THE JOURNAL OF THE AMERICAN DENTAL ASSOCIATION

J A D A

In Practice: How Going Digital Will Affect the Dental Office

Allan G. Farman, Claudio M. Levato, David Gane and William C. Scarfe

J Am Dent Assoc 2008;139;14-19

In practice

How going digital will affect the dental office

Allan G. Farman, BDS, PhD, DSc, MBA; Claudio M. Levato, DDS, FACD; David Gane, DDS; William C. Scarfe, BDS, MS, FRACDS

ABSTRACT

Background and Overview. The impact of digital imaging on dental practice depends upon the degree of planning conducted before implementation. Digital technologies have the potential to improve diagnosis; facilitate patient treatment procedures; and streamline storage, transfer and retrieval. These technologies also provide for secure backup of patients' image data, critical to re-establishing the practice should fire, flood or earthquake occur.

Conclusions. The decision to invest in digital radiographic equipment should be a simple one for dental practitioners. Although digital x-ray sensors have long equaled analog film for diagnostic tasks, they have several advantages over film radiography, including immediate image production with solid-state devices; interactive display on a monitor with the ability to enhance image features and make direct measurements; integrated storage with access to images through practice management software systems; security of available backup and off-site archiving; perfect radiographic duplicates to accompany referrals; security mechanisms to identify original images and differentiate them from altered images; the ability to tag information such as a patient identifier, date of exposure and other relevant details; and interoperability of the Digital Imaging and Communications in Medicine file format.

Clinical Implications. Most clinicians should contemplate integrating, at a minimum, intraoral digital x-ray sensors and a digital panoramic system into their practices.

Key Words. Dental radiography; Digital Imaging and Communications in Medicine; digital imaging; interoperability.

JADA 2008;139(6 supplement):14S-19S.

Digital imaging is not simply the display of filmless radiographs. More importantly, the images are captured in a computer and can be displayed almost instantaneously, facilitating operative procedures that now can be image-guided.

Digital radiographic images do not need to stand apart from film radiographs; in fact, many practitioners use both. There is nothing wrong with this hybrid solution. The first commercial digital intraoral systems were developed for operative procedures rather than as a replacement for film. Because the original sensors were bulky and the active area was small, they were not practical replacements for conventional film-based full-mouth series.

With advances in digital technology, however, the surface areas of sensors can be identical to their film counterparts in the case of storage phosphor systems, and they are similar in dimension for solid-state devices. Although a hybrid approach made the most sense in the early stages of digital imaging, an entirely digital approach now is a practical option. For two-dimensional (2-D) transmission x-ray imaging, the quality of digital systems generally has been found to

Dr. Farman is a professor, Radiology and Imaging Science, Department of Surgical/Hospital Dentistry, University of Louisville School of Dentistry, 501 S. Preston St., Louisville, Ky. 40292, e-mail "agfarm01@louisville.edu". Address reprint requests to Dr. Farman.
Dr. Levato is in private practice, Bloomingdale, Ill.
Dr. Gane is vice president, Dental Imaging, PracticeWorks, Atlanta.
Dr. Scarfe is a professor, Radiology and Imaging Science, Department of Surgical/Hospital Dentistry, University of Louisville School of Dentistry, Louisville, Ky.

be equivalent to film in terms of diagnostic yield.[1-6] However, with regard to record keeping, backup, transmission of images and integration with the practice management system and other digital diagnostic inputs, digital radiography outperforms film. Digital radiographic and photographic visible light images are the building blocks that eventually will take the dentist from the role of freehand artist to that of an architect of dental care. The computer is the major enabling technology.

