

# EAPD guidelines for use of radiographs in children

I. ESPELID\*, I. MEJÀRE\*\*, K. WEERHEIJM\*\*\*

**ABSTRACT.** Guidelines in dental radiology are designed to avoid unnecessary exposure to X-radiation and to identify individuals who may benefit from a radiographic examination. Every prescription of radiographs should be based on an evaluation of the individual patient benefit. Due to the relatively high frequency of caries among 5 year old children it is recommended to consider dental radiography for each child even without any visible caries or restorations. Furthermore, radiography should be considered at 8-9 years of age and then at 12-14, that is 1-2 years after eruption of premolars and second molars. Additional bitewing controls should be based on an overall assessment of the caries activity/risk. The high-risk patient should be examined radiographically annually, while a 2-3 years interval should be considered when caries activity/risk is low. Routine survey by radiographs, except for caries, has not been shown to provide sufficient information to be justified considering the balance between cost (radiation and resources) and benefit.

**KEYWORDS:** Practice guidelines, Dental radiography, Patient selection

## Introduction

Dental radiography is a useful diagnostic aid in oral examination of children. In many cases the radiographic findings add important information. However, the risks associated with radiography should not be neglected. Guidelines in dental radiology are designed to avoid unnecessary exposure to X-radiation and to identify those individuals who may benefit from a radiographic examination. Keywords for good practice are appropriate selection criteria for the use of radiography, optimised radiation protection and utilisation of the total amount of information in each radiograph.

## Indications for radiographs in children and adolescents

The major reasons for taking radiographs of teeth and supporting tissue in paediatric dentistry are: 1) detection of caries; 2) dental injuries; 3) disturbances in tooth development; 4) examination of pathological conditions other than caries. For

each individual a clinical examination, combined with an interpretation of previous radiographs, should be carried out before initiating a radiographic examination. There should be an individual indication for taking radiographs and these guidelines should serve as an aid and remainder in the planning of the examinations needed.

This general principle should also be followed during systematic examinations that are carried out to detect caries by clinical means and radiography. This should not, however, be performed in a routine manner using the same practice for all individuals [Faculty, 1998; Hanlon, 1985; Rohlin and White, 1992; Shwartz et al., 1987]. Radiography should only be performed when a patient's history and/or objective findings and symptoms lead to the conclusion that further useful information might be obtained (Table 1). If a radiograph is not expected to change diagnosis or treatment or add other useful information, it should not be taken.

*Principles for radiographic examination of asymptomatic children.* A systematic, radiographic examination carried out especially to detect a disease is based on the concept that it is so important to detect the condition at an early stage that radiographic examinations should be conducted, even if there are no signs of pathology prior to the test. In addition the

\*Department of Paediatric Dentistry and Behavioural Science, University of Oslo, Norway

\*\*Department of Paediatric Dentistry, Eastman Dental Institute, Stockholm, and Department of Pedodontics, Lund University, Sweden

\*\*\*Department of Cariology Endodontology Pedodontology, ACTA, Amsterdam, The Netherlands

Based on objective findings/symptoms	Based on anamnestic information
Caries	History of pain
Pulpal and periapical pathology	History of trauma to teeth
Traumatic injuries	Postoperative evaluation
Problems of eruption	Familial history of dental anomalies
Developmental anomalies	
Unexplained discolouration of teeth	
Orthodontic treatment planning and evaluation	
Evidence of swelling	
Unexplained tooth mobility	
Unexplained bleeding	
Deep periodontal pocketing	
Fistula formation	
Unexplained sensitivity of teeth	
Unusual spacing or migration of teeth	
Lack of response to conventional dental treatment	
Unusual tooth morphology, calcification or colour	
Evaluation of growth abnormalities	
Altered occlusal relationship	
Aid in diagnosis of systemic disease	

**TABLE 1** - Selection criteria for prescription of dental radiographs.

examination should be acceptable to the patient, have low inter and intraexaminer variation and be a valid estimator for the pathology it is intended to identify [Lervik and Cowley, 1983b].

*Informed consent.* The patient or parents have a legitimate right to be heard and approve the clinician's advice about any radiographic examination or screening procedure that might be matter of discussion. The clinician has to consider and respect the views, values and preferences (utility) which the patient and/or family express after having received and understood the information provided. However, strong recommendations might be appropriate when the clinician finds the examination highly beneficial for the patient. It is important for clinicians to be aware of the recommendations of guidelines that are generally accepted and if these are not followed the reasons should be discussed with the patient and recorded in the clinical case notes. In dental treatment cases of negligence the guidelines might have medical and legal implications.

