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FDA

DENTAL RADIOGRAPHIC EXAMINATIONS: RECOMMENDATIONS FOR PATIENT SELECTION AND LIMITING RADIATION EXPOSURE

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AMERICAN DENTAL ASSOCIATION
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DENTAL RADIOGRAPHIC EXAMINATIONS: RECOMMENDATIONS FOR PATIENT SELECTION AND LIMITING RADIATION EXPOSURE

BACKGROUND

The dental profession is committed to delivering the highest quality of care to each of its individual patients and applying advancements in technology and science to continually improve the oral health status of the U.S. population. These guidelines were developed to serve as an adjunct to the dentist's professional judgment of how to best use diagnostic imaging for each patient. Radiographs can help the dental practitioner evaluate and definitively diagnose many oral diseases and conditions. However, the dentist must weigh the benefits of taking dental radiographs against the risk of exposing a patient to x-rays, the effects of which accumulate from multiple sources over time. The dentist, knowing the patient's health history and vulnerability to oral disease, is in the best position to make this judgment in the interest of each patient. For this reason, the guidelines are intended to serve as a resource for the practitioner and are not intended as standards of care, requirements or regulations.

The guidelines are not substitutes for clinical examinations and health histories. The dentist is advised to conduct a clinical examination, consider the patient's signs, symptoms and oral and medical histories, as well as consider the patient's vulnerability to environmental factors that may affect oral health. This diagnostic and evaluative information may determine the type of imaging to be used or the frequency of its use. Dentists should only order radiographs when they expect that the additional diagnostic information will affect patient care.

Based on this premise, the guidelines can be used by the dentist to optimize patient care, minimize radiation exposure and responsibly allocate health care resources.

This document deals only with standard dental imaging techniques of intraoral and common extraoral examinations, excluding cone-beam computed tomography (CBCT). At this time the indications for CBCT examinations are not well developed. The ADA Council on Scientific Affairs has developed a statement on use of CBCT.[1]

INTRODUCTION

The guidelines titled, "The Selection of Patients for X-Ray Examination" were first developed in 1987 by a panel of dental experts convened by the Center for Devices and Radiological Health of the U.S. Food and Drug Administration (FDA). The development of the guidelines at that time was spurred by concern about the U.S. population's total exposure to radiation from all sources. Thus, the guidelines were developed to promote the appropriate use of x-rays. In 2002, the American Dental Association, recognizing that dental technology and science continually advance, recommended to the FDA that

the guidelines be reviewed for possible updating. The FDA welcomed organized dentistry's interest in maintaining the guidelines, and so the American Dental Association, in collaboration with a number of dental specialty organizations and the FDA, published updated guidelines in 2004. This report updates the 2004 guidelines and includes recommendations for limiting exposure to radiation.

PATIENT SELECTION CRITERIA

Radiographs and other imaging modalities are used to diagnose and monitor oral diseases, as well as to monitor dentofacial development and the progress or prognosis of therapy. Radiographic examinations can be performed using digital imaging or conventional film. The available evidence suggests that either is a suitable diagnostic method.[2-4] Digital imaging may offer reduced radiation exposure and the advantage of image analysis that may enhance sensitivity and reduce error introduced by subjective analysis.[5]

A study of 490 patients found that basing selection criteria on clinical evaluations for asymptomatic patients, combined with selected periapical radiographs for symptomatic patients, can result in a 43 percent reduction in the number of radiographs taken without a clinically consequential increase in the rate of undiagnosed disease.[6,7] The development and progress of many oral conditions are associated with a patient's age, stage of dental development, and vulnerability to known risk factors. Therefore, the guidelines in Table 1 are presented within a matrix of common clinical and patient factors, which may determine the type(s) of radiographs that is commonly needed. The guidelines assume that diagnostically adequate radiographs can be obtained. If not, appropriate management techniques should be used after consideration of the relative risks and benefits for the patient.

Along the horizontal axis of the matrix, patient age categories are described, each with its usual dental developmental stage: child with primary dentition (prior to eruption of the first permanent tooth); child with transitional dentition (after eruption of the first permanent tooth); adolescent with permanent dentition (prior to eruption of third molars); adult who is dentate or partially edentulous; and adult who is edentulous.

Along the vertical axis, the type of encounter with the dental system is categorized (as "New Patient" or "Recall Patient") along with the clinical circumstances and oral diseases that may be present during such an encounter. The "New Patient" category refers to patients who are new to the dentist, and thus are being evaluated by the dentist for oral disease and for the status of dental development. Typically, such a patient receives a comprehensive evaluation or, in some cases, a limited evaluation for a specific problem. The "Recall Patient" categories describe patients who have had a recent comprehensive evaluation by the dentist and, typically, have returned as a patient of record for a periodic evaluation or for treatment. However, a "Recall Patient" may also return for a limited evaluation of a specific problem, a detailed and extensive evaluation for a specific problem(s), or a comprehensive evaluation.

Both categories are marked with a single asterisk that corresponds to a footnote that appears below the matrix; the footnote lists "Positive Historical Findings" and "Positive Clinical Signs/Symptoms" for which radiographs may be indicated. The lists are not intended to be all-inclusive, rather they offer the clinician further guidance on clarifying his or her specific judgment on a case.

The clinical circumstances and oral diseases that are presented with the types of encounters include: clinical caries or increased risk for caries; no clinical caries or no increased risk for caries; periodontal disease or a history of periodontal treatment; growth and development assessment; and other circumstances. A few examples of "Other Circumstances" proposed are: existing implants, other dental and craniofacial pathoses, endodontic/restorative needs and remineralization of dental caries. These examples are not intended to be an exhaustive list of circumstances for which radiographs or other imaging may be appropriate.

The categories, "Clinical Caries or Increased Risk for Caries" and "No Clinical Caries and No Increased Risk for Caries" are marked with a double asterisk that corresponds to a footnote that appears below the matrix; the footnote contains links to the ADA Caries Risk Assessment Forms (0 – 6 years of age and over 6 years of age). It should be noted that a patient's risk status can change over time and should be periodically reassessed.[8]

The panel also has made the following recommendations that are applicable to all categories:

1. Intraoral radiography is useful for the evaluation of dentoalveolar trauma. If the area of interest extends beyond the dentoalveolar complex, extraoral imaging may be indicated.
2. Care should be taken to examine all radiographs for any evidence of caries, bone loss from periodontal disease, developmental anomalies and occult disease.
3. Radiographic screening for the purpose of detecting disease before clinical examination should not be performed. A thorough clinical examination, consideration of the patient history, review of any prior radiographs, caries risk assessment and consideration of both the dental and the general health needs of the patient should precede radiographic examination.[9-15]

In the practice of dentistry, patients often seek care on a routine basis in part because oral disease may develop in the absence of clinical symptoms. Since attempts to identify specific criteria that will accurately predict a high probability of finding interproximal carious lesions have not been successful for individuals, it was necessary to recommend time-based schedules for making radiographs intended primarily for the detection of dental caries. Each schedule provides a range of recommended intervals that are derived from the results of research into the rates at which interproximal caries progresses through tooth enamel. The recommendations also are modified by criteria that place an individual at an increased risk for dental caries. Professional judgment

should be used to determine the optimum time for radiographic examination within the suggested interval.

RECOMMENDATIONS FOR PRESCRIBING DENTAL RADIOGRAPHS

These recommendations are subject to clinical judgment and may not apply to every patient. They are to be used by dentists only after reviewing the patient's health history and completing a clinical examination. Even though radiation exposure from dental radiographs is low, once a decision to obtain radiographs is made it is the dentist's responsibility to follow the ALARA Principle (As Low as Reasonably Achievable) to minimize the patient's exposure.

Table 1.

