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Radiation exposure in pediatric dentistry: Current standards in pedodontic radiology with suggestions for alternatives

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Introduction

The most frequent radiographic examination for children is a dental radiographic examination. During the years from 1961 to 1970, there was a 34% increase in the number of dental radiographic visits for children (Table 1). During this same interval, there has been a decline in the average number of films exposed per visit. The trend, therefore, is for increasing numbers of children to be radiographed while visiting the dentist, but with fewer films per examination; the causes for this pattern are not clear. In large part, however, it may be accounted for by increasing numbers of children visiting the dentist.

Table 1. X-ray visit rate per 100 persons under 15 years of age.*

	1961	*1970*	*Percent Change*
Dental	21.4	28.7	+ 34
Medical	16.4	24.4	+ 49
Dental Films	1964	1970	
Per Visit	3.5	3.2	- 9

* Ref. 1

During this interval there was an increase in the number of people visiting their dentist (Number of dental visits per person per year: 1963 — 1.3; 1970 — 1.5, references 2, 3). It is also possible that the dentist is increasingly likely to decide to conduct a radiographic examination when a child presents for treatment.

It is interesting to note that during this period, 1964 to 1970, there was a 20% decrease in the mean radiation exposure at the skin surface, from 1,140 mR to 910 mR.[1] This decline has been attributed to the use of faster films.[3] Whatever the reason for an increase in the number of radiographs being exposed, it was occurring at a time of decreasing dental disease in primary teeth. Table 2 shows that during the 1960's there was a decrease in the number of def primary teeth with an increased number of DMF permanent teeth in children. Thus, the national pattern is one of increasing number of children exposed with reduced average exposure per child.

There is concern for the potential harmful effects of radiation on children, largely because of the known greater radiosensitivity of children to radiation than adults. Further, children have their entire reproductive life span ahead of them, giving rise to concerns for genetic consequences of exposure. While the diagnostic benefits to be derived from diagnostic exposure of children are reasonably clear, it is the opinion of many that there are numerous means available to dental practitioners to further reduce patient exposure without compromising the quality of patient care. The goal of all concerned in this area is to identify the radiographic procedures which result in the most safe and effective means of producing high quality radiographs which are effective in terms of influencing patient care.

Purpose

The purpose of this discussion is to present means readily available to the practicing dentist to reduce exposure to pediatric patients without loss of diagnostic information. Particular attention will be paid to the type and frequency of radiographic examinations,

Table 2. Comparison of def to DMF teeth.

	def Teeth	
Age	1963-65*	1971-74**
6-11	3.0	2.7
	DMF Teeth	
Age	1960-62*	1971-74**
6-11	1.4	1.7

* Ref. 4 ** Ref. 5

and the role of high-yield (or referral) criteria in the identification of patients for radiographic examination. Practices pertaining to radiation safety, quality assurance, and emerging technology such as rod-anode source radiography and xeroradiography will also be described.

Current Standards

The current standards for the type and frequency of the use of radiographs in pediatric dentistry is assumed to be the stated positions of the relevant professional organizations as well as the pertinent textbooks and periodic literature.

Professional Organizations

1. The American Association of Dental Schools at their annual meeting in March, 1980 passed resolution 19 S which states in part:

> Students should be trained to critically access the need for diagnostic radiographic information, evaluate the risk/benefit ratio for each diagnostic procedure, and establish an appropriate differential diagnosis based on clinical, laboratory, and radiographic information.

2. The American Academy of Pedodontics and The American Society of Dentistry for Children states in the section on radiology in the Manual for Children's Dental Care Programs:[6]

> The frequencies of radiographic exposure should be limited. Additional radiographs should be taken only when the dentist anticipates that the information he is likely to obtain will contribute materially to proper diagnosis and prevention of disease.

3. The American Dental Association suggests "Use professional judgment to determine the frequency and extent of each radiographic examination. Determine the minimum number of film exposures that will produce the desired information."[7]

Thus, various professional organizations are in agreement that professional judgment must be the basis for ordering radiographs. Such statements fall short, however, of offering functional guidelines useful for the clinician in common clinical situations.

Textbooks

In general, the recommendations of the authors of textbooks of radiology or pedodontics tend to stress regular and complete radiographic examinations (Table 3). Little or no emphasis is placed on the use of professional judgment. It is interesting that although these textbook recommendations are so consistent with each other, as are those of the professional organizations, the thrust of the recommendations from these two groups are quite different.