*Radiographic caries diagnosis in children adolescents.* In a population the use of bitewing radiography, in addition to clinical examination, increases the number of approximal lesions detected by a factor of between 2 and 8 [Faculty of General Dental Practitioners, 1998; Kidd and Pitts, 1990; Stephen et al., 1987]. The bitewing also offers excellent information about caries in the dentine under occlusal surfaces [Espelid et al., 1994; Ie and Verdonshot, 1994; Nyttun et al., 1992; Wenzel et al., 1990].

During the past 2-3 decades a number of changes related to bitewing radiography have taken place:

- the decrease in caries prevalence in the western industrialised world such that most of these populations experience a skewed caries distribution;
- the relatively slow rate of caries progression in populations regularly exposed to fluoride;
- a revision of the estimates of health detriment caused by exposure to low dose ionising radiation, particularly for children.

All of these changes have an impact on the view concerning when and how often radiographs should be taken in children and adolescents. These changes have resulted in a statement saying that every prescription of a radiograph should be based on an evaluation of the individual patient's benefit. In other words, it is no longer justified to take radiographs routinely and for screening purposes only.

This statement is, however, rather ambiguous and can have various meanings. One extreme of interpretation is never to take any radiographs for detecting caries. Then, the population will not be exposed to any low dose ionising radiation from bitewing radiography. The opposite extreme it is to say that new caries should always be suspected and therefore frequent bitewings are always necessary. The authors would like to use a pragmatic interpretation and try to make it useful in the clinical situation. The benefits of bitewing radiographs as aids for the caries diagnosis are to:

- detect caries that cannot otherwise be detected;
- estimate the extent of lesions;
- monitor lesion.

Good technical qualities of the radiographs and good diagnostic quality are of vital importance in this respect.

### Timing of the first (baseline) bitewing radiographs

When considering the time of the baseline bitewing radiographic examination, adequate selection criteria are necessary including information on:

- relevant epidemiological data on the caries prevalence and rate of progression in the population;

- caries experience;
- oral hygiene and dietary habits;
- exposure to fluorides;
- socioeconomic status.

Based on this knowledge, an individual risk assessment is carried out. It should be noted that bitewing radiographs should be taken only if they are considered necessary for adequate treatment. As an aid for deciding whether to take radiographs or not, some epidemiological data are given below.

### **Epidemiological data relating to taking dental radiograph**

*The primary dentition.* Recent studies have shown that even in populations with an overall low caries prevalence, more than one third of 5 year olds in Sweden and Norway had approximal carious lesions that could not be detected by visual inspection [Boman et al., 1999; Raadal et al., 2000]. In a Dutch study of Roeters et al [1992], between 10 and 60% extra information was gained by the use of the bitewing radiographs in this age group. It seems reasonable to suggest that 5 year olds should be considered for bitewing examination.

*The mixed dentition.* At the age of 9 years about one third of a cohort of Swedish children had dentine caries in at least one distal surface of the second primary molar, as judged radiographically. It was also shown that enamel or dentine caries in the distal surface of the second primary molar increased the risk about 15 times for the mesial surface of the first permanent molar to develop approximal caries. Furthermore, 15-20% of Swedish children developed dentine caries in at least one first permanent molar between 6 and 12 years of age [Kallestal et al., 2000; Mejåre and Stenlund, 2000].

Bitewing radiographs at the age of 8 years are also useful for deciding on the proper interval to the next bitewings. Thus, children who are caries free in approximal surfaces in their primary teeth at this age are likely to remain so including the first permanent molars up to at least the age of 12 years [Mejåre et al., 2001]. Therefore, bitewing radiographs should be considered at the age of 8-9 years.

*The young permanent dentition.* Baseline bitewing radiographs in the permanent dentition should be considered at the age of 12-14 years, that is 1-2 years after eruption of premolars and second molars. This concerns also populations with an overall low caries prevalence [de Vries et al., 1990].

It is important to note that no radiograph should be taken for routine purposes only, that is, children with negligible caries risk should be excluded from

bitewing radiographs as the diagnostic yield for these children may be minimal.