<table>
<tr><th rowspan="2">TYPE OF ENCOUNTER</th><th colspan="5">PATIENT AGE AND DENTAL DEVELOPMENTAL STAGE</th></tr>
<tr><th>Child with Primary Dentition (prior to eruption of first permanent tooth)</th><th>Child with Transitional Dentition (after eruption of first permanent tooth)</th><th>Adolescent with Permanent Dentition (prior to eruption of third molars)</th><th>Adult, Dentate or Partially Edentulous</th><th>Adult, Edentulous</th></tr>
<tr><td>New Patient*
being evaluated for oral diseases</td><td>Individualized radiographic exam consisting of selected periapical/occlusal views and/or posterior bitewings if proximal surfaces cannot be visualized or probed. Patients without evidence of disease and with open proximal contacts may not require a radiographic exam at this time.</td><td>Individualized radiographic exam consisting of posterior bitewings with panoramic exam or posterior bitewings and selected periapical images.</td><td colspan="2">Individualized radiographic exam consisting of posterior bitewings with panoramic exam or posterior bitewings and selected periapical images. A full mouth intraoral radiographic exam is preferred when the patient has clinical evidence of generalized oral disease or a history of extensive dental treatment.</td><td>Individualized radiographic exam, based on clinical signs and symptoms.</td></tr>
<tr><td>Recall Patient* with clinical caries or at increased risk for caries**</td><td colspan="3">Posterior bitewing exam at 6-12 month intervals if proximal surfaces cannot be examined visually or with a probe</td><td>Posterior bitewing exam at 6-18 month intervals</td><td>Not applicable</td></tr>
<tr><td>Recall Patient* with no clinical caries and not at increased risk for caries**</td><td colspan="2">Posterior bitewing exam at 12-24 month intervals if proximal surfaces cannot be examined visually or with a probe</td><td>Posterior bitewing exam at 18-36 month intervals</td><td>Posterior bitewing exam at 24-36 month intervals</td><td>Not applicable</td></tr>
</table>

TYPE OF ENCOUNTER (continued)	**Child with Primary Dentition** (prior to eruption of first permanent tooth)	**Child with Transitional Dentition** (after eruption of first permanent tooth)	**Adolescent with Permanent Dentition** (prior to eruption of third molars)	**Adult, Dentate and Partially Edentulous**	**Adult, Edentulous**
Recall Patient* with periodontal disease	Clinical judgment as to the need for and type of radiographic images for the evaluation of periodontal disease. Imaging may consist of, but is not limited to, selected bitewing and/or periapical images of areas where periodontal disease (other than nonspecific gingivitis) can be demonstrated clinically.				Not applicable
Patient (New and Recall) for monitoring of dentofacial growth and development, and/or assessment of dental/skeletal relationships	Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development or assessment of dental and skeletal relationships		Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development, or assessment of dental and skeletal relationships. Panoramic or periapical exam to assess developing third molars	Usually not indicated for monitoring of growth and development. Clinical judgment as to the need for and type of radiographic image for evaluation of dental and skeletal relationships.	
Patient with other circumstances including, but not limited to, proposed or existing implants, other dental and craniofacial pathoses, restorative/endodontic needs, treated periodontal disease and caries remineralization	Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of these conditions				

***Clinical situations for which radiographs may be indicated include, but are not limited to:**

A. Positive Historical Findings

1. Previous periodontal or endodontic treatment
2. History of pain or trauma
3. Familial history of dental anomalies

4. Postoperative evaluation of healing
5. Remineralization monitoring
6. Presence of implants, previous implant-related pathosis or evaluation for implant placement

B. Positive Clinical Signs/Symptoms

1. Clinical evidence of periodontal disease
2. Large or deep restorations
3. Deep carious lesions
4. Malposed or clinically impacted teeth
5. Swelling
6. Evidence of dental/facial trauma
7. Mobility of teeth
8. Sinus tract ("fistula")
9. Clinically suspected sinus pathosis
10. Growth abnormalities
11. Oral involvement in known or suspected systemic disease
12. Positive neurologic findings in the head and neck
13. Evidence of foreign objects
14. Pain and/or dysfunction of the temporomandibular joint
15. Facial asymmetry
16. Abutment teeth for fixed or removable partial prosthesis
17. Unexplained bleeding
18. Unexplained sensitivity of teeth
19. Unusual eruption, spacing or migration of teeth
20. Unusual tooth morphology, calcification or color
21. Unexplained absence of teeth
22. Clinical tooth erosion
23. Peri-implantitis

∗∗Factors increasing risk for caries may be assessed using the ADA Caries Risk Assessment forms (0 – 6 years of age and over 6 years of age).

EXPLANATION OF RECOMMENDATIONS FOR PRESCRIBING DENTAL RADIOGRAPHS

The explanation below presents the rationale for each recommendation by type of encounter and patient age and dental developmental stages.

New Patient Being Evaluated for Oral Diseases

Child (Primary Dentition)

Proximal carious lesions may develop after the interproximal spaces between posterior primary teeth close. Open contacts in the primary dentition will allow a dentist to visually inspect the proximal posterior surfaces. Closure of proximal contacts requires radiographic assessment.[16-18] However, evidence suggests that many of these lesions will remain in the enamel for at least 12 months or longer depending on fluoride exposure, allowing sufficient time for implementation and evaluation of preventive interventions.[19-21] A periapical/anterior occlusal examination may be indicated because of the need to evaluate dental development, dentoalveolar trauma, or suspected pathoses. Periapical and bitewing radiographs may be required to evaluate pulp pathosis in primary molars.

Therefore, an individualized radiographic examination consisting of selected periapical/occlusal views and/or posterior bitewings if proximal surfaces cannot be examined visually or with a probe is recommended. Patients without evidence of disease and with open proximal contacts may not require radiographic examination at this time.

Child (Transitional Dentition)

Overall dental caries in the primary teeth of children from 2-11 years of age declined from the early 1970s until the mid 1990s.[22-24] From the mid 1990s until the 1999-2004 National Health and Nutrition Examination Survey, there was a small but significant increase in primary decay. This trend reversal was larger for younger children. Tooth decay affects more than one-fourth of U.S. children aged 2–5 years and half of those aged 12-15 years; however, its prevalence is not uniformly distributed. About half of all children and two-thirds of adolescents aged 12–19 years from lower-income families have had decay.[25]

Children and adolescents of some racial and ethnic groups and those from lower-income families have more untreated tooth decay. For example, 40 percent of Mexican American children aged 6–8 years have untreated decay, compared with 25 percent of non-Hispanic whites.[25] It is, therefore, important to consider a child's risk factors for caries before taking radiographs.

Although periodontal disease is uncommon in this age group,[26] when clinical evidence exists (except for nonspecific gingivitis), selected periapical and bitewing radiographs are indicated to determine the extent of aggressive periodontitis, other forms of uncontrolled periodontal disease and the extent of osseous destruction related to metabolic diseases.[27,28]

A periapical or panoramic examination is useful for evaluating dental development. A panoramic radiograph also is useful for the evaluation of craniofacial trauma.[15,29,30] Intraoral radiographs are more accurate than panoramic radiographs for the evaluation of dentoalveolar

trauma, root shape, root resorption[31,32] and pulp pathosis. However, panoramic examinations may have the advantage of reduced radiation dose, cost and imaging of a larger area.

Occlusal radiographs may be used separately or in combination with panoramic radiographs in the following situations: 1. unsatisfactory image in panoramic radiographs due to abnormal incisor relationship, 2. localizations of tooth position, and 3. when clinical grounds provide a reasonable expectation that pathosis exists.[32-34]

Therefore, an individualized radiographic examination consisting of posterior bitewings with panoramic examination or posterior bitewings and selected periapical images is recommended.

