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Image Receptors: An update

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ABSTRACT: Image receptors has evolved in leaps and bounds from the time of discovery of x-radiations. This review article scans through the stages of development of image receptor from the conventional (films) to the digital (sensors) modes of image plates. An array of image receptors are available in the modern dentistry which leaves the dentist with a wide variety of options to confirm the clinical findings and thereby arrive at a clear diagnosis. It henceforthe helps in a better prognosis for the patient's ailment.

KEYWORDS: Image receptors, Conventional image receptors, Digital image receptors.

INTRODUCTION

An image is a reproduction, representation or imitation of the physical form of a person or thing. It is derived from Latin word for imitate. The inventor of photography was probably the Chinese about 3000 years ago. They possessed a light sensitive material that transferred the images of leaves onto the surface of pots and vases. Englishman William Henry Fox Talbot in 1841 developed negative and positive approach of image production.

Image is artificial imitation of external form of object and refers to picture and likeness of the object. Receptor refers to something that responds to the stimulus. Image receptors used in dentistry today are film, film-screen combinations, the electronic sensors used in digital imaging and computed tomography (CT). Some medical imaging systems, such as fluoroscopy systems, use X-rays as the energy source without film. Other systems such as CT, ultra sound (sound waves) and magnetic resonance imaging (MRI) (radio waves) system also do not use film to record the image. The 'films' seen in CT and MRI are actually print outs, referred to as hard copies, of the electronic image. Even with ever increasing use of digital imaging, film remains by far the most commonly used image receptor in dentistry today.[1]

Evolution of X ray films:

With the improvement of the power-supply, even the glass photographic plates previously used as the image receptors were replaced by the films. Until the First World War radiographic images were made on photographic plates. It is easy to imagine how easily these plates could break, especially in the mobile radiological units. The photographic cellulose film that had long been used for dental radiology replaced these plates.

First dental radiograph was made by Otto Walkhoff on the photo plate.

Photographic film and paper had been tried for recording of X-ray images as early as 1896.

- William J. Morton in 1896 used roll films manufactured by Eastman Kodak Company.
- Weston A. Price in 1900 designed celluloid base dental film.
- Kells in 1909 reported that he was cutting, wrapping and using roll type photographic film.

However, despite there cost, weight, bulk, fragility and patient discomfort in dental radiology, glass plates continued to be used.

- In 1913 hand wrapped, moisture-proof dental packet containing two films was placed in the market.
- In 1919, first machine wrapped dental film packet called Regular film (Kodak) became available in the market. It has emulsion on one side and was relatively slow; a molar exposure required 8-9 secs. However, it produced sharp images.
- In 1924, emulsion was placed on both the sides of film, which doubled film speed (reduced exposure to 50%) and reduced tendency of film to when it dried. Marketed under name Radiatized film (Kodak).

In 1924, the American Eastman Kodak Company became the pioneer of radiographic filming.

- In 1940, Ultra speed (Improved Raditized) film became available, which again doubled the film speed.
- In 1955, speed of both these films was again improved by factor of 8.
- In early 1980s, Ekta speed films again reduced exposure by 50%, and are currently undergoing the slow but apparently inevitable acceptance by the profession.
- After this, a new dental x-ray film Dentus M4 was introduced by Agfa.
- In 1994, Kodak Ekta-speed plus films were manufactured by Eastman Kodak Co.
- In 1997, Agfa Dentus M2 Comfort film was placed in the market.
- In 2001, F-speed films were introduced.

Legacy of this evolution of ever faster film has been a concomitant lower patient exposure.

While changes in the film speed accompanied, film base was also undergoing improvements.

- Early 1920s, cellulose nitrate was used, which was highly inflammable and when burned emitted large quantities of poisonous gases.
- Although invented in 1906, a non-inflammable cellulose triacetate base was not marketed till 1924. As it has disadvantage as film base:
  - Expensive
  - Subject to mold, wrinkle
  - Tendency to break

Consequently, cellulose nitrate continued to be the most popular base material until 1929, when a fire in Cleveland Hospital claimed more than 100 lives. After that cellulose acetate was used.

- In early 1960s, film base of polyester was introduced and has been the material of choice. It is stronger than cellulose acetate, so the film can be made thinner and does not tend to warp like its predecessor.

The technology used for extra-oral imaging is as old as discovery of X-rays. Yet today, imaging dentists are still perfecting extra-oral radiography. They are finding new ways to improve its diagnostic qualities while, at the same time, reducing radiation exposure levels.

