AN UPDATE ON
Bitewing Radiography Technology

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Dental caries continues to be a primary oral health issue, which requires a comprehensive consideration of caries risks, preventative oral health care by the patient and dental professional, and a series of clinical techniques to determine the presence and extent of caries involvement. Total patient care requires radiographic assessment of dental disease and is considered an essential tool in this assessment. Bitewing radiographs remain the primary diagnostic image for intraoral caries assessment with periapical imaging and extraoral imaging being used as adjunctive tools. Both film-based and digital intraoral bitewing images continue to provide the necessary resolution and evidence-based accuracy for diagnosis, while extraoral techniques require further study.

ABSTRACT

The overall goal of this article is to provide the reader with information on the use of radiography for caries detection. On completion of this article, the participant will be able to:

1. Review the types of oral radiographs used for caries detection;
2. Define sensitivity and specificity;
3. Contrast and compare the methodology and results for radiographic caries detection; and
4. List and describe the methods by which radiation exposure is reduced as well as the relative radiation exposure with different radiographic methodologies for caries detection.

EDUCATIONAL OBJECTIVES

Introduction

The discovery of X-rays by Röntgen, and early work by dentists, including Dr. C. Edmund Kells, led to significant developments and improvements over time in the ability of clinicians to diagnose medical and later dental conditions. Since these early developments, advances in oral radiography have resulted in a wide range of diagnostic options and improved capabilities for the detection of pathological lesions and other anomalies. The overall goals of caries detection are to determine whether caries is present, to determine its extent, and to detect it at an early stage when it is still susceptible to remineralization with the use of preventive agents, in particular fluoride. Incipient carious lesions are confined to enamel and have not yet breached the dentinoenamel junction (DEJ). Ideally, lesions will not develop but if they do it is optimal to detect them while they are still in the outer enamel, at which time there...
is the greatest opportunity to remineralize or arrest them. Paradoxically, incipient lesions are the most difficult to detect radiographically.\(^1\) Options for caries detection in addition to visual examination include oral radiography, transillumination, fluorescence and laser fluorescence, and through photothermal radiometry and luminescence. At the current time, visual examination plus oral radiography is the most commonly used method for caries detection and other technologies, including panoramic bitewings, are recommended as adjunctive devices.

Radiography for caries detection and the assessment of the depth of caries present involves the differential attenuation of X-rays through hard tooth structure that is sound or partially demineralized, with more X-rays passing through the less dense demineralized tooth structure to reach the image receptor. Use of a standardized and strict methodology for caries detection is necessary to enable appropriate preventive and restorative care. In addition to diagnostic accuracy, a further consideration of importance is the risk versus benefit of exposure to radiation and risk reduction through minimization of radiation exposure.

Desirable characteristics for any diagnostic tool require that a method offer high sensitivity, high specificity and high reliability. Sensitivity refers to the ability of a test to correctly identify when a condition is present – in the case of dental caries, sensitivity refers to the ability of an image to correctly identify when a carious lesion is present. Specificity, on the other hand, refers to the ability of images to detect when the tooth is sound and no carious lesion is present. Low sensitivity results in carious lesions being missed (and therefore not being treated preventively or restored), while low specificity would result in treatment of a lesion that in fact was not present.

**Radiographic Caries Detection**

Current radiographic techniques typically used for caries detection include the use of intraoral bitewings, panoramic radiographs, and extraoral “bitewings” from panoramic radiography. In addition to the detection of dental caries, other indications and uses of bitewings include monitoring the progression (and arrestment/reversal) of carious lesions as well as assessing existing restorations and periodontal status.

**Intraoral Bitewings**

Intraoral bitewing radiography has been performed since the introduction of X-rays in dentistry, primarily for the detection of proximal carious lesions. The technique derives its name from the bite tabs that were originally used around or as an attachment to film, and upon which patients bit to hold the film in position while the image was being acquired.\(^2\) Intraoral bitewings are acquired with traditional film or by using digital sensors. Detection of carious lesions of differing depths using bitewing radiography can be found in Figure 1.
Traditional Film

With traditional film, X-rays are attenuated differentially depending on the photon energy, thickness of the anatomy, the atomic number of the elements in the tissues, and the density of the tissue. Once acquired, the resulting film is processed and assessed for pathology. Drawbacks of traditional film have included the need for processing (developing and fixing) and the artifacts that can be introduced if the film is scratched or contaminated (e.g., processing chemicals) or if processing is improperly performed (Fig. 2). Incorrect processing or inadvertent exposure to light can result in the necessity for retaking images and more radiation exposure for the patient. The use of positioning instruments and film holders rather than tabs results in standardized positioning of bitewing films, increasing accuracy and reducing the potential for errors (Fig. 3).

