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Learning Objectives:

Gain understanding of digital system options available for panoramic radiography.

Learn the basic concept behind each approach along with the advantages and disadvantages of each option.

Review points to consider in analyzing options for your practice.

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Digital Options for Panoramic Radiology

By Dr. Allan G. Farman in conjunction with William Jacobs

Digital x-ray imaging is making substantial inroads into the dental practice. The purpose of this article is to provide a succinct overview of current digital options for panoramic dental radiography.

Introduction

The move to panoramic digital radiography in dentistry has been slower than the move toward intraoral digital radiography for a variety of reasons. Every dental practice is different and has unique needs and wants. Before making a decision on digital panoramic radiography, you must weigh carefully your unique operation, the type of practice and patient mix, your staffing, your goals and objectives, the systems available, the overall economics and costs involved, the timing, the state of the technology, and anticipated changes in technology. If you already have a digital intraoral system the move may make sense. If you do not, then maybe going to digital intraoral first is best. Perhaps it is something you want to delay to see how things develop and what new technologies are introduced in the next year or so. Perhaps you wish to take small steps, first incorporating secondary capture using a scanner to help you determine the best long-term approach for your practice. The decision is not an easy one and takes much thought and investigation. This newsletter will address the basics of digital radiography and show the alternative approaches available today.

Digital radiography encompasses all the techniques that produce digital (or computerized) images, as opposed to conventional radiography, which uses x-ray films. The first commercial dental intraoral sensor became available in the U.S. market in 1991. Since that year, a number of different systems have become available, and picking the right system for the job is not an easy task. Systems are different in nature, and comparison is made difficult because physical specifications do not easily translate into day-to-day dental operations.

An image is said to be digital when it is composed of separate (distinct) elements [1,2]. Each element is called a "picture element" or pixel. If an image is displayed on the monitor, and the pixel is smaller than the smallest detail the viewer's eye can see, it is hard to determine that the image is indeed a digital one. If this is not the case, that is the individual pixels can be spotted, the eye views the image as a mosaic of pixels.

Each pixel can only take on a limited number of gray shades. The number of possible gray shades depends on the number of bits (binary digits) that are used to store a pixel. A one-bit pixel can only take two values (0 or 1 - that is black or white). An 8-bit pixel can take any one of 256 (2^8) values. A 16-bit pixel can take more than sixty-five thousand grayscale values (2^{16}). It is generally accepted that the human eye can only distinguish about 20 magnitudes of light intensity, and is certainly unable to discern all 256 gray levels that a standard computer monitor can display. The total number of bits that are used to store an image is the number of pixels times the number of bits per pixel.

There are three methods available to produce digital images. First, it is possible to digitize conventional radiographs through secondary capture using transparency scanners or specialized digital cameras.

" Film scanners and digital cameras can be used to produce a digital image from a film radiograph."

Alternatively, digital images can be produced using storage phosphor plates or with solid-state systems, usually involving use of a charge-coupled device (CCD) comparable to the computer chip found in a digital camera.

Properties essential for digital panoramic radiography include:

- Images of diagnostic quality
- Radiation dose similar or reduced compared to film radiography
- Compatibility with existing panoramic x-ray generators
- Lossless archiving (storage of the full original radiographic image)
- Interoperability of image format so that the patient's information can be conveniently shared when professionally necessary.

Film Disadvantages

The following are some of the key disadvantages to using film radiography:

- Cost of consumables such as film and processing solutions
- Cost of processing equipment and darkroom space
- Time consumption in film processing and processor maintenance
- Processed film images are rarely optimal
- Used processing chemicals are toxic to the environment
- Film radiograph storage and retrieval can be problematic
- Duplicates made from film radiographs are invariably inferior to the original radiograph

Film Advantages

The following are some of the key advantages to using film radiography:

- Low initial cost, especially for manual processing
- Often already in place
- No changes or additional training required
- Known entity — proven output
- Relatively low cost of operation
- Excellent diagnostic clarity possible if exposed and processed optimally
- Widely accepted

Digital X-ray Imaging Disadvantages

The following are some of the key disadvantages of digital radiography:

- Added initial cost for equipment given you are presently using film
- Need for additional computers, monitors, networking and backup storage
- Sensors (both solid-state and phosphor systems) can add $15,000 to $25,000 to the cost of the panoramic system
- Changes in operations, systems and procedures require an investment in time and involve a learning curve
- Not all digital image formats are identical at this moment so interoperability can be problematic both in the same office and when making outside referrals
- Eventual hardware obsolescence