Adolescent (Permanent Dentition)

Caries in permanent teeth declined among adolescents, while the prevalence of dental sealants increased significantly.[35] However, increasing independence and socialization, changing dietary patterns, and decreasing attention to daily oral hygiene can characterize this age group. Each of these factors may result in an increased risk of dental caries. Another consideration, although uncommon, is the increased incidence of periodontal disease found in this age group compared to children.[36]

Panoramic radiography is effective in dental diagnosis and treatment planning.[30,37,38] Specifically, the status of dental development can be assessed using panoramic radiography.[39] Occlusal and/or periapical radiographs can be used to detect the position of an unerupted or supernumerary tooth.[40-42] Third molars also should be evaluated in this age group for their presence, position, and stage of development.

Therefore, an individualized radiographic examination consisting of posterior bitewings with panoramic examination or posterior bitewings and selected periapical images is recommended. A full mouth intraoral radiographic examination is preferred when the patient has clinical evidence of generalized oral disease or a history of extensive dental treatment.

Adult (Dentate or Partially Edentulous)

The overall dental caries experience of the adult population has declined from the early 1970s until the most recent (1999-2004) National Health and Nutrition Examination Survey.[43] However, risk for dental caries exists on a continuum and changes over time as risk factors change.[44] Therefore, it is important to evaluate proximal surfaces in the new adult patient for carious lesions. In addition, it is important to examine patients for recurrent dental caries.

The incidence of root surface caries increases with age.[45] Although bitewing radiographs can assist in detecting root surface caries in proximal areas, the usual method of detecting root surface caries is by clinical examination.[46]

The incidence of periodontal disease increases with age.[47] Although new adult patients may not have symptoms of active periodontal disease, it is important to evaluate previous experience with periodontal disease and/or treatment. Therefore, a high percentage of adults may require selected intraoral radiographs to determine the current status of the disease.

Taking posterior bitewing radiographs of new adult patients was found to reduce the number of radiological findings and the diagnostic yield of panoramic radiography.[48,49] In addition, the following clinical indicators for panoramic radiography were identified as the best predictors for useful diagnostic yield: suspicion of teeth with periapical pathologic conditions, presence of partially erupted teeth, caries lesions, swelling, and suspected unerupted teeth.[50]

Therefore, an individualized radiographic examination, consisting of posterior bitewings with selected periapical images or panoramic examination when indicated is recommended. A full mouth intraoral radiographic examination is preferred when the patient has clinical evidence of generalized oral disease or a history of extensive dental treatment.

Adult (Edentulous)

The clinical and radiographic examinations of edentulous patients generally occur during an assessment of the need for prostheses. The most common pathological conditions detected are impacted teeth and retained roots with and without associated disease.[51] Other less common conditions also may be detected: bony spicules along the alveolar ridge, residual cysts or infections, developmental abnormalities of the jaws, intraosseous tumors, and systemic conditions affecting bone metabolism.

The original recommendations for this group called for a full-mouth intraoral radiographic examination or a panoramic examination for the new, edentulous adult patient. Firstly, this recommendation was made because examinations of edentulous patients generally occur during an assessment of the need for prostheses. Secondly, the original recommendation considered edentulous patients to be at increased risk for oral disease.

Studies have found that from 30 to 50 percent of edentulous patients exhibited abnormalities in panoramic radiographs.[51-55] In addition, the radiographic examination revealed anatomic considerations that could influence prosthetic treatment, such as the location of the mandibular canal, the position of the mental foramen and maxillary sinus, and relative thickness of the soft tissue covering the edentulous ridge.[51,53,55] However, in studies that considered treatment outcomes, there was little evidence to support screening radiography for new edentulous patients. For example, one study reported that less than 4 percent of such findings resulted in treatment modification before denture fabrication, and another showed no difference in post-denture delivery complaints in patients who did not receive screening pretreatment radiographs.[54,56]

This panel concluded that prescription of radiographs is appropriate as part of the initial assessment of edentulous areas for possible prosthetic treatment. A full mouth series of periapical radiographs or a combination of panoramic, occlusal or other extraoral radiographs may be used to achieve diagnostic and therapeutic goals. Particularly with the option of dental implant therapy for edentulous patients,[57] radiographs can be an important aid in diagnosis, prognosis, and the determination of treatment complexity.

Therefore, an individualized radiographic examination, based on clinical signs, symptoms, and treatment plan is recommended.

Recall Patient with Clinical Caries or Increased Risk for Caries

Child (Primary and Transitional Dentition) and Adolescent (Permanent Dentition)

Clinically detectable dental caries may suggest the presence of proximal carious lesions that can only be detected with a radiographic examination. In addition, patients who are at increased risk for developing dental caries because of such factors as poor oral hygiene, high frequency of exposure to sucrose-containing foods, and deficient fluoride intake (see caries risk assessment forms, 0 – 6 years of age and over 6 years of age) are more likely to have proximal carious lesions.

The bitewing examination is the most efficient method for detecting proximal lesions.[16,18,58] The frequency of radiographic recall should be determined on the basis of caries risk assessment.[15,59,60] It should be noted that a patient's caries risk status may change over time and that an individual's radiographic recall interval may need to be changed accordingly.[61]

Therefore, a posterior bitewing examination is recommended at 6 to 12 month intervals if proximal surfaces cannot be examined visually or with a probe.

Adult (Dentate and Partially Edentulous)

Adults who exhibit clinical dental caries or who have other increased risk factors should be monitored carefully for any new or recurrent lesions that are detectable only by radiographic examination. The frequency of radiographic recall should be determined on the basis of caries risk assessment.[15,59,60] It should be noted that a patient's risk status can change over time and that an individual's radiographic recall interval may need to be changed accordingly.[61]

Therefore, a posterior bitewing examination is recommended at 6 to 18 month intervals.

Recall Patient (Edentulous Adult)

A study that assessed radiographs of edentulous recall patients showed that previously detected incidental findings did not progress and that no intervention was indicated.[62] The data suggest that patients who receive continuous dental care do not exhibit new findings that require treatment.

An examination for occult disease in this group cannot be justified on the basis of prevalence, morbidity, mortality, radiation dose, and cost.[53-55]

Therefore, no radiographic examination is recommended without evidence of disease.

Recall Patient with No Clinical Caries and No Increased Risk for Caries

Child (Primary and Transitional Dentition)

Despite the general decline in dental caries activity, recent data show that subgroups of children have a higher caries experience than the overall population.[63,64] The identification of

patients in these subgroups may be difficult on an individual basis. For children who present for recall examination without evidence of clinical caries and who are not considered at increased risk for the development of caries, it remains important to evaluate proximal surfaces by radiographic examination. In primary teeth the caries process can take approximately one year to progress through the outer half of the enamel and about another year through the inner half.[20,65-68] Considering this rate of progression of carious lesions through primary teeth, a time-based interval of radiographic examinations from one to two years for this group appears appropriate. The prevalence of carious lesions has been shown to increase during the stage of transitional dentition.[25,69] Children under routine professional care would be expected to be at a lower risk for caries. Nevertheless, newly erupted teeth are at risk for the development of dental caries.

Therefore, a radiographic examination consisting of posterior bitewings is recommended at intervals of 12 to 24 months if proximal surfaces cannot be examined visually or with a probe.

Adolescent (Permanent Dentition)
Adolescents with permanent dentition, who are free of clinical dental caries and factors that would place them at increased risk for developing dental caries, should be monitored carefully for development of proximal carious lesions, which may only be detected by radiographic examination. The caries process, on average, takes more than three years to progress through the enamel.[20,65-68] However, evidence suggests that the enamel of permanent teeth undergoes posteruptive maturation and that young permanent teeth are susceptible to faster progression of carious lesions.[70-73]

Therefore, a radiographic examination consisting of posterior bitewings is recommended at intervals of 18 to 36 months.

Adult (Dentate and Partially Edentulous)
Adult dentate patients, who receive regularly scheduled professional care and are free of signs and symptoms of oral disease, are at a low risk for dental caries. Nevertheless, consideration should be given to the fact that caries risk can vary over time as risk factors change. Advancing age and changes in diet, medical history and periodontal status may increase the risk for dental caries.

