

# Digital Imaging in Dentistry: Intraoral, Extraoral, and 3D Technology



**Course Author(s):** Connie M. Kracher, PhD, MSD

**CE Credits:** 2 hours

**Intended Audience:** Dentists, Dental Hygienists, Dental Assistants, Office Managers, Dental Students, Dental Hygiene Students, Dental Assistant Students

**Date Course Online:** 07/31/2017

**Last Revision Date:** 08/26/2021

**Course Expiration Date:** 08/25/2024

**Cost:** Free

**Method:** Self-instructional

**AGD Subject Code(s):** 731

**Online Course:** [www.dentalcare.com/en-us/professional-education/ce-courses/ce512](http://www.dentalcare.com/en-us/professional-education/ce-courses/ce512)

**Disclaimers:**

- P&G is providing these resource materials to dental professionals. We do not own this content nor are we responsible for any material herein.
- Participants must always be aware of the hazards of using limited knowledge in integrating new techniques or procedures into their practice. Only sound evidence-based dentistry should be used in patient therapy.

**Conflict of Interest Disclosure Statement**

- Dr. Kracher reports no conflicts of interest associated with this course. She has no relevant financial relationships to disclose.

**Introduction**

The primary objective of this course is to increase your general knowledge of digital imaging and the latest advances in digital technology.

## Course Contents

- Overview
- Learning Objectives
- Introduction
- Digital Imaging Basics
- Digital Image Receptor – Analog to Digital Converter
- Computer Hardware, Software, and Printer
- Digital Receptor Holding Devices
- Intraoral Digital Imaging Procedures
- Infection Control with Digital Imaging
- Characteristics of Digital Imaging Detectors
- Advantages of Intraoral Digital Imaging
- Disadvantages of Intraoral Digital Imaging
- Two-dimensional Extraoral Digital Imaging
- Three-dimensional Extraoral Digital Imaging
- Digital Applications in Orthodontics
- Digital Applications in Endodontics
- Digital Applications in Periodontics and Dental Implants
- Digital Applications in Diagnosing Temporomandibular Joint Disorders
- Conclusion
- Course Test
- References / Additional Resources
- About the Author

## Overview

Digital imaging was first introduced to the dental profession in the late 1980s. Since that time technology has evolved, allowing new types of imaging, e.g., cone-beam computed tomography to become more common in all areas of dentistry. Digital imaging is reliable and consistent, providing dental providers with more radiographic options to diagnose disease, anomalies, and other conditions.

## Learning Objectives

**Upon completion of this course, the dental professional should be able to:**

- Define digital imaging key terms.
- Discuss the fundamentals of digital imaging.
- Contrast radiation exposure to patients with digital imaging and film radiographs.
- Describe the digital imaging equipment.
- Describe the advantages and disadvantages of digital imaging.

## Introduction

When a dental practice decides to move from radiographic film to digital imaging, there are many variables to consider for the dental

practice. The primary objective of this course is to increase your general knowledge of digital imaging, latest advances in digital technology, as well as discuss tips, and advantages and disadvantages of digital imaging.

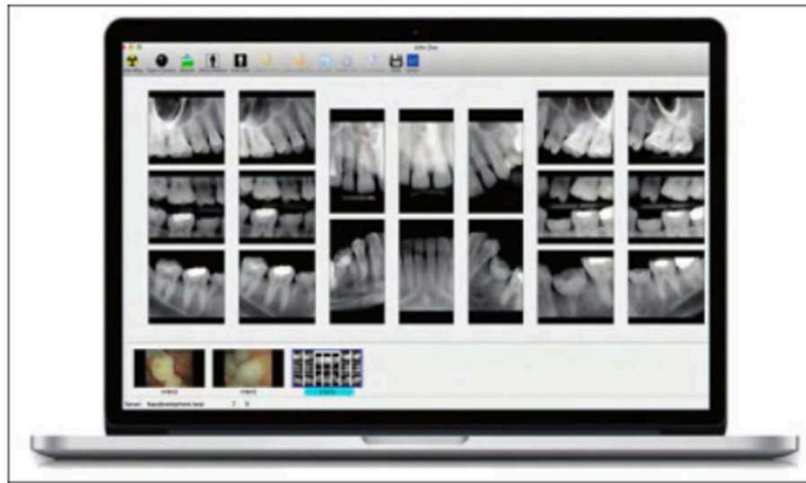
## Digital Imaging Basics

The production of digital images requires a process called Analog to Digital Conversion (ADC). Digital imaging is a radiographic technique that utilizes a wired or wireless hard sensor or phosphor plate sensors known as a receptor, instead of film. Digital images consist of pixels organized in a matrix of rows and columns. ADC consists of two steps: sampling and quantization. Sampling is a small range of voltage values that are grouped together as a single value. Once sampled, every sampled signal is assigned a value. For the dental provider to see the digital images, the computer must organize the pixels in their correct locations and display shades of gray that corresponds to the number that was assigned. This step is known as quantization.<sup>5</sup>

In digital imaging, the x-ray machine is still used, but the image is converted from analog to digital. When the photons from the x-ray tubehead strike the sensor, the analog image is converted to a digital image and then transferred to the digital imaging software (Figure 1). The digital images are composed of pixels or rows and columns of images aligned to represent the intensity (gray level) of the image. There is a value assigned to each pixel that represents the intensity or gray level of each location in the image.<sup>9</sup> The computer software organizes the pixels and displays the dentistry of the object via multiple shades of gray. Due to pixel technology in digital sensors, anatomy such as bone trabeculation, lamina dura, and DEJ are easier to diagnose due to high contrast in digital imaging.

## Digital Imaging Radiation Exposure

Even though digital imaging requires less radiation than radiographic film, radiation is still produced at the source, e.g., dental x-ray machine. Digital imaging reduces the amount of radiation to the patient due to the sensitivity of the digital imaging sensors. Depending on the radiographic film used in the dental practice, e.g., D- or F-speed, radiation



**Figure 1. Digital Full-mouth Series Displayed on a Laptop Computer.**  
Image Source: Suni Medical Imaging, Inc., San Jose, CA.

exposure time can be reduced as much as 90% when changing from radiographic film to digital sensors.<sup>1,5,6,7</sup> For example, an exposure time required to produce a digital image is 0.05 seconds, where a radiographic film would require an exposure time of 0.2 seconds. Standard radiation safety procedures still requires the dental provider be at least 6 feet from the x-ray tubehead and the patient be covered in a lead apron with a thyroid collar.

