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# EVALUATION OF THE COMPOSITION OF FILTERS ADDITIONAL OF EQUIPMENT RADIOLOGICAL INTRAORAL BY ENERGY DISPERSIVE X-RAY FLUORESCENCE (EDXRF)

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## ABSTRACT

The need for high quality standards for radiographic images in order to make a diagnosis assertive, and being the additional filtration required in the intraoral X-ray equipment show the need of evaluating these filters. This study aims to examine the influence of the elemental composition of the filters of X-ray of dental intraoral equipments in the radiographic images quality. The filters analysis were performed by using the energy dispersive X-ray fluorescence method (EDXRF). Ten conventional filters were analysed. In this study, 33 radiographic exposures were performed using films: twenty radiographs in the incisor region and ten in the molar region, three exposures were also made in the same regions with same conditions without using filter. After radiographs development, optical density was measure and all radiographs were submitted to subjective evaluation by dental radiologists. Data obtained were correlated to effects evaluation of the elemental composition of all filters in the quality of the radiographic images. The elements found were: aluminum, cobalt, copper, sulfur, iron, manganese, titanium, zinc, and zirconium. The images obtained were identified in groups: Molars to 0.3 s; Incisors to 0.2 s; Incisors to 0.3 s, and for the group without filters. From the results obtained it was concluded that both unclear radiographs and ideal radiographs were produced by using filters of elementary common. Therefore, conventional filters evaluated were an acceptable option to produce quality images in dental radiology, despite differences in the composition of the alloys.

## 1. INTRODUCTION

The intraoral radiography is an important test used as supplementary information in Dentistry [1]. The benefits of ionizing radiation include diagnostic indispensable for conduct that professionals will perform with the patient, but their use should be controlled. According to the National Commission of Nuclear Energy (CNEN) it must be respected the basic principles of radiation protection: justification, optimization and individual dose limit. This means that practices which use ionizing radiation should be justified by the benefit provided to the patient, and all the requirement of radioprotection should be followed, as the optimization of the dose levels safe for the patient, without losing image quality [2].

The radiology equipments are also adjuncts to radiation protection of patients, especially as regards to filters present in it. Filtration of secondary energy is important because it does not contribute in a beneficial way for the image, being more a risk factor of ionizing radiation in biological tissues.

To reduce secondary energy, two types of filtration devices are found in equipment: inherent and added filtration. The inherent filtration corresponds to elements that compose x-ray tube, oil and window of beryllium (Be). The added filtration is mostly in metallic plates which contribute to the absorption of photons of lower energy.

In this context, the added filtration meets the ALARA principle (As Low As Reasonably Achievable), reducing the percentage of energy that does not contribute to the radiological image quality. The ordinance n ° 453/98 determines that the equipment used in intraoral radiology must comply with the total filtration (inherent and added), with the minimum value of 2.5 mm [3].

X-ray fluorescence spectroscopy (XRF) is an analytical non-destructive technique, and aims to promote recognition of the elemental composition of samples of different natures, both quantitatively and qualitatively. To use the XRF an apparatus is required involving a X-ray tube (or radioisotope), and a detector. The setting tube and detector position vary for different XRF techniques, this paper will use Fluorescence Spectroscopy X-ray energy dispersive (EDXRF) [4].

Considering all the ways of radiation interaction with these samples, the one that matters most for XRF technique is the photoelectric effect. This happens when a photon interacts with matter, releasing an electron from the innermost layer of the sample. By filling the vacancy left, another electron from the outermost layer takes its place, releasing a photon of energy. This electronic transition provides identification of element, since each has a unique energy, and the released energy corresponds to the binding energy of the layer L with K element, and so on [5].

Since these photons are detected, they can be viewed on a computer screen, through the emission spectrum of the sample. It is noteworthy that, in order to detect the energies correctly, it is necessary to use the equipment calibration before starting the analysis.