X-ray Film:

Photographic film and paper had been tried for recording of x-ray images as early as 1896. William J Morton used roll film manufactured by Eastman Kodak Company when he examined teeth in April of 1896 and about 1900 Weston A Price, a Cleveland dentist designed a celluloid base dental film, which was manufactured. Kells reported that he was cutting, wrapping and using roll-type photographic film in 1909. However, despite their cost, weight, bulk, fragility and patient discomfort in dental radiology, glass plates continued to be used. In 1913, a hand-wrapped, a moisture-proof dental packet containing two films was placed on the market. The first machine-wrapped dental x-ray film packet, called Regular film (Kodak), which became commercially available in 1919. It had emulsion on only one side and was relatively slow; a molar exposure required 8 or 9 seconds. However, it produced sharp images. 5 years later, the emulsion was placed on both sides of the film, which doubled the film speed (reduced exposure by 50 %) and reduced the tendency for the film to curl when it dried. This film was marketed under the name Radia-tized film (Kodak). In 1940, Ultra Speed (Improved Radia-tized) film became available, which again doubled the film speed over that of original Radia-tized film (Kodak). In 1940, Ultra-Speed (Improved Radia-tized) film became available, which again doubled the film speed over that of the original Radia-tized film. The speed of both these films was again improved by a factor of about 8 in 1955. However, with the increased film speeds, there was an accompanying increase in grainness of the image, which detracts from photographic quality. EKTASPEED film (Kodak), introduced in early 1980 s, has again reduced exposure by 50 %, and is currently undergoing the slow, but apparently inevitable acceptance by the profession.

While the changes in film speed were being accomplished the film base was also undergoing improvements. Until the early 1920s, cellulose nitrate was used, which was highly flammable and when burned emitted large quantities of poisonous gases. Although invented in 1906, a non-flammable cellulose triacetate base was not marketed until 1924. It had some disadvantages as a film base: it was more expensive, was subject to mould, wrinkled and had tendency to break. Consequently, cellulose nitrate continued to be the most popular base material until 1929, when a fire in Cleveland Hospital claimed more than a hundred lives. After that, cellulose acetate was used. In the early 1960s, a film base of polyester (Darcon) was introduced and has since been the material of choice. It is stronger than cellulose acetate, so the film can be made thinner and doesn't tend to warp like its predecessor.

Digital image receptor:

Digital image receptor is the device that intercepts the X ray beam after it has passed through patient's body, produces an image in digital form, that is, a matrix of pixels each with a numerical value. It replaces the cassette containing intensifying screens and films that is used in conventional film screen radiography.

Digital image receptor is in the form of a matrix of individual pixel elements, which work based on certain technologies like solid state technology and photostimulable phosphor (PSP) plate technology.[2] When a pixel area is exposed by x ray beam (after passing through patient's body), X ray photons are absorbed and energy produces an electrical signal. This signal is in the form of analogue data that is then converted into a digital number and stored as one pixel in an image. Three types of solid state sensors are in use- Charge Couple Device (CCD), Complementary Metal Oxide Semiconductor (CMOS) and Thin film transistor (TFT).[3]

PSP consists of a phosphor coated on top of a plate in which latent image is formed after X-ray exposure. Latent image is converted to a digital image by a scanning device through stimulation by laser light. It is also referred to as storage phosphor on the basis of the notion that image formation is temporarily stored within the phosphor. The term image plates is used to differentiate it from films and solid state detectors. The use of PSP plates in medical radiology is referred to as computed radiography.[2]

Dental Roentgenograms:

A dental roentgenogram is a photographic film presenting a shadowgraph of dental tissues.

When an x-ray beam reaches the patient .Its contains no useful medical information. After the beam passes through and interacts with the tissues in the part examined, it contains all the information that can be revealed by that particular radiographs examination. This is represented by variation in the number of x-ray photons in different areas of the emergent beam. The most important material used to decade the information carried day the attenuated x-ray beam is photographic film/x-ray film

X-ray photons making up the radiographic image cannot be seen by the human eye this information is converted into visible image either by a photographic emulsion can be exposed to the x-ray directly or the x-ray energy is converted into visible light a can be used to expose x-ray film.

Photographic film and paper had been tried for recording of x-ray images as early as 1896-William J Morton

1900 Watson designed a celluloid base dental film. However despite their cost eight bulk fragilities and patient discomfort gleam plate continued was in use.

