Introducing Digital Radiography in the Dental Office: An Overview

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ABSTRACT

Digital radiography is gaining in popularity and many dentists are considering changing from a film-based system to this new technology. Dentists must clearly define their objectives for adopting digital radiography and be aware of the problems that may be encountered with this equipment, so that they can make an informed purchasing decision. This article provides an overview of digital radiographic equipment, experiences users have had with this technology and factors to consider when deciding to purchase a DR system.

MeSH Key Words: comparative study; radiography, dental, digital/instrumentation; technology, dental

Digital radiography (DR) first became available in dentistry in the mid-1980s, but many dentists have been reluctant to adopt this new technology. Many of the disadvantages of earlier equipment have been resolved: the bulkiness of image receptors has been reduced, image resolution has improved and advances in computer technology have resulted in higher processing speeds and better data storage and archiving solutions. Information on DR equipment is available from many sources, including dental journals, the Internet and sales representatives. However, little information has been published on the practical aspects of making a purchasing decision. Although most dentists will agree that DR has many distinct advantages over a film-based system, many are reluctant to make the change because they are unsure of what to expect during the change-over period and what type of problems they may encounter.

System Components

X-Ray Source

In most cases, existing intraoral x-ray units can be used for DR. The exposure factors for DR are lower than for film-based radiography, so it must be possible to adjust these parameters accordingly. Most modern x-ray units have this capability. For panoramic radiography, an adjustment or a retrofit of an existing unit may have to be done, depending on the image receptor system chosen and the design of the panoramic unit.

Image Receptor

In DR, conventional film is replaced by an image receptor. Two major types of systems are available: charge-coupled device (CCD) and storage phosphor (SP) systems. Both types of receptor yield diagnostically acceptable images, but each has distinct advantages and disadvantages that may make one or the other more suitable for a particular situation.

A CCD includes a sensor that is placed in the patient's mouth. A cable leads from the sensor to an interface, which is connected to a computer in the operatory (**Fig. 1**). The CCD also includes a pixel array (electron wells) on a silicon chip. After exposure, x-ray energy is converted to a proportional number of electrons, which are deposited in the electron wells, then transferred in a sequential manner to a read-out amplifier (charge coupling). This analog signal is converted to a digital signal

Figure 1: Intraoral charge-coupled device (Schick Technologies, Inc., Long Island City, N.Y.).

Figure 2: Intraoral charge-coupled device with plastic infection control sleeve in place.

Figure 3: Storage phosphor plate (Air Techniques, Hicksville, N.Y.) illustrating the active (tube side) surface of the plate (left) and plate placed in the infection control pouch (right). The plate is oriented with the tube side against the black (opaque) side of the pouch to limit exposure of the active side of the plate to ambient light.

Figure 4: DenOptix laser scanner (Gendex Dental Systems, Des Plaines, Ill.), illustrating the drum on which storage phosphor plates are clipped. The drum is inserted into the scanner and the lid is closed before scanning.

Figure 5: ScanX laser scanner (Air Techniques, Hicksville, N.Y.) Storage phosphor plates are inserted at the top of the scanner (top arrow) and ejected (bottom arrow) after scanning is complete.

and the x-ray image is visible almost instantaneously on the computer monitor.

The major drawback to CCD technology is that intraoral sensors are much thicker than film. The sensor may not be well tolerated by patients, so sensor placement may be difficult and more time-consuming compared with film. The cable attached to the sensor is easily damaged and may interfere with sensor placement. In addition, the entire surface of the sensor is not active, as some space is occupied by electronic components. As a result, the actual area available for image capture may be as little as 60% of the sensor area, although this varies with manufacturer and sensor size. The radiographic image will depict a proportionally smaller area than conventional film, occasionally resulting in the need for additional images to view the entire area of interest. Sensors are available in various sizes to simulate the different film sizes used clinically. For infection control, a plastic sleeve is fitted over the sensor and part of the cable, as the sensor cannot be autoclaved or disinfected (**Fig. 2**).