Digital X-ray Imaging Advantages

The following are some of the key advantages of digital radiography:

- Digital x-ray imaging saves time as there is no chemical processing
- Digital images are more consistent in quality for the same reason
- Digital images ease communication with patients
- Digital images are readily stored and retrieved
- Digital radiology opens the way to electronic interchange
- Consultation can be expedited

Fig. 1: Nikon CoolPix™ scanner with transparency adaptor in lid sufficient for extraoral radiograph duplication.

- Digital images allow perfect "clone" duplication and backup
- Post-processing can help optimize the diagnostic yield
- Digital radiology eliminates environmental silver contamination from spent fixer

If I decide to go digital, how do I get into it? What systems are available?

There are two ways to get into digital panoramic radiography; (1) buy a totally new integrated digital system; or (2) use your current panoramic system [3-5].

If you use your current panoramic system, undoubtedly the most economical method, there are three alternatives to look at: (1) Secondary Capture of analog film images using scanners, (2) photostimulable phosphor plates and (3) retrofit (add-on) solid- state systems with digital detectors[6]. TABLE 1.

DIGITAL METHODS

Film scanners and cameras

Film scanners and digital cameras can be used to produce a digital image from a film radiograph. In general, secondary capture is best achieved with a good quality scanner having a radiograph adaptor (i.e. scanning light in the lid to pass light through the radiograph, Fig. 1). Nikon and Epson produce excellent scanners for this purpose with the costs varying from around $600 to $1,500 for a quality system. A sharp black and white photograph setting is preferred. Scanners are preferred to digital cameras as they practically eliminate optical distortion and the reflection from the surface of the radiograph that would otherwise reduce image quality. Film scanners do not change the need to continue making radiographs with x-ray film. They introduce additional time-consuming activity to scan the images, but that is the price you pay to continue to use film radiographs while digitally storing images. No matter how good your film scanner is, scanned images can only be as good as the original film radiographs. The advantage here is that you can scan and archive your existing film files over time and you can also determine if digital panoramic is for you without spending a lot of money in purchasing sophisticated equipment. While Schultz et al (2002) found the sensitivity for detection of low-contrast simulated bone lesions was greater with film than after digitization, the absolute differences were small [7].

Photostimulable phosphor plates

A phosphor plate reader works very much like a film

Table 1: Alternative digital approaches.

EXISTING PANORAMIC GENERATOR
Film Based System

SECONDARY CAPTURE	PHOSPHOR PLATE	ADD ON/ RETROFIT CCD
• Scanner • Digital Camera	• Phosphor Plate • Plate reader/scanner linked to computer	• Sensor replaces film • Sensor linked directly to computer
BENEFITS	**BENEFITS**	**BENEFITS**
• No change to radiography generator or exposure • Try digital out • Low cost • Digitize all file radiographs	• Similar exposure procedures • No machine changes • Easy transition • Can be used with multiple machines	• Directly digital • "Instant" image on screen • Speed • No consumables (film and solutions)
COSTS	**COSTS**	**COSTS**
• Added procedure (time) • Attributes less reliable than with other methods	• Scanning high resolution takes time • Plates expensive and readily damaged	• Initial outlay: ~$20,000 for System • System dedicated to one generator type

PANORAMIC SYSTEM
Integrated Digital

Multiple Systems Available

scanner, except that an imaging plate is used instead of film (Fig. 2 & 3). Such reusable plates can have the same sizes as dental panoramic films. They contain a phosphor layer that "remembers" the image; hence, the name "storage phosphor". To read the image, phosphor plates need to be illuminated by a Helium-Neon laser beam. When a portion of the plate is illuminated, it emits light that is photomultiplied and collected by a digital imaging chip.

Photostimulable phosphor systems dedicated to dentistry are available from a number of manufacturers. Each system is comprised of the phosphor plates and a laser scanner that interfaces with a computer. The plates can be quite expensive, costing $500 to $1,000 each for extraoral purposes. While extraoral plates are not as sensitive to scratching as are the intraoral plates, care must still be taken not to scratch or contaminate them. The plates are very sensitive to ambient light, which can erase much of the latent image. Furthermore, they need extensive exposure to light in order to completely erase the image before reuse. On the other hand, storage phosphor systems are versatile in that they can be used with a wide range of different x-ray systems.