Types:

1. Films -

- Intraoral films
- Extraoral films
- Duplicating films
- Self developing films

2. Films depending upon their mode of action -

- Direct action /Non-screen films
- Indirect action /Screen films

3. According to emulsion coating -

- Double coated films
  - Direct exposure films (Non-screen films)
  - Screen type films (Double screen films)
- Single coated films
  - - Screen type films (single screen)
  - Photofluorographic films
  - Cathode ray tube films
  - Duplication films substracton films
  - Laser imaging films

4. According type of emulsion used -

- Blue sensitive films
- Orthochromatic films
- Panchromatic films
- Infrared films

Intraoral X-ray films:

- Periapical films: objective is to show the apex of the teeth and surrounding structures and it should also show the entire crown of teeth.
- Bitewing films: objective is to show crowns of the teeth of both the arches and their interproximal bone crests on one film.
- Occlusal films: objective is to show large segments of maxillary and mandibular arches, part of maxilla and floor of mouth.

Size of the intraoral films:

Films Periapical Bitewing Size

Child films 1.0 2.0 22x35mm

Ant. Adult films 1.1 2.1 24x40mm

Post. Adult films 1.2 2.2 31x41mm

Occlusal films 3.4 57x76mm

Contents of the film packet:

The intra-oral film packets are available in quantities of 25,100 or 150 films per container made of plastic trays or cardboard boxes. Boxes are labeled with type of film, film speed, size, total no. of films enclosed and expiration date.

Dental x-ray film packets have four basic components:

1) **X-ray film:** it is a double emulsion film and requires less radiation exposure to produce an image.

2) **Paper film wrapper:** to protect the film from light, saliva, damage by fingers during processing.

3) **Lead foil sheet:** thin lead foil sheet is positioned behind the film to shield the film :-

- From back scattered radiations that result in film fog.
- Absorbs some of the radiations after x-ray beam exposes and passes through the film.
- Contributes to the rigidity of the packet

4) **Outer package wrapping:** it is a soft vinyl wrapper, which protects the film from exposure to light and saliva.

Outer package wrapping:

- **Tube side:** it is solid white and has a raised bump in one corner and when placed in the mouth white side of the film packet must face the teeth.
- **Label side:** it has a flap used to open the film packet and is color coded.

One film packet Two film packet

Kodak ultra speed	Green	Grey
Kodak ekta speed	Blue	Pink

The following information is printed on label side:-

- Dot that corresponds with raised identification dot on the film
- Statement "opposite side towards tube"
- Manufacturer's name
- Film speed
- No. of films enclosed

Self-developing films:

The x-ray film is presented in a special sachet containing developer and fixer. Following exposure, the developer tab is pulled, releasing developer solution which is milked down towards the film and massaged around it. After 15 sec. fixer tab is pulled and fixer solution is milked down and agitates the film. After fixing chemicals are discarded and film is processed using conventional processing procedures.

Advantage: It eliminates the need of dark room for processing and it is time saving.

Disadvantages: Poor image quality, expensive, image deteriorates with time, no lead foil inside the film packet, film is very flexible and easily bent and these films are difficult to use in film holders.

Speed of the films

Film speed refers to amount of radiation required to produce an image of standard density. It is the efficiency with which the film responds to x-ray exposure.

Speed = 1/roentgen

X-ray film which requires very little exposure to radiation to produce the radiograph is considered as very sensitive, very fast and having high speed.

Speed range (Reciprocal roentgen)

Films	ADA classification (1983)	ISO classification (1991)
A (slowest)	1.5-3.0	--
B	3.0-6.0	--
C	6.0-12.0	7.0-14.0
D	12.0-24.0	14.0-28.0
E	24.0-48.0	28.0-56.0
F (fastest)	48.0-96.0	56.0-112.0

- Kodak ultraspeed (D speed) films were introduced in 1955 and were most commonly used in U.S.

- In 1981, Kodak Co. introduced faster dental films of speed group E i.e. ektaspeed capable of reducing radiation exposure to half.

Ektaspeed films are double emulsion films coated on blue polyester base, have high sensitivity, low base fog, high sharpness, high gloss radiographs and invariant when used in different processing solutions.

Study was conducted by **Kaffe I**.et al in 1983, to compare ultraspeed with ektaspeed films with regard to speed, sharpness, resolution, and contrast of resultant image. He found that E-speed films were twice as fast as D-speed films. Exposure time was reduced to 50% with no loss of contrast and resolution.

- After this Agfa introduced a new dental x-ray film i.e. Dentus M4.

Benz et al in their study showed that Dentus M4 film is better than ektaspeed film and with a speed range of 48-96.

In another study conducted by **Swenson et al** in 1992, found that there was rapid build up of fog and low inherent contrast in Dentus M4 film as compared to ektaspeed film and has a limited diagnostic value.