### Digital Imaging Equipment

Digital imaging requires an x-ray unit, sensors to capture the images, computer hardware and software to view, store, and transfer images, and if an indirect digital system, a scanning device.

### X-ray Unit

A standard intraoral dental x-ray machine (Figure 2) may be used with radiographic film and digital imaging. However, the control panel must use exposure time in 1/100 of a second and not impulses.<sup>5</sup> If the control panel cannot be converted to exposure time, the x-ray machine cannot be used with digital imaging. Contact your dental representative to see if your current x-ray machine can be used with a digital imaging system.

### Digital Image Receptor – Analog to Digital Converter

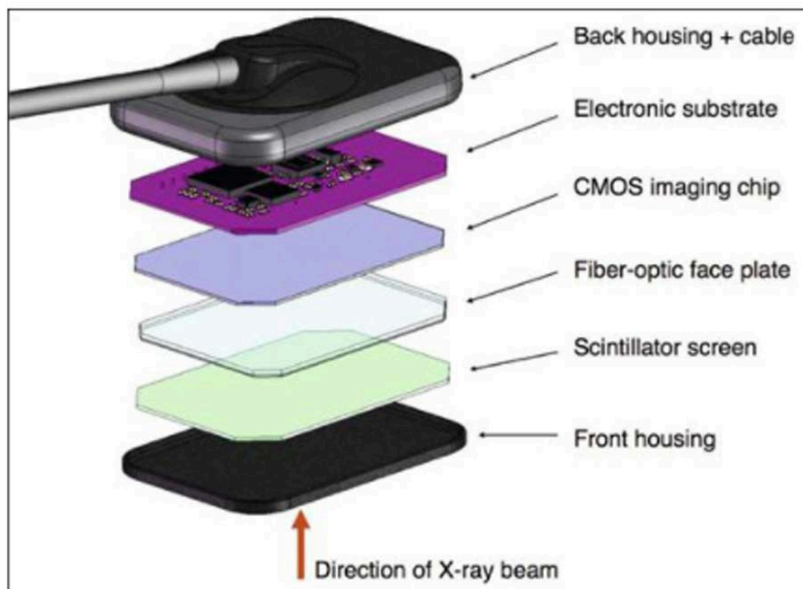
Sensors are the receptors for the digital image, instead of using traditional x-ray film. There are



**Figure 2. Intraoral X-ray Machine.**  
Image Source: Gendex Dental Systems, Hatfield, PA.

two types of digital image receptors or sensors. They include direct solid-state (Figure 3) and indirect photo-stimulable phosphor plates (PSP) that are similar to flexible radiographic film (Figure 4). The solid-state technology uses different semi-conductor-based detectors 1) CCD, 2) CMOS, and 3) flat panel.<sup>5,9</sup>

The solid-state intraoral receptors contain a charge-coupled device (CCD) with an electronic circuit inside the digital sensor (Figure 5). The



**Figure 3.** Components of a Direct Solid State Sensor.

Image Source: XDR Radiology, Los Angeles, CA.



**Figure 4.** Different Sizes of Indirect PSP Sensors.

Image Source: Gendex Dental Systems, Hatfield, PA.



**Figure 5.** Intraoral X-ray Machine.

Image Source: Gendex Dental Systems, Hatfield, PA.

silicon chip detector converts x-ray photons into an electrical charge. The electrons produced are deposited into small boxes called pixels. The pixels are the equivalent of silver halide crystals in traditional film. Pixels provide multiple shades of gray to allow better contrast than traditional x-ray film. When dental students and faculty at the University of Texas School of Dentistry at Houston evaluated the image quality and technical accuracy with photostimulable phosphor (PSP) plate and charge-coupled device (CCD), they found a significant difference in image quality

and technical accuracy, especially angulation with the photostimulable plates than with the charge-coupled device.<sup>11</sup>

The complimentary metal-oxide semiconductor imaging chip (CMOS) is sensitive to light and provides small details in the x-ray image by isolating each pixel from its neighboring pixels. Similar to CCD, electron hole pairs are generated within the pixels in relation to the amount of x-ray energy that is absorbed. This charge is transferred to the transistor as small voltage. The scintillator screen inside

the sensor is made of materials such as cesium iodide converting radiation into visible light and guides the light through a micro-columnar structure. Fiber optics transmit the light to the surface sensor allowing a high signal-to-noise ratio resulting in detailed images. The CMOS provides higher visible resolution, higher contrast and lower noise, diagnoses is enhanced. Some manufacturers can display 16,000 shades of gray using a 14-bit analog-to-digital converter, allowing more variation in densities that can be seen by the dental provider. CMOS also provides an enhanced quantum efficiency, allowing more consistent images within a range of exposure settings. This dynamic range provides a broad range of exposures, since quality assurance can be an issue with digital imaging. The enhanced quantum efficiency of some sensors can compensate for radiation variances with exposure times. The CMOS technology has been used since the 1960s in many consumer products such as digital cameras, video cameras, fax machines, microscopes, and telescopes.<sup>1,5,6,7,9</sup>

Flat panel detectors are used with medical imaging and extraoral imaging units. The photoconductor is made of selenium for more efficient x-ray absorption. The intensifying screens consist of an amorphous silicon photodiode circuitry layer and a semi-conductor device called a thin film transistor (TFT). When x-ray photons reach the scintillator, visible light is emitted and then recorded by an array of photodiodes and converted to electrical charges. The detectors provide large matrix areas with smaller pixel sizes allowing for direct digital imaging of larger areas of the body. Flat panel detectors have the advantage of a short exposure time of 10 seconds or less. Their disadvantage is their large size that cannot be used intraorally.<sup>5,9</sup>

Solid-state sensors have a fiber optic cable or wireless sensor that are powered by batteries and transmits data via radio waves. These options allow for toggling between hardwired USB and wireless WiFi, where staff can move between treatment rooms without carrying the detector sensors with the fiber optic cables. Manufacturers offer multiple fiber optic cable lengths, depending on the size of the dental

practice treatment rooms (Figure 6). This type of imaging is called direct digital imaging, as the hard sensors do not require scanners.

