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Lead foil in dental X-ray film: Backscattering rejection or image intensifier?

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ABSTRACT

Dental X-ray films are still largely used due to sterilization issues, simplicity and, mainly, economic reasons. These films almost always are double coated (double emulsion) and have a lead foil in contact with the film for X-ray backscattering rejection. Herein we explore the use of the lead foil as an image intensifier. In these studies, spatial resolution was investigated when images were acquired on the dental X-ray films with and without the lead foil. Also, the lead foil was subjected to atomic analysis (fluorescent measurements) and structure analysis (X-ray diffraction). We determined that the use of the lead foil reduces the exposure time, however, does not affect the spatial resolution on the acquired images. This suggests that the fluorescent radiation spread is smaller than the grain sizes of the dental X-ray films.

1. Introduction

In the last 15 years digital dental X-ray imaging has becoming accessible [1–2]. In this way, several recent works have been exploring the use and comparison between conventional and digital dental imaging [3–6]. Therefore, conventional dental X-ray imaging (by using X-ray films) is still largely used by the dentistry community. There are several different reasons for that, such as, sterilization issues, costs, and simplicity. Digital radiography costs are expensive for dentists (~U$ 15k for a wired sensor system). About infection control, most digital sensors are not able to be sterilized, requiring protective plastic barriers that must be changed between patients to prevent contamination. Also, some of CMOS detectors are very thin and fragile. Since a periapical X-ray film costs less than a U$ 1.00, the films are still the most popular option.

There are three types of dental X-ray films which are characterized by their speed (D-speed, E-speed and F-speed) in accordance with International Organization for Standardization (ISO). Dental X-ray films are sandwiched in a plastic packet which contains the film itself, a black paper envelope which protects the film and a lead foil. This foil has different functions: (i) reduce the backscattered radiation in the human tissues [7,8] which degrades the image contrast and; (ii) reduce the primary and secondary (scattered) radiation dose on the salivary glands (patient radiation protection) [9]. Another lead foil function, which we raised here, is its use as an "image intensifier" (ecran). For this work, we used E-speed (Kodak) periapical X-ray films. Fluorescent and diffraction measurements were carried out on the lead foil in order to check it is atomic and structure composition. Also, spatial resolution measurements were carried out at different voltages applied to the X-ray tube in order to explore its image intensifier properties.

2. Dental X-ray film and lead foil

Herein we used an E-speed film and W2 size (ISO/periapical X-ray film with 31 mm × 41 mm). These films are hermetically packed in a plastic opaque envelope. Inside the package they are sandwiched with a lead foil a paper leaf and the X-ray film itself (Fig. 1a). This lead foil is applied to reduce the back-scattered radiation which degrades the image quality on the film [7,8]. Also, it helps to reduce the dose on the salivary glands, extremely sensitive to radiation damage [9]. Here, we explore if the lead foil can also acts as an image intensifier, since the film is sensitive to the backscattering in the lead foil (Fig. 1b). The main X-ray interaction with the lead foil is photoelectric, however, Thompson and Compton scattering also play a role. If the incoming X-rays has energy greater than the Pb electron bonding energies, secondary