An alternative to CCD technology is complementary metal oxide semiconductor active pixel sensor (CMOS-APS) technology. These sensors do not require charge transfer, resulting in increased sensor reliability and lifespan. In addition, they require less system power to operate and are less expensive to manufacture.[1] Recently, wireless sensors have been introduced, eliminating the need for a cable attached to the sensor, but they may not be practical if there is electronic interference from external sources.

An SP system uses plates comprising a flexible polyester base coated with a crystalline emulsion of europium-activated barium fluorohalide compound. These plates are similar in size and thickness to conventional radiographic film and the entire surface area is active. For infection control, the plate is placed in a plastic pouch, which is sealed, preventing contact with oral fluids (**Fig. 3**). Incoming x-ray energy is stored in the emulsion and a latent image forms on the SP plate, analogous to the latent image that forms on a conventional film emulsion.

The plate is removed from the patient's mouth, the plastic pouch is discarded and the plate is placed into a laser scanner, which acts as an electronic processor

(**Figs. 4** and **5**). A laser beam sequentially scans the plate and the stored electrons are released as visible light, which is quantified. This analog signal is converted to a digital image, which is viewed on a computer monitor. Depending on the size and number of plates placed in the laser scanner and the desired resolution of the images, it may take from about 20 seconds to several minutes for the image to appear on the computer monitor. Because not all the energy stored on the SP plate is released during scanning, the plate must be "erased" by exposing it to a strong light source for several minutes before it can be reused. SP plates are available in sizes similar to sizes 0, 1, 2, 3 and 4 film, as well as larger sizes for extraoral imaging.

Computer and Monitor

A computer and monitor are necessary to process and view DR images. Both laptop and desktop systems are suitable for this purpose and the choice depends on a number of factors, including what types of computer already exist in the office, the manufacturer's recommendations and the amount of available space in the operatory. Installation of a computer network facilitates viewing images in several locations in the office. Although a conventional computer monitor can be used, subjective image quality is better when viewed on a high-resolution monitor, which may add considerable additional expense.

Software

The software bundled with a DR system has basic image-processing tools that allow adjustments in brightness and contrast and gamma correction, as well as annotation and measuring tools. Additional tools may also be available, depending on the manufacturer. In the past, there has been concern regarding the potential for fraud if digital radiographs are altered. The software provided with most systems today has safeguards in place to prevent replacing an original image with an altered image in the patient's electronic file. Before purchasing a system, it is important to determine whether the DR software is compatible with the practice management software used in the office, as incompatibilities will prevent integration of the radiographic images into the patient's electronic chart and may cause network conflicts.

Accessories

It will be necessary to purchase image receptor holders or positioning devices that have been adapted for the specific brand and type of image receptor used in the office, as CCD receptors from different manufacturers differ slightly in dimensions and shape. For SP plates, conventional film-positioning devices, such as the Rinn XCP film holding device (Dentsply Rinn, Elgin, Ill.) may be used. However, devices with clamping jaws, such as a Snap-A-Ray Film Holder (Dentsply) or a hemostat may damage the plates and alternative devices especially adapted for use with SP plates should be used instead. Plastic sleeves or pouches must be purchased for infection control purposes for CCD and SP systems, respectively, as described earlier.

Printer

Although one of the advantages of using DR is elimination of the need for hard copies, the dentist will inevitably need to print images. The most common reason for printing is for patient education, where one or more images is printed for the patient to take away with them, or when a referral is made to another dentist whose office does not have the capability to view digital images. The most common complaint about printed images is poor quality, often rendering the image non-diagnostic. The reason for this may be poor choice of paper (e.g., using regular instead of photo-quality paper) or poor printing technique (e.g., printer resolution is set too low). There are many good printers available that will produce acceptable radiographic prints. They range from ink-jet printers, which cost less than $500, to more sophisticated dye sublimation thermal printers, costing tens of thousands of dollars, which can print on paper or transparent film and are used in imaging centres and hospitals. It is important to use paper that is compatible with the brand of printer and suitable for printing images (glossy photo paper) as opposed to text only (plain paper).