### Computer Hardware, Software, and Printer

With digital imaging, the dental practice will need computers in the treatment rooms. Depending on the dental practice software being utilized, a digital imaging software might be able to be added to the current system. However, it is important to work with your sales representative to see if the digital system you would like to purchase is compatible with your current dental practice software. There are options to “bridge” one company’s dental practice software with another company’s digital imaging system. However, it’s important for the practice to investigate all options before investing in a digital imaging system. Figures 7-9 show three different types of indirect digital imaging systems. It’s always preferable to transmit digital images electronically. However, not all dental practices and third parties are able to transmit digital images. There will still be a need for hard copies when providing digital images. It’s recommended the dental practice work with their digital imaging manufacturer to find a printing system that is compatible with the digital software to provide the best copies possible with the imaging software and printer.



**Figure 6.** Different Sizes of Direct Solid-State Sensors.  
Image Source: Schick by Sirona, Sirona Dental, Inc., Long Island City, NY.





**Figure 7.** Indirect Photo-stimulable Phosphor Imaging System.

Image Source: Carestream Dental, LLC, Atlanta, GA.



**Figure 8.** Indirect Photo-stimulable Phosphor Imaging System.

Image Source: Henry Schein Air Techniques, Inc., Melville, NY.



**Figure 9.** Indirect Photo-stimulable Phosphor Imaging System.

Image Source: Gendex Dental Systems, Hatfield, PA.



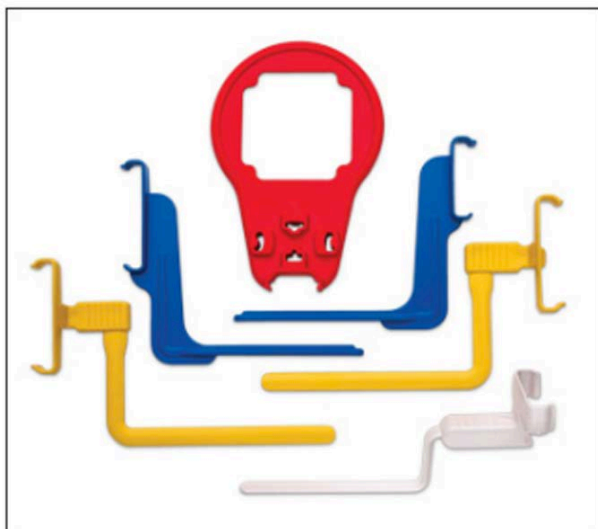
**Figure 10.** Different Types of Digital Imaging Receptors.

Image Source: Prof. Willie Leeuw, MS; Brandy Spaulding, MS; Sarah Pulver, MS; Indiana University, Fort Wayne, IN.

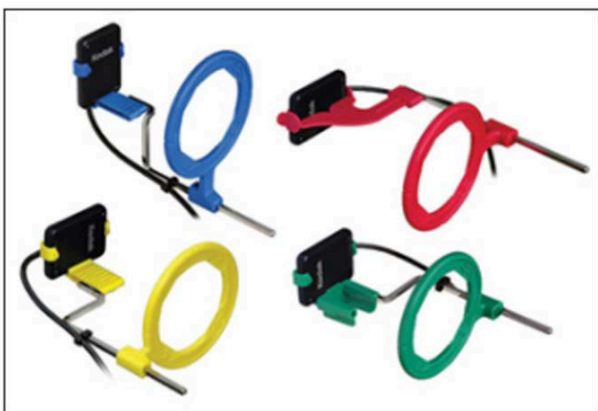
### Digital Receptor Holding Devices

Direct hard sensor receptor holders are similar to film holders, but require the dental practice to purchase special digital sensor receptor holding devices. With PSP sensors, film holders and bite-wing receptors can be used for periapical and bite-wing images. There are many different types of receptor holders available (Figure 10). It is recommended when the dental practice decides to purchase a digital imaging system they consult with

their colleagues as to what they use in their dental practices. The dental practice can then try other types of receptor holders in the future when they attend exhibits at state and national meetings (Figures 11-13). It is also recommended the dental practice schedule in-office trainings with the dental team beyond what is provided by the manufacturer, to ensure clinical providers are competent in trouble-shooting digital imaging issues.



**Figure 11. Direct Digital Imaging Receptor.**  
Image Source: Schick by Sirona, Sirona Dental, Inc., Long Island City, NY.



**Figure 12. Direct Digital Imaging Receptors.**  
Image Source: Dentsply International, York, PA.



**Figure 13. Close-up View of a Direct Universal Digital Imaging Sensor Receptor with Elastic Bands.**  
Image Source: Dentsply International, York, PA.

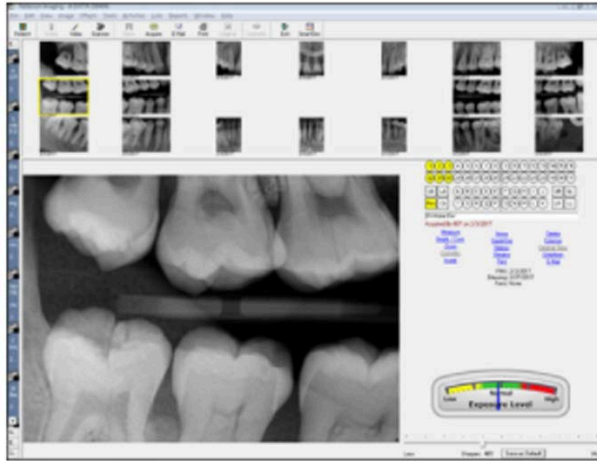
The dental practice may wish to purchase a radiology tooth model from a national dental educational sales manufacturer to allow clinical providers to practice.

### Intraoral Digital Imaging Procedures

Step-by-step digital imaging procedures vary by manufacturer. As with all aspects of dentistry, quality assurance is also vital with digital imaging. The National Council on Radiation Protection and Measurements Report 145 indicates there must be a written protocol for dental offices for their image receptor systems.<sup>7</sup> One research study found that many dental offices were using incorrect exposure settings resulting in lower diagnostic capabilities and higher radiation dosage.<sup>8</sup> Despite proper care and handling of PSP plates, loss in spatial resolution may occur. To reduce PSP plate deterioration resulting in surface damage and contamination, PSP plates should be handled carefully and cleaned according to manufacturer instructions.<sup>2</sup>

It is strongly recommended that the dental practice schedule more than one in-office training with clinical dental providers on the computer hardware and software, and the digital imaging equipment. The dental practice might need more time with the trainer than what is part of the digital image package pricing. The key to any practice is efficiency of time and energy for both the dentist and their staff. The more that clinical staff can troubleshoot digital imaging techniques, the more time they can dedicate to other dental practice treatment.