*Intervals between bitewing examinations.* The interval to the next bitewing examination should be based on previously obtained data including the number and extent of approximal lesions. These are categorised as follows:

A - low risk (caries free on approximal surfaces or an occasional lesion without other indications of high risk). Bitewing radiographs should be taken at 2-3 year intervals;

B - high risk (enamel/dentine lesions in approximal surfaces). Bitewing radiographs should be taken at 1 year intervals.

Examples of high risk are:

- in the mixed dentition (6-12 years of age), a first permanent molar with caries half way through the enamel;
- at age 12-13 years, at least one approximal dentine lesion/restored surface or 3 or more enamel lesions;
- approximal surface with unrestored dentine lesion;
- approximal surface with a recently restored neighbouring surface.

The rate of progression of lesions in the inner half of the enamel of the mesial surface of the first permanent molar is relatively fast between the ages of 6-12 years. About 20% progress into the dentine within a year [Mejåre and Stenlund, 2000]. The risk of developing new approximal lesions rises with increasing number of existing approximal lesions at the age of 11-13 years [Gröndahl et al., 1984; Lith and Gröndahl, 1992; Mattiasson-Robertson and Twetman, 1993; Mejåre et al., 1999; Gustafsson et al., 2000; Stenlund et al., 2002]. The progression rate of dentine lesions is considerably faster than in enamel [Mejåre et al., 1999], about 10 % progress in the dentine within a year. Importantly, if several lesions are present, there is an increased risk that one of them will progress relatively fast. Based on this study, specific surfaces at risk might be pointed out (Table 2). Approximal surfaces neighbouring a recently restored surface have a 4 fold risk of progressing compared with the contralateral approximal surface not neighbouring a restored surface [Qvist et al., 1992].

The baseline examinations and intervals to the next bitewing examination can be summarised as shown in Table 3.

A 6 month interval between bitewing examinations is seldom indicated. However, if several dentine lesions are left unrestored, there is an impending risk that one of them will progress to a deep dentine lesion within a year. If the clinician cannot take the

chance to wait more than 6 months before a new radiograph is wanted, it might be a better strategy to intervene with restorative care when dealing with surfaces at great risk for progression [Qvist et al., 1992; Mejàre et al., 1999].

**Population strategies**

Besides socioeconomic factors (such as less prosperous areas or schools), also at risk ages and tooth surfaces for caries can be identified and used for deciding on the timing of bitewing examinations. According to a Finnish expert group [Lahti et al., 2001] a lack of past caries experience in teenagers can be used to identify low risk

individuals and the proportion of false negatives that will be acceptable due to a relatively high specificity of the selection. Thus, the selected group can then be given more than one year intervals between bitewing radiographs. The remaining group containing both high risk and low risk patients are treated much the same way because they are not easily separated.

For occlusal surfaces of molars, the first 1-2 years after eruption should be considered as risk ages for new caries. Regarding approximal surfaces, the first 4-5 years after contact with the neighbouring tooth surfaces are the ages of a child when most new carious lesions occur [Stenlund et al., 2002] (Table 4).

Risk of:	Tooth surface
New carious lesions	5d, 6d
Progression of lesions from enamel to dentin	upper: 7m, 5d; lower: 6d
Progression of lesions in the dentin	upper: 5d; lower: 7m, 6d

**TABLE 2** - Risk surfaces for approximal caries on a cohort of 536 individuals followed from 12 to 22 years of age [Mejàre et al., 1999].

Baseline bitewing examination	Interval to next bitewing examination	
At age:	Low risk	High risk
5 years	3 years	1 year
8 or 9 years	3-4 years	1 year
12 to 16 years	2 years	1 year
16 years	3 years	1 year

**TABLE 3** - The baseline examinations and intervals to the next bitewing examination in children.

Time (months) from entering the study	Approximate age (years)	Caries rate* (100 person-years)	Number of individuals with first new approximal lesion (cumulative %)
0-12	14	36.6	165 (36)
12-24	15	30.8	98 (58)
24-36	16	24.0	57 (70)
36-48	17	27.1	49 (82)
48-60	18	26.0	35 (89)
60-72	19	15.2	16 (92)
72-84	20	13.7	12 (95)
84-96	21	17.0	12 (98)
96-108	21	9.8	5 (99)
108-120	22	14.6	3 (99)

\*To illustrate how this rate can be interpreted, take for example a caries rate = 27, that means that if we follow 100 persons for one year, we expect 27 individuals with a new lesion.

**TABLE 4** - Individual-based caries rates (number of individuals with their first new approximal lesion/100 person-years) related to age.