Therefore, a radiographic examination consisting of posterior bitewings is recommended at intervals of 24 to 36 months.

Recall Patient with Periodontal Disease

Child (Primary and Transitional Dentition), Adolescent (Permanent Dentition), and Adult (Dentate and Partially Edentulous)
The decision to obtain radiographs for patients who have clinical evidence or a history of periodontal disease/treatment should be determined on the basis of the anticipation that important diagnostic and prognostic information will result. Structures or conditions to be assessed should include the level of supporting alveolar bone, condition of the interproximal bony crest, length and shape of roots, bone loss in furcations, and calculus deposits. The

frequency and type of radiographic examinations for these patients should be determined on the basis of a clinical examination of the periodontium and documented signs and symptoms of periodontal disease. The procedure for prescribing radiographs for the follow-up/recall periodontal patient would be to use selected intraoral radiographs to verify clinical findings on a patient-by-patient basis.[28,74]

Therefore, it is recommended that clinical judgment be used in determining the need for, and type of radiographic images necessary for, evaluation of periodontal disease. Imaging may consist of, but is not limited to, selected bitewing and/or periapical images of areas where periodontal disease (other than nonspecific gingivitis) can be identified clinically.

Patient (New and Recall) for Monitoring of Dentofacial Growth and Development, and/or Assessment of Dental/Skeletal Relationships

Child (Primary and Transitional Dentition)
For children with primary dentition, before the eruption of the first permanent tooth, radiographic examination to assess growth and development in the absence of clinical signs or symptoms is unlikely to yield productive information. Any abnormality of growth and development suggested by clinical findings should be evaluated radiographically on an individual basis. After eruption of the first permanent tooth, the child may have a radiographic examination to assess growth and development. This examination need not be repeated unless dictated by clinical signs or symptoms. Cephalometric radiographs may be useful for assessing growth, and/or dental and skeletal relationships.

Therefore, it is recommended that clinical judgment be used in determining the need for, and type of radiographic images necessary for, evaluation and/or monitoring of dentofacial growth and development, or assessment of dental and skeletal relationships.

Adolescent (Permanent Dentition)
During adolescence there is often a need to assess the growth status and/or the dental and skeletal relationships of patients in order to diagnose and treat their malocclusion. Appropriate radiographic assessment of the malocclusion should be determined on an individual basis.

An additional concern relating to growth and development for patients in this age group is to determine the presence, position and development of third molars. This determination can best be made by the use of selected periapical images or a panoramic examination, once the patient is in late adolescence (16 to 19 years of age).

Therefore, it is recommended that clinical judgment be used in determining the need for, and type of radiographic images necessary for, evaluation and/or monitoring of dentofacial growth and development, or assessment of dental and skeletal relationships. Panoramic or periapical examination may be used to assess developing third molars.

Adult (Dentate, Partially Edentulous and Edentulous)
In the absence of any clinical signs or symptoms suggesting abnormalities of growth and development in adults, no radiographic examinations are indicated for this purpose.

Therefore, in the absence of clinical signs and symptoms, no radiographic examination is recommended.

Patients with Other Circumstances
(including, but not limited to, proposed or existing implants, other dental and craniofacial pathoses, restorative/endodontic needs, treated periodontal disease and caries remineralization)

All Patient Categories
The use of imaging, as a diagnostic and evaluative tool, has progressed beyond the longstanding need to diagnose caries and evaluate the status of periodontal disease. The expanded technology in imaging is now used to diagnose other orofacial clinical conditions and evaluate treatment options. A few examples of other clinical circumstances are the use of imaging for dental implant treatment planning, placement, or evaluation; the monitoring of dental caries and remineralization; the assessment of restorative and endodontic needs; and the diagnosis of soft and hard tissue pathoses.

Therefore it is recommended that clinical judgment be used in determining the need for, and type of radiographic images necessary for, evaluation and/or monitoring in these circumstances.

LIMITING RADIATION EXPOSURE

Dental radiographs account for approximately 2.5 percent of the effective dose received from medical radiographs and fluoroscopies.[75] Even though radiation exposure from dental radiographs is low, once a decision to obtain radiographs is made it is the dentist's responsibility to follow the ALARA Principle (As Low as Reasonably Achievable) to minimize the patient's exposure. Examples of good radiologic practice include

- use of the fastest image receptor compatible with the diagnostic task (F-speed film or digital);
- collimation of the beam to the size of the receptor whenever feasible;
- proper film exposure and processing techniques;
- use of protective aprons and thyroid collars, when appropriate; and
- limiting the number of images obtained to the minimum necessary to obtain essential diagnostic information.

RECEPTOR SELECTION

The American National Standards Institute and the International Organization for Standardization have established standards for film speed.[76,77] Film speeds available for dental radiography are D-speed, E-speed and F-speed, with D-speed being the slowest and F-speed the fastest. According to the U.S. Food and Drug Administration, switching from D to E speed can produce a 30 to 40 percent reduction in radiation exposure.[78] The use of F-speed film can reduce exposure 20 to 50 percent compared to use of E-speed film, without compromising diagnostic quality.[79-85]

Exposure of extraoral films such as panoramic radiographs requires intensifying screens to minimize radiation exposure to patients. The intensifying screen consists of layers of phosphor crystals that fluoresce when exposed to radiation. In addition to the radiation incident on the film, the film is exposed primarily to the light emitted from the intensifying screen. Previous generations of intensifying screens were composed of phosphors such as calcium tungstate. However, rare-earth intensifying screens are recommended because they reduce a patient's radiation exposure by 50 percent compared with calcium tungstate-intensifying screens.[86-89] Rare-earth film systems, combined with a high-speed film of 400 or greater, can be used for panoramic radiographs.[86] Older panoramic equipment can be retrofitted to reduce the radiation exposure to accommodate the use of rare-earth, high-speed systems.

Digital imaging provides an opportunity to further reduce the radiation dose by 40 to 60 percent.[90-93] In digital radiography, there are three types of receptors that take the place of conventional film: charge-coupled device (CCD), complementary-metal-oxide-semiconductor (CMOS), and photo-stimulable phosphor (PSP) plates. Systems that use CCD and CMOS-based, solid-state detectors are called "direct." When these sensors receive energy from the x-ray beam, the CCD or CMOS chip sends a signal to the computer and an image appears on the monitor within seconds. Systems that use PSP plates are called "indirect." When these plates are irradiated, a latent image is stored on them. The plate is then scanned and the scanner transmits the image to the computer.

RECEPTOR HOLDERS

Holders that align the receptor precisely with the collimated beam are recommended for periapical and bitewing radiographs. Heat-sterilizable or disposable intraoral radiograph receptor-holding devices are recommended for optimal infection control.[94] Dental professionals should not hold the receptor holder during exposure.[86] Under extraordinary circumstances in which members of the patient's family (or other caregiver) must provide restraint or hold a receptor holder in place during exposure, such a person should wear appropriate shielding.[86]

COLLIMATION

Collimation limits the amount of radiation, both primary and scattered, to which the patient is exposed. An added benefit of rectangular collimation is an improvement in contrast as a result of a reduction in fogging caused by secondary and scattered radiation.[89] The x-ray beam should not exceed the minimum coverage necessary, and each dimension of the beam should be collimated so that the beam does not exceed the receptor by more than 2 percent of the source-to-image receptor distance.[86] Since a rectangular collimator decreases the radiation dose by up to fivefold as compared with a circular one, [86,95,96] radiographic equipment should provide rectangular collimation for exposure of periapical and bitewing radiographs.[86] Use of a receptor-holding device minimizes the risk of cone-cutting (non-exposure of part of the image receptor due to malalignment of the x-ray beam). The position-indicating device should be open ended and have a metallic lining to restrict the primary beam and reduce the tissue volume exposed to radiation.[86] Use of long source-to-skin distances of 40 cm, rather than short distances of 20 cm, decreases exposure by 10 to 25 percent.[86,97] Distances between 20 cm and 40 cm are appropriate, but the longer distances are optimal.[86]

OPERATING POTENTIAL AND EXPOSURE TIME

The operating potential of dental x-ray units affects the radiation dose and backscatter radiation. Lower voltages produce higher-contrast images and higher entrance skin doses, and lower deep-tissue doses and levels of backscatter radiation. However, higher voltages produce lower contrast images that enable better separation of objects with differing densities. Thus, the diagnostic purposes of the radiograph should be used to determine the selection of kilovolt setting. A setting above 90 kV(p) will increase the patient dose and should not be used.[89] The optimal operating potential of dental x-ray units is between 60 and 70 kVp.[86,89]

Filmless technology is much more forgiving to overexposure often resulting in unnecessary radiation exposure. Facilities should strive to set the x-ray unit exposure timer to the lowest setting providing an image of diagnostic quality. If available, the operator should always confirm that the dose delivered falls within the manufacturer's exposure index. Imaging plates should be evaluated at least monthly and cleaned as necessary.