Solid-state digital x-ray detectors are based on a silicon chip that permits the acquisition of an image. Such a chip consists of a myriad of pixels; each pixel captures a small quantity of energy (usually light from a scintillator) and converts this radiant energy into electricity. For panoramic radiography, this generally involves a charge-coupled device (CCD) of sufficient dimensions to cover the secondary slit of the panoramic machine (i.e. tall and narrow). The CCD converts radiant photons into electrons. The ability of the current detectors to capture radiant energy is presently limited to visible photon capture. So x-ray photons need to be converted to visible photons for an image to be captured by the system. This is done by a scintillator layer, similar to the scintillators that are used as intensifying screens in analog film panoramic radiography (Fig. 4). An example of one of the earliest commercialized digital panoramic systems was that of the Trophy Digipan adaptor for the Instrumentarium OP 100 (Fig. 5A).

As with analog film, the panoramic image is pieced together during the scan. Unlike analog film radiography, the receptor is stationary and the image for each segment is read-out in appropriate sequence. Solid-state systems are available both to retrofit an existing panoramic system and as integrated units dedicated to a specific panoramic x-ray generator (Table 1). A potential concern with retrofitting a unit is that if something does go wrong you may find yourself working with the manufacturer of the panoramic system, the manufacturer of the retrofit system and the installer.

Fig. 2A: Air Techniques (Hicksville, NY) ScanX™ phosphor plate laser scanner.

Fig. 2B: DenOptix™ (Dentsply/ Gendex, Des Plaines, IL) laser scanner with phosphor plate attached to drum ready for processing.

Fig. 2C: Loading a phosphor plate into a soft cassette.

Radiation Dose

Unlike intraoral radiology, the switch to digital panoramic imaging

" Storage phosphor systems (photostimulable phosphors) specific to dentistry are available from a number of different manufacturers."

Fig. 2D: Orex's Paxorama Xi™ works with existing X-ray and phosphor plate.

does not generally result in a substantial dose reduction to the patient. In fact it is sometimes necessary to actually increase dosage to optimize image quality when using digital systems [6].

With intraoral film radiography, the emulsion is directly sensitive to x-rays, so adding a scintillating screen can improve the efficiency with which x-rays are detected. However, for extraoral radiography, an intensifying screen is generally employed – and this is not so very different from the scintillating layer used with solid-state detectors. Gijbels et al (2001) found no difference in exposure settings or organ doses between analog film and indirect digital panoramic radiography using photostimulable phosphor plates [9].

Costs

Determining the true cost of system ownership is not an easy matter. Certainly the basic expenditure on the system is easily measured. However, one also needs to factor in possible savings in terms of consumables such as film and processing solutions, the possible value of time-savings, or of the increased time used. Even more difficult to determine is the diagnostic gain or loss.

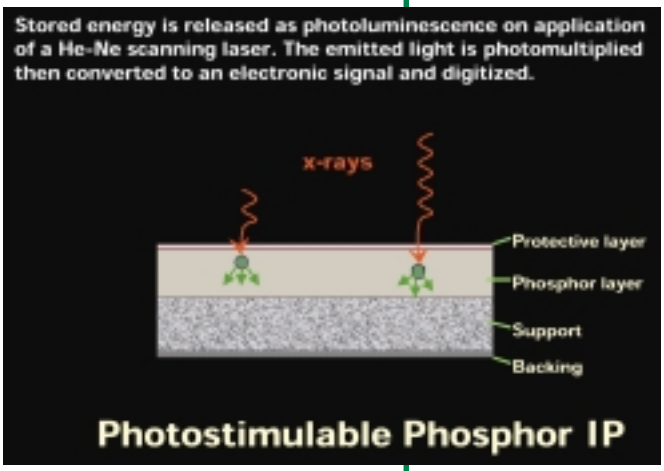

Fig. 3: Imaging using storage phosphor plate.