The sequencing of how the clinical provider exposes bite-wing and periapical digital imaging can be the same as traditional films. However, the dental manufacturer representative who sets up your digital imaging system will discuss the number of digital images you wish to use for full-mouth series and bite-wing series, as well as sequencing to see what you prefer (Figure 14). These in-office trainings, without radiation, allow staff to troubleshoot placement with different receptors in each other's mouths. Figures 15-18 show the clinical provider using different autoclavable direct sensor receptors. Note the plastic barrier over the fiber optic cable.



**Figure 14. Digital Full-mouth Series.**  
Image Source: Dentsply International, York, PA.



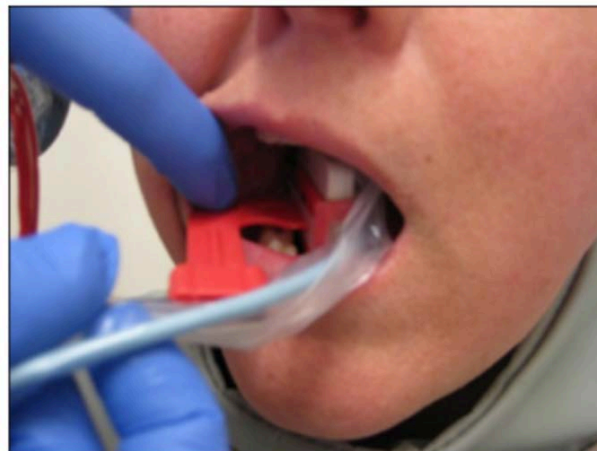
**Figure 15. Bite-wing Direct Digital Imaging.**  
Image Source: Prof. Willie Leeuw, MS; Brandy Spaulding, MS; Sarah Pulver, MS; Indiana University, Fort Wayne, IN.



**Figure 16. Posterior Periapical Direct Digital Imaging.**  
Image Source: Prof. Willie Leeuw, MS; Brandy Spaulding, MS; Sarah Pulver, MS; Indiana University, Fort Wayne, IN.



**Figure 17. Anterior Periapical Direct Digital Imaging.**  
Image Source: Prof. Willie Leeuw, MS; Brandy Spaulding, MS; Sarah Pulver, MS; Indiana University, Fort Wayne, IN.



**Figure 18. Bite-wing Direct Digital Imaging.**  
Image Source: Prof. Willie Leeuw, MS; Brandy Spaulding, MS; Sarah Pulver, MS; Indiana University, Fort Wayne, IN.

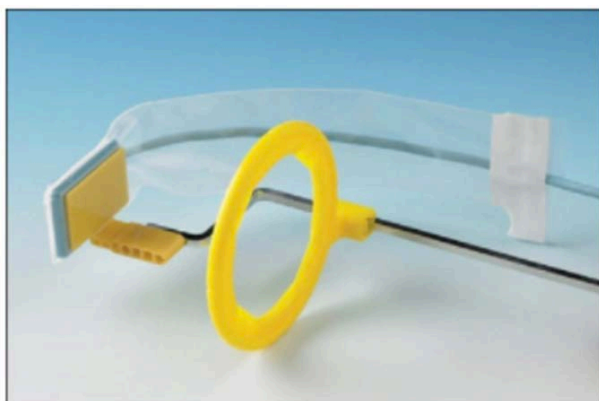


## Infection Control with Digital Imaging

As with any type of radiology imaging, infection control methods should be utilized to not cross contaminate when exposing images. With digital imaging, barriers must be placed on the sensors. Sensors cannot be sterilized. There are many types of plastic barriers available for indirect phosphor plate and hard sensors used in direct digital imaging. The wired direct sensors will need barriers over the fiber optic cables and hard sensor. The direct wireless sensor will also need a barrier (Figures 19-22). Many of the digital image receptors are autoclavable. There are also some digital receptors that are autoclavable, but have disposable intraoral components (Figure 23). It's recommended you talk to your dental sales representative and your colleagues as to what they recommend with your type of digital imaging system, as well as finding samples at regional and national dental conferences to try out. When working with phosphor plates, each sensor must be wrapped in a plastic barrier envelope to protect the sensor from saliva (Figure 24). If the sensor becomes contaminated, check manufacturer instructions to see how the sensors can be disinfected. If contaminated, the CDC recommends an EPA-registered intermediate-level disinfectant after removing the barrier and before using the sensor on the next patient.

## Characteristics of Digital Imaging Detectors

Contrast resolution is an important characteristic in analog and digital imaging. The ability to differentiate amongst densities is



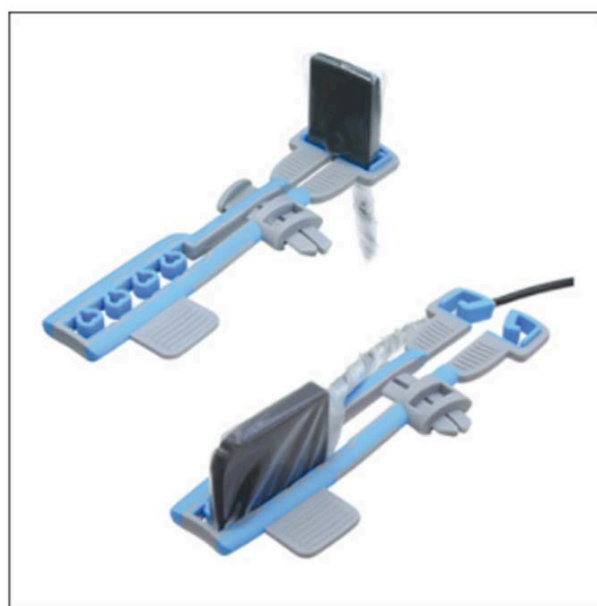
**Figure 19.** Autoclavable Digital Receptor with Barrier Covering Sensor and Cable.

Image Source: Schick by Sirona, Sirona Dental, Inc., Long Island City, NY.



**Figure 20.** Autoclavable Digital Receptor with Barrier.

Image Source: Clik Ray, Clik Tech, LLC, Scottsdale, AZ.