## Occlusal surfaces of molars and bitewing examination

Occlusal surfaces of molars are still considered to be more caries-prone than approximal surfaces. Furthermore, the phenomenon of hidden caries, that is radiographically visible dentine caries under a seemingly "sound" surface, as judged from visual inspection, has been highlighted [Creanor et al., 1990; Hintze and Wenzel, 1994; Weerheijm et al., 1997]. The prevalence of hidden caries is uncertain and depends on the quality of the clinical inspection. There are no obvious reasons for special recommendations for the prescription of bitewing radiographs for these surfaces. Instead, available radiographs should also be used for the detection of any occlusal dentine caries of these surfaces.

*Conclusions.* Systematic, radiographic examinations for caries have traditionally been considered to be cost-effective. However, there will always have to be a balanced view taken between the cost in time, effort, radiation and false positive diagnoses as well as the value of early detection [Hanlon, 1985; Lervik and Cowley, 1983a]. Thus, guidelines and examination strategies should continuously be re-evaluated to see if any of the underlying conditions, such as caries prevalence, have changed [Espelid, 1987; Gröndahl, 1979; Lervik and Cowley, 1983a]. It is a dentist's responsibility to consider the benefits of bitewing examination and an individual caries risk assessment should always precede any bitewing radiograph being taken. Important factors to consider in caries risk assessment are the caries prevalence and distribution in the local population at hand, the rate of caries progression and the accuracy of predicting new caries and/or caries progression. Furthermore, the diagnostic quality of bitewing radiography is of paramount importance. Thus, overall, good quality of radiographs and radiographic diagnosis is more important than frequent examinations.

## Systematic examinations for other conditions than caries?

Routine survey by radiographs, except for caries, has not been shown to provide sufficient information to be justified [Stephens and Kogon, 1990; Henderson and Crawford, 1995]. This is also seen in medicine, where screening radiography is not used in children and adolescents. It has not been shown by cost/benefit analyses that tooth eruption should be monitored using radiographic screening procedures. The eruption of the upper permanent canines, for example, should be evaluated by clinical means and radiographic examination performed only on individual indications.

The radiographic examination should be based on clinical findings on eruption and not chronological age [Ericson and Kurol, 1986]. If the canines cannot be palpated at the age of 10 years or an ectopic eruption of the maxillary canines is suspected, radiography is indicated [Ericson and Kurol, 1988]. Although more than 5% of the population has a developmental dental anomaly, there is little justification for routine radiography for conditions like supernumerary or missing teeth [Lervik and Cowley, 1983b; Stephens and Kogon, 1990]. Studies show that panoramic screening is not indicated for detection of tooth aplasia [Wenzel, 1991]. In conclusion, no other conditions than caries justify systematic radiographic examinations in the age group from 0 to 18 years. However, when a bitewing examination is made, it is important to extract as much information as possible about the marginal bone and calculus formation. Juvenile periodontitis may have its onset already in the primary dentition [Sjödin et al., 1993].

## How to minimise patient exposure?

The radiation dose should be kept as low as can reasonably be achieved both for patient and operator. Usually there will be no damage of clinical significance caused by low level X-rays used in dental radiography. However, the hypothesis in modern radiation protection is that any dose of radiation has the potential to cause biological harm. "It is impossible to relate any specific dental exposure to any specific cancer. All we can say is that the evidence indicates that even very small doses carry the potential for causing cancer" [Smith, 1987]. The probability of long-term effects (stochastic effects) of radiation increases with the dose of exposure, but the severity of the consequential effect when it occurs, such as cancer, is not affected. That means that the probability for cancer is related to radiation dose, but when the disease unfortunately breaks out, the severity of the disease will not depend on the radiation dose. The younger the individual, the higher the vulnerability to radiation is because of the large number of cell divisions occurring in small children. Children also have a higher proportion of the bone marrow located in the skull than adults have. Smith [1992] has shown in a calculation of risk estimates that about one induction of malignant disease per 1,000,000 dental exposures of 5 year old children can be expected. The International Commission on Radiological Protection [ICRP, 1991] has proposed the estimate for a single small dose at the age of 5, which is used in calculations. The risk is reduced when the fastest films available, or digital radiography, are used due to the lower dose needed.

### Patient protection

Dental films are commercially available in speed groups D and E as defined by the International Organization for Standardization [ISO, 1996]. E-films are more sensitive to radiation (faster) and should be used, as no loss of diagnostic information has been demonstrated using Kodak Ektaspeed Plus (Speed group E) instead of the slower Kodak Ultraspeed (Speed group D) [Svenson et al., 1997]. Recently Kodak has introduced the intraoral film InSight (Speed group F), which is claimed to reduce the dosage by up to 20%.