A good quality scanner will cost between $600 and $1,500 and can be used for general scanning purposes beyond radiographs. The system can be attached to the practice management computer, and many practice management software packages include modules for the capturing and storage of secondary images. This is certainly an inexpensive way to become familiar with digital images — and it also replaces the need to use duplicating film and a duplicator to create duplicates. Such a system could be worthwhile in any dental office regardless of whether or not other digital methods are also to be incorporated. Furthermore, a scanner allows you to incorporate prior radiographic images into the electronic patient record. Problems with relying on scanning are (1) this does not remove the darkroom issues that often lead to suboptimal analog radiographs, and (2) scanning is an added task for your assistants to perform; time for which you are not being additionally reimbursed.

Storage phosphor systems (photostimulable phosphors) specific to dentistry are available from a number of different manufacturers. In most cases the cost of the basic package is roughly $20,000 — but that price can escalate if you purchase multiple extraoral phosphor plates at as much as $1,000 each. In most instances, the plate cassette is loaded and unloaded manually. Without using caution, this can lead to wear of the expensive plates — and also can lead to suboptimal images through the effects of ambient lighting on exposed plates being loaded into the scanner. Further, processing of extraoral plates in medium to high resolution can be quite time consuming — no big time savings, if any, over film processing. The advantage of such a system is that the images are stored digitally in computer memory and can be easily duplicated for safe storage and retrieval. Moreover, a single storage phosphor processor can be used with multiple x-ray generators.

Retrofit solid-state digital panoramic imagers have the advantage of providing a virtually instant image on the screen – so if you are in a high

" There are several excellent dedicated digital panoramic systems on the market, however, the costs of such systems range from $25,000 to $60,000 depending on the degree of sophistication desired."

volume practice or have other reasons for needing immediate images, these are an excellent alternative (Fig. 5; Table 1). They can provide most, if not all, of the digital capabilities of the integrated digital units without the cost of buying a new machine. Retrofit systems generally cost around $20,000. If you have a relatively inexpensive panoramic system and do not utilize it to a substantial degree, then this added cost might not be warranted given your business situation.

There are several excellent dedicated digital panoramic systems on the market (Fig. 6; Table 1), however, the costs of such systems range from $25,000 to $60,000 depending on the degree of sophistication desired. To select such a unit requires a careful assessment of your practice and an individualized cost-benefit analysis. It should be remembered that reimbursements per panoramic procedure are not generally proportional to your investment. Whatever device you select should fit with the type of practice and patients you serve.

Interoperability

It is not unusual to review film radiographs that are decades old – especially when demonstrating "classical" radiographic features of disease entities at a continuing education forum [10]. Archived film images that are decades old are usually still of high quality and can be viewed by anyone who happens to have a view box to transmit light through the radiographs. One might question whether the digitized versions will be as readily accessible as the analog film versions decades into the future. The likelihood of being able to retrieve digital images is dependent upon both hardware and software/file format considerations. Regarding hardware issues, one simply needs to back up all files on new media as they become accepted. For example, you cannot play music from an old record directly using a tape player or 8-track – and you cannot play a music tape on a CD or MP3 player. Similarly, it is now difficult to find a computer with a 5.25" floppy disk drive and standard "A" drives are rapidly disappearing to be replaced by CD-R, DVD-R, Flash Memory and USB-Mass Storage Devices. If you intend to use digital images then you should expect to make periodic storage hardware upgrades.

Regarding the matter of software/file format interoperability, the digital x-ray industry and practice management system vendors are presently working together to facilitate digital image interoperability using specifications from the DICOM (Digital Image Communication) standards that were developed initially for medical radiology. This specification includes image format rules and associated information for transmission of radiographs used in dentistry including intraoral surveys and panoramic images. Working Group 12.1 of the American Dental Association has been tasked with developing appropriate specifications. It must be cautioned, however, that no guidelines or specifications will guarantee interoperability.