Periodic Literature

The professional literature dealing with the issue of the type and frequency of radiographic examination for children shows evidence of change in the last few decades. Feasby[8] surveyed this literature previous to 1960 and found a consensus — that in preschool children an 8-film survey was recommended, while in children with a mixed dentition a 14-film survey was recommended. These recommendations are consistent with those of the authors of textbooks (Table 3) and others.[9,10] More recently, however, Khanna has found that the use of two bitewing and two occlusals and a panoramic film was as diagnostically useful as an 8- or 14-film survey.[11] Also, Valachovic and Lurie have recommended a 6-film survey (2 occlusals and 4 periapicals) at the age of 6 to 8 years with subsequent bitewings as needed for caries detection.[12] Zamir and collegues recommend bitewings only every two years due to the slow progression of caries in permanent teeth.[13] The professional literature is quite diverse in its recommendtions but there is a recent discernible trend towards the reduced use of "routine" radiographs.

Table 3. Textbook recommendations for pedodontic radiographic examinations.

Finn	Bitewings every 6 months
Landland Sippy	Complete survey at first dental visit
Law	Complete survey as soon as practicable
McDonald Avery	Radiographs at regular intervals
Wuehrmann Manson-Hing	Full-mouth examination every five years

Current Radiographic Practice

Given this spectrum of recommendations from organizations, textbooks and professional literature, Khanna surveyed pedodontists to determine their actual practice. He found that the vast majority of pedodontists use bitewing examination (Table 4).

Table 4. Pedodontic radiographic examinations.*

	Age		
	2-6	6-9	9-12
8-Film Survey	0%	3%	3%
Bitewings only	67.3%	96.2%	98.5%

*Ref. 11

While it is certain that full-mouth examinations are more commonly taken in dental schools, no other data could be found to corroborate or refute these findings. The data from Khanna is almost a decade old and it

might be speculated that panoramic examinations are being used with increasing frequency in recent years.

Conclusions

There is no general consensus on what constitutes an appropriate radiographic examination for children. Professional organizations stress judgment, the textbooks stress periodic full-mouth examinations, the literature is diverse, and the pedodontist takes mostly bitewings.

Alternatives to Current Standards

The issue still facing pedodontists is, then, "What protocol for radiography shall I use in my practice?" In seeking an answer to this question, there are several assumptions that might be made.

Assumptions

1. The goal of a radiographic examination is to seek information which will influence patient care. If a radiographic examination does not influence a clinician's treatment of the patient then it has not benefited the patient. Note that this principle does not include the value of negative information.

2. The exposure of patients should be as individualized as their treatment. Since patients' conditions and needs are variable, so their radiographic needs should reflect their individual circumstances.

3. Radiation is potentially hazardous and should be used only when indicated. A considerable body of radiobiologic data gathered in the last several decades has been evaluated by the BEIR III Committee of the National Academy of Science.[14] This group has concluded that the major population hazard from low-level exposure is the possibility of cancer induction. The exact level of risk is not known.

4. The decision to expose a patient should be governed solely by clinical indication; not for perceived legal, documentary, teaching, or administrative purposes. The practicing dentist wishing to avoid legal problems is likely to error on the side of obtaining more radiographs than might be otherwise indicated strictly for diagnostic reasons alone. This issue is complex and requires a more complete evaluation than can be provided here.

Another concern is the possibility that third-party payment programs might control radiographic practices. When an insurance company will pay for radiographs but not for a clinical examination which leads to the conclusion that no radiographs are indicated, then we all have a problem. This situation might result in unnecessary exposure to the patient, wasted time by the dental team, and unnecessary expense for the insurance company.

In summary, these assumptions suggest that the radiographic examination should be only as frequent as is necessary for the proper management of oral disease.

Pedodontic Diseases

Oral disease in children will be considered in the following categories: caries, developmental disturbances, and special circumstances.

1. **Caries.** a. *Caries begins early and has a high prevalence.* By 36 months, 45% of children have one or more carious lesions.[15] By two years after eruption of the first permanent molars one or more of these teeth are decayed in 75% of children and all are decayed in 37% of children.[16]

b. *Smooth surface caries progresses slowly, particularly in the permanent teeth of children.* Several studies have found that enamel lesions in the proximal surfaces of permanent teeth of children 11 to 15 tend to require 2 or 3 years to reach the DEJ, and many do not progress at all[13,17-20] (Table 5). Lesions may progress more rapidly in primary teeth, however. In one study, 69 of 71 lesions, which had penetrated on radiographs through more than 50% of the enamel thickness, had radiographically reached the DEJ by the time of a second examination one year later.[20] As children grow older (early teens to late teens), they tend to get fewer new lesions.[15,21,22]

Table 5. Rate of caries progression in permanent teeth of children.