PATIENT SHIELDING AND POSITIONING

The amount of scattered radiation striking the patient's abdomen during a properly conducted radiographic examination is negligible.[98] The thyroid gland is more susceptible to radiation exposure during dental radiographic exams given its anatomic position, particularly in children.[93,99,100] Protective thyroid collars and collimation substantially reduce radiation exposure to the thyroid during dental radiographic procedures.[101,102] Because every precaution should be taken to minimize radiation exposure, protective thyroid collars should be used whenever possible. If all the recommendations for limiting radiation exposure are put into practice, the gonadal radiation dose will not be significantly affected by use of abdominal shielding.[86] Therefore, use of abdominal shielding may not be necessary.

Protective aprons and thyroid shields should be hung or laid flat and never folded, and manufacturer's instructions should be followed. All protective shields should be evaluated for damage (e.g. tears, folds, and cracks) monthly using visual and manual inspection.

Proper education and training in patient positioning is necessary to ensure that panoramic radiographs are of diagnostic quality.

OPERATOR PROTECTION

Although dental professionals receive less exposure to ionizing radiation than do other occupationally exposed health care workers,[75,86] operator protection measures are essential to minimize exposure. Operator protection measures include education, the implementation of a radiation protection program, occupational radiation exposure limits, recommendations for personal dosimeters and the use of barrier shielding.[103] The maximum permissible annual dose of ionizing radiation for health care workers is 50 millisieverts (mSv) and the maximum permissible lifetime dose is 10 mSv multiplied by a person's age in years.[86] Personal dosimeters should be used by workers who may receive an annual dose greater than 1 mSv to monitor their exposure levels. Pregnant dental personnel operating x-ray equipment should use personal dosimeters, regardless of anticipated exposure levels.[86]

Operators of radiographic equipment should use barrier protection when possible, and barriers should ideally contain a leaded glass window to enable the operator to view the patient during exposure.[86] When shielding is not possible, the operator should stand at least two meters from the tube head and out of the path of the primary beam.[103] The National Council on Radiation Protection & Measurements report "Radiation Protection in Dentistry" offers detailed information on shielding and office design.[86] State radiation control agencies can help assess whether barriers meet minimum standards.

HAND-HELD X-RAY UNITS

Hand-held, battery-powered x-ray systems are available for intra-oral radiographic imaging. The hand-held exposure device is activated by a trigger on the handle of the device. However, dosimetry studies indicate that these hand-held devices present no greater radiation risk than standard dental radiographic units to the patient or the operator. No additional radiation protection precautions are needed when the device is used according to the manufacturer's instructions. These include: 1. holding the device at mid-torso height, 2. orienting the shielding ring properly with respect to the operator, and 3. keeping the cone as close to the patient's face as practical. If the hand-held device is operated without the ring shield in place, it is recommended that the operator wear a lead apron.

All operators of hand-held units should be instructed on their proper storage. Due to the portable nature of these devices, they should be secured properly when not in use to prevent accidental damage, theft, or operation by an unauthorized user. Hand-held units should be stored in locked cabinets, locked storage rooms, or locked work areas when not under the direct supervision of an individual authorized to use them. Units with user-removable batteries should be stored with the batteries removed. Records listing the names of approved individuals who are granted access and use privileges should be prepared and kept current.

FILM EXPOSURE AND PROCESSING

All film should be processed following the film and processer manufacturer recommendations. Once this is achieved, the x-ray operator can adjust the tube current and time and establish a technique that will provide consistent dental radiographs of diagnostic quality. Poor processing technique, including sight-developing, most often results in underdeveloped films, forcing the x-ray operator to increase the dose to compensate, resulting in patient and personnel being exposed to unnecessary radiation.

A safelight does not provide completely safe exposure for an indefinite period of time. Extraoral film is much more sensitive to fogging. The length of time for which a film can be exposed to the safelight should be determined for the specific safelight/film combination in use.

QUALITY ASSURANCE

Quality assurance protocols for the x-ray unit, imaging receptor, film processing, dark room, and patient shielding should be developed and implemented for each dental health care setting.[86] All quality assurance procedures, including date, procedure, results, and corrective action, should be logged for documentation purposes. A qualified expert should survey all x-ray units on their placement and should resurvey the equipment every four years or after any

changes that may affect the radiation exposure of the operator and others.[86] Surveys typically are performed by state agencies, and individual state regulations should be consulted regarding specific survey intervals. The film processor should be evaluated at its initial installation and on a monthly basis afterward. The processing chemistry should be evaluated daily, and each type of film should be evaluated monthly or when a new box or batch of film is opened.[86] Abdominal shielding and thyroid collars should be inspected visually for creases or clumping that may indicate voids in their integrity on a monthly basis.[86] Damaged abdominal shielding and collars should be replaced. Table 2 lists specific methods of quality assurance procedures, covering not only inspection of the x-ray unit itself but also of the film processor, the image receptor devices, the darkroom and abdominal shielding and collars.[103,104]

It is imperative that the operator's manual for all imaging acquisition hardware is readily available to the user, and that the equipment is operated and maintained following the manufacturer's instructions, including any appropriate adjustments for optimizing dose and image quality.

TECHNIQUE CHARTS/PROTOCOLS

Size-based technique charts/protocols with suggested parameter settings are important for ensuring that radiation exposure is optimized for all patients. Technique charts should be used for all systems with adjustable settings, such as tube potential, tube current, and time or pulses. The purpose of using the charts is to control the amount of radiation to the patient and receptor. Technique charts are tables that indicate appropriate settings on the x-ray unit for a specific anatomical area and will ensure the least amount of radiation exposure to produce a consistently good-quality radiograph.

Technique charts for intraoral and extraoral radiography should list the type of exam, the patient size (small, medium, large) for adults and a pediatric setting. The speed of film used, or use of a digital receptor, should also be listed on the technique chart. The chart should be posted near the control panel where the technique is adjusted for each x-ray unit. A technique chart that is regularly updated should be developed for each x-ray unit. The charts will also need to be updated when a different film or sensor, new unit, or new screens are used.

RADIATION RISK COMMUNICATION

Dentists should be prepared to discuss with their patients the benefits and risks of the x-ray exam.[105] To help answer patient and parent questions about dental radiology radiation safety, the American Academy of Oral and Maxillofacial Radiology and the Alliance for Radiation Safety in Pediatric Imaging partnered to create a brochure targeted at parents and patients.[106]

Table 2.

