

## FEATURES SECTION

# An introduction to digital radiography in dentistry

**J. Brennan**

St Luke's Hospital, UK

### Abstract

The aim of this article is to explain the basic principles of digital radiography, and to discuss the intra- and extra-oral imaging systems currently available. There are two main types of digital sensors available. One is based on charge coupled device technology and the other consists of phosphor storage plates. The advantages and disadvantages of each are highlighted with particular attention to orthodontics.

### Index words:

Charge coupled devices, digital radiography, orthodontics.

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## Introduction

Digital radiography has been used widely in medicine, but it was only in the 1980s that the first intra-oral sensors were developed for use in dentistry. Unfortunately, the early systems could not capture panoramic and cephalometric images, and this made it impossible for surgeries to abandon film processing and adopt digital technology. Recently, the development of cost-effective intra- and extra-oral digital technology coupled with an increase in computerization of practices has made digital imaging a superior alternative in many respects to conventional film imaging.

Advantages of this type of system for the orthodontist and the patient include the ability to gain cephalometric analysis and superimposition quickly on the chairside computer, manipulation of images to aid diagnosis, dose reductions, and the ease of storage. This article aims to introduce the basic principles behind digital radiography and also to discuss some problems, such as set-up costs and cross-infection control issues that can affect the systems currently available

## Principles

### *Conventional imaging*

Conventional intra-oral radiographic film consists of silver halide grains in a gelatine matrix. When this film is exposed to X-ray photons the silver halide crystals are sensitized and are reduced to black during the developing process. The film acts as both the radiation detector and the image display.

With extra-oral films indirect action receptors are used to help record the image. This type of film is sensitive to light photons which are emitted by adjacent intensifying screens. Although the film is constructed of silver halide crystals these are primarily sensitive to light rather than X-rays. The use of intensifying screens reduces the dose and can be used where fine detail is not required.

### *Digital imaging*

In digital radiography, instead of the silver halide grain the image is constructed using pixels or small light sensitive elements. These pixels can be a range of shades of grey depending on the exposure, and are arranged in grids and rows on the sensor, unlike the random distribution of the crystals in standard film. However, unlike film the sensors are only the radiation detector and the image is displayed on a monitor.

The signal that is produced by the sensor is an analogue signal, i.e. a voltage that varies as a function of time. The sensor is connected to the computer and the signal is sampled at regular intervals. The output of each pixel is quantified and converted to numbers by a frame grabber within the computer. The range of numbers is normally from 0 to 256 with 0 representing black, 256 representing white and all others are shades of grey.

The number of grey levels relates to contrast resolution and the size of the pixels is related to spatial resolution. Together these determine the overall resolution (i.e. the ability to distinguish between small objects close together) of the image. Resolution can also be expressed in line pairs per millimetre. Most conventional E speed films have a resolution of 20 LP/mm whereas with digital

images the resolution ranges from 7–10 LP/mm. The reduced resolution should not interfere with clinical diagnosis.

## Image acquisition

There are two ways to acquire a digital image.

### *Indirect acquisition*

A digital image can be produced by scanning conventional radiographs using a flatbed scanner and a transparency adaptor, or by using a charged coupled device camera instead of the flatbed scanner. This image can then be manipulated using software packages or be passed on to a second party via a modem.

### *Direct digital imaging*

There are two systems available, one produces the image immediately on the monitor post-exposure and is therefore called Direct Imaging. The second has an intermediate phase, whereby the image is produced on the monitor following scanning by laser. This is known as semi-direct imaging.

*Semi-direct image plate systems.* The image plate method involves the use of a phosphor storage plate (PSP). This plate stores energy after exposure to radiation and emits light when scanned by a laser. The scanner stimulates the phosphor plate and stores a record of the number of light photons detected.

Loading of the scanners generally only requires subdued lighting as the plates are slightly sensitive to visible light. However, some products are more light sensitive than others. The lasers used are centred around the 600-nm band and are usually of the helium-neon variety. Scanners, the size of a breadmaker, can accommodate multiple image plates at any one time. The exact numbers varies between manufacturers. There is a delay while the image is 'developed' before it appears on the monitor. Up to eight bitewing radiographs take about 90 seconds and a panoramic image can take approximately 3 minutes to be scanned. Again, the scan times do vary between manufacturers. Although the plate can store energy for a number of days, information starts to be lost within minutes after exposure and it is advised to scan the plates quite quickly to optimize the image recovered. To fully remove the latent image the plate should be exposed to high intensity light (as found on viewing boxes).

Image plates are available in exactly the same sizes as conventional film and come with disposable plastic barriers. They have no wires attached and are reusable for thousands of exposures, but do need careful handling to avoid surface damage. Current systems have a spatial resolution of 6–8 LP/mm.

*Direct sensor systems.* The sensor for the radiation image is usually a Charge Coupled Device (CCD). It consists of silicon crystals arranged in a lattice and converts light energy into an electronic signal. This technology is widely used in video cameras. The sensor cannot store information and must be connected via fibre optic wires to the monitor, which can make the sensor bulky and awkward to use.

The greatest advantage of the direct sensor system is the gain in time. The image is directly projected onto the computer screen. Originally, the active areas of the sensors were smaller than conventional film, which increased the incidence of 'coning off' and required repeat exposures to capture all the desired information. Recent innovations have produced sensors approaching or equal to standard film sizes.