Zamier[13]	In 14-15 y.o.'s:	Incipient lesions take 26 mo. to reach DEJ
	In 21-24 y.o.'s:	Incipient lesions take 32 mo. to reach DEJ
	Less than 20% of incipient lesions reach DEJ in less than 24 mo.	
Haugejorden and Slack[20]	In 13-15 y.o.'s:	56% of lesions did not progress 24% of lesions do progress 7% of lesions reverse 24% of lesions were restored
Berman and Slack[19]	In children 11 to 14, there was no progression in 50% of proximal enamel lesions	
Backer Dirks[18]	Enamel maturation in children 9-15: 50% of proximal enamel lesions do not progress in 4 years 33% of proximal enamel lesions do not progress in 6 years 26% of proximal enamel lesions do not progress in 8 years	

c. *The distribution of caries is non-random.* Children with a high caries experience tend to continue to have higher caries activity than children with a low caries experience.[15,22,23]

d. *Radiographs are useful in detecting posterior proximal carious lesions.* In children up to 36 months, 76% of all posterior interproximal carious lesions were found by radiographs only[24] while in children 5-1/2 to 7-1/2, 67% of interproximal lesions were found by radiographs alone.[25]

Table 6. Developmental anomalies of the primary dentition.

Reference	Sample	Age	Missing Teeth	Supernumerary Teeth	Fused Teeth
12	2209	2-6	0.09%	0.23%	0.14%
12	1173	3-5	0.4%	0.3%	0.5%

2. **Developmental Anomalies.** Approximately 1% of children have anomalies of the primary dentition (Table 6), and 4 to 10% of children have developmental anomalies of the permanent dentition (Table 7).

Of these conditions, radiographic detection of missing teeth or supernumerary teeth is most likely to influence patient treatment.

3. **Special Circumstances.** There are, of course, a wide variety of other diseases and conditions affecting the jaws which the dentist or pedodontist must appreciate and manage. Such special circumstances may be fairly common, such as traumatized or abscessed teeth, or quite rare such as ameloblastic fibroma or eosinophilic granuloma.

4. **Conclusions.** On the basis of the foregoing considerations, I would draw the following conclusions:

a. Because caries has a high prevalence, clinicians must seek out caries with careful clinical and radiographic examinations;
b. Clinicians should seek out developmental conditions when the findings will influence patient treatment;
c. Special circumstances should be evaluated when indicated by signs, symptoms or history.

High-Yield Criteria

It would be desirable to have a set of guidelines or decision rules for exposing pediatric patients to radiation which would accomplish these goals. Such decision rules are often called high-yield criteria or referral criteria. High-yield criteria have been used in radiography for approximately 10 years for the identification of patients who are likely to have positive radiographic findings. Their use increases the probability of detecting positive findings while reducing the number of unproductive radiographic examinations. Such criteria serve as a set of decision rules for patient selection, increasing the likelihood of achieving a useful result. Accordingly, they assist the clinician in ordering radiographs on the basis of broad experience. High-yield criteria should only be considered as guidelines, since individual exceptions will occur which require examinations not conforming to usual circumstances.

Table 7. Developmental anomalies of the permanent dentition.

Reference	Sample	Missing Teeth	Supernumerary Teeth	Fused Teeth	Peg Teeth
18	10,000	3.4%	0.6%	—	—
41	733	3.0%	2.3%	—	—
21	1,006	6.1%	—	—	1.7%
32	1,717	7.4%	3.6%	—	—
12	457	4.1%	3.1%	0.2%	0%
13	1,688*	7.1%	2.7%	0.2%	0.5%

*As modified by ref. 26

The major benefit from the use of referral criteria is optimizing the utilization of radiographic examinations. This benefit is accomplished by reducing the number of unproductive radiographic examinations and patient radiation exposure. A secondary benefit of this goal is reduction of health care costs. Because the use of high-yield criteria implies a decrease in the number of radiographic examinations, there is an increased probability of missing a positive finding. This possibility can only be accepted when there is clear evidence that the use of referral criteria results in a risk/benefit ratio which is clearly in the best interests of the whole population of patients.

