# X – RAY DEPARTMENT

**Lecture 3.** د. ســناء القصــاب

## HISTORY OF DENTAL X-RAY FILM

From 1896 to 1913. dental x-ray packets consisted of glass photographic plates or film cut into small pieces and hand-wrapped in black paper and rubber. The hand-wrapping of intraoral dental x-ray packets was a time-consuming procedure. In 1913 the Easiman Kodak Company manufactured the first prewrapped intraoral films and consequently increased the acceptance and use of x-rays in dentistry. The first machine-made periapical film packets became available in 1920.

Today, the films used in dental radiography are greatly improved compared with the films of the past.

Present-day fast film requires a very short exposure time. which in turn reduces the radiation exposure received by the patient. The fast film used today requires one-fifth of the amount of exposure required 25years ago.

## DEFINITION

Dental x-ray film as an image receptor has evolved over many years. Currently the most sensitive and fastest film for intraoral use is Kodak Ektaspeed* (E-speed) film. However, despite the film's availability and reduced x-ray dose to the patient, this film has not been as widely adopted by dentists as it should be. The most popular dental x- ray film is D-speed film, called Ultraspeed. This film requires approximately 40% more exposure time than Ektaspeed. It has been proved in several studies that there is absolutely no loss of information with the use of the faster film, yet the perception of most dentists is that the film is "less detailed" or "grainier" than their beloved Ultraspeed.

These same arguments were raised over two decades ago, when clinicians were asked to try Ultraspeed (D-speed) film as a replacement for a single-emulsion, radiatized film (type C). Patience and education prevailed, and the dental community eventually adopted the change. New information contained in the BEIR (Biological Effects of Ionizing Radiation) IV report would suggest that all educators of dental or oral and maxillofacial radiology teach radiographic techniques that employ only E-speed film.

Only in this way will the patient finally reap the benefits of intraoral film advances. In Chapter 8 we will see that new image receptors, called charge-coupled devices or CCDs, which are solid-state image detector arrays, are currently under development and should eventually replace intraoral dental film.

In the previous discussion, there were several terms used that will be explained in the remaining portion of the chapter. Film *speed* and film *detail* or resolution, as well as film *grain*, are but a few of the terms that must be understood in order to master the overall concept of x-ray imaging. First, let us study the physical make-up of dental x-ray film.

## X-RAY FILM CONSTRUCTION/ COMPOSITION

All contemporary dental x-ray film is direct-exposure film. Direct exposure means that the incoming x rays striking the dental, x-ray film surface interact directly with the materials coated on the film to create a on- image. The initial image created is an invisible one, termed a *latent image.*

The backbone or *base* of dental x-ray film is a polyester plastic (polyethylene terephthalate) that is semitransparent. This plastic film base is coated on each side with an *emulsion,* consisting of a homogeneous mixture of silver halide crystals held together by gelatin. These silver halides AgBr (silver bromide) and AgI (silver iodide), store the x-ray energy to which they have been exposed. If an x ray does not strike one of these crystals, it is nonenergized and will wash off when processed, leaving a clear or white area (radiopaque).

Energized silver halide crystals will react with the developer in the processing machine, because they are highly reactive, and deposit metallic silver in the area to form a black (radiolucent) region. Over the emulsion is a gelatin *supercoat,* added primarily to prevent emulsion damage by rollers in an automatic processor.

This dental x-ray film "sandwich" is wrapped in black paper. A single piece of lead foil is placed on one side of black paper, between the film and the plastic outer packaging. The dental x-ray film is clearly marked on one side "opposite side toward tube." This is to ensure that the lead foil, placed to reduce the numbers of x rays exiting the film and thus exposure to the patient, is not between the film and the x-ray source. If the film is so placed, that is, backwards, then the resultant image will be too light and the image information obscured by the pattern on the lead foil. The exterior, sensitive side of the film packet also reveals a raised or embossed "dot". This dot also helps the radiographer to orient the sensitive side of the film toward the anode (source) and can be placed in the "slot" of the biteblock when exposing periapical radiographs, to assist with film orientation and to keep it from being superimposed over region of interest, like an apex.