## Extra-oral digital imaging

Extra-oral digital imaging is available using both systems. However, the larger CCD sensors are extremely expensive and usually requires the purchase of new X-ray generators, although a 'retro-fit' system has been developed in the USA. These constrictions effectively mean that the PSP method is the one most commonly used.

### *Panoramic radiography*

The PSP method of panoramic digital imaging is very similar to conventional film. The film and intensifying screen are replaced by a storage phosphor plate. The plate is scanned after exposure, which can take up to 3 minutes or longer depending on the product used. The resolution of these systems is greater than 4 LP/mm.

### *Cephalometric radiography*

Naslund *et al.* investigated the effect of dose reduction obtained with PSP on the identification of cephalometric landmarks and concluded that dose reductions of up to 75 per cent did not effect the localization of cephalometric landmarks.<sup>1</sup> It is also worth noting that

with CCD sensors the image is acquired over 15 seconds as the sensor and narrow X-ray beam move up the facial bones and could lead to an increase in the incidence of movement artefact.

## Advantages of digital imaging

### *Dose reduction*

Dose reductions of up to 90 per cent compared to E-speed film have been reported by some authors in the diagnosis of caries.<sup>2</sup> Although some researchers do claim dose reductions compared with conventional extra-oral film, in practice the background noise rises to unacceptable levels. It is now accepted that there is no appreciable reduction compared with films used in conjunction with rare earth intensifying screens.

### *Image manipulation*

This is perhaps the greatest advantage of digital imaging over conventional film. It involves selecting the information of greatest diagnostic value and suppressing the rest. Manufacturers provide software programmes with many different processing tools, however some are more useful than others and these include:

*Contrast enhancement.* This can effectively compensate for over or under exposure of the digital image. It has been shown that contrast enhancement of CCD devices were more accurate than E-speed film for detecting simulated caries under orthodontic bands.<sup>3</sup>

*Measurements.* Digital callipers, rulers and protractors are some of the many tools available for image analysis. Many authors have reported on their application in cephalometric analysis.<sup>4,5</sup> The images can also be superimposed onto each other and onto digital photographs.

*3-D reconstruction.* This application can be theoretically used to reconstruct intra- and extra-oral images. The uses range from profiling root canals to visualizing facial fractures in all three dimensions.

*Filtration.* The addition of filters to the airspace around the face can clarify the soft tissue profile if the original soft tissue image was poor.

### *Time*

Much time is gained especially with the CCD system where the image is displayed at the chairside immediately

post exposure. Although a lag time between scanning and the appearance of an image exists with the PSP method it is still substantially faster than conventional developing processes in general use.

### *Storage*

Storage was initially a problem before the development of DVDs and CD ROMs as three peri-apical images would fill a floppy disc. However, now a CD ROM can hold over 30,000 images. This means that images can be stored cheaply and indefinitely.

### *Teleradiology*

The digital image file can be further reduced in size by compression techniques, and sent via a modem and telephone line to colleagues for review. This had the advantages of not losing radiographs in the post and saving time if an urgent appointment is required. The operator at the other end can also manipulate the image if desired.

### *Environmentally friendly*

No processing chemicals are used or disposed of. Both CCD sensors and the PSP plates are capable of being reused for many thousands of exposures. They can, however, become scratched and damaged if not handled carefully.

## Disadvantages of digital imaging

The majority of the disadvantages are associated with the CCD system.

### *Cost*

Currently, the cost of converting from intra-oral film to digital imaging is approximately 6600 Euros. This initial outlay should be offset against the time saved and the efficiency of storage of the images.

### *Sensor dimensions*

These are still quite bulky for the CCD system and awkward to position due to trailing fibre optic wires. The original problem of small sensor active areas has been rectified and the same amount of information can be captured as conventional film.

### *Cross-infection control*

Each intra-oral sensor and plate must be covered by a plastic bag, and this bag is changed between patients. However, if they become directly contaminated there is no way of sterilizing them and they should be discarded regardless of expense.

### *Medicolegal*

Concerns have been raised in the past about the ability to manipulate the images for fraudulent purposes. Manufacturers of software programmes have installed 'audit trails', which can track down and recover the original image. Many insurance companies in the USA are accepting digital images as valid attachments when the claims are electronically claimed.

## Conclusions

The technology is now available to run a practice almost paper free. It is theoretically possible to store clinical notes, photographs, radiographs, and study models on disc, and refer or consult online. The future of digital imaging could include the testing and upgrade of X-ray equipment and software on-line. Research is also continuing into the development of a credit card sized 'smart card', which could carry a patient's medical and dental notes along with their radiographic images. It is important that advances in technology are accepted and the benefits that they produce utilized in order that clinical practice and patient care continue to improve.

## Useful Websites

<http://www.Schicktech.com/>—This is the website of one of the largest manufacturers of CCD systems.

<http://www.gendexxray.com/>—Dentsply run this site and give information about the Denoptix PSP systems available.

<http://www.odont.aau.dk/rad/Digitalx.htm>—Useful site with links to all the manufacturers of digital imaging equipment. Highlights intra-oral, panoramic, and cephalometric products, and which system they use.

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