**Figure 21.** Autoclavable Digital Receptor with Sensor Barriers.

Image Source: Dentsply International, York, PA.



**Figure 22.** Autoclavable Digital Receptor with Sensor Barriers.

Image Source: Schick by Sirona, Sirona Dental, Inc., Long Island City, NY.



**Figure 23.** Autoclavable Digital Receptor with Disposable Intraoral Component.

Image Source: Dentsply International, York, PA.

vital for the dentist when diagnosing diseases and conditions. Current digital detectors capture data from 8-16 bits. The bit depth is at a power of 2. This means that the detectors can capture 256 (28) or higher of gray levels. A high contrast-to-noise ratio provides the closely spaced gray values needed for higher contrast when diagnosing diseases and conditions. Current computer monitors can detect 242 levels of gray, and the human eye can detect about 60 gray levels (Figure 25). The level of ambient light in the treatment rooms do not affect digital image viewing compared to conventional radiographs on a view box.<sup>5,9</sup> One recent research study found a degradation in spatial resolution after the same PSP plates had been used 48 times. This finding is important, as PSP plates have been shown to have low spatial resolution compared to other intraoral imaging receptors.<sup>2</sup>

Spatial resolution provides the fine detail needed to view an image. Resolution can be measured in units of line pairs per mm. At least two columns of pixels are required for the line pairs to create light and dark spaces. Some of the newer solid-state sensors have excellent resolution that is helpful in diagnosing incipient lesions. Although the sensors are



**Figure 24.** Indirect Photo-stimulable Phosphor Plates with Disposable Barrier Envelopes.

Image Source: Henry Schein Air Techniques, Inc., Melville, NY.



**Figure 25.** Digital Imaging Hardware and Software.

Image Source: Carestream Dental, LLC, Atlanta, GA.

thicker than other manufacturers, the contrast is exceptional. The loss of spatial resolution with PSP plates is determined by the construction of the plate and the physical design and laser scanner settings.<sup>5,9</sup> Signs of malfunction of the laser scanner include lines across the image due to scanner belt slippage or photomultiplier tube malfunction, inconsistent shading and enlarged window display if the size 2 image due to photomultiplier tube filter malfunction. Several research studies have indicated replacing PSP plates after 50-60 uses. Some of the primary reasons to replace PSP plates are the presence of scratches on the plates and loss of spatial resolution. The use of aluminum step wedges and contrast wells in research studies was helpful in determining contrast changes.<sup>2</sup>

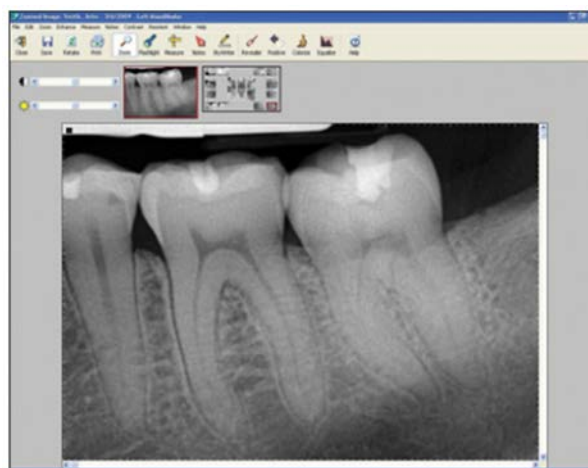
Image enhancement is used to view digital images. For example, digital systems can magnify images four times the original size to diagnose dental diseases and conditions. Many digital systems software includes a measurement tool for endodontic or dental implant therapies. Some of the digital systems provide split screen technology allowing the dental provider the ability to compare multiple images together and color for contrast during diagnoses.

### Advantages of Intraoral Digital Imaging

**Image Quality** – there is diagnostic value with enhanced gray-scale resolution. Digital imaging uses up to 256 shades of gray compared to radiographic film that shows only 16-25 shades of gray. This allows for better detection of disease, e.g., incipient lesions due to enhanced contrast that can be manipulated, along with density by the dental radiographer (Figure 26). The provider can also change the color of the image to highlight anatomic features, brightness and contrast adjustments, image filters, geometric correction, image reconstruction, and measure morphology (Figure 26). Due to potential legal issues, manufacturers include a warning feature that appears if the enhanced image does not match the original image. It is recommended copies of the original images be stored on the computer or network server.<sup>12</sup>

**Time Savings and Patient Experience** – with hard sensor digital images, the time from exposing the sensor to radiation and viewing digital images is decreased. As soon as the x-ray machine exposure button is pressed, the digital image appears on the computer screen when the dental provider walks back into the room. This immediate viewing assists the dental provider with retakes, if applicable, and also helps the provider in educating their patient as they discuss the images displayed on the computer screen, instead of a view box.

**Patient Safety** – sensor detector sensitivity to radiation requires less exposure time and therefore less radiation to patients. Depending on the radiographic film used in the dental practice, e.g., F-speed, radiation exposure time



**Figure 26. Magnified Digital Image for Diagnoses.**  
Image Source: Schick by Sirona, Sirona Dental, Inc., Long Island City, NY.

can be reduced approximately significantly when changing from radiographic film to digital PSP sensors. PSP sensors do require more radiation than solid-state sensors. However, the amount of exposure to radiation is less with PSP sensors than with radiographic film. Due to the ease of retaking digital imaging, the dental practice is strongly encouraged to plan more than one in-office training with the manufacturer's trainer or local professionals who could provide training sessions with your staff. The time dedicated to troubleshooting different digital receptors will benefit everyone, including less time retaking digital images.

**Environment** – elimination of radiographic supplies, such as radiographic film and processing solutions. Digital imaging is also beneficial to reduce hazardous waste materials, such as lead foil and silver salts.

### Disadvantages of Intraoral Digital Imaging

**Costs**<sup>5</sup> – the initial costs associated with digital equipment is one major disadvantage with dental practices. To purchase the computer hardware and software, and the digital imaging sensors can be costly. And just like dental equipment there is maintenance, repairs, software updates, and equipment replacement that must be considered when changing from radiographic film to digital imaging. Just as it is with radiographic film, digital imaging will require providers to think about asepsis or

infection control when they're taking images. The practice will need to purchase disposable barriers to be placed over phosphor plates and hard sensors, as the sensors cannot be sterilized. Phosphor plates can be reused a number of times before they need to be replaced. plates can obscure the image not allowing the dentist to make a thorough diagnoses.