ADVANTAGES OF DIGITAL RADIOGRAPHY

The decision to invest in digital radiographic equipment should be a simple one for dental practitioners, even though the capital costs may be high. While digital x-ray sensors have long equaled analog film for diagnostic tasks, they have several advantages over film radiography, including the following:

- immediate image production with solid-state devices such as a charge-coupled device (CCD) and a complementary metal-oxide semiconductor (CMOS);
- interactive display on a monitor with the ability to enhance image features and make direct measurements;
- integrated storage, providing access to images through practice management software systems;
- security of available backup and off-site archiving;
- perfect image duplicates to accompany referrals to other practitioners;
- security mechanisms to identify original images and differentiate them from altered images;
- ability to tag information such as a patient identifier, date of exposure and other relevant details;
- interoperability of the Digital Imaging and Communications in Medicine (DICOM) (National Electrical Manufacturers Association, Rosslyn, Va.) file format, which enables practitioners with different equipment and software to view and enhance the same images.

Most dental practitioners should contemplate integrating, at a minimum, intraoral digital x-ray sensors and a digital panoramic system. These are important, irrespective of specialty. Orthodontists and maxillofacial surgeons need a cephalometric system to obtain images of the patient's entire head. They should decide whether their practice would benefit by converting from traditional x-ray film to 2-D digital images versus the three-dimensional capabilities of cone beam computed tomographic (CBCT) x-ray systems. CBCT is rapidly becoming the standard of care for such procedures as dental implantation.[7-9] The figure shows the possible components of an integrated digital dental office.

Levels of integration. The level of integration will depend on the desire and capability of each practitioner. Practitioners have four distinct choices regarding digital x-ray imaging integration.

- Analog only: Stay with analog radiography using silver halide film. The advantages are no immediate outlay of capital. The disadvantages are that practices experience none of the benefits of digital technology and face the likelihood of eventual obsolescence.
- Hybrid: Combine the strengths of digital systems and analog film. The advantages are a decreased immediate investment. The disadvantages are decreased access to the benefits of digital technology and the continued costs of maintaining an analog system.
- Completely filmless (digital imaging, but not integrated with a digital practice management system): The advantages include having a greater ability to manage the radiographic component of the practice and the benefits of digital radiology applications. The disadvantages are the lack of a completely digital practice record and the capital costs and ongoing maintenance costs.
- Completely digital: This is the integrated digital practice. The advantages are improved efficiency and management of all clinical, administrative and communication practice applications. The disadvantages are the capital costs and ongoing maintenance and training costs.

Practical applications of a fully digital environment. Starting with the acquisition of data and including the use of electronic charting, digital radiographic images, photographic images and dictated or typed progress notes, the practi-

ABBREVIATION KEY. CBCT: Cone beam computed tomography. **CCD:** Charge-coupled device. **CMOS:** Complementary metal-oxide semiconductor. **CRT:** Cathode ray tube. **DICOM:** Digital Imaging and Communications in Medicine. **PSP:** Photostimulable phosphor plate. **RAM:** Random access memory. **RF:** Radio frequency. **TCP/IP:** Transmission control protocol/Internet protocol. **2-D:** Two-dimensional. **USB:** Universal serial bus.

tioner now has a complete dental record that is secure and accurate. He or she can share any part of this record internally with staff members or externally with insurance companies and/or dental laboratories, as well as use this record for referrals.

One of the most powerful outcomes of integrated technology is the potential to organize the pertinent data in a format that is readily available to educate the patient in real time. Use of the patient's own images helps accelerate his or her acceptance of dental care. When the practitioner combines this visual information with available electronic patient education programs, he or she has provided a credible second opinion on the same day as the consultation.