1. **High-Yield Criteria in Medical Radiology.** High-yield criteria have been found useful in a variety of medical radiographic examinations. In a classic study of skull radiographic examinations exposed following trauma, Bell and Loop[27] found that by the use of clinical criteria for ordering skull radiographs, the yield of positive examinations could be improved dramatically. Assignment of patients to high-yield groups on the basis of clinical examination resulted in the detection of positive findings in 1 of 11.5 patients while the rate of positive finding in the low-yield group was only 1 in 435 patients. Subsequently Phillips,[28,29] investigating the use of refined high-yield criteria in ordering skull examinations, was able to demonstrate a 40% reduction in the number of skull films exposed following the adoption of high-yield criteria. By the general use of high-yield criteria for skull examinations, Phillips estimated that an annual savings of $240,000,000 could be realized in the United States.[30] Other studies have confirmed these findings and indicated that routine skull films are not effective contributions to the diagnosis, treatment, or outcome of acute brain injury.[31-33]

2. **High-Yield Criteria in Dental Radiology.** The value of radiography in dentistry is clear. The use of bitewing radiographs results in an increased detection of interproximal caries; more benefit being reported for posterior teeth than anterior teeth.[34] Bitewing radiographs are not routinely effective in detecting developmental anomalies however.[35] Panoramic radiographs are ineffective for detection of early carious lesions.[36-39] Further, the vast majority of positive

findings which are unique to the panoramic radiographs (not seen on full-mouth sets) do not require treatment (e.g., mucous retention cysts, calcified lymph nodes, calcified stylohyoid ligaments).[40] In a study of dental patients at UCLA it was found that when a panoramic radiograph is ordered for "screening" purposes and is accompanied by a complete-mouth (21 film) set of radiographs, the panoramic radiograph has essentially no influence on the treatment plan.[41] However, panoramic radiographs provide coverage outside the region covered by the dental films and may be useful in the absence of intraoral films.[42-44]

Considerably more work needs to be done to identify those individuals who are most likely to benefit from specific examinations and to determine the optimum examination format.

3. **Strategies To Develop High-Yield Criteria.** High-yield critera have generally been developed in two ways: 1) by panels of experts making a list of appropriate indications for a specific radiographic examination, or 2) by empirical studies which test and identify criteria which are useful. "Expert" referral criteria may be compiled rather rapidly, but tend to be complex and may be biased by the experiences of those making the list of criteria. Empirical studies typically generate short lists of high-yield criteria but such studies are time-consuming and expensive. An alternative strategy might be to empirically test expert referral criteria in a variety of practice settings to determine the optimum criteria.

4. **Conclusions.** The use of referral criteria has been found useful in reducing unnecessary medical radiographic examinations. This is an area which must be investigated more thoroughly in dentistry. Just as a routine full skeletal radiographic examination would not be appropriate without a specific indication, so too should the dentist not feel compelled to radiograph the entire facial skeleton in the absence of specific indications. While numerous studies have compared the yields from various types of examinations, much more work is needed to identify individuals who are likely to benefit from specific examinations.

Proposed Pedodontic Radiographic Protocol

The following protocol is suggested on the basis of our knowledge of disease in children and a desire to be more efficacious in the use of radiation.

1. **First Visit.** If contacts are closed and no recent films available, expose left and right bitewing radiographs.

2. **Repeat Visits.** With clinical or radiographic evidence of caries progression, expose right and left bitewings yearly. Without evidence of caries progression expose bitewing radiographs on alternate years.

3. **Special Circumstances. a.** Maxillary occlusal radiograph to be exposed at age six to check for mesiodens and again at age nine to check for position of maxillary canines. **b.** Panoramic radiograph may be taken at age 16 to evaluate position of third molars. **c.** Any film may be taken at any time for other special circumstances (see Table 8). Under these conditions clinicians must decide what radiographic coverage is appropriate.

Table 8. Examples of special circumstances.*

History of pain	Lack of response to conventional dental treatment
Evidence of swelling	Unusual tooth morphology, calcification or color
Trauma to teeth or jaws	Evaluation of growth abnormalities
Mobility of teeth	Altered occlusal relationships
Unexplained bleeding	Aid in diagnosis of systemic disease
Deep periodontal pocketing	Familial history of dental anomalies
Fistula formation	Postoperative evaluation
Unexplained sensitivity of teeth	Deep or rampant caries
Evaluation of sinus condition	Preorthodontic evaluation
Unusual eruption pattern	Others
Unusual spacing or migration of teeth	

*Modified from Valachovic and Lurie.[12]

Quality Assurance Program

In addition to optimizing the type and frequency of radiographic examinations, there are a number of other steps the dentist can take to minimize patient exposure. Systematic practices in the dental office which reduce patient and operator exposure may be considered as a quality assurance program. A radiographic quality assurance program is one which takes overt measures to assure that the many steps required to produce a diagnostically useful radiograph are all operating correctly. A thorough program would regularly verify that the X-ray machine is functioning and operating properly and that the film processing solutions are functioning properly.