**Patient Comfort**<sup>5</sup> – direct sensors are hard and not flexible like film. They can be rather thick, depending on the manufacturer. However, some of the hard sensors on the market have excellent contrast and density, allowing for enhanced diagnoses of incipient lesions. In fact, just in the last few years the diagnostic value has increased considerably due to increased technology of hard sensors. However, patient comfort and limited positioning of the sensor intraorally due to patient anatomy, is one disadvantage that prohibits some dental practices from considering purchasing hard sensors. With all types of digital sensors, training will be needed to show dental providers how to place sensors to allow for the most coverage of anatomy.

**Medico-legal**<sup>5</sup> – concerns regarding manipulating images has been addressed by manufacturers. Dental software has warning features if the enhanced image does not match the original image. It is recommended copies of the original images be stored on the computer or network server. Researchers in the area of

fraudulent digital dental records recommend digital content have attached metadata. In forensic dentistry metadata and watermarking be added to discourage tampering documents.<sup>3,5</sup>

## Two-dimensional Extraoral Digital Imaging

There are many digital panoramic and cephalometric imaging systems available. As with intraoral digital imaging, extraoral digital imaging requires less radiation to the patient. Current panoramic digital imaging technology has improved by expanding the focal trough and narrowing collimation, allowing better anterior image quality compared to the traditional panoramic imaging (Figures 27-28). Two-dimensional digital systems provide detailed panoramic and cephalometric images, including sectional imaging of specific areas of the patient. Most 2D imaging software provides an implant planning library, length and angle measurements, calibrated measurements based on reference markers, text annotation, and freehand and shape drawing for patient education.

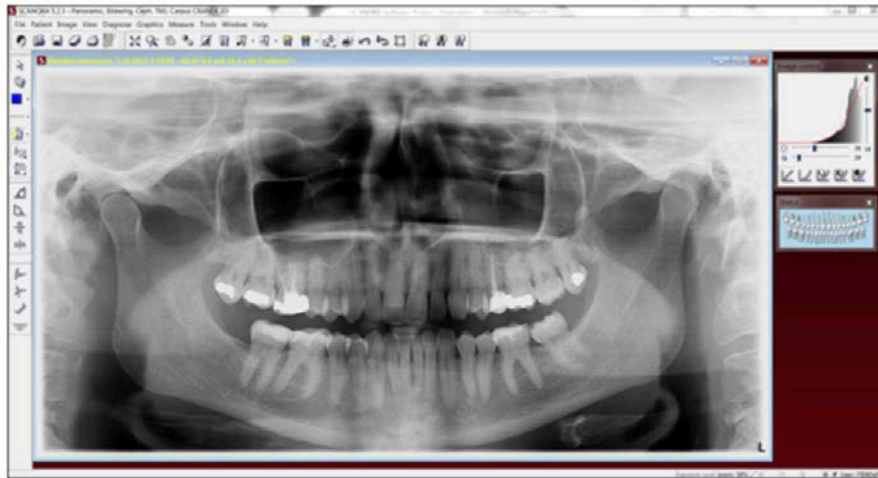
## Three-dimensional Extraoral Digital Imaging

The advances in Cone Beam Computed Tomography (CBCT) allowing three-dimensional digital imaging in the last decade is impressive. General and specialty dental practices certainly benefit from a 3D digital system that includes panoramic, cephalometric, and Cone Beam imaging programs (Figures 29-30). When



**Figure 27. Digital Panoramic Image.**  
Image Source: Carestream Dental, LLC, Atlanta, GA.





**Figure 28. Digital Panoramic Image.**

Image Source: Sordex, Kavo Kerr Group Powai, Mumbai.



**Figure 29. 3D Digital Imaging Software.**

Image Source: Sordex, Kavo Kerr Group Powai, Mumbai.

choosing a CBCT system diagnostic need is the priority. The most important parameters are the scan field size or field of view (FOV), scan time with voxel-size, mA or beam intensity, and the potential of the kVp.<sup>10</sup>

The digital panoramic images are clear and detailed. With the new technology, dental providers can take partial panoramic views of a certain area, instead of a full panoramic image. Imaging system options include TMJ and sinus views, endodontics, dental and bone fractures,

impacted teeth, abnormal anatomy, measuring bone dimensions for dental implants, and cleft palate assessment.

### Digital Applications in Orthodontics

Orthodontic and pediatric dental practices can benefit from digital cephalometric imaging, allowing full width lateral, posterior anterior, and reduced width lateral views. The detail from digital imaging also allows for cephalometric hard and soft tissue tracing by exporting DICOM files into specialized software



**Figure 30. 3D Digital Imaging System.**

Image Source: Schick by Sirona, Sirona Dental, Inc., Long Island City, NY.

programs for treatment planning. As with other forms of radiation, clinicians need to identify radiology equipment that produces quality images, but also has a lower dosage of radiation. With the CBCT clinicians can choose a unit with a smaller field of view (FOV), thereby reducing the amount of radiation.<sup>13-14</sup>

### Digital Applications in Endodontics

Dental practices that perform endodontic treatment can also benefit from digital imaging including pre-, working, and post-imaging diagnoses. As we know, endodontic radiographs can be challenging.<sup>4</sup> In endodontics a CBCT also acquires a small FOV with a small voxel size, resulting in higher resolution and less radiation. There has been a long-standing belief that lesions are difficult to diagnose radiographically when they are in cancellous bone. Researchers at Texas A&M College of Dentistry examined periradicular lesions in periapical digital radiographs and found high inter-reliability when examining the lesions confined to cancellous bone (97.6%, 94.1%, 91.6%, 89.3%).<sup>13,15</sup> Considering a recent research study of U.S. postdoctoral endodontic programs showed that student CBCT-educational experiences varied widely amongst

programs and residents were less confident about interpreting CBCT images, we concur with the researchers that educational efforts with CBCT instruction should be expanded in resident endodontic programs.<sup>16</sup>

### Digital Applications in Periodontics and Dental Implants

The American Academy of Periodontics (AAP) best evidence review supports the use of CBCT-derived implant surgical guides. However, one recent study of all postdoctoral periodontal programs showed that all specialty programs in the U.S. had CBCT equipment in their clinics. However, only 14% of students used a surgical guide fabricated with a CBCT scan for dental implant cases.<sup>17-18</sup>

### Digital Applications in Diagnosing Temporomandibular Joint Disorders

When examining osseous structures such as the long axis of the mandibular condyle, researchers recommend computer tomography (CT) or cone-beam computed tomography (CBCT). At the workstation digital images can be temporarily manipulated using DICOM-viewing software when examining sagittal oblique and coronal oblique planes.