Leaded protective aprons with a thyroid collar should be provided for the child and for the accompanying person if assisting during its exposure. Intraoral radiography might be a frightening experience to the child. The pointing cone is close to the face and an unpleasant film is placed intraorally. Techniques to reduce fear should be used when necessary. Importantly, child's co-operation reduces the need for retake. Some measures to reduce radiation are listed in Table 5.

Technical measure	Approximate reduction in dose to the patient
Digital system (Phosphor plate) vs. E-speed film	75%
Rectangular vs. circular collimator	50%
Digital system (CCD) vs. E-speed film	50%
Long cone vs. short cone	50%
65kV vs. 50kV set	50%
E-speed vs. D-speed film	40%
Optimal vs. "slight processing routines"*	30%
Direct current (DC) constant potential set**	20%

\*"Slight processing routines" indicates poor processing using exhausted developer, too short developing time etc compensated by increased exposure time.

\*\*Direct current constant potential X-ray generator converts mains voltage into a constant stream of radiation instead of a series of pulses and this shorten exposure time. Conventional AC generators produce unwanted low energy radiation that is absorbed into the tissue without contributing to the picture formation.

**TABLE 5** - The effect of various technical measures to reducing radiation dose to the patient [Faculty of General Dental Practitioners, 1998; Rohlin and White, 1992].

### Digital radiography

Digital radiography is now possible with either charge-coupled devices (CCD) or phosphor imaging plates. A CCD is an intraoral silicon sensor, sensitive to X-rays, that is directly connected to a personal computer. The image is displayed on the screen immediately after exposure and this is time saving, because there is no processing. In the phosphor imaging system, the latent image on the plates has to be digitised. This takes place in a processing unit connected to the PC and takes, depending on the system, 20 seconds to 2 minutes. Both systems require lower doses of radiation compared with E-films. By manufacturers' improvements of film, reductions in exposure time of 20-60% (CCD systems) and approximately 50% (phosphor imaging plates) are claimed. In daily practice it seems that dose reduction is less than these percentages, which will be enhanced by the fact that dentists using CCD are taking more X-rays. The bulky CCD sensors are usually smaller than conventional films and more exposures are needed to cover the same area compared with conventional radiography or phosphor imaging plates. Therefore, more retakes are reported in connection with CCD sensors compared with conventional film [Versteeg et al., 1998].

The image quality could be as good as that of conventional films, but depends on the digital system used. At the moment there are large variations in quality between the different systems. In a recent study dentists considered the user-friendliness of the handling of the two different digital systems before taking a radiograph as less than for the conventional film [Berkhout et al., 2002]. The patient's comfort was also mentioned as unfriendly especially when the systems were used for children. In the case of digital radiography, the elimination of the chemistry of film processing after taking the radiograph was considered an advantage. Digital images are best viewed on a good computer screen and often loose quality when printed. Such images are like any computer files and may be stored on disks and easily transferred to other computers. In the future, "expert" systems may provide decision support based on automated image analysis [Firestone et al., 1998; White, 1999]. In conclusion, digital radiography has advantages over conventional radiography, but the bulky sensor systems with attached cable and the need for a computer are clinical inconveniences. No studies concerning the use of digital radiography in children are available, but it seems likely that at present time the advantages of these systems are cancelled out by the disadvantages such as acceptance of the sensor or

phosphor plate by the child. In the future, improvements of the devices can be expected, but for the moment, on balance, conventional films may be more suitable for young children.

### Extraoral radiography

Extraoral radiography comprises the lateral oblique projection, dental panoramic radiography and cephalometry. In all extraoral techniques intensifying screens are used. In specialised clinics for maxillofacial radiography, advanced techniques, such as computer tomography, are commonly used. In paediatric dental practice panoramic radiography is useful when a more complete evaluation of the patient's jaws and teeth is needed, but the image does not have such fine resolution as intra oral radiography, so the quality of the image of the radiographed teeth is lower. The radiation dose is relatively low and the method is convenient to use. However, it requires an exposure time of several seconds and uneasy patients may move during exposure. Panoramic radiography is not indicated for general screening purposes.