The calibration is performed by standard which certify the location of the center of the peak obtained with the corresponding channel (detector). This process makes calibration curves be performed and thus, it is possible to compare the elements and concentrations of the sample to bend.

Thereby, it is possible to analyze many samples. The main objective of this work is evaluate the elemental composition of the filters used in intraoral radiology equipment and its impact on radiographic images.

## 2. LITERATURE REVIEW

In 1987, [6] in order to evaluate the filtering effects in contrast image of intraoral radiographs, tested aluminum (Al) filters in four thicknesses, samarium (Sm) and gadolinium (Gd) filters in three thicknesses and added isolated plates intensifying regular Kodak Lanex and slim Lanex from filtration. For each combination filter/thickness, the exposure time was adjusted. The study obtained optical densities and calculated the contrast index, also assessed the exposure dose to patients using ionization chamber. Have concluded that the filters with the rare earth elements can reduce exposures without affecting the image contrast. However, the more the thickness filter the more will be the exposure time, but the contrats image decrease. [6].

Aluminium-yttrium (Al-Y) filters were evaluated by [7] regarding image quality and its effect on dose to the patient. The exposures were made varying the kilovoltage and used the Ektaspeed film. The authors compared the results with 2.7 mm Al and 0.1mm Y filter placed between a 2.7 mm Al filter and an additional 1.0 mm Al filter. The Al-Y filter reduced the contrast in two voltages (90kVp and 70 kVp). This reduced the absorbed dose by the patient (40% and 25% respectively), increases the exposure time about 50% though. However, concerning image quality for diagnostic purposes subjective analysis of radiographs taken for nine periodontists, showed preferably by conventional Al filter, furthermore the contrast image were considered unsatisfactory for the tested filter [7].

The research [8] studied the aluminum-copper (Al-Cu) filter and its effects on intraoral dental radiography. In comparison with the conventional Al filter, it has observed that the alloy did not represent a loss in image quality [8].

A piece of aluminium (density scale) was undergone to X-ray beam with two filter, 0.1 mm Al and 1.5 mm Cu, separately [9]. The objective was to evaluate the effects of alternative Cu filtration on radiographic contrast, and remained such factors: exposure time, air kerma rate and kilovoltage controlled. In addition, the research performed images densitometry of steps obtained by the two types of filters. To evaluate the contrast, two-tailed Mann-Whitney test was used and the results show statistical diference between two groups. Therefore reached the conclusion that the use of filter Cu, although requiring longer exposure time, reduces the air Kerrma rate and leads to higher contrast values than those obtained with Al filter [9].

In the study of aluminum-zinc alloy (Zn-Al) as an alternative filtration, made by [10] filters were prepared with different percentages of Zn in the alloy (2%, 3%, 4% and 5%) and different thicknesses for each percentage group. They also used conventional Al filter. As the results, no loss in quality image has not observed by using alternative filtration [10].

## 3. MATERIALS AND METHODS

Materials and methods correspond to various steps of this research: filters and radiographs acquisition that were performed in the Federal University of Paraná (UFPR); EDXRF equipment belongs to Federal Technological University of Paraná (UTFPR); analysis of the optical density of radiographs in the Company Engisa - Inspection Applied Research and Industry LTD.

## 3.1. Materials

### 3.1.1. Filters

Ten additional filters removed from intraoral radiographic equipment, all belonging to Gnatus brand, model Timex 66, were used. The equipments, as well as the filters belong to the Federal University of Paraná (UFPR) - Sector of Health Sciences.

The filters were cataloged by letters in order to do not be exchanged. Among the ranked filters three of them do not have the inscription which informs the material they are made of and them thickness, as shown in Fig 1. Each letter corresponds to a different equipment.

