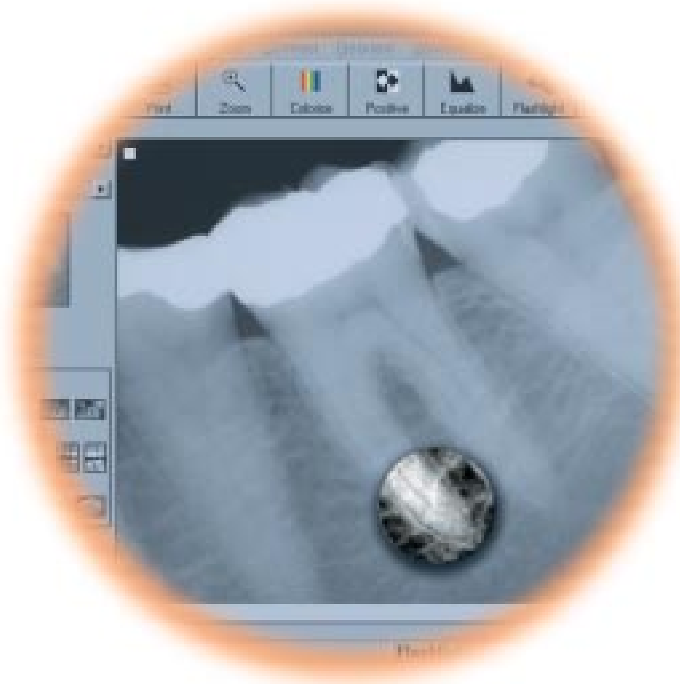
Making sense of sensors
A guide to choosing digital radiography sensors

By Dr. Larry Emmott

The heart of a digital radiography system is the sensor, and choosing the right one for your practice is not only costly but can be confusing. Digital radiography sensors come in three types: the CCD (charge-coupled device), the CMOS (complementary metal-oxide semiconductor) with active pixel sensors (APS), and the PSP (photostimulable phosphor plate). There are many issues to consider when examining sensors, including the resolution the device delivers, materials the sensor chip is made from, and physical size and comfort of the sensor when it is placed in the mouth.

This month's report, which includes details about sensors from Dr. Dale A. Miles, a leading educator in the field of digital radiography, takes a look at four key elements of digital radiography sensors, namely:

1. Types of sensors
2. Resolution
3. Ease of use
4. Interoperability



CCD
CHARGED-COUPLE DEVICE

CMOS/APS
COMPLEMENTARY METAL-OXIDE SEMICONDUCTOR WITH ACTIVE PIXEL SENSORS

PSP
PHOTOSTIMULABLE PHOSPHOR PLATE

"Any of the three sensor types — CCD, CMOS, or PSP — will produce an acceptable digital x-ray image. They will all increase your diagnostic efficiency."

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Digital radiography is to film-based radiography as word processing is to typing. The advantages of digital radiography over conventional film are so powerful, every dental office should be going digital. In the years to come, an x-ray developer will be seen as a quaint relic similar to an IBM Selectric typewriter. So what's holding things up? In my opinion, it is the cost of the systems coupled with uncertainty. Dentists want to go digital, but they are afraid of making an expensive mistake.

There are two parts to any digital radiography system. First is the sensor: the device that takes the place of the film packet and actually captures the image. The second part of the system is the software that stores, retrieves, displays, and enhances the image.

When most dentists examine a digital radiography product at a trade show, all they are really seeing is the software. This is important. However, the sensor is the heart of the system, and sensors are much harder to compare.

In the last few years, we have been subjected to what I call the "Sensor Wars." Vendors are touting various sensors and are trying to compare resolution. They are comparing sensors to film. They are promoting different chip materials, different sensor sizes, various capture systems, and an array of pixel sizes. It is confusing. What really matters and what doesn't?

What follows is a look at four important elements to consider when choosing a digital radiography sensor: types of sensors, resolution, ease of use, and interoperability. The purpose here is not steer you to any individual type or brand of sensor, but to help familiarize you with the distinctive characteristics of each family of sensors and how they all can be used to deliver diagnostic-quality digital images.

1. Types of sensors

There are two distinct types of sensors: corded sensors, which capture and digitize the image directly, and non-corded or wireless sensors, which capture the image indirectly, and then digitize it with a scanner.

The corded sensors look like chubby black film packs with a cord attached. The wireless sensors look more like the typical white film packs we are accustomed to using. Here are more details on corded and wireless sensors.

Corded sensors (CCD, CMOS/APS)

The corded sensors have a computer chip receptor embedded in them. Currently, corded sensors use either of two types of chips: CCD (charged-couple device) chips or CMOS (complementary metal-oxide semiconductor) chips with active pixel sensors (APS).

These chips are not solely found in digital radiography sensors. Digital cameras for consumers have image sensors based on either CCDs or CMOS, as well.