If an intraoral radiograph shows uncommon structures or findings that cannot be explained by normal anatomy or covered by a single exposure, the examination has to be supplemented by extraoral radiography. There is no reason to screen for jawbone lesions in healthy, asymptomatic children and adolescents [Matteson et al., 1991].

### Principles for interpretation of radiographs

Radiographs should be reviewed systematically and under proper viewing conditions. An X-ray viewer with magnifying lens and radiographs in a mount ensure that extraneous light is not transmitted to the eye. Areas of special interest should be compared with previous radiographs if available. The basis of judgement of pathology is knowledge and experience of normal anatomy and its variants.

The principle of radiographic interpretation can be compared with any laboratory test in medicine or dentistry. A perfect test should always be positive in the presence of disease and negative in its absence. Unfortunately, in reality, tests are biased and two types of errors occur:

- over registration (false positives);
- under registration (false negatives).

The other two possible outcomes of a test are true positive and true negative findings. Usually, low disease prevalence increases the probability of false positive diagnoses and high prevalence increases the likelihood of false negative diagnoses. There are

many aspects that should be taken into consideration in the diagnostic process, such as within and between observer variation, quality of radiographs and the validity of the two dimensional representation of a three dimensional object. Many aspects related to the radiographic diagnosis of caries are discussed by Gröndahl [1996] and this textbook chapter is recommended as supplementary reading.

### Evidence-based guidelines?

The guidelines presented are based on the current dental literature combined with the clinical experience and judgement of the authors. We have tried to find the best research evidence in the clinically relevant studies and clinical expertise. There have been some systematic attempts to search the literature. The NIH Consensus Conference on caries (including diagnosis) held in Bethesda (2001) reviewed 1,407 diagnostic studies [Agency for Healthcare Research and Quality, 2001], but it was concluded that there were limitations in terms of the number of studies, of methods tested, of teeth and surfaces studied, and weakness in the research designs of the studies [Coulter, 2001]. One of the panel's conclusions was that radiology has acceptable diagnostic efficacy in detecting larger cavitated lesions. Regarding the future needs in the field of caries diagnosis, the panel said: "There is currently no diagnostic modality that can differentiate between microbiologically active caries and demineralized dentine without caries activity beneath a restoration. This is a critical weakness in view of the significant percentage of restorations inserted to replace existing ones. The need for the identification and clinical staging of the presence, activity and severity of dental caries is of paramount importance in the deployment of treatment strategies that employ increasingly important non-surgical modalities, such as fluoride, antimicrobials, sealants and no treatment. Some diagnostic modalities are currently in various stages of development and testing; these modalities will need to be evaluated, using rigorously controlled clinical trials. Such studies will promote true staging of carious lesions, based on highly sensitive and specific diagnoses, followed by appropriate, linked, treatment-planning decision algorithms" [National Institutes of Health, 2001]. Whether these needs may be fulfilled by other means than dental radiography remains to be seen, but until then the most convenient and cost-effective method for caries detection of approximal caries and dentine lesions in occlusal surfaces is dental radiography.

In the "Selection criteria for dental radiography" developed in the UK [Faculty of General Dental Practitioners, 1998] the authors have linked recommendations with levels of evidence. This work demonstrated how difficult it is to find good evidence from the dental literature for many of the procedures used in dental radiography. This opens many perspectives for dental research in the future.

