, an unscheduled bitewing examination may be advisable.

In schoolchildren for whom an X-ray interval of 1 year is scheduled, this interval may be prolonged if no progression of lesions is observed during 1 or 2 years.

In schoolchildren who do not reach age 7 in the first school year, or schoolchildren with delayed eruption of first molars, bitewing examination must be postponed to the second school year.

Previous recommendations

The dental literature contains various recommendations on the length of the X-ray intervals (Tab. III). The authors proposed intervals of 6 months to 1 year in the case of high caries risk; in the case of low caries risk, intervals of 1 to 3 years were recommended. These intervals are considered to be too short, based on the current caries risk in Switzerland. The cited studies provided no information with respect to the predictive power of the predictors that were used to determine the risk.

Less exposure to radiation

X-ray intervals that are twice to four times as long as the previous recommendations of the SSO (Swiss Dental Association) (Tab. III) are suggested here. Accordingly, this entails only a quarter to half the exposure to radiation.

Prevention rather than X-rays

Extending the X-ray intervals should go hand in hand with a greater focus on prevention. The application of fluoride varnish on approximal surfaces of molars and premolars is thus recommended for all schoolchildren as part of the school dental service. A semi-annual application of fluoride varnish can greatly diminish the development of approximal caries (Sköld et al. 2005).

Presently, preventive activities are being moved forward to the pre-school age. If caries experience can be diminished further, this would also speak in favor of longer X-ray intervals.

Costs

Based on the present recommendations, approximately 3 bitewing examinations during the school years would be necessary per child (75% of the schoolchildren need only 2 bitewing examinations, 25% need more than 2). It is not known how many X-ray examinations are currently performed during schooling. Consequently, it is impossible to tell whether the recommendations would increase or decrease the costs involved.

Résumé

De courts intervalles entre la prise de radiographies (bite-wing) favorisent une détection précoce des lésions carieuses aux faces approximales. De longs intervalles permettent de réduire l'exposition aux rayons x. De là se pose la question quels sont les délais appropriés entre les prises de radiographies.

Les intervalles entre la prise de radiographies devraient être adaptés au risque de carie aux faces approximales des molaires et des prémolaires. Les données longitudinales de 591 élèves du canton de Zurich ont été analysées afin d'estimer le risque de carie de la population scolaire en Suisse. Les élèves avaient été soumis à deux examens bucco-dentaires dans l'intervalle de quatre ans.

La proportion d'élèves âgés de 7 ans avec de nouvelles caries en quatre ans était de 7,1%; cela veut dire que le risque de carie dans la population était de 7,1%. Chez les élèves âgés de 11 ans, le risque de carie était de 17,6%.

Les écoliers de 7 ans sans caries aux faces approximales sélectionées avaient un faible risque de carie de 2,2%. Par contre, les écoliers de 7 ans ayant déjà des caries avaient un risque de carie élevé de 24,2%. De même, le risque de carie était faible chez les écoliers de 11 ans sans caries (7,5%) et haut chez ceux avec caries (38,5%).

Pour les élèves de 7 ans sans caries approximales, un délai de 8 ans jusqu'au prochain examen radiographique est proposé. Pour ceux qui, à cet âge, ont déjà développé des lésions carieuses approximales, ce délai est de 1 an seulement.

Tab. III Recommended X-ray intervals for children and adolescents

Authors	Age	X-ray intervals where there is a high caries risk	X-ray intervals where there is a moderate caries risk	X-ray intervals where there is a low caries risk
Pitts & Kidd 1992	7–13 14–17	6 months 6 months	1 year 1 year	1–2 years 2 years
Espelid et al. 2003	5[1] 8/9[1] 12/13/14[1] 16[1]	1 year[2] 1 year[2] 1 year[2] 1 year[2]	–	3 years[2] 3–4 years[2] 2 years[2] 3 years[2]
European Commission 2004	Children	6 months	1 year	1–2 years
ADA 2004	Children Adolescents	6–12 months 6–12 months	–	1–2 years 1.5–3 years
SSO 2005	7–25	6 months	1 year	2 years
Present study	7[1]	1 year[2]	–	8 years[2]

[1] Initial bitewing X-ray examination
[2] Interval until the next bitewing X-ray examination

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