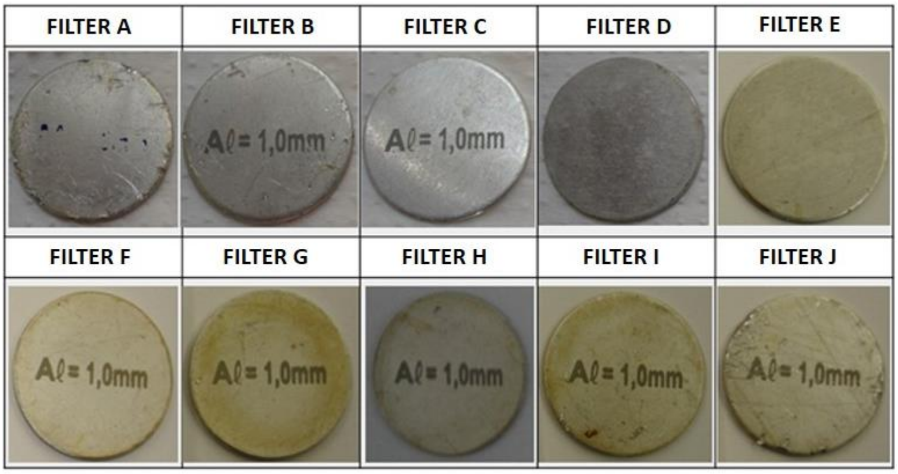

**Figure 1: Filters cataloged by letter showing the letter A, D and E without the inclusion of composition and thickness.**

The filters's thickness were confirmed as 1.0 mm using caliper rule to make sure that the written were correct.

### 3.1.2. Intraoral X-ray equipment

The intraoral X-ray equipment (Fig. 2) used for image acquisition was also the brand Gnatus, model Timex 66 with the exposure specification parameters: voltage and current fixed (66 kV and 6.5 mAs), with time variable.

**Figure 2: Intraoral X-ray equipment.**

### 3.1.3. Radiographic film

For best radiographic images performance, we used a high-speed radiographic film, so the quality of the images was not affected by this factor. Kodak Insight was choosen.

### 3.1.4. Phantom

A phantom was used as an experimental model in order to represent bones. This phantom is a macerated humam jaw covered with red wax (1.0 cm thick) to simulate soft tissues (gum), shown in Figure 3. In order to standardize the techinique, the positioner was used.

**Figure 3: A phantom used with experimental model in order to represent bones.**

### 3.1.5. Processadora automática

The automatic processor used is the brand Revell at 27° C and Prograd branded chemicals were prepared to be revealed in 3X1 ratio (15 liters of water and 5 liters of developer) and the fixer part A (10 liters of water and 5 liters of fixed) and part B (4 liters of water and 1 liter of fixed), totaling 40 liters of solution.

### 3.1.6. Equipment Energy Dispersive X-ray Fluorescence (EDXRF)

The EDXRF equipment available in the Laboratory of Ionizing Radiation of Federal Technological University of Paraná (UTFPR) contains two X-ray tubes, Mini-X model, with silver (Ag) and gold target (Au) and two semiconductor detectors Si(Li) (4096 channels), model X-123SDD all brand Amptek. The X-ray tube operates with a voltage that varies from 10 kV to 40 kV and a current from 5 µA to 200 µA, and time is determined by the operator manually.

The equipment was mounted on a movable base, which enables the tube-detector system movements' without affects the angle between the tube and the detector. The distance between the system and the sample was set as 1.0 cm, as according to manual. Thus, the tube and the detector remain fixed with an angle of 135 °, as exemplified in Figure 4.

The emission spectra analysis was accomplished through computer DPP-MCA software.

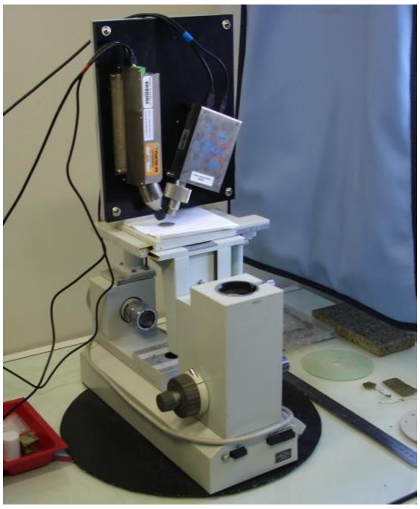

**Figure 4: EDXRF equipment mounted on a differentiated structure.**

### 3.1.7. Densitometer

The densitometer (SpeedMaster brand, model SM-14) was used to analyse the optical density of radiographs, which belongs to Engisa - Inspection and Research Applied to Industry LTD.