## IMAGE CHARACTERISTICS

### Density

Radiographic or film density is the overall degree of blackness of an x-ray film or radiograph. A very black film has greater film density than a very light film. The term *density* refers to the degree of optical transmission of light rays through a processed film. Film density is affected by mA (milliamperage), kVp (kilovoltage peak or operating voltage), and time. In general, any increase in any of these factors, separately or in combination, will increase the overall radiographic density. Increasing the kV increases the density by increasing the mean energy of the x-ray beam and producing higher energy x rays. Increasing the mA increases the density by producing more x rays as a result of increased numbers of electrons produced at the cathode and hence subsequent x – rays at the anode. Increasing the time of exposure also increases film density by increasing the number of x-ray photons that will ultimately reach the film surface. The density of a film also depends on the amount of radiation reaching the film or the distance of the film from the source—the source-to- film distance (SFD). The *inverse square law* states that the intensity of the x-ray beam varies inversely as the square of the distance from the source.

This can be written as:

$$I = \frac{1}{d^2}$$

where I= intensity
d= density

Thus, if one changes the cone length from 8 inches to 16 inches—or double the SFD—the intensity of the x-ray beam reaching the film would be $(1/2)^2$ or 1/4 as intense. This would affect density and must be compensated for by increasing the exposure time. Film density may also increase by prolonging the development time during processing or increasing the temperature of the developer. These last two factors, related to processing, usually degrade the radiographic image by producing film *fog;* that is, increased blackness with no additional useful information.

Patient parameters that also affect film density and over which the radiographer has no control are patient or subject thickness and object density. Larger patients with greater tissue thickness will require longer exposures (time) or increased mA settings. Furthermore, object density affects the film density. Denser objects, such as bone and enamel (versus less-dense objects, such as soft tissue), will attenuate more x-rays in the x-ray beam; that is, they let fewer x rays pass through to the film. For example, no x rays pass through metallic fillings to strike the film and thus interact with the silver halide. Consequently, those regions will be radiopaque or whit on the film. Conversely, soft tissues attenuate fewer x rays, and thus those increased number of x rays passing through the structures make the film darker or radiolucent.

## Speed

Film *speed* is an inherent film property related to the silver halide grain size in the emulsion of dental x-ray film. The larger the grain size, the faster the film speed. E-speed film (film A) is faster than D-speed film (film B). As you can see from the curves, it takes much less exposure time to produce an identical optical density using E-speed film than it does with D-speed film. This is translated into a reduction in x-ray absorbed dose to the patient.

## Contrast

*Radiographic contrast* is defined as the range of useful densities on an x-ray film. Densities on radiographs are not simply black and white but encompass multiple shades of gray (called scale of contrast), which reflect the attenuation properties of the various tissues and restorative materials present in the oral cavity. High-contrast images (short-scale contrast) would be black and white with few gray shades. Low-contrast images (long-scale contrast) usually contain a wide range of shades of gray with subtle contrast differences.

High-kV techniques—for example, 90 kV—produce long-scale radiographic contrast; that is, many shades of gray or wide *latitude.* Low-kV techniques—for example,70 kV—produce short-scale radiographic contrast; that is, blacks and whites. From this discussion, you might guess that dentists like low-kV, high-contrast radiographic techniques for detection of interproximal caries by bitewing radiographs. However, periodontists, who wish to see subtle bone changes and structures such as cementum, might prefer higher kV techniques to produce more gray scale.

Subject contrast depends on several factors: the size or thickness, density, and even the atomic number of a particular structure in a particular patient. The subject contrast has a direct bearing on the radiographic contrast. The selection of the kilovoltage can assist the penetration of the x rays through the subject. Remember from the previous chapters that higher-kV x rays are more penetrating. Therefore, high-kV techniques may be used to help penetrate larger patients or thicker structures; however, this is accomplished only with a reduction in over all radiographic contrast. Remember also that increasing the kV will also increase the overall film density. This problem is compensated for by reducing the exposure time (but once again reducing the overall subject contrast).

In addition to the subject contrast, the radiographic contrast is also dependent on the inherent film contrast. This is a factor over which the clinician has no control other than film selection. With direct-exposure dental film (as opposed to extraoral film/screen combinations), there is no high-contrast film available. The contrast of an E-speed film will be more apparent only at increased density values.