As you talk with system vendors or perhaps read the scientific literature on the relative merits of both CCD and CMOS/APS sensors, you'll find there is much debate comparing and contrasting these technologies.

Few experts believe that one of these two technologies will displace the other. Rather, both technologies have a future. Still, there are significant differences in cost and other aspects of these two sensor families.

What's the difference between these two chips when applied to dental digital radiography sensors? Many of the details that follow come from Dr. Dale A. Miles, who has many years of experience with digital radiography and lectures extensively on the topic.

CCD receptors have been used in radiography for many years. The silicon chip embedded into CCD sensors is sensitive to x-rays or light. The x-ray photons that come into contact with the CCD cause electrons to be released from the silicon and produce a corresponding electronic charge. When x-rays activate electrons and produce such electronic charges, an electronic latent image is produced; the latent image is then transmitted and stored in a computer and can be converted to a visible image on a computer monitor.[1]

CMOS-based sensors have been introduced more recently for use in radiography, but this technology has been around about as long as that of CCD sensors—more than 30 years. In the early years, CMOS sensors were more expensive to develop than CCD sensors and lacked the same image-production quality, leading CCD sensors to become the product of choice in many high-resolution applications.

In the early 1990s, however, NASA's Jet Propulsion Laboratory introduced a second-generation CMOS solid-state sensor dubbed the active pixel sensor (APS). This new-generation sensor was cheaper to produce than the CCD, reduced power consumption, and delivered improved image resolution and greater durability.

No doubt, the debate over the merits of CCD vs. CMOS will continue in many industries that use imaging, not just dentistry.

Wireless sensors (PSP)

The wireless sensor is made from a plastic plate coated with a phosphor material sensitive to x-rays. The plate is called a PSP (photostimulable phosphor plate).

The PSP sensor is exposed to an x-ray, which creates a latent image, stored on the plate. This image is then digitized with a special scanner. A plate must then be cleared by light exposure for several minutes before it can be used again.

2. Resolution

This is probably the area most often debated in the "Sensor Wars." Every company wants to claim that their product has the best resolution, or is the most like film. What do these claims mean, and what really matters?

The fact is that a digital radiograph contains much more information, or data, than we can see. The trick is turning that data into useful diagnostic information. After all, the real question should not be, "What's the best resolution I can get?" Rather, it should be, "What's the most diagnostic information I can get using this digital radiography system?"

That being said, here are a couple of terms used to measure resolution:

Line pairs per millimeter (lp/mm)

The most common measure of resolution is line pairs per millimeter (lp/mm). This refers to the ability of the sensor to distinguish between very small lines placed together.

Obviously, the higher the number of line pairs, the greater the detail and the resolution. Companies claim current sensors have a resolution of anywhere from six to 22 lp/mm. The higher numbers are actually better than film.

However, the unaided human eye can only distinguish about eight to 10 lp/mm. Does that mean that any resolution greater than 10 lp/mm doesn't matter? There is no clear answer.

Clinical research indicates that all of the current digital x-ray systems use sensors capable of capturing a diagnostically acceptable image. On the other hand, image processing, using software-enhancement tools and diagnostic software, allows us to use the additional detail we can't see to improve diagnostic efficiency.

Gray scale

This is another confusing area. Some sensors are capable of capturing a 12-bit image. That means they could, in theory, distinguish 4,096 shades of gray (two raised to the 12th power). However, it doesn't matter because a monitor is only capable of displaying an eight-bit image or 256 shades of gray. Even that doesn't matter, though, because the human eye can only see about 64 shades.

For now, we are limited not by the technology, but by what we can see. Based on the limits of our eyes, all the current sensors are good enough. However, if you don't accept the limits of our eyes, the additional data available on a high-resolution sensor, with enhancement software, may give us even better results in the future.

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3. Ease of use

The next consideration is ease of use and patient acceptance. During the image capturing process, PSP sensors are handled and positioned in a manner similar to how we use traditional film. For taking the x-ray, there is little new for operators to learn, and patients probably won't notice any difference from film. In addition, the PSP system produces a digital image of diagnostic quality. However, the wireless PSP process is slower because the sensor is then placed in a scanner to create the image to be viewed on the monitor.

Conversely, the corded sensors are stiff and slightly bulkier. While users note that mastering the handling and positioning of CCD and CMOS/APS sensors requires some change in technique, the learning curve is relatively simple. And in my practice, patient acceptance has been very positive. The only patients who had problems with the sensor were those who would have had problems with film; that is, those with large tori (swelling) or overly sensitive gaggers. Additionally, the image appears directly on the monitor, without the intermediate scanning process.

From sensor placement to display on the monitor, PSP as well as CCD and CMOS/APS images require significantly less time than traditional film processing. So the choice is basically a matter of personal preference.

4. Interoperability

Interoperability is, "The ability of software and hardware on different machines from different vendors to communicate," according to *www.webopedia.com*, an online dictionary and search engine for computer technology.