The use of high-speed films has reduced radiation exposure significantly, since less exposure time is required due to modified silver halide crystals being used in the emulsion. Studies have confirmed that the diagnostic accuracy of caries detection with high-speed film is equivalent to that of lower-speed films with no statistically significant differences. An in vitro study comparing four different speeds of film and digital oral radiography for detection of mesial and distal caries in 48 extracted posterior teeth found no statistically significant differences either in interobserver evaluations or in the diagnostic imaging results of E- or F-speed film or digital radiography. In one study, no statistically significant difference in the diagnostic accuracy of proximal caries detection was found comparing ultra-speed (high-speed) film with slower film. If, however, developer solution was older than 3 weeks, high-speed film was actually more accurate than slower-speed film.

Digital Intraoral Bitewing Radiography

Digital intraoral bitewing radiography is performed using direct digital sensors or using photostimulable phosphor storage plates (PSP). In the case of PSP, image acquisition is indirect, with the energy absorbed from the X-rays stored...
in the phosphor crystals. The PSP is then scanned using a laser, and the scan converted to electrical signals that are then processed to create a digital image (Fig. 4). PSPs are typically the same size as traditional film, and although they were prone to artifacts as a result of scratching, plates are now available that are scratch-resistant. Poor images can result from improper handling, including over- or under-exposing the PSP or placing it backwards (Fig. 5). As with film, digital intraoral bitewing radiography results in excellent images (Fig. 6).

Digital sensors (Fig. 7) result in nearly immediate image display and reduced radiation exposure when compared to
An Update on Bitewing Radiography Technology

film acquisition. These types of sensors use charge coupled devices (CCDs) or complementary metal oxide semiconductors (CMOS), or they include an active pixel in the CMOS technology and are then referred to as CMOSP. Direct digital acquisition results in images being available on the computer screen for viewing in a matter of seconds. However, care must be taken when placing sensors, as with traditional film, to ensure accurate positioning. Other considerations are that the sensors are rigid and the size of the sensors being used may make them uncomfortable for certain patients. Recent designs for sensors include some that are smaller than earlier versions as well as having rounded edges. These modifications have resulted in greater patient comfort and improved positioning of the sensor (reducing the risk of it being moved by the patient to a more comfortable position). Earlier versions resulted in discomfort relative to traditional film. Bitepieces that fit over the sensor are similar to bitewing tabs and help to hold the sensor in position (Fig. 8). For optimal results, arm and ring positioning devices should also be used (Fig. 9).

Advantages of digital radiography versus traditional film radiography include ease of use (no developing or fixing is required) and potential reductions in radiation exposure, as well as the ability to digitally archive and digitally enhance the images (for example, altering the brightness and contrast to view suspect areas or different anatomical structures).

Diagnostic Accuracy of Intraoral Bitewing Radiography

In general, bitewing radiographs offer low sensitivity for the detection of occlusal caries compared to use of the International Caries Detection and Assessment System (ICDAS) (a visual methodology) and laser fluorescence. In extracted primary molars, Neuhaus et al found that ICDAS