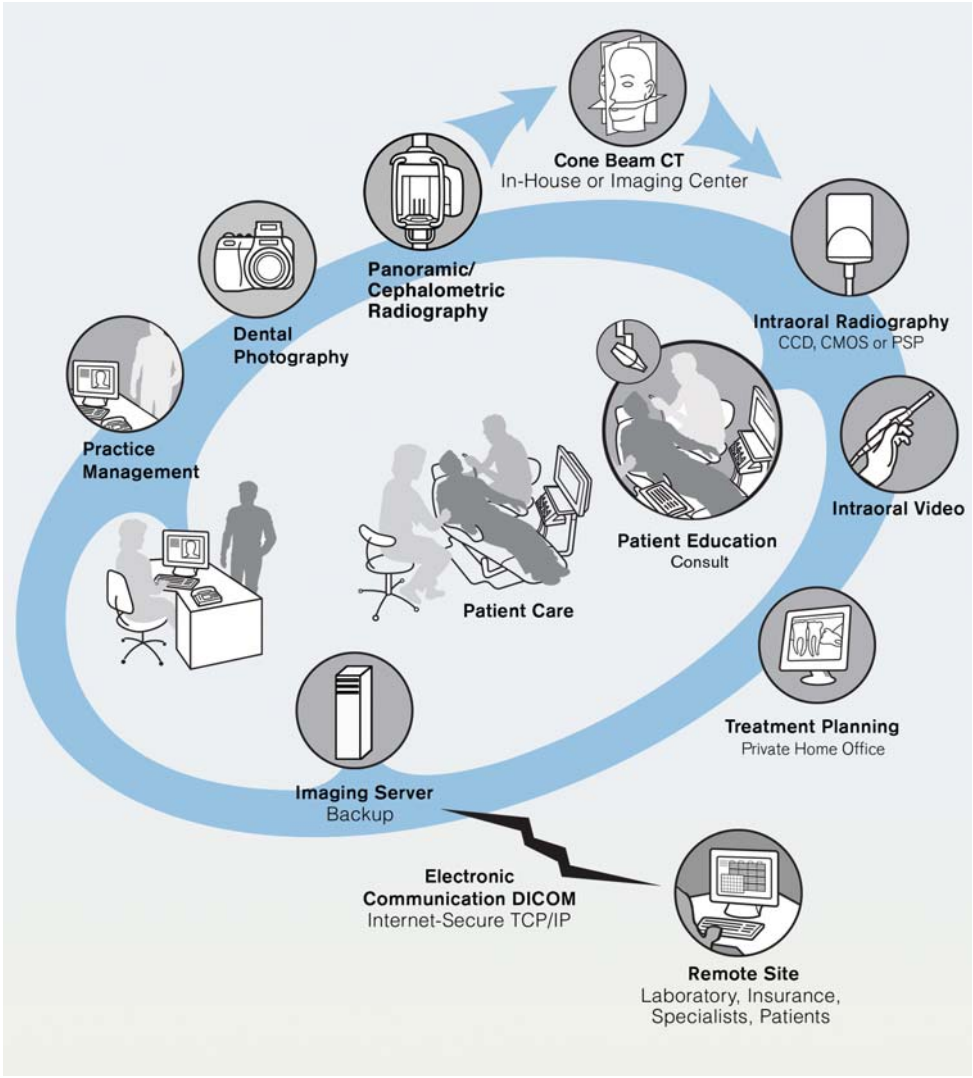

Figure. Possible components of an integrated digital dental office. CCD: Charge-coupled device. CMOS: Complementary metal-oxide semiconductor. CT: Computed tomography. DICOM: Digital Imaging and Communications in Medicine (National Electrical Manufacturers Association, Rosslyn, Va.). PSP: Photostimulable phosphor plate. TCP/IP: Transmission control protocol/Internet protocol.

With digital technology, the dentist can read radiographs and plan treatment in any location that has a workstation. This allows the dentist to take advantage of any open time and provides him or her with immediate access to the patient information. Using multiple windows, monitors and/or a laptop computer connected to the network facilitates multitasking for the dentist. Specifically, it allows the dentist to work with multiple images, as well as charting programs and treatment planning programs, thus greatly reducing the time needed to create treatment options for patients. If the practitioner is connected to the Internet, this also enables him or her to share information with a colleague who may need to be part of the patient's care.

Approach to integration. Regardless of how the dentist decides to approach technology integration, he or she needs a plan.[10,11] For an existing practice, a gradual approach is acceptable. For example, the dentist can begin with one sensor attached to a solitary personal computer, which can be used for operative procedures. This approach permits a relatively inexpensive trial of the technology and minimizes the learning curve while stimulating the attention of the dental team. For a new facility or an office that is to undergo a complete renovation, we advocate total networking. For a newly opened general practice, the clinician might consider replacing a traditional film full-mouth series with digital

panoramic images in addition to bitewings and selected periapical radiographs. As with any new technology, developing competency in digital imaging involves a learning period for the practitioner trained in film radiography. However, in our experience, students who have been trained in both analog film and digital x-ray systems find the latter to be easier to learn.