## References

- Agency for Healthcare Research and Quality. Diagnosis and Management of Dental Caries. Summary, Evidence Report/Technology Assessment: Number 36. AHRQ Publication No. 01-E055; Agency for Healthcare Research and Quality, Rockville, MD, February 2001.
- Berkhout WE, Sanderink GC, Van der Stelt PF. A comparison of digital and film radiography in Dutch dental practices assessed by questionnaire. *Dentomaxillofac Radiol* 2002 Mar;31(2):93-9.
- Boman R, Enochsson B, Mejäre I. Bör vi ta bitewingbilder på till synes kariesfria 5-åringar? *Tandläkartidningen* 1999;91(9):37-40.
- Coulter ID. The NIH consensus conference on diagnosis, treatment and management of dental caries throughout life: Process and outcome. *J Evid Base Dent Pract* 2001;158-63.
- Creanor SL, Russell JI, Strang DM, Stephen KW, Burchell CK. The prevalence of clinically undetected occlusal dentine caries in Scottish adolescents. *Brit Dent J* 1990 Sep 8;169(5):126-9.
- De Vries HC, Ruiken HM, König KG, van't Hof MA. Radiographic versus clinical diagnosis of approximal carious lesions. *Caries Res* 1990;24(5):364-70.
- Ericson S, Kurol J. Radiographic assessment of maxillary canine eruption in children with clinical signs of eruption disturbance. *Eur J Orthod* 1986 Aug;8(3):133-40.
- Ericson S, Kurol J. Resorption of maxillary lateral incisors caused by ectopic eruption of the canines. A clinical and radiographic analysis of predisposing factors. *Am J Orthod Dentofacial Orthop* 1988 Dec;94(6):503-13.
- Espelid I. Radiographic diagnoses and treatment decisions on approximal caries. University of Bergen: Dr. odont. thesis; 1987.
- Espelid I, Tveit AB, Fjelltveit A. Variations among dentists in radiographic detection of occlusal caries. *Caries Res* 1994;28(3):169-75.
- Faculty of General Dental Practitioners (UK). Selection criteria for dental radiography. Royal College of Surgeons of England; 1998.
- Firestone AR, Sema D, Heaven TJ, Weems RA. The effect of a knowledge-based, image analysis and clinical decision support system on observer performance in the diagnosis of approximal caries from radiographic images. *Caries Res* 1998;32(2):127-34.
- Gröndahl HG. Radiographic caries diagnosis. A study of caries progression and observer performance. *Swed Dent J Suppl* 1979;(3):1-32.
- Gröndahl HG. Radiologic diagnosis in caries management. In: A. Thylstrup, O. Fejerskov, editors. *Textbook of clinical cariology*. Copenhagen: Munksgaard; 1996. pp. 367-82.
- Gröndahl HG, Andersson B, Torstensson T. Caries increment and progression in teenagers when using a prevention- rather than restoration-oriented treatment strategy. *Swed Dent J* 1984;8(5):237-42.
- Gustafsson A, Svenson B, Edblad E, Jansson L. Progression rate of approximal carious lesions in Swedish teenagers and the correlation between caries experience and radiographic behavior. An analysis of the survival rate of approximal caries lesions. *Acta Odontol Scand* 2000 Oct;58(5):195-200.
- Hanlon PM. Radiographic considerations in pedodontics. *J Pedod* 1985 Summer;9(4):285-301.
- Henderson NJ, Crawford PJ. Guidelines for taking radiographs of children. *Dent Update* 1995 May;22(4):158-61.
- Hintze H, Wenzel A. Clinically undetected dental caries assessed by bitewing screening in children with little caries experience. *Dentomaxillofac Radiol* 1994 Feb;23(1):19-23.
- ICRP. 1990 Recommendations of the International Commission on Radiological Protection, Ann ICRP; Pergamon Press, 1991, vol. 21, pp 1-201.
- Ie YL, Verdonschot EH. Performance of diagnostic systems in occlusal caries detection compared. *Community Dent Oral Epidemiol* 1994 Jun;22(3):187-91.
- ISO 3665 Photography - Intra-oral dental radiographic film-Specification. International Organization for Standardization; 1996.
- Kallestal C, Flinck A, Allebeck P, Holm AK, Wall S. Evaluation of caries preventive measures. *Swed Dent J* 2000;24(1-2):1-11.
- Kidd EA, Pitts NB. A reappraisal of the value of the bitewing radiograph in the diagnosis of posterior approximal caries. *Br Dent J* 1990 Oct 6;169(7):195-200.
- Lahti SM, Hausen HW, Widstrom E, Eerola A. Intervals for oral health examinations among Finnish children and adolescents: recommendations for the future. *Int Dent J* 2001 Apr;51(2):57-61.
- Lervik T, Cowley G. Dental radiographic screening in children. *ASDC J Dent Child* 1983 Jan-Feb;50(1):42-7.
- Lervik T, Cowley G. Dental radiographic screening in children. *ASDC J Dent Child* 1983 Mar-Apr;50(2):128-35.
- Lith A, Gröndahl HG. Predicting development of approximal dentin lesions by means of past caries experience. *Community Dent Oral Epidemiol* 1992 Feb;20(1):25-9.
- Matteson SR, Joseph LP, Bottomley W, Finger HW, Frommer HH, Koch RW, Matranga LF, Nowak AJ, Rachlin JA, Schoenfeld CM, et al. The report of the panel to develop radiographic selection criteria for dental patients. *Gen Dent* 1991 Jul-Aug;39(4):264-70.
- Mattiasson-Robertson A, Twetman S. Prediction of caries incidence in schoolchildren living in a high and a low fluoride area. *Community Dent Oral Epidemiol* 1993 Dec;21(6):365-9.
- Mejäre I, Stenlund H. Caries rates for the mesial surface of the first permanent molar and the distal surface of the second primary molar from 6 to 12 years of age in Sweden. *Caries Res* 2000 Nov-Dec;34(6):454-61.