Demographics of DR Users

Surveys in Norway[2,3] indicate that 14% of dentists use DR and of the digital group, 61% use SP, 35% use CCD or CMOS and 1.3% use both. Similar patterns are found in the Netherlands[4] where 67.5% of the digital group use SP and 32.5% use CCD. Gender, age and number of years in practice were not factors in the decision to use DR, although use of DR was more common in group practices with multiple operatories, presumably because costs could be shared among several dentists. Use of DR was highest among dentists aged 35–54 years, although 77% of the film users surveyed expected to purchase DR equipment at some point in the future.

Experience of DR users

Technical problems encountered by users may be related to the computer or to the DR equipment itself. Reports of computer problems include hardware, software, networking problems or a combination of the three.[3] CCD users report occasional difficulty in positioning CCD sensors due to their thickness, the need for a greater number of exposures to image an area because of the smaller active surface area of the sensor, and the increased need for retakes because of positioning difficulties. Some CCD users also report difficulty using the sensor holder. SP users report patient complaints regarding the sharpness of the plate edges and problems with the laser scanners.

Wenzel and Møystad[3] reported that approximately half of the CCD users still used film compared with 38% of the SP users. Film was most often used for bitewing examinations, particularly for CCD users who did not have the larger-size sensor. The reason for this is that the cable attached to the sensor prevents closure of the teeth into occlusion, so an image of the alveolar crest may not be visible in the digital bitewing image.

Berkhout and others[4] described user-friendliness of DR versus film before and after x-ray exposure. DR was deemed less user-friendly than film before exposure because the CCD or SP plates had to be placed into infection control sleeves or pouches and a computer program had to be started before x-ray exposure. Also, positioning digital detectors in the mouth was more difficult than positioning film. After patient exposure, digital systems were more user-friendly than film in terms of handling the images, as there was no need for chemicals, image processing was easy and storage was automated.

The Decision to Adopt DR

The decision to purchase DR equipment, either as a conversion from film-based radiography or as an initial radiography set-up in a new office, has ramifications in terms of both financial outlay and office routine. Before deciding to purchase DR equipment, dentists should list their objectives for using DR, then ask themselves if use of the system will realistically fulfill all of their objectives (**Box 1**). Some of the typical objectives given for using DR include:

- elimination of chemical processing
- time savings
- reduction in radiation dose to patients
- patients' perception of the office as "modern" or "state of the art"
- ability to integrate radiographic images with digital camera images for patient education and presentation of the treatment plan
- improved diagnostic accuracy.

Advantages of Using DR

The main advantage of DR is that many tasks associated with film use are simplified or eliminated. Chemical processing is eliminated, which has significant environmental benefits. Quality assurance checks on a processor no longer have to be completed and staff time previously used for processor cleaning and maintenance can be used for other tasks. In offices with panoramic x-ray units, consideration must be given to whether panoramic radiographs can also be acquired digitally. If DR is used for intraoral radiographs only, the chemical processor will not be eliminated as it will be needed to process panoramic films. If panoramic views will also be digital and the existing panoramic unit will be not be replaced, this may influence the choice between a CCD and an SP system, as it is

Box 1 Is DR for Me? Should I Give Up Film?

The decision to "go digital" should include consideration of the following:

1. What will be the return on my investment? How many radiographs do I typically take in a day? How long will I be practising dentistry? Being close to retirement is not necessarily a deterrent to purchasing digital equipment as it may enhance the value of the practice when the practice is sold.
2. What types of examinations do I typically perform? Will digital equipment work for all situations? Given my practice situation, is CCD or SP more suitable? For example, if there are a lot of pediatric patients in the practice, younger patients may not tolerate intraoral placement of a CCD and, therefore, an SP system may be more suitable. Dentists who perform a large number of endodontic procedures may prefer the instantaneous image produced by a CCD system.
3. Will other imaging devices, such as an intraoral camera, be used with this system? If so, how well will they integrate? It is important to discuss this with DR vendors to ensure that the software allows photographic images to be integrated into the patient's electronic chart.
4. Will I still need a processor? If the office also performs panoramic imaging, consideration must be given to digitizing the images, which will be an added expense. If panoramic images remain film-based, the objective of eliminating film processing and the use of chemicals will not be met.
5. Am I (and my staff) comfortable with computer technology? Offices that are only minimally computerized will have a longer learning curve when adopting digital technology although the software for DR is intuitive and easy to learn.
6. What do the other members of the dental team think? Introducing DR will not be successful if they are unwilling to use this new technology.
7. Are the company and product reliable? Some purchasers have been disappointed because they bought equipment from companies that subsequently went out of business and support and parts for the equipment were no longer available.
8. What warranty, upgrade or replacement offers are available for the equipment? What is included in the service agreement and what is the fee?
9. Is technical support readily available?