Before buying. Digital radiography is not inexpensive. Hence, clinicians should "test drive" several systems to determine which sensor and software fulfill the needs and style of the practice. The appropriate place to evaluate such systems is the dentist's own office, where he or she can compare products in a standardized manner with images that are not preselected. This usually is possible while the vendor's representative is present. In addition, it is important to work in one's own office environment to determine whether the existing x-ray generators are acceptable or should be replaced. Only in the dentist's own office environment can he or she examine the ergonomics of using the system and plan integration.

HARDWARE CONSIDERATIONS

Sensor type. *CCD and CMOS.* The scientific literature reveals little difference between the CCD and CMOS chips for solid-state imaging in terms of physical image properties.[12] The CMOS chip, however, requires less energy, so it is possible to connect it directly to the computer via a universal serial bus (USB) rather than needing an additional external signal amplifier. Furthermore, CMOS technology has permitted the development of wireless sensors. However, the latter will involve the additional cost of disposable batteries. Solid-state sensors typically range in cost from $5,000 to $8,000 each, with wireless sensors costing up to 50 percent more. Solid-state x-ray sensors produce an almost immediate radiographic image.

Photostimulable phosphor plate. An alternative to solid-state technology is the photostimulable phosphor plate (PSP). The advantage of this technology is that the sizes of the phosphor plates are almost identical to those of traditional film radiographs. The disadvantages include a propensity of intraoral sensors to degrade owing to scratching, the time needed to prepare and package the plates, and the time needed to scan with a laser the exposed plates to process the latent image. Producing an image with PSP is not immediate. The cost of PSP plates varies from tens to hundreds of dollars depending on the size of the plate.

Number of sensors. In deciding the number of intraoral solid-state sensors to purchase, the dentist should factor in the need for cold disinfection of sensors between patients, the flow of patients through the office, and the various sizes and shapes required for patients of different ages and sizes. Clinicians need not buy all of their sensors from a single vendor as long as the systems are DICOM-conformant and the images produced are interoperable.[1] It is always prudent to insist that the vendor, as a condition of purchase, integrate the selected system into the existing practice management system. For PSP devices, clinicians should purchase at least twice the number of plates as the practice uses in a given period to allow sufficient time for them to be erased and repackaged before reuse. They also should purchase additional plates to replace those damaged by wear and tear.

Sensor specifications. Most, if not all, current systems are adequate in terms of contrast and spatial resolution. When it comes to diagnostic quality, the clinician should trust his or her own eyes.

Physical connection to computer. Clinicians can choose between wired and wireless sensors for solid-state technology (CMOS using radio frequency [RF] transmission) and for PSP. If a wire is used to attach the sensor to the computer, ensure that the length of the wire is sufficient for the working environment. If the practice is using a wireless system, however, it is important to make sure that the permitted range of a wireless RF or Bluetooth system is adequate. Placement of the wire also is important, as it can have implications for the types of exposures that can be made. If, for example, the dentist wants the instant image feature of a solid-state intraoral sensor and also wishes to obtain vertical bitewing radiographs, he or she should use a sensor with the wire attached at the back; otherwise, it is acceptable to use a sensor with the wire attached at one end.

Sensor sizes. When evaluating different systems in the office with patients during vendor demonstrations, dentists should make sure that the range of available sensor sizes is acceptable. In our experience, sensor sizes no. 2 and no. 1 are useful, whereas size no. 0 is of limited utility. Regarding the thickness of CCD and CMOS intraoral sensors, we find that slightly thicker sensors are easiest to place, as they do not cut into the patient's tissues.

Sensor positioning devices. The positioners are not much different from those used with intraoral film radiography.