- In 1994, Eastman Kodak co. introduced newest E-speed film called Ektaspeed plus films with flat tabular emulsion technology used in extra oral radiography.

The increased surface area that this tabular shape provided resulted more efficient way of producing density which is a key for good contrast radiographs.

Study conducted by **Conover Gary L. et al** in 1995 concluded that ektaspeed plus films are superior to E-speed and D-speed films and have similar contrast and image quality at reduced exposure.

- In 1997, Agfa introduced a new Dentus M2 comfort dental film in the market. This new film was described as E-speed film comparable to Kodak ektaspeed plus films with minimum background fog, fine grain size, and high sharpness and contrast.

- In 2001, F-speed films were introduced in the market by Kodak co.

Study was conducted by **John B. Ludlow et al** in 2001 to compare the film speed, contrast, and exposure latitude of ultraspeed. Ektaspeed plus and insight films. In his study he confirmed the characteristics of insight film as ISO F-speed intraoral film. He found that developer solution exhaustion caused performance of ultraspeed to decrease, performance of ektaspeed was steady and performance of insight film increased.

Resolution was same in all the three films.

Latitude – insight provided 93% of exposure latitude of ektaspeed plus.

Film quality – insight displayed better contrast (1.6), better tonality (1.8), better uniformity (1.9) and greater graininess (2.4).

Digital Image Receptors:

Digital imaging is very similar to film-based imaging in that it requires x-ray interaction with a receptor, latent image processing and subsequent viewing of the image. In digital imaging, the receptors are highly sensitive sensors that require considerably less radiation exposure than film. The data acquired by the receptor is analogue data in the form of a continuous gray scale and must be converted to digital data to be useful. The ADC or analogue-to-digital converter transforms analogue information into numerical information based on the binary number system. Computers operate on the binary number system in which two digits (0 and 1) are used to represent data or information. These two characters are called bits (binary digit) and they form words eight or more bits in length termed bytes. The total number of possible bytes for 8-bit language is 28 = 256. The voltage of the output signal is measured and assigned a number from 0 (black) to 255 (white) according to the intensity of the voltage. These numerical assignments translate into 256 shades of gray. Some digital systems sample the raw data at a resolution of more than 256 gray values such as 10 bit or 12 bit values but are reduced to 256 shades of gray [4]. Once the computer processes the data, the image appears on the monitor for interpretation, enhancement and storage.

Digital radiography receptors include “direct” and “indirect” receptors.

Direct receptors communicate with the computer through an electronic cable or, more recently, wirelessly.

Indirect receptors require a scanning step.

Direct Digital Image receptors:

The charge-coupled device (CCD), complementary metal oxide semiconductor (CMOS), and the complementary metal oxide semiconductor active pixel sensor (CMOS-APS) are all direct receptors. These receptors are rigid, solid-state detectors made of silicon that are arranged in an array of x-ray or light sensitive pixels.

All three of these sensors use similar technology with differences in power requirements, internal components, charge transfer and manufacturability.[5,6] Each pixel is approximately 40µ to 20µ15 in size and is configured into rows arranged in a matrix of 512 x 512 pixels. The pixel size varies depending on the digital receptor, and the size of the pixel has an influence on the image resolution. For example, a 40μ-50μ pixel size results in an image resolution of approximately 10 to 11 lp/mm.16 Solid state sensors used for intraoral imaging are area arrays with two basic formats, direct and fibre optically coupled. Direct sensors capture the image directly like film while fibre optically coupled sensors utilize a scintillation screen coupled to a CCD. When x-rays strike the screen material light photons are produced, detected and stored by the CCD. Direct sensors communicate with the computer via an electrical cable, although wireless sensors recently have been introduced for direct digital intraoral imaging. Direct sensors are available in sizes comparable to 0, 1, and 2 films but are thicker and more rigid in their construction. The active image area is smaller than film so the area of coverage is somewhat diminished. Direct detectors can be reused for each successive projection and the acquired image can be viewed almost instantaneously after exposure.

Indirect Digital Image Receptors:

Photostimulable phosphor plates (PSP), also known as storage phosphor plates (SPP), use indirect receptors. PSP/SPP are flexible, wireless receptors that are similar in size and thickness to film.

Phosphor plates are available in the same sizes as intraoral film including 0, 1, 2, 3 and 4. An individual plate must be used for each projection in the survey, just like film. The phosphor plates consist of a polyester base that is coated with a crystalline halide emulsion of a europium activated barium fluorohalide compound.[7]

When x-rays interact with the phosphor, a latent image is formed and stored until the energy is released during a scanning process.