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<td>Underexposure</td>
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<td>Improper handling of sensors/PSP</td>
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<td>Improper handling of film</td>
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<td>Scratching of receptor surface</td>
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<td>Film contamination</td>
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<td>Incorrect film processing</td>
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and laser fluorescence devices offered greater accuracy for occlusal caries detection. In other studies of occlusal caries detection, a bitewing radiograph was found to be less accurate than other methods. Diniz et al studied occlusal caries in permanent molars in an in vivo study, comparing the use of ICDAS, bitewing radiography, laser fluorescence and a fluorescence camera. Histological comparison was used as the gold standard after extraction. Visual inspection (ICDAS) was found to be more accurate than bitewing radiography and the fluorescence camera. Another study using the same detection methods for occlusal surfaces in primary molars found that bitewings offered the highest specificity at the D1 lesion level. However, overall, for the detection of both enamel and dentinal lesions, bitewing radiography offered less specificity and sensitivity than the other methods used. On proximal surfaces in extracted primary molars (n=135), Chawla et al compared caries detection with laser fluorescence, digital radiography and transillumination. Histology sections were used as the gold standard against which specificity and sensitivity were measured. Visual inspection was the most accurate detection method for dentinal lesions and the second most accurate for enamel plus dentinal lesions, while digital radiography was most accurate for dentinal lesions and the second most accurate method for enamel plus dentinal lesions. Transillumination and laser fluorescence were less accurate than either digital radiography or visual inspection. Although visual inspection was found to be the most accurate, these were proximal lesions and in vivo this would be possible only if sufficient spacing was present or if interproximal wedges were used. Bitewing radiographs were found in another study to be more accurate than visual inspection of visible proximal lesions once the lesion reached beyond the outer third of the dentin.

Given that bitewings are primarily indicated for the detection and monitoring of proximal caries in the presence of contact points (ie, where the surfaces are not accessible for visual inspection), the more interesting question is the diagnostic accuracy of intraoral bitewing radiography for the detection of proximal caries.

Proximal Caries Detection with Intraoral Bitewing Radiography

In combination with visual inspection, bitewing radiography has been found to be diagnostically accurate for the detection of proximal caries. Studies have compared the use of faster-speed film versus slower-speed film and the accuracy of traditional film bitewing radiography versus digital intraoral bitewing radiography. In a comparison of proximal caries diagnostic accuracy with traditional X-ray films (Ektaspeed Plus) and digital radiography with a charge-coupled (CMOS) sensor, an assessment by 6 observers of the proximal surfaces of 40 extracted teeth using these techniques led to the conclusion that these techniques were similar, with no statistically significant differences in diagnostic accuracy for the film or low- or high-resolution digital radiographs (P = 0.70). In contrast, in a study comparing the use of E- or F-speed film with digital radiography (CCD) for the detection of proximal caries in the mixed dentition, with 5 pediatric dentists assessing 270 proximal surfaces in extracted teeth (primary canine to first permanent molar), it was found that the diagnostic accuracy of the clinicians, using a 4-point scale, was greater with the use of E- or F-speed film than with digital radiography. However, the accuracy of some of the observers increased the second time they viewed the direct digital images. Comparisons were made with histology sections of all observed teeth to determine the actual versus diagnosed proximal caries. Another study, involving 48 extracted posterior permanent teeth, found no statistically significant differences in the diagnostic accuracy of traditional bitewing film and digital intraoral radiographs for the detection of proximal caries.

Hintze et al assessed the diagnostic accuracy of proximal enamel caries and occlusal dentinal caries detection using D- or E-speed film or digital radiography. The study included 122 proximal surfaces assessed by 3 observers and 65 occlusal surfaces assessed by 2 observers. The evaluations were also compared with histology sections of all sampled teeth. No statistically significant differences were found in the accuracy of any of the methods stud-
ied, although all were found to be of very limited value in detecting proximal enamel caries and of some value in the detection of dentinal occlusal caries. In a study of 56 premolar surfaces, two different E-speed films, two CCD digital radiography brands and two PSP digital radiography brands were compared. No statistically significant differences were found in the diagnostic accuracy of any of the methodologies used.

The diagnostic fidelity of both traditional film and digital radiographic images is influenced by the manner in which these receptors are handled and processed. Artifacts with traditional film include areas on the film that have been scratched, where deposits were present during processing, and due to contamination by developer and fixer. In digital radiography, image processing can result in artifacts that appear to be pathological lesions, as confirmed in a 2011 audience participation test at a specialist radiographic conference. Therefore, regardless of the method used, attention to detail and following a standard protocol are essential.

In summary, overall studies of film and intraoral digital bitewing radiography support the accuracy of both techniques for the detection and monitoring of proximal caries lesions.
Panoramic and Extraoral Panoramic Bitewing Radiography

Traditional panoramic radiography provides an overview of the maxilla and mandible in a two-dimensional image. Panoramic radiography, however, is known to have low diagnostic capabilities for the detection of proximal caries, in part due to the overlapping of proximal surfaces on the radiograph and to decreased resolution when compared to intraoral imaging (Fig. 10). Several studies have been conducted comparing the diagnostic accuracy of extraoral and intraoral radiography.