Quality Assurance Procedures for Assessment of Radiographic Equipment		
The following procedures for periodic assessment of the performance of radiographic equipment, film processing, equipment, image receptor devices, dark room integrity, and abdominal and thyroid shielding are adapted from the National Council for Radiation Protection and Measurements report, "Radiation Protection in Dentistry."[86] Please refer to state guidelines for specific regulations.		
Equipment	**Frequency**	**Method**
X-ray Machine	On installation At regular intervals as recommended by state regulations Whenever there are any changes in installation workload or operating conditions	Inspection by qualified expert (as specified by government regulations and manufacturers recommendations).
Film Processor	On installation Daily	**Method 1: Sensitometry and Densitometry** A sensitometer is used to expose a film, followed by standard processing of the film. The processed film will have a defined pattern of optical densities. The densities are measured with a densitometer. The densitometer measurements are compared to the densities of films exposed and processed under ideal conditions. A change in densitometer values indicates a problem with either the development time, temperature or the developer solutions. *Advantages* Accuracy Speed *Disadvantage* Expense of additional equipment **Method 2: Reference Film** A film exposed and processed under ideal conditions is attached to the corner of a view box as a reference film. Subsequent films are compared with the reference film. *Advantage* Cost effectiveness *Disadvantage* Less sensitive
Image Receptor Devices	Monthly With each new batch of film	**Method 1: Sensitometry and Densitometry** (as described above) **Method 2: Reference Image** (as described above)
Intensifying Screen and	Every six months	Visual inspection of cassette integrity Examination of intensifying screen for

Extraoral Cassettes		scratches Development of an unexposed film that has been in the cassette exposed to normal lighting for one hour or more
Darkroom Integrity	On installation Monthly After a change in the lighting filter or lamp	While in a darkroom with the safelight on, place metal object (such as a coin) on unwrapped film for a period that is equivalent to the time required for a typical darkroom procedure Develop film Detection of the object indicates a problem with the safelight or light leaks in the darkroom
Abdominal and Thyroid Shielding	Monthly (visual and manual inspection)	All protective shields should be evaluated for damage (e.g., tears, folds, and cracks) monthly using visual and manual inspection. If a defect in the attenuating material is suspected, radiographic or fluoroscopic inspection may be performed as an alternative to immediately removing the item from service. Consideration should be given to minimizing the radiation exposure of inspectors by minimizing unnecessary fluoroscopy.

TRAINING AND EDUCATION

Where permitted by law, auxiliary dental personnel can perform intraoral and extraoral imaging.[103] Personnel certified to take dental radiographs should receive appropriate education. Practitioners should remain informed about safety updates and the availability of new equipment, supplies and techniques that could further improve the diagnostic quality of radiographs and decrease radiation exposure. Free training materials are available for limiting radiation exposure in dental imaging through the International Atomic Energy Agency.[107]

CONCLUSION

Dentists should conduct a clinical examination, consider the patient's oral and medical histories, as well as consider the patient's vulnerability to environmental factors that may affect oral health before conducting a radiographic examination. This information should guide the dentist in the determination of the type of imaging to be used, the frequency of its use, and the number of images to obtain. Radiographs should be taken only when there is an expectation that the diagnostic yield will affect patient care.

Dentists should develop and implement a radiation protection program in their offices. In addition, practitioners should remain informed on safety updates and the availability of new equipment, supplies, and techniques that could further improve the diagnostic ability of radiographs and decrease exposure.

REFERENCES

1. The American Dental Association Council on Scientific Affairs. The use of cone-beam computed tomography in dentistry. *J Am Dent Assoc* 2012;143(8):899-202.

2. Anbiaee N, Mohassel AR, Imanimoghaddam M, Moazzami SM. A comparison of the accuracy of digital and conventional radiography in the diagnosis of recurrent caries. *J Contemp Dent Pract* 2010;11(6):E025-032.

3. Senel B, Kamburoglu K, Ucok O, et al. Diagnostic accuracy of different imaging modalities in detection of proximal caries. *Dentomaxillofac Radiol* 2010;39(8):501-11.

4. Ulusu T, Bodur H, Odabas ME. In vitro comparison of digital and conventional bitewing radiographs for the detection of approximal caries in primary teeth exposed and viewed by a new wireless handheld unit. *Dentomaxillofac Radiol* 2010;39(2):91-4.

5. Tracy KD, Dykstra BA, Gakenheimer DC, et al. Utility and effectiveness of computer-aided diagnosis of dental caries. *Gen Dent* 2011;59(2):136-44.

6. Atchison KA, White SC, Flack VF, Hewlett ER. Assessing the FDA guidelines for ordering dental radiographs. *J Am Dent Assoc* 1995;126(10):1372-83.

7. Atchison KA, White SC, Flack VF, Hewlett ER, Kinder SA. Efficacy of the FDA selection criteria for radiographic assessment of the periodontium. *J Dent Res* 1995;74(7):1424-32.

8. Pitts NB, Kidd EA. The prescription and timing of bitewing radiography in the diagnosis and management of dental caries: contemporary recommendations. *Br Dent J* 1992;172(6):225-7.

9. Smith NJ. Selection criteria for dental radiography. *Br Dent J* 1992;173(4):120-1.

10. Hintze H. Screening with conventional and digital bite-wing radiography compared to clinical examination alone for caries detection in low-risk children. *Caries Res* 1993;27(6):499-504.

11. Hintze H, Wenzel A. Clinically undetected dental caries assessed by bitewing screening in children with little caries experience. *Dentomaxillofac Radiol* 1994;23(1):19-23.

12. Ferguson F, Festa SA. Radiography for children and adolescents. *N Y State Dent J* 1993;59(2):25-9.

13. Henderson NJ, Crawford PJ. Guidelines for taking radiographs of children. *Dent Update* 1995;22(4):158-61.

14. Wenzel A. Current trends in radiographic caries imaging. *Oral Surg Oral Med Oral Pathol* 1995;80(5):527-39.

15. White SC, Heslop EW, Hollender LG, et al. Parameters of radiologic care: An official report of the American Academy of Oral and Maxillofacial Radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001;91(5):498-511.

16. Newman B, Seow WK, Kazoullis S, Ford D, Holcombe T. Clinical detection of caries in the primary dentition with and without bitewing radiography. *Aust Dent J* 2009;54(1):23-30.

17. Clark HC, Curzon ME. A prospective comparison between findings from a clinical examination and results of bitewing and panoramic radiographs for dental caries diagnosis in children. *Eur J Paediatr Dent* 2004;5(4):203-9.

18. Hopcraft MS, Morgan MV. Comparison of radiographic and clinical diagnosis of approximal and occlusal dental caries in a young adult population. *Community Dent Oral Epidemiol* 2005;33(3):212-8.

