Xeroradiography – Review Article

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ABSTRACT:

Xeroradiography is a highly accurate electrostatic imaging technique. In this technique a conventional single-phase dental x-ray unit is used as an x-ray source, but instead of a silver-halide film image, a uniformly charged selenium alloy plate housed in a light-proof cassette is used. It is used for detecting carious lesions, calculus deposits, periodontal disease and interpreting periapical structures.

Keywords: *Oral Medicine, Xeroradiography, Selenium***.**

INTRODUCTION:

Xeroradiography is the production of a visible image utilising the charged surface of a photoconductor (amorphous selenium) as the detecting medium, partially dissipating the charge by exposure to x-ray to form a latent image and making the latent image visible by xerographic processing. [1][2]. Xeroradiography which is a method of imaging uses the xeroradiographic copying process to record images produced by diagnostic x-rays.[1]

It differs from halide film technique in that it involves neither wet chemical processing nor the use of dark room.[1]

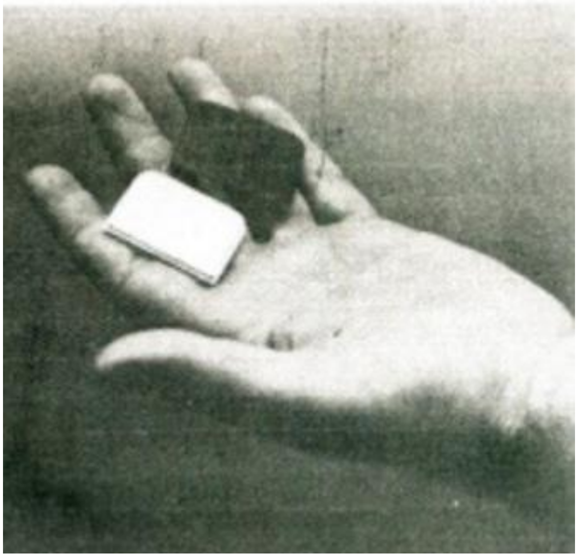
There are several features of xeroradiography that makes it as attractive imaging system in specific diagnostic situations, like:

1. Pronounced edge enhancement.
2. High contrast.
3. A choice of positive and negative displays.
4. Good detail.
5. Wide latitude. [2]

There are two systems in Xeroradiography;

The Medical 125 System

The Dental 110 System[2]



The image receptor plates are size no 1 and 2 films and fit well in oral cavity

DEVELOPMENT OF XERORADIOGRAPHY:

Over the past 40 years, 125 system became applicable in medical sciences. A prototype Xeroradiographic imaging system specific for intraoral use was later developed. Following these clinical trials showed that xeroradiography is superior for imaging of dental structures necessary for successful periodontal and endodontic therapy. Xeroradiographic radiation of 90% of more than that for silver halide radiograph has been reported, while others found that Xeroradiographic radiation is one third to half of that for halide radiograph.[3] The imaging method was discovered by an American physicist, Chester Carlson in 1937. Later, the Xerox Company followed with laboratory investigations of the technique and its potential applications in medical sciences. Others like Binnie

FIG. 15-26. Dental 110 system showing output station *(black arrow)* and input station *(white arrow)*.

et al, Grant et al and White et al worked on phantoms and cadavers, using the 125 system. Their works led to the development and marketing of intraoral xeroradiographic system. Xeroradiography may be new in dentistry, but in medicine, it had long been used in the diagnosis of breast diseases, imaging of the larynx, and respiratory tract for foreign bodies, temporomandibular joint, skull, and Para osseous soft tissues.[3]

Pogorzelska-Stronczak became the first to use xeroradiography to produce dental images, while Xerox 125 medical system got adapted for extra oral dental use in cephalometry, sialography, and panoramic xeroradiography. Later, a prototype xeroradiographic imaging system, specific for intraoral use, was acclaimed to be superior over halide-based intraoral technique.[3]

A Cephalometric appraisal of Xeroradiography by CHATE – AJO-DO 1980:[4]

Aim:

To estimate the effect of Xeroradiography technique on the degree of inter and intra observer error in cephalometric landmarks identification.