Akkaya et al conducted an *in vivo* trial with 79 participants and 3 observers, to compare the diagnostic accuracy of panoramic and intraoral full mouth radiographs for the detection of proximal caries throughout the dentition. Receiver operating characteristic curve analysis (ROC) was used to compare accuracy (Fig. 11). The results showed that panoramic radiography was not as diagnostic for the assessment of premolar and molar teeth when compared to intraoral imaging. Supplemental bitewing radiography was required for proximal caries assessment in premolar and molar teeth, and supplemental anterior periapicals were also recommended for complete diagnoses. A full mouth series was comparable to this combination.24

Flint et al assessed the diagnostic yield of intraoral and panoramic radiographs in the detection of dental pathology in 30 Air Force personnel. Panoramic surveys were the least accurate based on the consensus of radiographs by the observing general dentists. Bitewings were required in addition to panoramic survey for diagnostic accuracy with respect to caries.25 A third study also found diagnostic ability to be low for proximal caries detection, whether or not the images were filtered, in comparison to traditional and digital intraoral bitewing radiographs.26

Extraoral Panoramic Bitewing Radiography

Recently, bitewing “images” produced by panoramic machines have been introduced, which involves the use of software programs and in some cases different hardware configurations. This technique offers the production of screening bitewing images for patients who have difficulty tolerating intraoral film, plates, or sensors. These images, while appearing similar to intraoral bitewings, frequently exhibit horizontal overlap of the premolar contacts and often lack the resolution necessary to clearly define the true extent of caries.

### TABLE 2. Panoramic versus intraoral radiographs

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<th>Panoramic radiographs</th>
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<td>Akkaya et al</td>
<td>Panoramic radiographs less diagnostic for posterior teeth than intraoral bitewings</td>
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<td>Supplemental bitewings required</td>
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<td>Flint et al</td>
<td>Panoramic radiographs less accurate than intraoral imaging</td>
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<td>Akarslan et al</td>
<td>Panoramic radiographs have lower caries diagnostic ability than intraoral radiographs</td>
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#### Extraoral ‘bitewings’

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<th>Intraoral bitewings significantly superior to extraoral bitewings or panoramic radiography</th>
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Figure 11. Example of ROC Curve
Diagnostic Accuracy

In a study comparing extraoral bitewing radiography, traditional high-speed film radiography, and panoramic radiography, 80 extracted molar and premolar teeth were evaluated by 3 observers twice for the detection of mesial and distal caries, and the diagnoses compared with gold standard histology sections of the teeth. The assessment of accuracy used the Receiver Operating Characteristics (ROC) test, which considers both sensitivity and specificity curves. No statistically significant differences in accuracy were found between the extraoral bitewings and extraoral panoramic radiographs. Statistically significant differences in diagnostic accuracy were found between intraoral and extraoral bitewing radiographs, with intraoral bitewing radiography found to be significantly superior to the use of extraoral bitewing and panoramic radiography and with similar results found for each observer and between observers. In a second ex vivo study, the accuracy in detecting proximal incipient lesions was compared for intraoral BW using PSP or CMOS, and extraoral BW radiography, and using histological assessment as the reference standard. The highest specificity was observed using extraoral BW and the highest sensitivity using CMOS for intraoral BW. However, no significant differences were found for the diagnostic accuracy of the three techniques. It was also noted that unlike in vivo assessment, ex vivo comparison meant that tight and overlapping contacts were absent, as were positioning errors. Future in vivo studies were recommended. Recently, an in vivo study was conducted to assess the accuracy of extraoral BW for the detection of proximal caries in clearly observable surfaces, using intraoral BW from the same patients as the reference. Extraoral BW were found to result in false positives 38% of the time, which was significantly greater than for intraoral BW, and false negatives 28% of the time. Overlapping contacts were noted in approximately 12% of observable surfaces.

Radiation Exposure

Acquiring clinically justified radiographs also involves consideration of the risks and benefits of radiation exposure. The ALARA (As Low As Reasonably Achievable) principle serves as a guideline to all diagnostic imaging in dentistry.