19. Tinanoff N, Douglass JM. Clinical decision-making for caries management in primary teeth. *J Dent Educ* 2001;65(10):1133-42.
20. Arrow P. Incidence and progression of approximal carious lesions among school children in Western Australia. *Aust Dent J* 2007;52(3):216-26.
21. Lith A. Frequency of radiographic caries examinations and development of dental caries. *Swed Dent J Suppl* 2001(147):1-72.
22. National Institute of Dental Research. The prevalence of dental caries in United States children, 1979-1980. *Department of Health and Human Services - National Institutes of Health.* 1981;NIH publication no. 82-2245.
23. National Institute of Dental Research. The national survey of dental caries in U.S. School Children: 1986-1987. *Department of Health and Human Services - National Institutes of Health.* 1989;NIH publication no. 89-2247.
24. Kaste LM, Selwitz RH, Oldakowski RJ, et al. Coronal caries in the primary and permanent dentition of children and adolescents 1-17 years of age: United States, 1988-1991. *J Dent Res* 1996;75 Spec No:631-41.
25. National Center for Chronic Disease Prevention and Health Promotion. Oral Health: Preventing Cavities, Gum Disease, Tooth Loss, and Oral Cancers at a Glance 2011. www.cdc.gov/chronicdisease/resources/publications/AAG/doh.htm (accessed November 14, 2011).
26. Research Science and Therapy Committee American Academy of Periodontology. Position paper: Periodontal diseases of children and adolescents. *J Periodontol* 2003;74(11):1696-704.
27. Oh TJ, Eber R, Wang HL. Periodontal diseases in the child and adolescent. *J Clin Periodontol* 2002;29(5):400-10.
28. Corbet EF, Ho DK, Lai SM. Radiographs in periodontal disease diagnosis and management. *Aust Dent J* 2009;54 Suppl 1:S27-43.
29. Hollier LH, Jr., Sharabi SE, Koshy JC, Stal S. Facial trauma: general principles of management. *J Craniofac Surg* 2010;21(4):1051-3.
30. Alcala-Galiano A, Arribas-Garcia IJ, Martin-Perez MA, et al. Pediatric facial fractures: children are not just small adults. *Radiographics* 2008;28(2):441-61; quiz 618.
31. Sameshima GT, Asgarifar KO. Assessment of root resorption and root shape: periapical vs panoramic films. *Angle Orthod* 2001;71(3):185-9.
32. Witcher TP, Brand S, Gwilliam JR, McDonald F. Assessment of the anterior maxilla in orthodontic patients using upper anterior occlusal radiographs and dental panoramic tomography: a comparison. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2010;109(5):765-74.
33. Tai CC, Miller PA, Packota GV, Wood RE. The occlusal radiograph revisited. *Oral Health* 1994;84(11):47-50, 53.
34. Taylor NG, Jones AG. Are anterior occlusal radiographs indicated to supplement panoramic radiography during an orthodontic assessment? *Br Dent J* 1995;179(10):377-81.
35. Tomar SL, Reeves AF. Changes in the oral health of U.S. children and adolescents and dental public health infrastructure since the release of the Healthy People 2010 Objectives. *Acad Pediatr* 2009;9(6):388-95.
36. Albandar JM, Tinoco EM. Global epidemiology of periodontal diseases in children and young persons. *Periodontol 2000* 2002;29:153-76.

37. Atieh MA. Diagnostic accuracy of panoramic radiography in determining relationship between inferior alveolar nerve and mandibular third molar. *J Oral Maxillofac Surg* 2010;68(1):74-82.
38. Le T, Nassery K, Kahlert B, Heithersay G. A comparative diagnostic assessment of anterior tooth and bone status using panoramic and periapical radiography. *Aust Orthod J* 2011;27(2):162-8.
39. Nohadani N, Ruf S. Assessment of vertical facial and dentoalveolar changes using panoramic radiography. *EurJ Orthod* 2008;30(3):262-8.
40. Garvey MT, Barry HJ, Blake M. Supernumerary teeth--an overview of classification, diagnosis and management. *J Can Dent Assoc* 1999;65(11):612-6.
41. Tsai HH. Panoramic radiographic findings of the mandibular growth from deciduous dentition to early permanent dentition. *J Clin Pediatr Dent* 2002;26(3):279-84.
42. Anthonappa RP, King NM, Rabie AB, Mallineni SK. Reliability of panoramic radiographs for identifying supernumerary teeth in children. *Inter J Paediatr Dent* 2012;22(1):37-43.
43. National Institute for Dental and Craniofacial Research. Dental Caries (Tooth Decay) in Adults (Age 20 to 64). http://www.nidcr.nih.gov/DataStatistics/FindDataByTopic/DentalCaries/DentalCariesAdults20to64 (accessed March 21, 2012).
44. Centers for Disease Control and Prevention. Recommendations for using fluoride to prevent and control dental caries in the United States. *MMWR* 2001;50(No. RR-14).
45. Ritter AV, Shugars DA, Bader JD. Root caries risk indicators: a systematic review of risk models. *Community Dent Oral Epidemiol* 2010;38(5):383-97.
46. Topping GVA, Pitts NB. Clinical Visual Caries Detection. *Monogr Oral Sci* 2009;21:15-41.
47. Hugoson A, Sjodin B, Norderyd O. Trends over 30 years, 1973-2003, in the prevalence and severity of periodontal disease. *J Clin Periodontol* 2008;35:405-14.
48. Rushton VE, Horner K, Worthington HV. Screening panoramic radiography of new adult patients: diagnostic yield when combined with bitewing radiography and identification of selection criteria. *Br Dent J* 2002;192(5):275-9.
49. Rushton MN, Rushton VE. A study to determine the added value of 740 screening panoramic radiographs compared to intraoral radiography in the management of adult (>18 years) dentate patients in a primary care setting. *J Dent* 2012;40(8)661-9.
50. Rushton VE, Horner K, Worthington HV. Routine panoramic radiography of new adult patients in general dental practice: relevance of diagnostic yield to treatment and identification of radiographic selection criteria. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2002;93(4):488-95.
51. Jindal SK, Sheikh S, Kulkarni S, Singla A. Significance of pre-treatment panoramic radiographic assessment of edentulous patients--a survey. Med Oral Patol Oral Cir Bucal. Jul 2011;16(4):e600-6.
52. Edgerton M, Clark P. Location of abnormalities in panoramic radiographs of edentulous patients. *Oral Surg Oral Med Oral Pathol* 1991;71(1):106-9.
53. Sumer AP, Sumer M, Guler AU, Bicer I. Panoramic radiographic examination of edentulous mouths. *Quintessence Int* 2007;38(7):e399-403.
54. Masood F, Robinson W, Beavers KS, Haney KL. Findings from panoramic radiographs of the edentulous population and review of the literature. *Quintessence Int* 2007;38(6):e298-305.

55. Awad EA, Al-Dharrab A. Panoramic radiographic examination: a survey of 271 edentulous patients. *Int J Prosthodont* 2011;24(1):55-7.
56. Bohay RN, Stephens RG, Kogon SL. A study of the impact of screening or selective radiography on the treatment and postdelivery outcome for edentulous patients. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998;86(3):353-9.
57. Feine JS, Carlsson GE, Awad MA, et al. The McGill consensus statement on overdentures. Mandibular two-implant overdentures as first choice standard of care for edentulous patients. Montreal, Quebec, May 24-25, 2002. *Int J Oral Maxillofac Implants* 2002;17(4):601-2.
58. da Silva RP, Assaf AV, Pereira SM, et al. Validity of caries-detection methods under epidemiological setting. *Am J Dent* 2011;24(6):363-6.
59. Steiner M, Buhlmann S, Menghini G, Imfeld C, Imfeld T. Caries risks and appropriate intervals between bitewing x-ray examinations in schoolchildren. *Schweiz Monatsschr Zahnmed* 2011;121(1):12-24.
60. Patel S, Bay RC, Glick M. A systematic review of dental recall intervals and incidence of dental caries. *J Am Dent Assoc* 2010;141(5):527-39.
61. Pitts NB. The use of bitewing radiographs in the management of dental caries: scientific and practical considerations. *Dentomaxillofac Radiol* 1996;25(1):5-16.
62. Garcia RI, Valachovic RW, Chauncey HH. Longitudinal study of the diagnostic yield of panoramic radiographs in aging edentulous men. *Oral Surg Oral Med Oral Pathol* 1987;63(4):494-7.
63. Dye BA, Thornton-Evans G. Trends in oral health by poverty status as measured by Healthy People 2010 objectives. *Public Health Rep* 2010;125(6):817-30.
64. Dye BA, Arevalo O, Vargas CM. Trends in paediatric dental caries by poverty status in the United States, 1988-1994 and 1999-2004. *Int J Paediatr Dent* 2010;20(2):132-43.
65. Shwartz M, Grondahl HG, Pliskin JS, Boffa J. A longitudinal analysis from bite-wing radiographs of the rate of progression of approximal carious lesions through human dental enamel. *Arch Oral Biol* 1984;29(7):529-36.
66. Berkey CS, Douglass CW, Valachovic RW, Chauncey HH. Longitudinal radiographic analysis of carious lesion progression. *Community Dent Oral Epidemiol* 1988;16(2):83-90.
67. Mejare I, Kallest l 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.
68. Sheiham A, Sabbah W. Using universal patterns of caries for planning and evaluating dental care. *Caries Research* 2010;44(2):141-50.
69. Chankanka O, Marshall TA, Levy SM, et al. Mixed dentition cavitated caries incidence and dietary intake frequencies. *Pediatr Dent* 2011;33(3):233-40.
70. Gruythuysen RJ, van der Linden LW, Woltgens JH, Geraets WG. Differences between primary and permanent teeth in posteruptive age dependency of radiological changes in enamel during the development of approximal caries. *J Biol Buccale* 1992;20(1):59-62.
71. Kotsanos N, Darling AI. Influence of posteruptive age of enamel on its susceptibility to artificial caries. *Caries Res* 1991;25(4):241-50.
72. Woltgens JH, Etty EJ, Geraets WG. Posteruptive age dependency of cariogenic changes in enamel of permanent teeth of children. *J Biol Buccale* 1990;18(1):49-53.