Method:

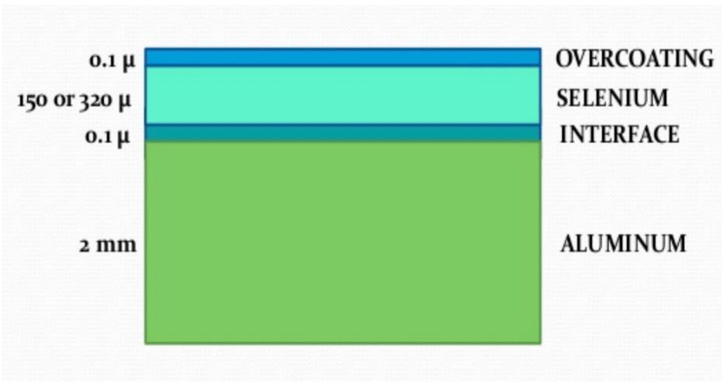
This study involved identification by four observers of 16 cephalometric landmarks on 12 Xeroradiographs and on 12 radiographs on 2 separate occasions.

Conclusion:

1. Neither technique provided a significant decrease in inter observer differences.
2. However, for 8 of 32 variables, Xeroradiography produces a significant reduction in interobserver error in comparison to radiography

COMPONENTS OF XERORADIOGRAPHY:

1. Xerographic plate
2. Croton
3. Cassette
4. Toner
5. Special paper



A schematic figure of a xeroradiography plate

The Xeroradiography Plate: This plate is made up of a 9 ½ by 14-inch sheet of aluminium, a thin layer of vitreous or amorphous selenium photoconductor, an interface layer, and an over coating on the thin selenium layer.[12]

a) The Aluminium Substrate:

The substrate for the selenium photoconductor should present a clean and smooth surface. Surface defects affect the Xeroradiographic plate’s sensitivity by giving rise to changes in the electrostatic charge in the photoconductor.[3]

b) The Interface Layer:

This is a thin layer of aluminium oxide between the selenium photoconductor and aluminium substrate. The oxide is produced by heat treating the aluminium substrate. As a non-conductor, the interface layer prevents charge exchange between the substrate and the photoconductor surface.[3]

c) *The Selenium Coating:*

The thickness of this layer varies from 150-micron meter for powder toner development. Amorphous or vitreous selenium coating, is formed by depositing a vapour form of liquefied selenium in a high vacuum. Because of its ease of use, fabrication and durability, inherent property of electrical conduction when exposed to x-rays and ability to insulate well when shielded from all sources of light, make selenium a Xeroradiographic material of choice. On the other hand, any form of impurity adversely affects its performance. Amorphous form is used in Xeroradiography because crystalline selenium's electrical conductivity is very high which makes it unsuitable in Xeroradiography. However, amorphous selenium undergoes a dark decay of about 5% per minute. A new system of xeroradiography which uses plates with thicker selenium layer (320-micron meter) gives about 50% x-ray absorption.[3]

d) *Selenium Protective Coating:*

The protective coating is a 0.1-micron meter cellulose acetate overcoat. The coat bonds intimately with selenium photoconductor. It helps to prevent degradation of electrostatic lateral image through the prevention of lateral conduction of electrostatic charges. Also it impacts positively on the shelf life of the Xeroradiographic plate.[3]

Photoconductor:

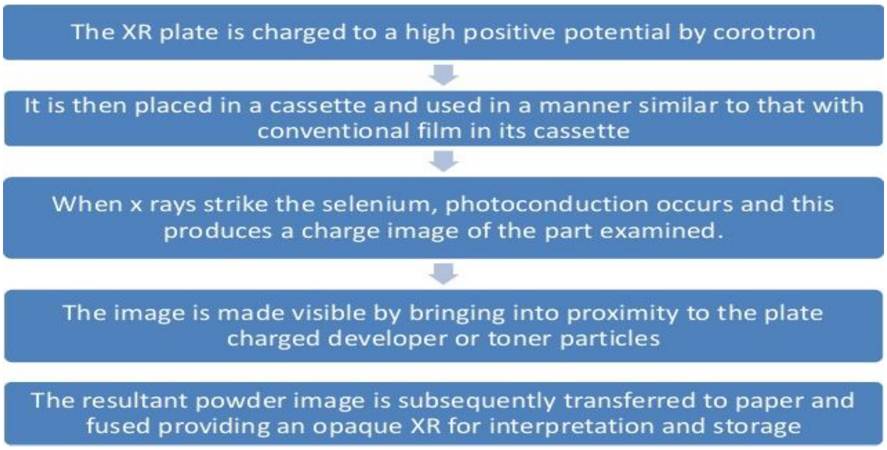
Solid material may be classified as conductors, semiconductors, and insulators. This classification depends on whether or not the solid is capable of sustaining a current (moving electron) if a voltage is applied. The band with the highest energy that also has a electron is called the valence band. The next highest permissible band is the conduction band. Conductor band has small forbidden gap and non-conductor has large forbidden gap.[3]