easier and cheaper to adapt an existing panoramic unit to an SP system than to a CCD system.

Because images are in electronic form, the chore of labelling and mounting films is eliminated and images can be viewed with a few mouse clicks, eliminating the need to retrieve the patient chart and find the radiographs of interest. Images can be transmitted electronically for patient consults or insurance claims, eliminating the need for making film copies and incurring mailing or courier costs. However, time saved with use of DR may not be as great as anticipated. Although chemical processing time is eliminated and radiographs do not have to be placed in film mounts, "time delays" may be encountered due to added time spent positioning the CCD in the mouth or packaging individual SP plates in infection control pouches.[3] CCD users also tend to need more retakes, which require additional time.[3,5,6] Once images are acquired, time may also be spent orienting (e.g., rotating, arranging) images or image processing (usually brightness and contrast adjustments) on the computer monitor. SP users will also spend time removing SP plates from the infection control pouches, feeding SP plates into the laser scanner, waiting for the plates to be scanned and later erasing the plates.

Although it has been reported that the radiation dose in DR may be decreased by 50% or more compared with film-based radiography, in reality the decrease is not nearly that great. Berkhout and others[5] found a dose reduction of only 25%, whereas Wenzel and Møystad[3] found no clinical evidence of dose reduction, largely due to the fact that digital users take more radiographs. Berkhout and others[5] reported that SP and CCD users took 32% and 49% more radiographs, respectively, than film users. They postulated that this may be because of the need for more radiographs to cover the area of interest and because the relatively short period between exposure and display of the radiograph may tempt some dentists to take more radiographs. Computer or other technical errors may also necessitate retakes.

A major advantage of using digital technology is that the exposure time (and therefore radiation dose) can be markedly reduced, while still providing good image quality. The range of exposures that result in a diagnostically acceptable image is termed the dynamic range of the system. Typically, CCD systems have a narrower dynamic range than SP systems. For both systems, if the exposure time is reduced too much, image quality deteriorates, due to increased noise, which affects visibility of structures in the image. Increasing exposure time decreases noise and improves image density and contrast. In examining dose reduction versus image quality, Berkhout and others[7] found that dentists prefer radiographs taken with longer exposure times, even if a diagnostically acceptable image can be achieved with a lower radiation dose, because the higher-dose image is "nicer," i.e., less noisy. Furthermore, because the dynamic range of SP systems is so wide, some dentists may not decrease the exposure time compared with that used for film, so there is no radiation dose savings.

Having computerized technology in the office may create the impression of a "modern" or "state of the art" office and use of DR in this context may be a useful marketing tool. Even more powerful is the ability to view and print radiographic images along with digital intraoral photographs for treatment plan presentation, enhancing doctor–patient communication.

Some equipment manufacturers claim that diagnostic accuracy of DR images is greater than for film-based images but this has not been supported in the literature. A number of studies have examined diagnostic accuracy for various tasks, such as identification of caries,[8–18] identification of periapical lesions,[6,19–25] periodontal measurements[26] and root fracture detection.[27] The conclusions of most of these studies are that there is no significant difference in diagnostic accuracy between DR (both CCD and SP) and film. Uprichard and others[14] reported that accuracy in identification of caries using DR improved with practice. Wallace and others[25] came to a similar conclusion for identification of periapical lesions. Nair and others[17] found that accuracy in caries identification using DR improved with image processing. On the other hand, Tyndall and others,[13] Kullendorff and others[19] and Barbat and Messer[21] found that processing images to identify caries or periapical lesions actually worsened diagnostic accuracy. The literature supports the fact that diagnostic accuracy using DR is not necessarily better or worse than diagnostic accuracy using film.