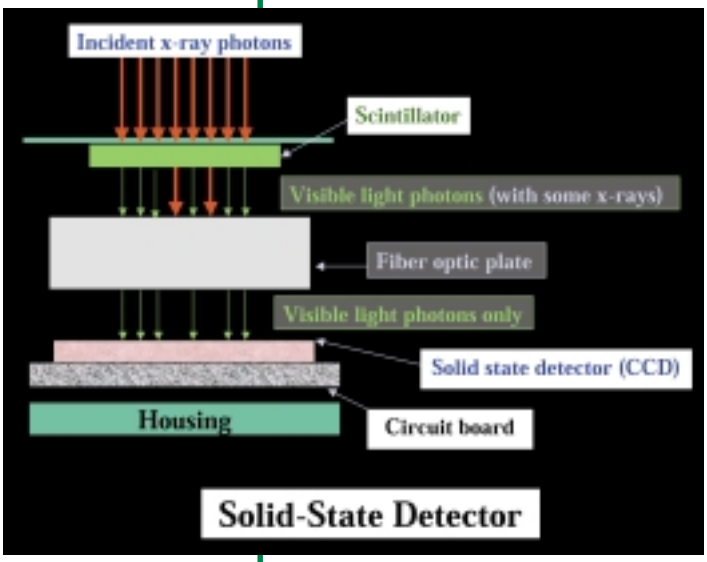

Fig. 4: Schematic representation of a solid-state detector.

Fig. 5A: One of the earliest commercialized digital panoramics was the Trophy Digipan™ used with the Instrumentarium OP 100™ panoramic system in place of the film cassette. A variety of "add-on" systems from several different vendor sources are now available for most panoramic systems.

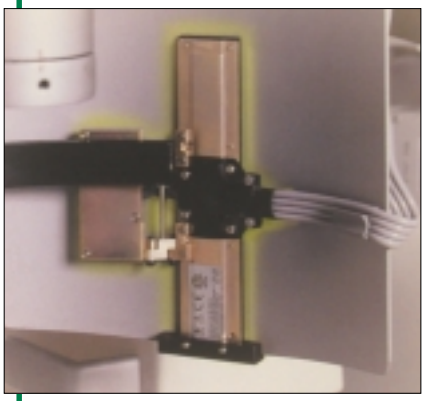

Fig. 5B: Schick CDRPan™ (Long Island City, NY) digital retrofits are available for a number of panoramic systems including the Panoramic Corporation PC-1000™.

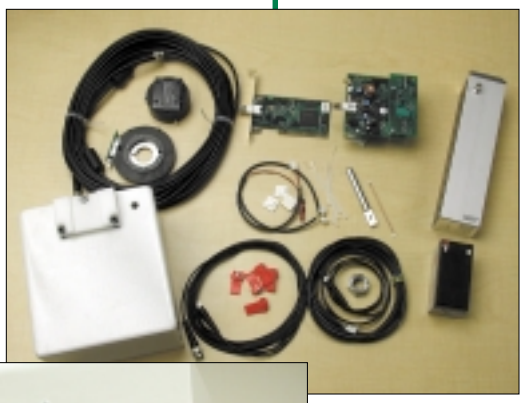

Fig 5C: Components of the DXIS® (Direct X-ray Imaging System).

Fig. 5D: DXIS® system installed on a Panoramic Corporation PC-1000.

Interoperability needs to be demonstrated practically. Such practical demonstrations were initiated at the ADA Annual Congress in New Orleans in 2002 where 10 companies demonstrated that interoperability of their image files could be achieved satisfactorily. Interoperability within the DICOM standards is important so that the dentist can integrate data from different digital sources and read diagnostic images referred from outside sources where different systems may have been used. Otherwise there could be inconvenience both for the patient and for the practitioner.

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Fig. 6A: An example of a dedicated solid-state digital panoramic system is the Instrumentarium OP 100-D™ (Tuusula, Finland).

Fig. 6B: Another dedicated solid-state panoramic system is the TrophyPan™ (PracticeWorks/Trophy, Atlanta, GA).

In The Recent Literature:

Dosage: It is possible to reduce radiation dose by substituting solid-state imaging devices for analog film during panoramic radiography; however, dose savings from solid-state panoramic imagers are not as large as found when changing to digital imaging for intraoral radiography.

Visser H, Hermann KP, Bredemeier S, Kohler B. Dose measurements comparing conventional and digital panoramic radiography. Mund Kiefer Gesichtschir 2000;4:213-216. [From the Abteilung Parodontologie, Georg-August-Universitat Gottingen, Germany.]

This study measured and compared patient exposure by digital and conventional panoramic radiography. Dose measurements were carried out on an anthropomorphic phantom, which was specially developed for dental radiography. Panoramic radiographs were taken with three different conventional devices and two solid-state digital devices The exposure conditions followed clinical routine. The energy dose was measured at 28 places inside and on the surface of the phantom by using a set of 108 thermoluminescence detectors. Additionally, exposure time, tube voltage, central-beam dose, and dose-area products were measured. The effective doses were calculated on the basis of the absorbed doses. In each case, the highest energy doses were recorded at the parotid gland, the mandibular angle, the submandibular gland, and the skin in the neck. Panoramic radiographs made with the conventional units yielded effective doses in the range of 16-21 µ Sv, the digital units yielded 5-14 µ Sv. Hence, in comparison with conventional techniques, patient exposure was reduced by solid-state digital panoramic radiography. The extent of dose reduction depended on the device employed and was generally smaller than the dose reduction that can be achieved by digital imaging devices in intraoral radiography.