Photoconductive layer:

There are three properties required of a photoconductor used in xeroradiography

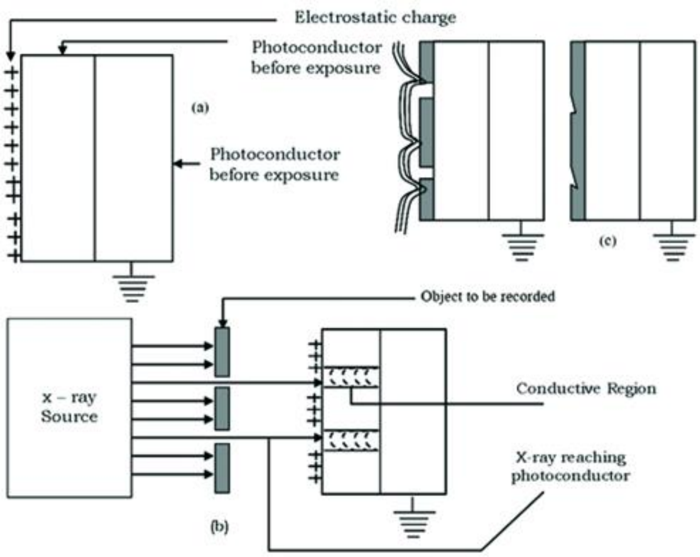
1. The electric conductivity of the dark must be that of a good insulator so that a charge pattern present on the surface will be retained long enough to complete the steps of development.
2. The material must become electrically during exposure to X-ray so that an electrostatic image pattern can be formed on its surface by the exposure.
3. It must have mechanical properties of durability and ease of fabrication. The photoconductor that presently fulfils these criteria or commercial use is selenium. [4]

PRINCIPLE:



THE FUNCTIONAL STEPS:

Xeroradiography is an electrostatic process which uses an amorphous selenium photoconductor material, vacuum deposited on an aluminium substrate, to form a plate. The plate, enclosed in light tight cassette, may be likened to films used in halide-based technique.[4]



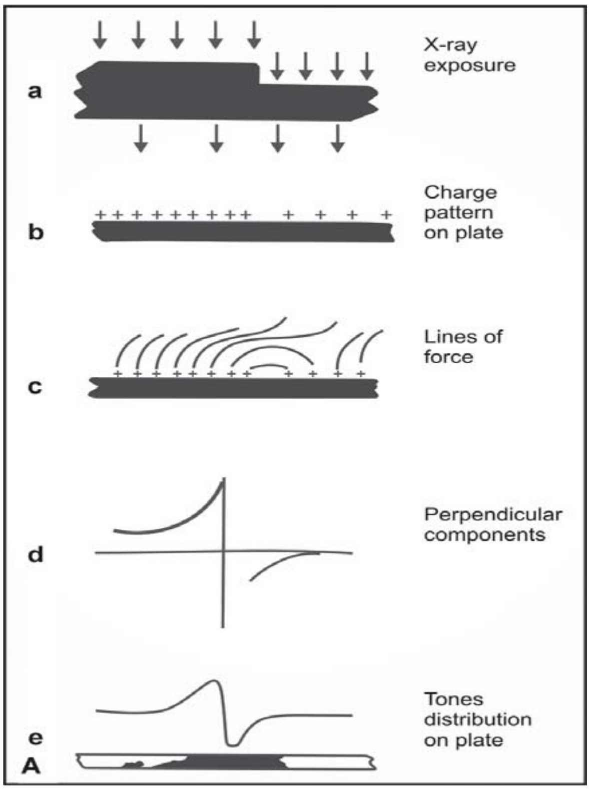
A schematic figure of the Xeroradiography process by Rawls and Owen19: (a) The charged photoconductor acting as an insulator; (b) Exposure ensures charge to be conducted away from the surface; (c) particles collect in charged areas, giving positive image[4]

The steps are,

Conventional X-ray source is used in the production of xeroradiographs. The film, however, is replaced by a selenium-coated photoreceptor (Xerox Plate), which has a uniformly distributed electrostatic charge.

