

Digital imaging for dentists

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Abstract

This review of digital imaging and the technical aspects of radiographic equipment manufactured for dentists is designed to provide practical information to assist in the decision making process and purchase of radiographic digital imaging for clinical use.

Key words: Digital imaging for dentists.

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INTRODUCTION

The intent of this review is to provide the reader with rudimentary information on the current status of digital imaging in dentistry. The citation of overly technical information has been avoided. This is intended to be a readable overview of dental digital imaging.

At least 22 companies deal in dental digital radiography equipment. However, occasional name changes, new vendors and advertising strategies often make it difficult to identify the source of production, marketing and extent of product distribution. These factors frequently result in inadequate operating instructions, difficulty obtaining service backup and poor technical support. Difficulties also arise when products are licensed under other manufacturers' names and badged accordingly even though the original manufacturer may be selling this same hardware/software under their name.

Manufacturers cannot agree on product uniformity, database organisation and image file format. To be different is a marketing strategy which hinders rather than helps in the establishment of logical uniformity of software. Very few dental equipment manufacturers provide and distribute reasonably adequate information on technical aspects of the hardware and software employed in the manufacture of their product. Even fewer manufacturers provide comprehensive training courses at the time of installation or later. To some extent, though, dentists are at fault in that they do not ask for and perhaps do not know what information they need to enable them to make the best of their

equipment's potential. It might well be that, in seeking to simplify instructions, some manufacturers are unwittingly contributing to an ongoing ignorance or incomplete understanding of the imaging modality used by a dentist.

While most general dentists and endodontists want an immediate image on their digital imaging screen/display, there are some important factors to consider. Before the advent of digital imaging, dentists had to wait minutes before an acceptable film based image was processed (endodontists used 'yoghurt heaters'). However, an immediate image might not be all that critical.

Digital imaging systems

Intra-oral digital imaging radiography is becoming well established in Australian dental clinical practice. There are two choices of imaging systems – charge coupled device (CCD) based and storage phosphor systems (SPS), which is sometimes referred to either as imaging plate systems (IPS) or phosphor stimulable plate systems (PSP).

Solid state detectors

The CCD is a receptor connected by an insulated wire cable to a computer and image processor. The CCD image output is almost immediate. The earlier large and bulky CCD receptors are now regarded as outdated. The new complimentary metal oxide semiconductor (CMOS) incorporating the active pixel sensor (APS) system and the more advanced CCD receptors are much thinner and less bulky sensors with improved resolution characteristics (Fig 1).

CCD to improved CMOS-APS

The original manufacturing technique adapted from CCD video camera technology only allowed recording of a rather small area and the bulky sensors covered only two or three teeth. Today, the more sophisticated sensors cover a larger surface area, an area similar to the newly marketed intra-oral film sizes. A suitable occlusal sized receptor is still on the drawing board. Unfortunately, some CCD sensors are still bulky, inflexible and, in use, have a cable extension out of the oral cavity. Care must be exercised as CCD sensors are

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Fig 1. A Schick CMOS-APS SSD system with positioning device.

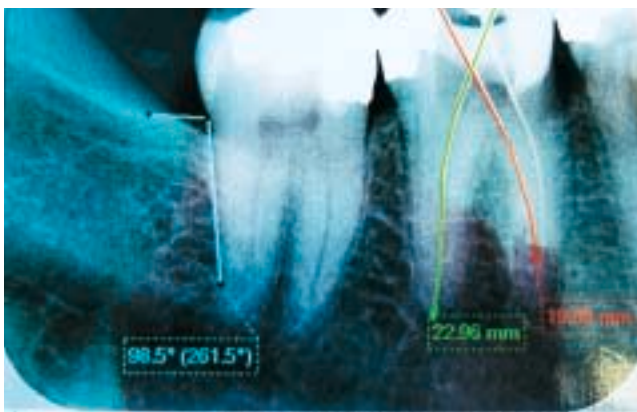


Fig 2. Standard system software for onscreen assessments and manipulation.

fragile and very expensive to replace. The recent development of a semiconductor chip that allows high speed wireless communication could play a part in SSD technology.