Financial and Time Commitment

The purchase of a DR system is a substantial financial commitment. Aside from the cost of the system itself, it may be necessary to purchase one or more additional computers for the office and, depending on the size and design of existing operatories, remodelling may be necessary to accommodate computers in the treatment areas. Furthermore, it may be necessary to install a computer network. Consideration should also be given to having a computer maintenance and upgrade contract in place. Computer-related problems such as system crashes, archiving or back-up problems are not uncommon and it is necessary to have reliable and knowledgeable computer consultants available. There are also long-term costs associated with image receptor replacement. CCD sensors are delicate and may be easily damaged, particularly if they are dropped or if the cable becomes damaged. Replacement of CCD sensors may cost several thousand dollars. SP plates can also be damaged from rough handling or surface scratches, and replacement costs start at about $40, depending on the size of the plate.

Training time must be scheduled and all staff must be prepared for additional computer use, which may include

a temporary interruption of office routine and the possibility of computer-related problems at the outset or in the future. Furthermore, the change-over period from film to DR may result in patient records that are partly in hard copy and partly in digital form. Choosing a digital system is also time-consuming. Existing computer equipment may have to be upgraded or additional equipment may have to be purchased, such as a better-quality monitor, printer and paper, and possibly additional workstations so that the digital radiographs can be viewed in multiple areas in the office.

Other Factors to Consider

It is imperative that sales representatives bring equipment to the office to demonstrate the system and allow the dental team to see how the units operate and to try out the software. The type of system (CCD/CMOS vs. SP) should be decided on first, then the manufacturer should be chosen. Special attention should be given to the computer system requirements outlined by the manufacturer, as the equipment will function optimally only if the manufacturer's recommendations are followed. In planning the system installation, thought should be given to ergonomic placement of keyboard and monitor, while also protecting the privacy of patient information that may be visible on the monitor to staff or patients in the office.

When purchasing a CCD system, will only one system be purchased for the entire office or will a system be installed in every operatory? If only one operatory is outfitted, the initial cost will be lower, but only one patient can be imaged at a time; patients in other operatories will have to wait to have radiographs taken until the system becomes available. If making an initial single-system purchase, it is wise to plan ahead and buy a system that allows expansion or addition of other components later on. Ideally, more than one size of CCD sensor should be purchased to accommodate a greater variety of clinical situations and to have a back-up sensor available in case one gets damaged.

If an SP system is purchased, consideration should be given to how long it takes to scan the SP plates. Some systems are faster than others and scan time will also be influenced by the size of the plates being scanned, the number of plates being scanned at one time and the scanning resolution chosen. It is also important to examine how convenient it is to scan the plates. For example, the DenOptix system (**Fig. 4**) uses a drum on which multiple plates may be loaded and scanned at one time whereas the ScanX system (**Fig. 5**) is comparable to a conventional film processor where plates are fed into the scanner individually. Systems may also differ in terms of the sizes of plates that can be scanned; some systems can accommodate all sizes of intraoral and extraoral plates whereas other systems may be more limited. Consideration should be given to how much handling the plates will receive as they are introduced into the scanner, as physical damage to plates degrades the images and shortens the lifespan of the plates.[28] The clinician should expect to have to replace intraoral SP plates on a fairly regular basis and the cost of these replacements should be factored into the budget for this equipment.

Conclusions

DR is an excellent alternative to film-based radiography and continues to grow in popularity. Diagnostic accuracy using DR is as good as with film in most cases and disadvantages associated with earlier types of equipment have been resolved with advances in technology. However, regardless of the type of system purchased, users should expect some technical problems and the need for future upgrades of hardware (computer and DR equipment) and software. With careful purchase planning and realistic expectations, users will avoid disappointment in system performance. Information on DR systems is provided on the Internet by the University of Aarhus in Denmark (www.odont.au.dk/rad/Digitalx.htm). The site has links to all of the major manufacturers and is updated regularly.

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