1. The sensitisation of the photoconductor plate in the charging station by depositing a uniform positive charge on its surface in the dark.

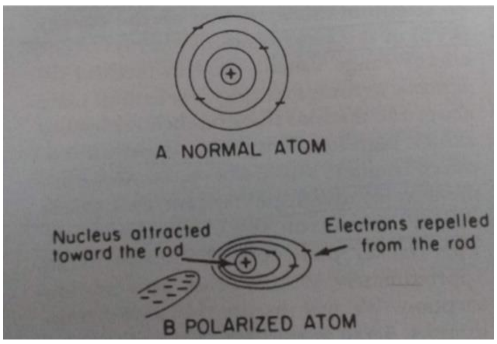
2. During an exposure, X-rays that penetrate a body part or object are absorbed by the surface of the selenium plate causing selective discharging.
3. The distribution and the amount of discharge is related to the distribution and amount of radiation striking the xerox plate and, therefore, the information in the transmitted.



An X-ray beam passing through an object is differentially attenuated according to the absorption characteristics of the object. **B.** The disruption of transmitted X-ray photons alters the charge pattern on the Xerox plate. **C.** Lines of the force produced as a result of the difference in charge densities on the plate surface. **D.** These lines of forces have perpendicular components. **E.** These components affect the distribution of the toner particles on the plate

4. X-ray beam is left as a charged pattern on the plate. A capacitor or a condenser consists of two sheets of conducting material between them. One plate is charged positive and the other is negative. So, a potential difference or voltage exists between two plates. This insulator material in between is known
as dielectric.

5. The negative poles of each atom are attracted towards the positive charge, causing the



atomic layer adjacent to the aluminium substrate present a positive charge at the selenium-aluminium interface.

6. In the absence of electromagnetic radiation, the photoconductor remains nonconductive and with its uniform electrostatic charge when radiation is passed through an object which will vary the intensity of the radiation.
7. The greatest amount of charge remains beneath the thickest part of the object where most radiation was absorbed. In areas where less absorption occurred, the penetrating radiation dissipates a greater amount of charge from the selenium surface.
8. At the interfaces between the areas of greater and lesser absorption, the electrostatic forces are distorted.
9. The resulting electric fields produce the same effect as the production of bands which occur at the boundaries of objects with different densities because of a phenomenon called lateral extinction which occurs in the retina.
10. Hence latent image is formed.[5]

IMAGE DEVELOPMENT:

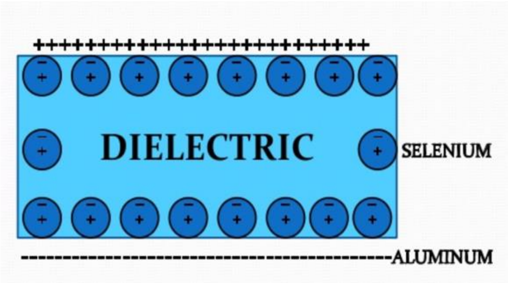
The generated latent image is developed through an electrophoretic development pro-cess using liquid toner. The process involves the migration to, and subsequent deposition of toner particles suspended in a liquid onto an image reception under the influence of electrostatic field forces.

That is, by applying negatively charged powder (toner) which is attracted to the residual positive charge pattern on the photoconductor, the latent image is made visible and the image can be transferred to a transparent plastic sheet or to paper.

The toner is thereafter fixed to a receiver sheet onto which a permanent record is made.

In the final image, dense objects appear white or radiopaque, and less dense objects appear dark or radiolucent.