Methods to reduce exposure to radiation also include using lead aprons during imaging and using rectangular collimation. Lead collars, which protect the thyroid, should also be used, except when taking panoramic radiographs as they obstruct...
taking these radiographs.\textsuperscript{30} Significant reductions in radiation result from these precautions. Acquiring as few radiographs as necessary for diagnosis and only when they are needed, selecting radiograph imaging that results in less exposure to radiation and taking care to use a precise technique to avoid retakes all helps to reduce potential radiation exposure.\textsuperscript{31}

When acquiring intraoral bitewing radiographs, appropriate collimation and filtration of the X-ray beam will reduce exposure to radiation. There are two types of collimation — rectangular and circular. Rectangular collimation reduces the X-ray beam exposure area considerably compared to circular collimation, decreasing scatter (Fig. 12). Reducing scatter will improve image quality, aiding diagnosis and reducing the likelihood of a retake being necessary. Higher-speed traditional bitewing films have reduced the time required to take the radiograph, reducing exposure compared to older, slower-speed (D) films. Automated film processors also help to reduce processing errors and the need for retakes.

With earlier versions of panoramic film radiography versus film bitewings, the reduction in radiation exposure was up to 50%; however, the use of faster-speed films and digital imaging has reduced these differences. Also, although panoramic radiographs result in less radiation exposure than a full-mouth series, for caries detection supplemental bitewing radiographs are necessary to improve caries diagnoses, and extraoral panoramic bitewing radiography is less accurate than intraoral radiography.\textsuperscript{32} Compared to traditional bitewing radiographs, digital bitewing radiography in principle offers a lower radiation dose. Care must be taken to capture images that offer diagnostic ability and to avoid retakes by following sound protocols, and all principles of ALARA should be followed when performing oral radiography.

Conclusion

Radiographic imaging is an integral tool in the assessment and diagnosis of dental caries. The evidence clearly shows that with prudent and careful consideration of its use, intraoral bitewing imaging is still the modality of choice when assessing the presence and extent of caries in proximal tooth structure. While techniques such as panoramic bitewing imaging are being further developed to use in diagnosis, it remains to be seen if the evidence will support its exclusive use for complete diagnoses.

References

3. ibid.

**Webliography**


1. The overall goal of caries detection is to __________.
   a. determine whether caries is present
   b. determine the extent of caries
   c. detect caries at an early stage
   d. all of the above

2. When photostimulable phosphor plates are used for images, their acquisition is __________.
   a. indirect
   b. direct
   c. inferior to traditional film
   d. none of the above

3. Radiography for caries detection and assessment involves the differential __________ of X-rays through hard tooth structure that is sound or partially demineralized.
   a. reflection
   b. attenuation
   c. scattering
   d. refraction

4. High-speed traditional films involve the use of __________ in the emulsion.
   a. modified silver halide crystals
   b. modified silver iodide crystals
   c. modified silver bromide crystals
   d. none of the above

5. Sensitivity refers to the ability of a test to correctly identify when a condition is __________.
   a. present
   b. absent
   c. ameliorating
   d. none of the above

6. Specificity refers to the ability of images to detect __________.
   a. the extent and severity of a lesion
   b. the absence of a lesion
   c. the presence of anomalies
   d. all of the above

7. Intraoral bitewing radiography has been performed since the introduction of X-rays in dentistry, primarily for the detection of __________ lesions.
   a. periapical
   b. proximal carious
   c. occlusal carious
   d. b and c

8. The __________ affects the attenuation of X-rays used for traditional film.
   a. photon energy
   b. thickness of the anatomy and density of the tissue being radiographed
   c. atomic number of the elements in the tissues being radiographed
   d. all of the above

9. The use of positioning instruments and film holders rather than ‘tabs’ results in __________.
   a. standardized positioning of bitewing films
   b. increased accuracy
   c. reduced potential for errors
   d. all of the above

10. Studies have confirmed that the diagnostic accuracy of caries detection with high-speed film is __________ to that of lower-speed films, with no statistically significant differences.
    a. inferior
    b. equivalent
    c. superior
    d. none of the above

11. __________ lesions are the most difficult to detect radiographically.
    a. Dentinal
    b. Advanced
    c. Incipient
    d. Pulpal