Computer requirements. In general, if a computer is more than one year old, it is probably worth upgrading the computer system when investing in digital imaging. Dentists should not try to skimp on random access memory (RAM), read-only memory or speed. As a rule of thumb, 4 gigabytes of RAM is optimal. The processor speed of the central processing unit should be at least 3 gigahertz. A terabyte of storage is not excessive for the server, and mirrored storage drives are desirable. In a networked environment with a dedicated server, workstations do not need much storage capacity, so a hard drive of 500 GB is adequate. Extra slots and USB connections are always useful.

Storage. Digital file storage need not be expensive. Dentists can purchase a terabyte of storage capacity for less than $500. All data should be backed up both locally (by using mirrored drives—two drives that contain the exact same information) and at a secure remote site several miles from the practice. A simple means of backup is a removable drive that can be copied to the secure remote system on a daily basis. Keep in mind that the practice is the patient data, not the physical equipment. The dentist can replace physical equipment readily, but he or she must carefully protect unique patient data.

Monitor selection. The physical specifications and settings of the monitor ultimately will determine the appearance of any digital image, as well as the image of the practice to patients. Flat panel monitors look modern, cathode ray tube (CRT) monitors look like antiques. Flat panel monitors are economical with regard to space, while CRT monitors are inefficient. Clinicians should purchase a high-resolution monitor with a wide grayscale contrast capability. In most cases, an upper-end nonmedical-grade monitor is sufficient for administrative or nonclinical locations. In the operatory, we recommend medical-grade flat-plane monitors that have sealed nonglare glass fronts. This is most consistent with infection control protocols, permitting disinfection along with the rest of the operatory between patients.

Printer. It is not essential to have a printer if practitioners and other third parties to whom the dentist transmits images can handle digital images transmitted as DICOM files. The printed image invariably is of lower quality than the originally displayed image, and clinicians should not consider it to be diagnostic.

Networking. To achieve a fully integrated practice, we prefer a hard-wired network over a wireless network. However, depending on space requirements and accessibility, the practice can use a combination of both. Keep in mind that wireless applications are more susceptible to electrical interference, are less secure and are slower in transmitting larger file sizes (such as images from high-end digital cameras or volumetric radiographic images). The maximum wireless data transmission speed is 55 megabits per second, while the maximum speed of a hard-wired category 5E cable is about 350 Mb per second and that of a category 6 cable is 1 gigabit per second.

The quality of the diagnostic image depends on the weakest link in the imaging chain. Clinicians should consider this when deciding whether or not to upgrade the x-ray generator. Typically, they should replace x-ray units that are more than 10 years old, but newer units also should be replaced if the timer is incapable of making reproducible short exposures or if the image quality is suboptimal.

SOFTWARE CONSIDERATIONS

Operating system. The operating system must be compatible with the digital imaging system, and it also must be compatible with other software used on the same computer or network.[13] At the time of purchase, the dentist must be assured that the vendor will update the digital imaging system to be compatible with future modifications made to the computer operating system.

File format. The American Dental Association[14] has resolved that interoperability should be established according to the DICOM standard.[15] DICOM is a standard of the International Organization for Standardization.[16] Dentists need to make sure that the system they purchase conforms with the DICOM standard and permits the export and import of DICOM files. File interoperability protects patients' data and the dentist's investment so that he or she cannot be "held hostage" by the proprietary file formats of an individual vendor.

Ergonomics. The digital imaging system should require a minimum number of keystrokes and preliminary screens. The dentist and staff members should be sure that they have no problems using the software.

Integration. Ideally, digital images are acces-

sible via the practice management software. Leading practice management software systems provide for the importation of images in DICOM format. The DICOM image file tags can populate new patient information, saving staff members' time and reducing the likelihood of making errors.

MAINTENANCE

Warranty. Digital imaging systems are a fairly expensive investment. Thus, the manufacturer's warranty is important. Practitioners should read the small print carefully to ensure that their investment will be protected adequately.

Hardware service contract. We recommend that dentists obtain a hardware service contract. For intraoral solid-state sensors, this should provide for overnight replacement. In our experience, hardware failure is unusual; however, when it does occur, immediate replacement is needed.

Software service/update contract. A software service contract, including upgrades, is needed, and it should include support when the computer operating system or practice management software is upgraded.