The plates must be carefully transferred and inserted into a scanning device in which a helium-neon laser beam is applied to release the energy in the form of light. The intensity of the emitted light is proportional to the amount of x-ray energy absorbed by the phosphor plate. The light is captured and intensified by a photomultiplier tube, which converts the light into an electronic signal. The analogue-to-digital converter digitizes the data and displays the image on the computer monitor. Before the plates can be reused, the remnant energy must be removed or erased by exposure to intense light. This can be accomplished by exposing the plates to view box light or by use of commercially produced devices that are less likely to scratch the plates.

There are a number of phosphor plate systems available for digital imaging. Like direct sensors, the primary advantage is exposure reduction. In addition, PSP receptors have wider dynamic range, a larger active area, are thin and wireless and can be used like film. However, the image resolution is lower than direct sensors and film,[8] a processing step is required like film and, thus, image display is delayed. The time delay varies from seconds to minutes depending on the system and the type and number of projections taken. The plates require careful infection control and gentle plate handling to avoid image artifacts. A study conducted by Bedard et al [9] investigated the durability of phosphor plates and the degradation of image quality due to emulsion scratches. They found that plate placement on the scanner drum had a significant impact on the number of scratches produced as did increased usage per plate.[9] Therefore, the plates need to be checked for wear on an on-going basis and may need to be replaced after 50 uses.[9]

Another study investigated the effects of different storage conditions and varying time intervals between exposure and scanning of the plates.[10] Martins et al found that with one PSP system certain storage conditions and time delay in processing the plates resulted in loss of image density, which could have an impact on image interpretation.[10] Therefore, the plates must be protected from storage conditions that might degrade the image and processed closer to the time of exposure to help prevent density alteration of the image.

Film-based images can be scanned to digitize radiographic information. Scanned radiographs are another form of indirect digital imaging. Since the scanning process produces a second version of the original image, some information is lost in translation. This technique requires an optical scanner that is capable of scanning at 600 dpi, able to process transparent images and has the appropriate software to produce the digital image.[11] This method allows digitization of film-based radiographic images so that they can be stored and incorporated into the digital patient record when the dental office makes the transition from conventional to digital radiography. The radiographic images are then available for comparison to newly acquired images and all information is organized and stored in one source for retrieval.

CONCLUSION

Digital radiography is the latest advancement in radiographic imaging in dentistry. Digital radiography systems utilize computer technology and radiation sensitive detectors that capture the image, convert it into numeric data and permit image display on a monitor. Digital images may be enhanced once acquired, conveniently stored, accessed, printed or transmitted. Digital radiography reduces patient radiation exposure and eliminates the need for the darkroom and chemical processing. The quality of the images produced remains dependent on the technical skills of the clinician. Digital radiographic images are considered to be equivalent to film in their ability to diagnose caries, periodontal bone loss and periapical lesions.

REFERENCES

[1] Radiology for the Dental Professional. 9th Edition by Frommer, Stabulas-Savage.

[2] Oral Radiology- Principles and Interpretations. 2nd Edition by Stuart C White and Michael J Pharoh.

[3] Gerard C H Sanderink and Dale A Miles. Intraoral Detectors CCD, CMOS, TFT and other devices. Dental Clinics of North America 2000;44(2):249-55.

[4] Van der Stelt PF. Principles of digital imaging. Dent Clin North Am2000;44(2):237-48.

[5] Paurazas SB, Geist JR, Pink FE, et al. Comparison of diagnostic accuracy of digital imaging by using CCD and CMOS-APS sensors with E-speed film in the detection of periapical bony lesions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000; 89(3):356-62.

[6] Fossum ER. Active pixel sensors: Are CCDs dinosaurs? International Society for Optical Engineering (SPIE) 1993;1900:2-14.

[7] Hildebolt CF, Couture RA, Whiting BR. Dental photostimulable phosphor radiography. Dent Clin North Am. 2000;44(2):273-97.

[8] Huda W, Rill LN, Benn DK, Pettigrew JC. Comparison of a photostimulable phosphor system with film for dental radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1997;83(6):725-31.

[9] Bedard A, Davis TD, Angelopoulos C. Storage phosphor plates: how durable are they as a digital dental radiographic system? J Contemp Dent Pract. 2004;15;5(2):57-69.

[10] Martins MG, Haiter Neto F, Whaites EJ. Analysis of digital images acquired using different phosphor storage plates (PSPs) subjected to varying reading times and storage conditions. Dentomaxillofac Radiol. 2003;32(3):186-90.

[11] Parks ET, Williamson GF. Digital radiography: an overview. J Contemp Dent Pract. 2002;15;3(4):23-39.