73. Cardoso CA, Magalhaes AC, Rios D, Lima JE. Cross-sectional hardness of enamel from human teeth at different posteruptive ages. *Caries Res* 2009;43(6):491-4.
74. Gutteridge DL. The use of radiographic techniques in the diagnosis and management of periodontal diseases. *Dentomaxillofac Radiol* 1995;24(2):107-13.
75. National Council on Radiation Protection and Measurements, ed *NCRP Report No. 160 - Ionizing Radiation Exposure of the Population of the United States*. Bethesda: National Council on Radiation Protection and Measurements; 2009.
76. American National Standards Institute. Photography - Intra-oral dental radiographic film - Specification. *New York: American National Standards Institute.* 1997;ANSI/NAPM IT2.49-1997. ANSI/ISO 3665:1996.
77. American National Standards Institute. Photography - Direct-exposing medical and dental radiographic film/process systems - Determination of ISO speed and ISO average gradient. *New York: American National Standards Institute.* 1983;ISO 5799:1991. ANSI PH2.50-1983.
78. U.S. Food and Drug Administration. Dental Radiography: Doses and Film Speed. *http://www.fda.gov/Radiation-EmittingProducts/RadiationSafety/NationwideEvaluationofX-RayTrendsNEXT/ucm116524.htm.* (accessed August 2011).
79. Farman TT, Farman AG. Evaluation of a new F speed dental X-ray film. The effect of processing solutions and a comparison with D and E speed films. *Dentomaxillofac Radiol* 2000;29(1):41-5.
80. Hadley DL, Replogle KJ, Kirkam JC, Best AM. A comparison of five radiographic systems to D-speed film in the detection of artificial bone lesions. *J Endod* 2008;34(9):1111-4.
81. Alkurt MT, Peker I, Bala O, Altunkaynak B. In vitro comparison of four different dental X-ray films and direct digital radiography for proximal caries detection. *Oper Dent* 2007;32(5):504-9.
82. Schulze RK, Nackat D, D'Hoedt B. In vitro carious lesion detection on D-, E-, and F-speed radiographic films. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2004;97(4):529-34.
83. Sheaffer JC, Eleazer PD, Scheetz JP, Clark SJ, Farman AG. Endodontic measurement accuracy and perceived radiograph quality: effects of film speed and density. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2003;96(4):441-8.
84. Syriopoulos K, Velders XL, Sanderink GC, van Der Stelt PF. Sensitometric and clinical evaluation of a new F-speed dental X-ray film. *Dentomaxillofac Radiol* 2001;30(1):40-4.
85. Woolhiser GA, Brand JW, Hoen MM, et al. Accuracy of film-based, digital, and enhanced digital images for endodontic length determination. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2005;99(4):499-504.
86. National Council for Radiation Protection & Measurements, ed. *NCRP Report No. 145 - Radiation Protection in Dentistry*. Bethesda: National Council on Radiation Protection and Measurement; 2003.
87. Gratt BM, White SC, Packard FL, Petersson AR. An evaluation of rare-earth imaging systems in panoramic radiography. *Oral Surg Oral Med Oral Pathol* 1984;58(4):475-82.
88. Kaugars GE, Fatouros P. Clinical comparison of conventional and rare earth screen-film systems for cephalometric radiographs. *Oral Surg Oral Med Oral Pathol* 1982;53(3):322-5.

89. Goren AD, Lundeen RC, Deahl II ST, et al. Updated quality assurance self-assessment exercise in intraoral and panoramic radiography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000;89(3):369-74.
90. Gavala S, Donta C, Tsiklakis K, et al. Radiation dose reduction in direct digital panoramic radiography. *Eur J Radiol* 2009;71(1):42-8.
91. Alcaraz M, Parra C, Martinez Beneyto Y, Velasco E, Canteras M. Is it true that the radiation dose to which patients are exposed has decreased with modern radiographic films? *Dentomaxillofac Radiol* 2009;38(2):92-7.
92. Dannewitz B, Hassfeld S, Eickholz P, Muhling J. Effect of dose reduction in digital dental panoramic radiography on image quality. *Dentomaxillofac Radiol* 2002;31(1):50-5.
93. Kaeppler G, Dietz K, Herz K, Reinert S. Factors influencing the absorbed dose in intraoral radiography. *Dentomaxillofac Radiol* 2007;36(8):506-13.
94. Centers for Disease Control and Prevention. Guidelines for Infection Control in Dental Health-Care Settings - 2003. *MMWR* 2003;52(No. RR-17):31.
95. Freeman JP, Brand JW. Radiation doses of commonly used dental radiographic surveys. *Oral Surg Oral Med Oral Pathol* 1994;77(3):285-9.
96. Gibbs SJ. Effective dose equivalent and effective dose: comparison for common projections in oral and maxillofacial radiology. *Oral Surgery Oral Med Oral Pathol Oral RadiolEendod* 2000;90(4):538-45.
97. Gibbs SJ, Pujol A, Jr., Chen TS, James A, Jr. Patient risk from intraoral dental radiography. *Dentomaxillofac Radiol* 1988;17(1):15-23.
98. Gibbs SJ. Biological effects of radiation from dental radiography. Council on Dental Materials, Instruments, and Equipment. *J Am Dent Assoc* 1982;105(2):275-81.
99. Hujoel P, Hollender L, Bollen AM, et al. Head-and-neck organ doses from an episode of orthodontic care. *Am J Orthod Dentofacial Orthop* 2008;133(2):210-7.
100. Ohman A, Kull L, Andersson J, Flygare L. Radiation doses in examination of lower third molars with computed tomography and conventional radiography. *Dentomaxillofac Radiol* 2008;37(8):445-52.
101. Kircos LT, Angin LL, Lorton L. Order of magnitude dose reduction in intraoral radiography. *J Am Dent Assoc* 1987;114(3):344-7.
102. Sinnott B, Ron E, Schneider AB. Exposing the thyroid to radiation: a review of its current extent, risks, and implications. *Endocr Rev* 2010;31(5):756-73.
103. Lambert K, McKeon T. Inspection of lead aprons: criteria for rejection. *Health Phys* 2001;80(5 Suppl):S67-9.
104. Michel R, Zorn MJ. Implementation of an X-ray radiation protective equipment inspection program. *Health Phys* 2002;82(2 Suppl):S51-3.
105. U.S. Food and Drug Administration. Pediatric X-ray Imaging. 2012 *http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/MedicalImaging/ucm298899.htm.* (accessed August 2012).
106. Alliance for Radiation Safety in Pediatric Imaging in partnership with the American Academy of Oral and Maxillofacial Radiology. What Parents Should Know about the Safety of Dental Radiology. 2011 *http://www.pedrad.org/associations/5364/files/What%20Parents%20Should%20Know%20aboutthe%20Safety%20of%20Dental%20Radiology.pdf.* (accessed August 2012).

107. International Atomic Energy Agency. Diagnostic and Interventional Radiology. 2012 *https://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Training/1_TrainingMaterial/Radiology.htm.* (accessed August 2012).