Before purchasing a system, the dentist should call technical service to make sure that someone answers the telephone. Continued technical support should be part of the warranty and maintenance contract.

Several companies have been in the dental digital radiography business for more than one decade. Such long-term survival suggests that customers are satisfied. While past performance is no guarantee of future results, it certainly is a factor in determining the company with which to work.

Costs. To determine the total costs of going digital, the dentist needs to consider the following:

- capital costs of hardware and software;
- continuing costs of disposable items (for example, plastic wraps for sensors);
- costs of secure data backup;
- maintenance costs;
- initial and ongoing training costs.

Dentists also should consider the costs that would apply if they decided not to go digital. These include film, processing solutions, processor maintenance, darkroom space, film mounts and storage of film radiographs.

CONCLUSION

We have given a brief synopsis of the factors involved in going digital with regard to dental imaging. Certainly, practice prestige and work flow ergonomics can be enhanced greatly by careful integration of digital imaging systems. The key to success is to assess the needs of the individual practice and to observe, in the practice setting, demonstrations of the systems under consideration. Digital intraoral radiography is a mature industry, with many vendors having survived one decade or more. Survival in the business is a good sign that consumers are happy with the products being marketed. ■

Disclosure. Dr. Gane is an employee of PracticeWorks Inc., Atlanta, and is a partner of Orbit Imaging Inc., Vancouver, British Columbia. The other authors did not report any disclosures.

1. van der Stelt PF. Modern radiographic methods in the diagnosis of periodontal disease. Adv Dent Res 1993;7(2):158-162.
2. Wenzel A, Pitts N, Verdonschot EH, Kalsbeek H. Developments in radiographic caries diagnosis. J Dent 1993;21(3):131-140.
3. Sanderink GC, Huiskens R, van der Stelt PF, Welander US, Stheeman SE. Image quality of direct digital intraoral x-ray sensors in assessing root canal length: the RadioVisioGraphy, Visualix/VIXA, Sens-A-Ray, and Flash Dent systems compared with Ektaspeed films. Oral Surg Oral Med Oral Pathol 1994;78(1):125-132.
4. Farman AG. Fundamentals of image acquisition and processing in the digital era. Orthod Craniofac Res 2003;6(suppl 1):17-22.
5. Farman AG. Image-guidance ... the revolution in dental treatment facilitated by digital radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;101(3):273-275.
6. Farman AG, Scarfe WC. Digital dental radiography is not an "all or nothing" decision. Contemp Esthet Restor Pract 2006;10(3): 12, 14-15.
7. Levato CM. Technology integration: a journey, not a destination. Compend Contin Educ Dent 2002;23(10 suppl 2):4-10.
8. Sato S, Arai Y, Shinoda K, Ito K. Clinical application of a new cone-beam computerized tomography system to assess multiple two-dimensional images for the preoperative treatment planning of maxillary implants: case reports. Quintessence Int 2004;35(7):525-528.
9. Guerrero ME, Jacobs R, Loubele M, Schutyser F, Suetens P, van Steenberghe D. State-of-the-art on cone beam CT imaging for preoperative planning of implant placement. Clin Oral Investig 2006;10(1):1-7.
10. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc 2006;72(1):75-80.
11. Levato CM. New technologies: their implementation and the future. Alpha Omegan 2001;94(4):20-23.
12. Kitagawa H, Scheetz JP, Farman AG. Comparison of complementary metal oxide semiconductor and charge-coupled device intraoral X-ray detectors using subjective image quality. Dentomaxillofac Radiol 2003;32:408-411.
13. Schleyer TK. Integrating dental office technology: the next frontier. Dent Abstracts 2003;48(3):112-113.
14. American Dental Association. B-164-2000 and B-165-2000. 2000 Transactions. 141st Annual Session. Chicago: American Dental Association; 2000:408.
15. Farman AG. Raising standards: digital interoperability and DICOM. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;99(5):525-526.
16. ISO 12052:2006. Health informatics: digital imaging and communication in medicine (DICOM) including workflow and data management. "www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=43218". Accessed April 18, 2008.