There has been significant change in interoperability in recent years. Early products had no interoperability; they were completely proprietary. Now, most vendors' products have some ability to work with other programs. In addition, many vendors are adopting the DICOM (Digital Imaging and Communications in Medicine) standard for digital radiology.

DICOM is the standard of the American College of Radiology and the National Electrical Manufacturers Association. DICOM is the result of efforts by users of medical and dental imaging to develop a common "language" for formatting and exchanging images and information. The standard is becoming widely accepted by the healthcare industry; it is endorsed by the American Dental Association's Standards Committee on Dental Informatics (information management).

Interoperability and standards are important considerations when making a buying decision. Be sure to ask the vendor:

- "Will your software accept images from other sensors?"
- "If so, which sensors?"

On the other hand, also ask the vendor:

- "Will your sensors work with other software programs?"
- "If so which other software programs?"

And also ask:

- "Is your product DICOM conformant?"

If the products you choose conform to standards and have some interoperability, you will, to a great extent, decrease your risk of purchasing a system that may soon become obsolete.

What sensor should you get? Any of the three sensor types—CCD, CMOS, or PSP—will produce an acceptable digital x-ray image. They all will increase your diagnostic efficiency. CCD and CMOS have the added benefit of greater speed and lower complexity.

Keep in mind that sensors are only half of the digital radiography equation; you will also need to evaluate the software. With interoperability, though, you may have several software choices. The final decision in choosing software and sensors may come down to your relationship with the vendor and the quality of local serv-

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ice and support.

All the experts agree that digital x-rays will be the technology of the future, and whatever sensor you choose remember; the future is coming and it will be amazing! DPR

Dr. Dale A. Miles *MS, FRCD, a professor of Oral and Maxillofacial Radiology at the University of Kentucky, has had more than 20 years of teaching experience at universities in Canada and the United States. He has authored three textbooks in radiology and more than 120 scientific papers for dental journals. He has been guest editor for three volumes of* ***Dental Clinics of North America****, two of them on digital imaging, and for a recent* ***Oral and Maxillofacial Surgery Clinics of North America*** *on maxillofacial imaging. He lectures extensively on digital radiology. His Web sites are* ***www.learndigital.net****, for digital information, and* ***www.edts.net****, for digital training.*

Dr. Larry Emmott, *a recognized authority on dental technology in America, is a practicing general dentist in Phoenix, Ariz. He also is an award-winning speaker who has addressed hundreds of professional groups. He is a featured Instructor at the Las Vegas Institute and a member of the American Academy of Dental Practice Administration. He has written hundreds of articles on dentistry, computer use, and management. Since 1995, he has written a monthly electronic newsletter,* ***Emmott on Technology****, which shows dentists how to minimize costs and maximize profits in practices through effective use of technology. Visit his computer-users Internet Web site:* ***www.drlarryemmott.com.***

Reference

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Photo credits

• Photo of digital radiography software on page 36 courtesy of Schick Technologies Inc.

SENSOR TERMS

Here's a look at 12 of the terms used in this guide to choosing digital radiography sensors:

CCD: Charged-couple device; a chip used in corded sensors.

CMOS/APS: Complementary metal-oxide semiconductor; a chip used in corded sensors. APS stands for Active Pixel Sensor, the second generation of CMOS.

Corded sensor: Captures and digitizes an image directly. Looks like a chubby black film pack. Embedded with CCD or CMOS chip.

Cordless sensor: Captures an image indirectly; then digitizes it with a scanner. Looks like a typical white film pack. Made from a photostimulable phosphor plate (PSP) coated with a phosphor material sensitive to x-rays.

DICOM: Digital Imaging and Communications in Medicine standard of the American College of Radiology and the National Electrical Manufacturers Association; Web site: *http://medical.nema.org*. The DICOM standard is endorsed by the American Dental Association; Web site: *www.ada.org*.

Gray scale: A measure of the numbers of shades of gray a sensor can capture. Some sensors can capture a 12-bit image or 4,096 shades of gray. A monitor can display only an 8-bit image or 256 shades of gray. The human eye can distinguish only about 64 shades of gray. Based on the limits of our eyes, all current sensors' gray scales are adequate for digital radiography.

Interoperability: The ability of software and hardware on multiple machines from multiple vendors to communicate.

Line pairs per millimeter (lp/mm): The most common measure of resolution of radiographic image details. The unaided human eye can distinguish about 8 to 10 lp/mm. Current sensors have a resolution of anywhere from 6 to 22 lp/mm.

PSP: Photostimulable phosphor plate, used in cordless sensors. The PSP is exposed to an x-ray, which creates a latent image, stored on a plate. This image on the plate is digitized with a special scanner.

Sensor: In digital radiography, a device that captures a radiographic image; the device can be a CCD- or a CMOS-wired sensor or a PSP wireless sensor.

Sensor types: CCD, CMOS/APS, or PSP.

Software: A program that stores, retrieves, displays, and enhances a digital radiography image captured by a sensor.

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