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- Mejàre I, Stenlund H, Julihn A, Larsson I, Permert L. Influence of approximal caries in primary molars on caries rate for the mesial surface of the first permanent molar in Swedish children from 6 to 12 years of age. *Caries Res* 2001 May-Jun;35(3):178-85.
- Mejàre I, Kallestal 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.
- Mejàre I, Sundberg H, Espelid I, Tveit B. Caries assessment and restorative treatment thresholds reported by Swedish dentists. *Acta Odontol Scand* 1999 Jun;57(3):149-54.
- National Institutes of Health. Diagnosis and Management of Dental Caries Throughout Life. NIH Consensus Statement Online 2001 March 26-28;18(1): 1-24.; National Institutes of Health, 2001, vol. 2001.
- Nytun RB, Raadal M, Espelid I. Diagnosis of dentin involvement in occlusal caries based on visual and radiographic examination of the teeth. *Scand J Dent Res* 1992 Jun;100(3):144-8.
- Qvist V, Johannessen L, Bruun M. Progression of approximal caries in relation to iatrogenic preparation damage. *J Dent Res* 1992 Jul;71(7):1370-3.
- Raadal M, Amarante E, Espelid I. Prevalence, severity and distribution of caries in a group of 5-year-old Norwegian children. *Eur J Paed Dent* 2000;113-20.
- Roeters J. Prediction of future caries prevalence in preschool children. Thesis. University of Nijmegen; 1992.
- Rohlin M, White SC. Comparative means of dose reduction in dental radiography. *Curr Opin Dent* 1992 Jun;2:1-9.
- Shwartz M, Pliskin JS, Gröndahl H-G, Boffa J. Benefits of alternative schedules for bitewing radiographs; U.S. Department of health and human services, 1987, vol. DHHS Publication No. (PHS) 87-3407, p 20.
- Sjödén B, Matsson L, Unell L, Egelberg J. Marginal bone loss in the primary dentition of patients with juvenile periodontitis. *J Clin Periodontol* 1993 Jan;20(1):32-6.
- Smith NJ. Risk assessment: the philosophy underlying radiation protection. *Int Dent J* 1987 Mar;37(1):43-51.
- Smith NJ. Selection criteria for dental radiography. *Br Dent J* 1992 Sep 5;173(4):120-1.
- Stenlund H, Mejare I, Kallestal C. Caries rates related to approximal caries at ages 11-13: a 10-year follow-up study in Sweden. *J Dent Res* 2002 Jul;81(7):455-8.
- Stephen KW, Russell JJ, Creanor SL, Burchell CK. Comparison of fibre optic transillumination with clinical and radiographic caries diagnosis. *Community Dent Oral Epidemiol* 1987 Apr;15(2):90-4.
- Stephens RG, Kogon SL. New U.S. guidelines for prescribing dental radiographs: a critical review. *J Can Dent Assoc* 1990 Nov;56(11):1019-24.
- Svenson B, Welander U, Shi XQ, Stamatakis H, Tronje G. A sensitometric comparison of four dental X-ray films and their diagnostic accuracy. *Dentomaxillofac Radiol* 1997 Jul;26(4):230-5.
- Versteeg CH, Sanderink GC, van Ginkel FC, van der Stelt PF. An evaluation of periapical radiography with a charge-coupled device. *Dentomaxillofac Radiol* 1998 Mar;27(2):97-101.
- Weerheijm KL, Kidd EA, Groen HJ. The effect of fluoridation on the occurrence of hidden caries in clinically sound occlusal surfaces. *Caries Res* 1997;31(1):30-4.
- Wenzel A. Radiographic screening for identification of children in need of orthodontic treatment? *Dentomaxillofac Radiol* 1991 Aug;20(3):115-6.
- Wenzel A, Fejerskov O, Kidd E, Joyston-Bechal S, Groeneveld A. Depth of occlusal caries assessed clinically, by conventional film radiographs, and by digitized, processed radiographs. *Caries Res* 1990;24(5):327-33.
- White SC. Decision support systems in dentistry. *Dentomaxillofac Radiol* 1999 Jan;28(1):59-60.