Third molar assessment: Digital panoramic radiography proved equal to film imaging for assessing unerupted third molar teeth.

Benediktsdottir IS, Hintze H, Petersen JK, Wenzel A. Accuracy of digital and film panoramic radiographs for assessment of position and morphology of mandibular third molars and prevalence of dental anomalies and pathologies. Dentomaxillofac Radiol. 2003;32:109-115. [From Department of Oral Radiology, Royal Dental College, Faculty of Health Sciences, University of Aarhus, Denmark.]

This study compared the accuracy of digital and film panoramic radiographs for determining (1) the position and shape of mandibular third molars before surgical removal and (2) the prevalence of dental anomalies and pathologies. Three hundred and eighty-eight third mandibular molars were available for examination. Position and morphology of third molars observed on film radiographs and on digital panoramic images from five different systems were recorded by two observers and were compared with surgeons' findings at the time of the operation. One observer further recorded the prevalence of dental anomalies and pathologies on both imaging modalities. Few differences were found between the digital and film-based panoramic systems in the assessment of accuracy of position and morphology of mandibular third molars. The prevalence of dental anomalies and pathologies determined with the two modalities was similar. The five digital panoramic systems evaluated in this study were evaluated to be equally as useful for third molar treatment planning and diagnosis of dental anomalies and pathologies as conventional film-based panoramic radiographs.

Soft versus hard copy: Digital panoramic images were judged to have better quality when viewed on the computer monitor than when printed; however, diagnostic utility was found to be comparable when it came to viewing anatomic features.

Guerrant GH, Moore WS, Murchison DF. Diagnostic utility of thermal printed panographs compared with corresponding computer monitor images. Gen Dent 2001;49:190-196. [From the Wilford Hall USAF Medical Center, Lackland AFB, Texas, USA.]

Digital panoramic radiographs can be either viewed on computer monitors or archived as thermal or laser prints. To compare the available diagnostic information from thermal print images to that of corresponding computer monitor images, four calibrated evaluators performed a qualitative analysis of 13 specified anatomic features in 60 pairs of digital panoramic images presented in random order on a computer monitor and as thermal printed images. Each anatomic site was rated both for subjective diagnostic quality and diagnostic utility using a nominal scale. Computer monitor images more often were subjectively judged to have better quality. Within the parameters of this study, both formats had acceptable diagnostic utility for the majority of the anatomic features evaluated.

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CE TEST: Digital Options for Panoramic Radiology

1. Duplicate images of digital radiographs made with charge-coupled devices or photostimulable phosphors are inferior to the original image.
   ☐ True ☐ False

2. Digital imaging systems not utilizing analog film are environmentally friendly.
   ☐ True ☐ False

3. Solid-state digital technologies include photostimulable phosphor plates.
   ☐ True ☐ False

4. Digital panoramic radiographs generally require a reduced dosage in comparison with traditional film/screen radiography.
   ☐ True ☐ False

5. Strict adherence to DICOM file formats is a guarantee of interoperability between different digital systems used in dentistry.
   ☐ True ☐ False

6. Hardware upgrades in storage devices are likely to be needed periodically to preserve the availability of digital images.
   ☐ True ☐ False

7. Scanning, generally using a He-Ne laser, is necessary to process the latent image when using photostimulable phosphors for panoramic radiography.
   ☐ True ☐ False

8. Achievement of digital imaging using an existing panoramic unit is possible using secondary capture, phosphor plate or retrofit (add-on) solid-state systems.
   ☐ True ☐ False

9. For digital panoramic radiography using a solid-state system, the solid-state sensor moves in a similar manner to analog film during the exposure.
   ☐ True ☐ False

10. Gijbels et al (2001) found a substantial difference in exposure settings and organ doses between analog film and indirect digital panoramic radiography using photostimulable phosphor plates.
    ☐ True ☐ False

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