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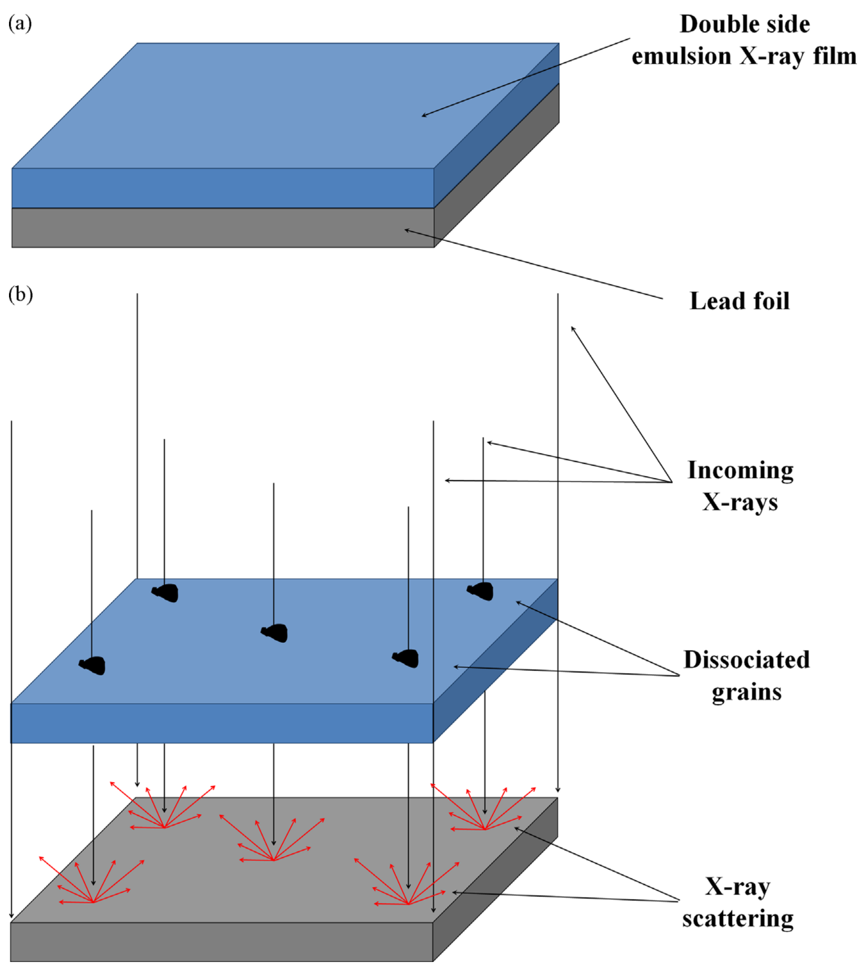

Fig. 1. (a) Schematic representation on the dental X-ray film mounted inside a plastic envelope. (b) Dissociation effect on the film when exposed to the X-rays. The scattering on the lead foil is also schematically drawn. Since there are several Pb emission lines, as stated by Table 1, several fluorescent effects take place.

Table 1
Energy of Pb emission lines.

Emission line	Energy (eV)	Relative intensity
Pb $K\alpha_1$	74,969.4	1
Pb $K\alpha_2$	72,804.2	0.6
Pb $K\beta_1$	84,936	0.23
Pb $K\beta_2$	87,320	0.08
Pb $K\beta_3$	84,450	0.12
Pb $L\alpha_1$	10,551.5	1
Pb $L\alpha_2$	10,449.5	0.11
Pb $L\beta_1$	12,613.7	0.66
Pb $L\beta_2$	12,622.6	0.25
Pb $L\gamma_1$	14,764.4	0.14
Pb $M\alpha_1$	2345.5	1

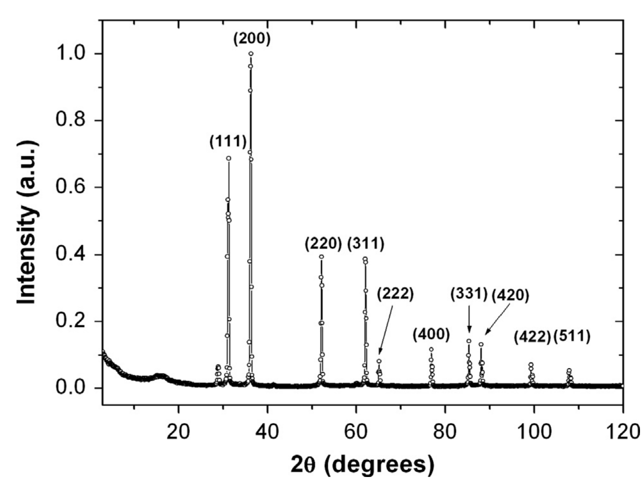

Fig. 2. X-ray diffraction of a lead foil for the E-speed film taken with the Bragg–Brentano geometry and Cu target X-ray tube. This diffractogram shows that such foil is basically crystalline Pb as indexed and checked by a Powder Diffraction File (PDF) number 4-686.

radiation with different energies can be produced as stated in Table 1 and characterized by fluorescence.

3. Exploring the lead foil: fluorescence and X-ray diffraction measurements

In order to verify if the lead foil can be an image intensifier, we had to check its properties. One way to do that is by studying its atomic and structural composition. In this way, two different measurements were carried out: X-ray diffraction [10] and X-ray fluorescence [11]. The main objective of X-ray diffraction was to check the crystalline structure of the lead foil while the main objective of X-ray fluorescence was to check its element composition. The diffraction measurements were carried out by using a Bragg–Brentano setup [10] in theta-two theta geometry provided