12. PSP are __________.
    a. typically the same size as traditional film
    b. now available as plates that are scratch-resistant
    c. prone to chemical contamination
    d. a and b

13. Digital sensors result in __________.
    a. nearly immediate image display
    b. indirect image acquisition
    c. reduced radiation exposure when compared to film acquisition
    d. a and c

14. __________ is an advantage of digital radiography versus traditional film radiography.
    a. Ease of use
    b. Potential reductions in radiation exposure
    c. The ability to digitally archive and enhance images
    d. all of the above

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CE QUIZ

15. ________ can cause an artifact on traditional film images.
   a. Scratches on the film
   b. Deposits on the film
   c. Contamination by fixer and developer
   d. all of the above

16. Proximal caries diagnostic accuracy with traditional high-speed X-ray films and digital radiography with a charge-coupled sensor have overall been found to be ________.
   a. equally accurate diagnostically
   b. inferior to PSP
   c. differentially accurate
   d. none of the above

17. The diagnostic fidelity of traditional film and digital radiographic images is influenced by ________.
   a. the manner in which these receptors are handled and processed
   b. the size of the lesion
   c. the X-ray beam
   d. none of the above

18. Receiver operating characteristic curve analysis is used to compare the ________ of radiography techniques.
   a. images
   b. accuracy
   c. cost
   d. all of the above

19. Panoramic radiography is known to have low diagnostic capabilities for the detection of proximal caries, in part due to the ________.
   a. overlapping of proximal surfaces on the radiograph
   b. size of the film
   c. decreased resolution when compared to intraoral imaging
   d. a and c

20. If using panoramic radiography, ________ are required for proximal caries assessment in premolar and molar teeth.
   a. supplemental periapical radiographs
   b. supplemental bitewing radiographs
   c. supplemental lateral films
   d. all of the above

21. Bitewing images produced by panoramic machines ________.
   a. involve the use of software programs
   b. in some cases involves different hardware configurations
   c. are necessary
   d. a and b

22. Reducing scatter ________.
   a. improves image quality
   b. aids diagnosis
   c. reduces the likelihood of a retake being necessary
   d. all of the above

23. Panoramic bitewing images offer the production of bitewings for patients who have difficulty tolerating ________.
   a. intraoral film
   b. plates
   c. sensors
   d. all of the above

24. ________ is/are a frequent occurrence with panoramic bitewing images.
   a. Horizontal overlap of the premolar contacts
   b. Vertical overlap of the molar contact
   c. Artifacts
   d. all of the above

25. Extraoral BW has as been compared to intraoral BW exclusively in ex vivo studies.
   a. True
   b. False

26. The ALARA principle is related to radiation exposure and stands for ________.
   a. ‘As Low As Reasonably Accessible’
   b. ‘As Low As Reasonably Achievable’
   c. ‘As Light As Reasonably Achievable’
   d. none of the above

27. Lead collars ________.
   a. protect the thyroid
   b. should be used when taking any radiograph
   c. should be used except when taking panoramic radiographs as they obstruct the taking of these radiographs
   d. a and c

28. Using ________ is a method to reduce exposure to radiation.
   a. a lead apron
   b. a lead collar
   c. rectangular collimation
   d. all of the above

29. ________ collimation reduces the X-ray beam exposure area considerably compared to ________ collimation.
   a. Circular; vertical
   b. Circular; rectangular
   c. Rectangular; circular
   d. Rectangular; oblique

30. Compared to ________, ________ in principle offer a lower radiation dose.
   a. digital bitewing radiography; traditional bitewing radiographs
   b. traditional bitewing radiographs; digital bitewing radiography
   c. traditional bitewing radiographs; chest X-rays
   d. none of the above
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**CE ANSWER FORM** (E-mail address required for processing)

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**EDUCATIONAL OBJECTIVES**
- Review the types of oral radiographs used for caries detection;
- Define sensitivity and specificity;
- Contrast and compare the methodology and results for radiographic caries detection; and
- List and describe the methods by which radiation exposure is reduced as well as the relative radiation exposure with different radiographic methodologies for caries detection.

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Please evaluate this course using a scale of 3 to 1, where 3 is excellent and 1 is poor.

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