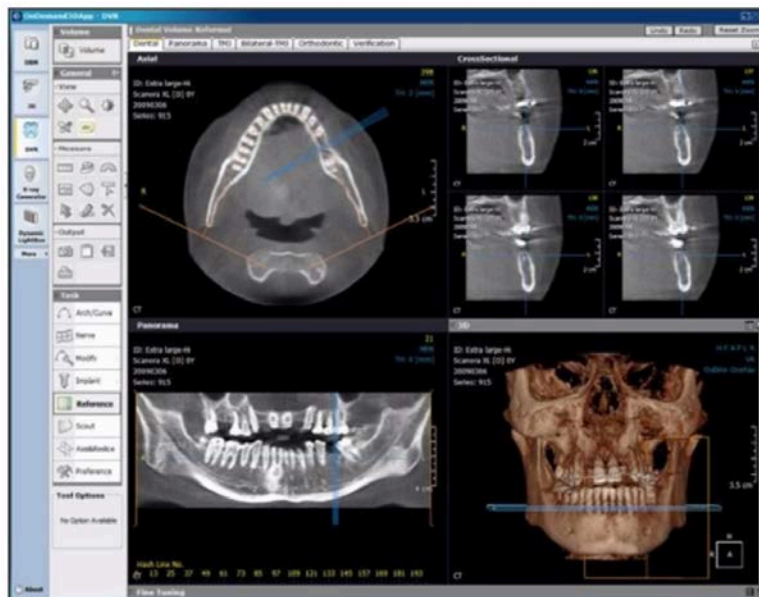
With soft tissues Tamimi et al recommends magnetic resonance imaging (MRI), as this type of imaging can ensure the images capture the correct spatial relationship of the disc to the condyle and fossa. MRI also provides a more accurate diagnoses with the direction of displacement (rotational or sideways).<sup>19</sup> As with intraoral digital imaging, extraoral digital imaging requires less radiation to the patient, compared with medical computed tomography (CT). Scanning time is approximately 8-10 seconds. This is also helpful for cancer patients who have been exposed to medical therapy radiation (Figures 31-33).

With 3D digital imaging, the results are detailed and can be enhanced with digital imaging software for region-of-interest (ROI) magnification and equalization. Dental practices that place dental implants will also have access to an extensive implant library from manufacturers. Some disadvantages with CBCT include the cost of the equipment, lack of training in interpreting structures outside what dental providers were taught with two-

dimensional digital imaging, and mistakes with dental providers not including a field of view (FOV) wide enough to diagnose diseases and conditions.<sup>2,5,9</sup>

## Conclusion

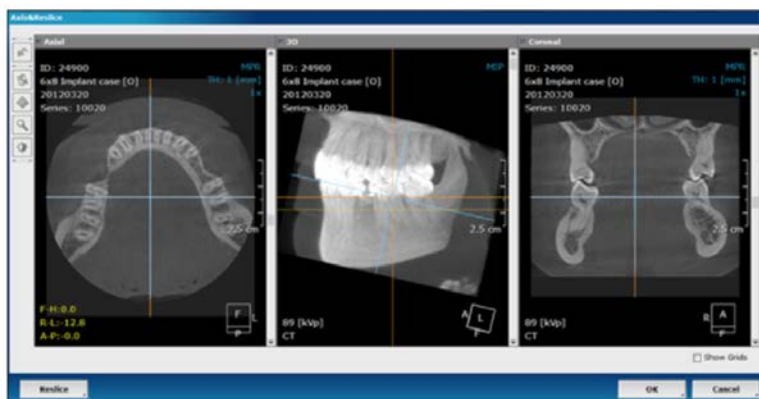
Digital imaging has become more popular in dental offices due to several factors, including less radiation to patients, less equipment and supplies to purchase in the future and, most importantly, the gray-scale resolution that is vital in diagnosing diseases and conditions. As with any equipment purchase, dentists need to decide what type of digital system works best with their practice. Since hardware and software digital systems are expensive, consulting with colleagues about their digital systems will help dentists and their staff learn more about various digital imaging systems before they invest in a specific digital imaging system. Digital imaging systems are reliable and consistent, providing dentists and their staff with more radiographic options to diagnose disease, anomalies, and other conditions.



**Figure 31. 3D Imaging for Diagnoses.**  
Image Source: Sordex, Kavo Kerr Group Powai, Mumbai.



**Figure 32. 3D Imaging for Diagnoses.**  
Image Source: Sordex, Kavo Kerr Group Powai, Mumbai.



**Figure 33. 3D Dental Implant Treatment Planning.**  
Image Source: Sordex, Kavo Kerr Group Powai, Mumbai.



## Course Test Preview

To receive Continuing Education credit for this course, you must complete the online test. Please go to: [www.dentalcare.com/en-us/professional-education/ce-courses/ce512/test](http://www.dentalcare.com/en-us/professional-education/ce-courses/ce512/test)

- 1. The production of digital images requires a process called Analog to Digital Conversion. Digital images consist of pixels organized in a matrix of rows and columns.**
  - A. Both statements are true.
  - B. The first statement is true. The second statement is false.
  - C. The first statement is false. The second statement is true.
  - D. Both statements are false.
- 2. Depending on the radiographic film used in the dental practice, radiation exposure time can be reduced as much as \_\_\_\_% when changing from radiographic film to digital sensors.**
  - A. 10
  - B. 50
  - C. 75
  - D. 90
- 3. Digital imaging reduces the amount of radiation to the patient due to the sensitivity of the sensors.**
  - A. True
  - B. False
- 4. The digital images are composed of pixels or rows and columns of images aligned to represent the intensity (gray level) of the image. There is a value assigned to each pixel that represents the intensity or gray level of each location in the image.**
  - A. Both statements are true.
  - B. The first statement is true. The second statement is false.
  - C. The first statement is false. The second statement is true.
  - D. Both statements are false.
- 5. Standard radiation safety procedures still require the dental provider be at least \_\_\_\_\_ from the x-ray tubehead and the patient be covered in a lead apron with a thyroid collar.**
  - A. 1 foot
  - B. 3 feet
  - C. 6 feet
  - D. 12 feet
- 6. The silicon chip detector converts x-ray photons into an electrical charge. The electrons produced are deposited into small boxes called \_\_\_\_\_.**
  - A. transistors
  - B. voxels
  - C. semiconductor
  - D. pixels