1. **Exposure Procedures.** There are a variety of straight-forward technical procedures which the dentist and the dental auxillary may perform in the pedodontic office which will reduce patient exposure.

a. The use of *high KVP and short exposure times* will minimize patient exposure and reduce the chance of patient movement and the subsequent retaking of the examination.
b. The use of *open-ended cylinders* will reduce the risk of scatter radiation to the patient.
c. The use of *leaded aprons* and *thyroid shields* will decrease patient exposure.
d. The use of *beam aiming devices* will reduce the requirement for retake examinations. The use of rectangular collimation will reduce the patient dose more than two fold.

e. Certainly a *D speed of film* should be routinely employed. Currently there is the imminent prospect of an E speed film on the market which is more sensitive to radiation than D speed film, hence will allow a reduction of patient exposure.
f. There are a number of *measurements of performance of an X-ray machine* that should be made on an annual basis to assure its proper functioning. These include exposure output, local spot size, accuracy of timer, beam alignment, accuracy of KVP and mA controls, and measurement of half-value layer.
g. *Xeroradiography* is currently under development and may be expected to be commercially available in many parts of the country in the next few years. To date, this technology offers a promise of high quality images at patient exposures of about one-half those currently employed.
h. *Rod-anode (intraoral) source radiography* is currently commercially available and has been investigated in a number of institutions. This technology offers a prospect of high-quality images at doses considerably less than that encountered in conventional radiography.

The use of the technology described in items "a" through "e" above may result in at least a two-fold reduction in patient dose and possibly much more. It should be noted that this does not require use of new equipment, rather the proper application of existing instrumentation. The advent of E speed film, xeroradiography, or widespread use of rod-anode source radiography would all further reduce patient exposure.

2. **Processing Procedures.** The average dentist exposes his patient to doses more than twice as high as is necessary by virtue of poor film processing procedures. This results largely from poor processing procedures necessitating increased radiation exposures. With the use of proper film processing procedures the patient dose may be reduced from an average of 540 milliroentgens, to values more in the range, 200 mR. This may be accomplished simply by following the manufacturers' recommendations on the processing solutions. It is important for the general practitioner to have a simple means for assuring the quality of his processing procedures. The most straightforward means of accomplishing this are as follows: 1) prepare fresh developer and fixer according to the manufacturers recommendations, 2) expose the patient and process the radiograph using the time and temperature method suggested with the solutions, and 3) evaluate the density of the resultant radiograph. If the film is too dark after full processing (optimally 4 1/2 to 5 minutes at 68°F) then the exposure duration on the X-ray machine should be reduced. Studies have shown that offices which sight-develop their films have a much higher skin exposure than offices which use the time-temperature method.[45]

When the proper exposure time has been found to produce an optimal quality radiograph, a sample radiograph of this high quality should be mounted on a view box near the darkroom. As subsequent radiographs are processed they should be compared to the reference film. As films become lighter and lose their contrast in comparison to the reference film it will be clearer when it is time to change the developer and fixer. As the solutions are depleted they will lose their ability to properly develop adequate density and contrast in radiographs.

Education

Reduction in unnecessary patient exposure requires that X-ray equipment operators be informed of the biologic risks and be educated in proper radiographic procedures. Knowledge by the operator of the actions of ionizing radiation and processing solutions on film are critical to intelligent analysis of common problems in film processing. For example, when a light radiograph is obtained, the operator must understand that this may be caused by multiple factors including underexposure, insufficient developing time, insufficient developing temperature, depleted developing solutions, large size of patient, insufficient milliamperage, insufficient KVP, or other factors. The operator must be able to go through an intelligent and systematic process of identifying the cause of any suboptimal film in order that it may be appropriately corrected without causing undue patient exposure. Further, a knowledge of dental anatomy is required for optimum film positioning. It is incumbant upon the clinician to be skilled in radiographic interpretation as well, so that the radiographs may be used as effectively as possible.

Summary

Numerous mechanisms are available to the pediatric dentist to readily and significantly reduce patient exposure while achieving a gain in diagnostic information. The most prominent of these include:

A. Exposing radiographs only when there are specific indications — the word "routine" should not be a part of our radiographic vocabulary;
B. Employing beam restricting film holders, leaded aprons and thyroid collars;
C. Using proper processing procedures coupled with an understanding of the process;
D. Further dose restrictions may be anticipated with the use of new technologies including the development of an E speed film, xeroradiographic processing system, and rod-anode source radiography;
E. Most importantly, an awareness on the part of the dentist and the operator of the importance of dose reduction and of the means available to accomplish

this end. In radiation protection, a gram of brain is worth more than a pound of lead.

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