The ASSD (amorphous silicon solid state) systems with almost limitless plate size possibilities will eventually be adapted to dental digital imaging.

Sanitisation

In dental digital imaging, sanitisation is the preferred method of infection control. Disposable plastic envelope style covering of the sensor and wire is mandatory. In a paper examining patient discomfort with imaging devices and also cross-infection, Wenzel et al¹ concluded that, in addition to patients expressing a preference for phosphor plate system sensors, provided quite simple standard hygiene procedures were adopted, cross-contamination posed only a minor problem for either SSD or IPS systems.

Phosphor plate systems

Manufacturers of phosphor plate storage systems have produced plates of various sizes which have similar dimensions and close to the same thickness as film. The plates, which are easier to use with intra-oral positioning devices than CCD systems, are to some extent flexible but cannot be bent. Tests have shown

they are much more comfortable for patients than CCD.¹ The infection control management employed includes the use of sealed plastic envelopes with a specific control protocol at the feeder entrance to the processor. The SPS is a chemically (rare earth) coated reusable plate capable of energy storage. With systems such as Digora (Fig 3, 4), DenOptix (Fig 5) and CD-Dent, the scanning laser beam directed at the surface of the plate releases latent energy which is measured at each pixel in possibly over 200,000 locations on the plate. The resultant electrical analog signal is converted into a digital signal via an analog/digital (A/D) converter and subsequently, after being digitised and transmitted over the interface cable, it is presented as a screen image. The entire operation is carried out in a specifically designed digital processor. These processors and other hardware/software features differ quite significantly between the makes.

Advantages of intra-oral digital imaging systems

The time lapse between exposure and image is greatly reduced with intra-oral digital imaging systems and there are no hazardous chemicals or mess. A reduction in the radiation dose is possible, greatly aided by the dynamic range of the system. Phosphor stimulable plate systems have a broader dynamic range than film and CCD. User interface options include task dependent hardware/software, electronically controlled archiving and transmission of images. The dynamic computer systems with ever improving software allow image manipulation and subjective image enhancement (Fig 2).

With all these advantages, it's time to look seriously at implementing digital imaging into the dental practice. However, it won't be the answer for all dentists – the cost/ benefit aspect and level of computer literacy will influence decisions. The ability to read soft-copy instead of a traditional film is an initial challenge and the environment in which the screen/monitor is used will be a very important issue.

Image characteristics

It is anticipated there will be similar or better quality images from an IP system (SPS) to film, but over a much increased exposure range. The CCD images do not enjoy this flexibility but exhibit excellent imaging and superior resolution. However, it should be remembered that if overly high exposure values are used, radiographic burnout is likely to occur. For example, adverse root size/thickness and cervical imaging will be recorded and areas of saturation may be produced within the CCD images.

The overexposure effect is less with the SPS/IP systems. In fact, this is often regarded as a disadvantage because the clinician may not be aware if there has been overexposure as a result of faulty technique or timer irregularity/malfunction.

Digital imaging, while producing reasonably satisfactory images, results in a lower patient radiation



Fig 3. Digora fmx hardware. Processor add-ons cope with full mouth survey or high volume film taking.



Fig 4. Digora imaging plates of various sizes arranged in racks.



Fig 5. DenOptix imaging plate system hardware. Periapical and panoramic films are placed on a cylindrical insert that rotates within the laser beam scanner/processor.

dose. The downside is that fewer primary photons (quanta) produce greater noise (quantum mottle), potentially compromising interpretation and diagnosis.

In a study comparing four digital intra-oral radiographic systems, Araki et al² concluded that, of the four systems tested, the Trophy RVG-4 had the highest resolution with the narrowest latitude, whereas Digora produced a much wider latitude but with the lowest resolution. Many systems will perform within these parameters but vary in the balance between resolution and latitude.