7. **Despite proper care and handling of PSP plates, loss in spatial resolution may occur. To reduce PSP plate deterioration resulting in surface damage and contamination, PSP plates should be handled carefully and cleaned according to manufacturer instructions.**  
A. Both statements are true.  
B. The first statement is true. The second statement is false.  
C. The first statement is false. The second statement is true.  
D. Both statements are false.
8. **If contaminated, the CDC recommends an EPA-registered \_\_\_\_\_ disinfectant after removing the barrier and before using the sensor on the next patient.**  
A. low-level  
B. intermediate-level  
C. high-level  
D. advanced-level
9. **With digital imaging, barriers must be placed on the sensors. Sensors cannot be sterilized.**  
A. Both statements are true.  
B. The first statement is true. The second statement is false.  
C. The first statement is false. The second statement is true.  
D. Both statements are false.
10. **One recent research study found a degradation in spatial resolution after the same PSP plates had been used \_\_\_\_\_ times.**  
A. 11  
B. 48  
C. 78  
D. 98
11. **Signs of malfunction of the laser scanner include lines across the image due to \_\_\_\_\_.**  
A. scanner belt slippage  
B. photomultiplier tube malfunction  
C. vacuum seal enhancement  
D. Both A and B
12. **Some of the primary reasons to replace PSP plates are \_\_\_\_\_.**  
A. scratches on the plates  
B. loss of spatial resolution  
C. there is no reason to replace PSP plates  
D. A and B only
13. **Digital imaging uses up to \_\_\_\_\_ shades of gray compared radiographic film that shows only 16-25 shades of gray. This allows for better detection of disease.**  
A. 56  
B. 99  
C. 199  
D. 256

**14. What is one primary advantage with digital imaging?**

- A. Image quality
- B. Cost
- C. Patient comfort
- D. Medico-legal

**15. What is one disadvantage of with digital imaging?**

- A. Time
- B. Patient comfort
- C. Spatial resolution
- D. Image quality

## References

1. American College of Radiology. Radiation Dose in X-ray and CT Exams. Radiologyinfo.org. Accessed August 18, 2021.
2. Buchanan A, Benton B, Carraway A, et al. Perception Versus Reality-Findings From a Phosphor Plate Quality Assurance Study. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2017 Apr;123(4):496-501. doi: 10.1016/j.oooo.2016.12.004. Epub 2016 Dec 24.
3. Chowdhry A, Sircar K, Popli DB, et al. Image Manipulation: Fraudulence in Digital Dental Records: Study and Review. *J Forensic Dent Sci*. 2014 Jan;6(1):31-5. doi: 10.4103/0975-1475.127767.
4. U.S. Food and Drug Administration. Dental Cone-Beam Computed Tomography. Accessed August 18, 2021.
5. Iannucci JM, Howerton LJ. *Dental Radiography: Principles and Techniques*, 5th Ed. St. Louis, MO. Elsevier. 2017.
6. National Council on Radiation Protection and Measurements. Report No. 172 - Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States. 2012. Accessed August 18, 2021.
7. National Council on Radiation Protection and Measurements. Report No. 145 - Radiation Protection in Dentistry. 2003. Accessed August 18, 2021.
8. Walker TF, Mah P, Dove SB, et al. Digital Intraoral Radiographic Quality Assurance and control in private practice. *Gen Dent*. 2014 Sep-Oct;62(5):22-9.
9. White SC, Pharoah MJ. *Oral radiology: Principles and Interpretation*, 7th Ed. St Louis, MO. Mosby. 2014.
10. Vandenberghe B. The Crucial Role of Imaging in Digital Dentistry. *Dent Mater*. 2020 May;36(5):581-591. doi: 10.1016/j.dental.2020.03.001
11. Zhang W et al. Comparison of Efficiency and Image Quality of Photostimulable Phosphor Plate and Charge-Coupled Device Receptors in Dental Radiography. *J Dent Educ*. 2019 Oct;83(10):1205-1212. doi: 10.21815/JDE.019.120
12. Yoon DC, et al. Digital Radiographic Image Processing and Analysis. *Dent Clin N Am*. 2018;62:341-359.
13. Flint DJ, Ruiz Velasco RC. Cone-Beam Computed Tomography (CBCT) Applications in Dentistry dentalcare.com CE531. 2017 Jan.
14. Abdelkarim A. Cone-Beam Computed Tomography in Orthodontics. *Dent J*. 2019 Sep;7(3):89. doi: 10.3390/dj7030089.
15. Chang L et al. Periradicular Lesions in Cancellous Bone can be Detected Radiographically. *J Endod*. 2020 Apr;46(4):496-501. doi: 10.1016/j.joen.2019.12.013
16. Rabiee, H et al. Endodontics Program Directors', Residents', and Endodontists' Considerations About CBCT-Related Graduate Education. *J Dent Educ*. 2018 Sep;82(9):989-999.
17. Beals DW et al. CBCT in Advanced Dental Education: A Survey of U.S. Postdoctoral Periodontics Programs. *J Dent Educ*. 2020 Mar;84(3):301-307.
18. Rios, HF et al. The Use of Cone-Beam Tomography in Management of Patients Requiring Dental Implants: An American Academy of Periodontology Best Evidence Review. *J Periodontol*. 2017 Oct;88(10):946-959.
19. Tamimi D. et al. Temporomandibular Joint Imaging. *Radiol Clin N Am*. 2018 Jan;56(1):157-175. doi: 10.1016/j.rcl.2017.08.011

## Additional Resources

- No Additional Resources Available



## About the Author

### Connie M. Kracher, PhD, MSD



Dr. Kracher is an Associate Professor of Biology and Director of University Research and Innovation at Purdue University Fort Wayne. Dr. Kracher is a national Key Opinion Leader (KOL) for several R&Ds, consultant for national dental organizations, and has presented for the American Dental Association, American Dental Education Association, and the World Dental Federation. Dr. Kracher is a member of several professional organizations, including the American Association of Dental Research.

Email: [kracher@ipfw.edu](mailto:kracher@ipfw.edu)