Xeroradiograph can be viewed in reflected or transmitted light. When the latent image is transferred from plate to paper, the original image is reversed 180° and is seen as a mirror image.[5]



DENTAL XERORADIOGRAPH:

The dental xeroradiograph system has a different physical design. The image receptors are charged and processed into a final permanent image in a single piece of equipment. To make an image, the photo receptor is charged at the output station. It is then put intraorally, exposed, and returned to the input station. The plate passes over a toner station, where charged toner particles suspended in a liquid vehicle are deposited on the plate to develop the image. Next the plate is dried to remove the liquid vehicle. The image is recovered from the plate by using a clear adhesive transfer station. The adhesive tape is brought into contact with the plate and pulls off all the toner particles. The image is protected by applying the adhesive with the image to a translucent backing strip. [2]

The electric field distribution above latent image:

Plate cleaning:

All the toner must be removed before the plate is to be reused. The plate is exposed to a light source (electroluminescent strip) that reduces the bond holding the residual toner to the place. The pre-clean croton exposes the plate to an alternating current that serves to neutralise the electrostatic forces holding toner to the plate. A cleaning brush then mechanically brushes the residual toner from the *plate.*[6]

Relaxation:

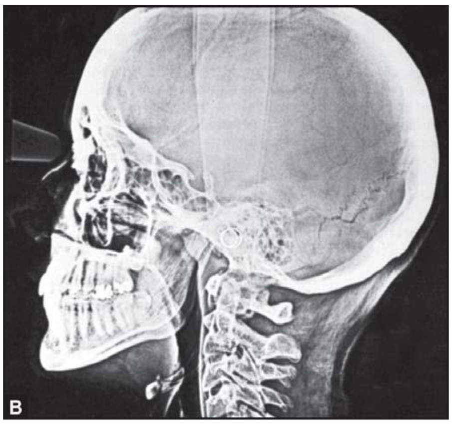
To prevent faint ghost images. Absorption of X-ray in the selenium produces alteration in the physical property of selenium that causes some photoconductivity to persist for as long as several hours after exposure. If the plate were changed for a new exposure without allowing it to rest, a ghost image of a previous exposure will appear on development.This rest period can be reduced to 2-3 mins if the plate is relaxed by heating it to 140 F for 150 secs.[6]

Storage:

The cleaned and relaxed plate is then held in the storage compartment at 89 F until needed for another exposure.[6]

DIFFERENCE BETWEEN XERORADIOGRAPHY AND CONVENTIONAL RADIOGRAPHY:

It does not require silver halide containing films such as those commonly used for conventional radiography. Xeroradiography, which requires only about one-third of the dose required for conventional radiographs [1][7]



In this cephalometric image, the most dense structures are light and the least dense structures are dark. The visibility of both soft and bony structures in a single radiograph illustrates the wide latitude of the xeroradiographic process

ADVANTAGES:

1. High contrast.
2. Greater ability to resolve fine structures.
3. They require 1/3rd the exposure of conventional radiographs.
4. Easy to use.
5. Produces permanent dry images for viewing in about 20 seconds after the exposed photoreceptor is returned to the machine.
6. Image is easily reversible.
7. For diagnostic purpose, as this method gives excellent definition of thin, fine structures due to edge enhancement,
   a. Height of alveolar crest better visualized.
   b. Caries seen more readily.
   c. Useful in endodontics.
   d. Detection of cancer.
   e. Imaging biomaterials.[3][10]

DISADVANTAGES:

1. Edge enhancement artefacts.
2. Processors are expensive.
3. High radiation dose needed for extra oral techniques. It was 2.4-16.2 times larger than conventional film techniques. [3][11]

USES:

1. Mammography.
2. Cephalometry.
3. Evaluation of bone lesions in the mandible.
4. Sialography.
5. Study of variety of dental and non-dental structures.
6. TM joint tomography.[12]

INDICATIONS IN HEAD AND NECK REGION:

1. Periodontal and periapical assessment to show good bony details.
2. Cephalometric radiography to show the required hard and soft tissue landmarks on one film.
3. Sialography to show fine duct structure.
4. Assessment of soft tissue shadows in the pharynx and larynx[12]

CONCLUSION:

Dental xeroradiography has peculiar positive properties which enable both detailed bony and soft tissue examination, as well as subtle visualisation of structures.[12]

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