In summary, better image quality is achieved over a much wider exposure range (latitude) with the IP storage phosphor system than with film or CCD systems. The main objection to IP systems is that, depending on the task, there is a 25-60 second wait for an image to be presented. In fact, one system initially took about five minutes to process a panoramic image!

It could be that periodontists and those interested in caries detection would find PSP a more suitable task orientated system whereas endodontists might have a preference for CCD/CMOS-APS technology. The other inference is that endodontists seem to want an immediate image and thus CCD is most popular with them. Greater radiographic information is possible with the technology and slower processing features of IP systems. So, if time is not quite the critical factor, for a periodontist requiring very accurate positioning of the sensor, IP systems could be a distinct advantage. Another important issue raised by Ludlow et al³ is their

comparative test of the Trophy RVG UI sensor and Kodak Ektaspeed Plus film. The RVG was tested in periodontal mode and recorded a resolution of 10.5lp/mm and a high resolution mode of 15.3lp/mm. By comparison, the tests showed Ektaspeed film returned a resolution of 20lp/mm, suggesting that manufacturers' claims might not match academic research.

Radiation reductions

Much is made of the considerable reduction in patient radiation dose achieved by digital imaging. Another important consideration is the dynamic range of a system. Dynamic range is the measure of the ability of a total imaging system to record acceptable images over a broad range of x-ray exposure factors. Higher image quality is achieved over a much wider exposure range with PSP. Phosphor stimulable plate systems have a larger dynamic range – an acceptable image quality for procedures such as caries detection and endodontics can be kept at 6-8 per cent of the exposure factors needed for E-speed film.^{4,6} However, it is debatable if timer and tube performance can be consistently maintained at this factor of time reduction. Of course, there will be numerous occasions when greater exposure is required.

The CCD sensors work at exposure levels 25-50 per cent less than E-speed film and they have a narrower

dynamic range than PSP.⁶ Over-exposure (accidental or deliberate) is much better coped with by PSP than CCD as CCD will show blooming or overexposed black patches. Fundamentally, CCDs do not tolerate errors of overexposure and there can be some loss of important information with underexposure. Blooming deteriorated images from SSD systems at lower exposures than burnout effects deteriorated conventional radiographs and images from PSP systems.⁷ Lower exposure factors with CCDs and PSPs increase the noise in the screen image and may adversely influence the diagnostic accuracy, especially in endodontics. Again, in endodontics, over-exposure with CCDs gives an incorrect imaging record of file length and root dimensions. Therefore, in the subjective manipulation of an under- or over-exposed image, it is possible that an image which looks aesthetically acceptable to an inexperienced or untrained eye could not meet full diagnostic requirements.

Collimation

Creating to a 60-80 per cent decrease in radiation exposure, collimation has always been recommended in intra-oral radiography. Because there is reduced scatter radiation influencing the film, there is an overall improvement in clarity and production of a precise image. All CCD and IP systems, using appropriately sized technical aids, should have specific collimation. With smaller CCDs, the difference between standard round and specific size collimation is significant, leading to a substantial improvement in image quality.⁸

Cost benefits

Time management is crucial in modern dental practices and operator time is an expensive area where savings can be made. However, clinicians must be reminded that the digital imaging system is not a toy and that manipulating images to entertain the patient will erode any cost benefit. Manufacturers of digital imaging systems should concentrate on producing a user-friendly machine with a fully utilisable image which needs no manipulation or enhancement. Sidexis has a built-in proprietary pre-processing filter that optimises the image histogram prior to pre-processing. In IP systems, the DenOptix unit is set up for most suitable (usual) viewing. However, if very low exposure factors are used, Digora would need some manual enhancement – the image management is task dependent.⁹ Soredex-Orion is working on software upgrades for Digora.