## Latitude

In the previous discussion of contrast, the term *latitude* was introduced. This factor refers to the range of useful densities that are recorded on a film. For example. Film A has a narrower latitude than film B because it requires less exposure to render the film too dark (measured as optical density units) to be useful. Film B, on the other hand, is a very forgiving one; many different exposures may be used to produce a film with useful optical density for clinical interpretation. How this relates to contrast is described as:

***High-kV technique produces wide-latitude,***
***low-contrast images.***
***Low-KV technique produces narrow-latitude,***
***high-contrast images.***

## Resolution/Detail

A film is said to have good *resolution* or *detail* if small objects placed closely together can be seen as separate. There should be no unsharpness (that is, the edges can be distinguished), distortion, or overlapping of these objects. Resolution depends on several factors, including:

1. Radiographic contrast
2. Focal spot size
3. Image geometry
4. Sharpness/edge enhancement
5. Film grain

If radiographic contrast is poor, then the edges of the objects to be resolved will be difficult to distinguish. If there is a distinct difference in attenuation properties between two borders, this edge will be seen if the contrast difference is sufficient. Thus, we see that sharpness—the ability to define an edge or boundary—is intimately related to radiographic contrast. Xeroradiography was an exciting prospect just a few years ago because of the inherent edge-enhancement properties of that system, which allowed the clinician to distinguish the edge between two objects—*even if there was low contrast between them*. Processing artifacts and other factors hampered the technique, and thus it was largely abandoned.

Unsharpness can also lead to loss of resolution because of poor *image geometry*. The radiographic shadow (the umbra) of an object is also surrounded by a zone offuzziness or unsharpness called a *penumbra,* which can be pronounced with certain intraoral radiographic techniques.

Most importantly, the *focal spot size* influences the resolution of a system. The smaller the focal spot size, the better the resolution. Most dental x-ray machines have focal spot sizes between 0.6 mm and 1.0 mm. Most medical x-ray units have focal spots of 0.3 mm or smaller. Dental x-ray tubes have fixed anodes that do not dissipate the heat away from the target as quickly as the rotating anodes of medical machines. Most recently, one manufacturer has reduced the focal spot size to 0.3 mm on a constant potential dental x-ray machine, called the PXS-70, a hand-held x-ray unit.

There is a difference in the *actual focal spot* size and the *effective focal spot* size. By angling the anode target approximately 20°, the effective focal spot size is reduced, thus resulting in better resolution or more "detailed" film.

## IMAGE GEOMETRY

As we have seen, there is a loss of sharpness due to the different angulations of various radiographic views. There are ways of reducing unsharpness inherent in certain techniques (especially the bisecting of the angle technique). These are to:

1.Reduce the object-to-film distance (OFD)

2.Increase the source-to-film distance (SFD) (both of which reduce magnification)

3.Keep object and film parallel

The use of paralleling" technique is probably the most effective way to reduce unsharpness due to image geometry. By using the "long-cone" (increased SFD), this technique compensates more than adequately for the minor increase in the object-to-film distance (OFD) that occurs when using a biteblock

## INTENSIFYING SCREENS

No discussion of image characteristics would be complete without describing the use of intensifying screens and screen/film combinations. *Intensifying screens* are plastic sheets coated with inorganic phosphors that are sensitive to x rays and that emit visible light either in the blue or the green spectrum, in a process called fluorescence. These screens are used in extraoral radiography to convert incoming x-rays to light, which then exposes the x-rayfilm. Film used in a screen/film combination is sensitive to either *blue* light (used with calcium tungstate, CaW04 screens), *green* light (used with terbium-activated lanthanum oxysulfide, $La_2O_2S:Tb$; or terbium-activated gadolinium oxysulfide, $Gd_2O_2$ S:Tb),or a combination of blue-green sensitivity (used with terbium-activated yttrium oxysulfide, $Y_2O_2S:Tb$). The phosphors used should have the following properties:

1. High atomic number (to increase the probability of x-ray interaction)—also called the QDE or *quantum detection efficiency*

*2.* High light emission output per x-ray interaction—called the x-ray *conversion efficiency*

3. Light emission that matches the x-ray film color sensitivity—called *spectral matching*

4. *Minimal afterglow* from the phosphor