Since the introduction of digital imaging, dentists are likely to expose more of the radiographic examinations made in the practice. Dental personnel are unlikely to expose so many radiographs and, with digital imaging technology, no longer have to do chemical processing, cleaning up, film mounting and filing. As a result of this streamlining of operations, work practices and radiography skills will change within dental practices.

Medico-legal aspects

In any modern dental practice, it is essential to have adequate and easily accessible records. A vital part of any dental recordkeeping is the ability to import and export radiographic images. Data protection is an integral part of any efficient office procedure.

It is a relatively simple task to export an image into a program, alter it and then reimport it back into the records. Digital images are easily manipulated and, unless data is protected adequately, there is a risk that patient and insurance company frauds will be perpetrated.

As there is easy and regular access to the graphic user interface, staff fraud and illegal access by outsiders remain possibilities. Password protection and ensuring the activity and security of hardware and software are essential.

TACT in dentistry

Tuned aperture computed tomography (TACT) is a flexible 3D imaging method that converts any number of 3D projections produced from any number of arbitrary or even unknown projection source positions and angles into a true 3D image. The image produced is similar to viewing the original object with unlimited visual access through a window or aperture whose size is determined by the original projection.¹⁰

It's a software driven imaging innovation for intra- and extra-oral procedures which can produce 3D concepts of the teeth or structures within the recorded region.¹¹ Such 3D displays could be useful for caries/demineralisation detection. The displays are useful in the determination of root fractures, especially vertical fractures. Such sophisticated techniques will also allow better perception of significant periodontal lesions. Three-dimensional technology enables reconstructions, with suitable enhancement and refining of the digital image, from up to seven images of the region of interest at different angles. At the moment, the development of TACT in dentistry is centred on using a panoramic system as the radiation source.

CRTs

Cathode ray tubes (CRT) have different luminance characteristics and default features that are not suitable for grey scale viewing. Because of this, CRTs provide variable diagnostic accuracy. If the luminance is too high or too low, the detection rate for many lesions is decreased. Research work on luminance, in relation to oral radiology, is in its infancy and variation in detectability at different noise levels needs to be further developed.

Printers

Many of the printers currently used by operators of digital imaging equipment are adequate but there is no genuine excitement about the results which, after all, are essentially photographs. Expensive laser dry-printer

systems such as the Imation Dry View 8300 are excellent, but probably too expensive for the budget of the general practitioner.

CONCLUSION

For a seamless transition to a filmless world, more digital imaging equipment improvements will be necessary. The dental profession should take a more proactive stance in informing manufacturers what they really want. We must persist in making manufacturers aware of three shortcomings:

Inconsistent diagnostic image quality

Even though the diagnostic quantum efficiency, spatial resolution (lp/mm) and contrast can be optimised, there is no guarantee of a consistent high quality clinical image.

Hardware management

Image management is an essential system element. There is also a need for improvements in archiving methods, fileserver activity and optimising performance, connectivity and ease of accessing information/data. Compromises in computer hardware should be actively discouraged and emphasis placed on well written equipment specifications for workstations and associated peripheral hardware.

System integration

For easy clinical patient record access, it is essential that information systems be integrated.

SUMMARY

Digital imaging is a matter of perspective and cost benefit. Research indicates most digital imaging modalities do not significantly differ in their diagnostic efficiency to that of conventional Kodak Ektaspeed-Plus film. The more recently produced Kodak Ektaspeed Plus film has a potential of 18-20lp/mm resolution and the new Kodak Insight E/F-speed film has a similar resolution but at about only 77 per cent of the exposure required for Ektaspeed Plus film.¹²⁻¹³ Manufacturers' image resolution claims for many sensors are not necessarily accurate or the essential factor to consider in a purchase. The most important criterion is the overall spatial resolution of the total

system from the sensor through to and including the monitor.

There is also a need to recognise and appreciate the significant differences in observer diagnostic abilities and far more attention really needs to be directed toward that aspect of diagnosis/interpretation.

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