### 3.2. Methods

The first stage of the research was the acquisition of the filters and their analysis by EDXRF technique, which was calibrated before purchase. Tubes, Ag and Au, were used so that the defects in the spectrum that is related to the element of the tube would be discarded, Figure 5. The filters were irradiated with voltage of 30 kV and 15 µA for 300 and 600 s in the center and on the edge of the filter. The center was irradiated, because the alloy was shown homogeneous for this analysis and time of 600 s was chosen for a safety margin.

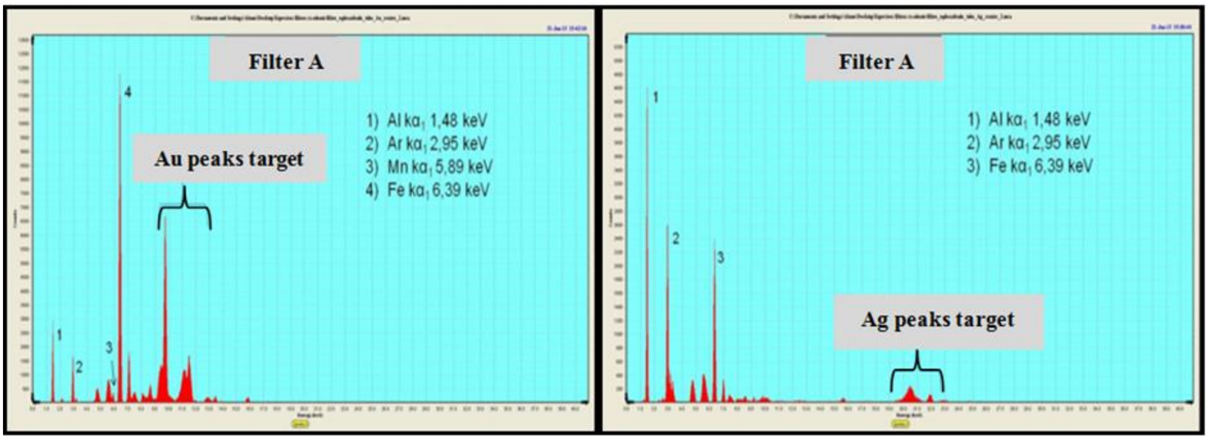

**Figure 5: Spectra showing Au and Ag peaks.**

Subsequently, the radiographic images were acquired by using parallelism technique with focus-film distance of 27.5 cm in molars and incisors. Exposure times were determined based on the requirements of radiation protection, molars with 0.3 s and incisors with 0.2 and 0.3 s. All radiographs were performed in the same apparatus under the same conditions, only by changing the filter, and only one place without filter, totalizing 33 radiographs. For development, the radiographs were classified to avoid exchanges.

The images obtained were identified in groups: 20 to 29 - Molars to 0.3 s; 30 to 39 - Incisors to 0.2 s; 40 to 49 - Incisors to 0.3 s. And for the group without filters: 50 - Incisors to 0.2 s; 51 - Incisive to 0.3; and 52 - molar to 0.3 s, Figure 6.

**Figure 6: Periapicals radiographs identified by numbers and letters.**

The groups were evaluated by densitometer, in order to identify the optical densities of each radiograph, promoting greater reliability of results. The densitometer was calibrated and then three regions were selected for each radiography. For radiographs of molars the regions were: crown of the tooth 37, the alveolar region near the root of the tooth 38 and the dark region of the film on the upper side to the tooth 38, Figure 7.

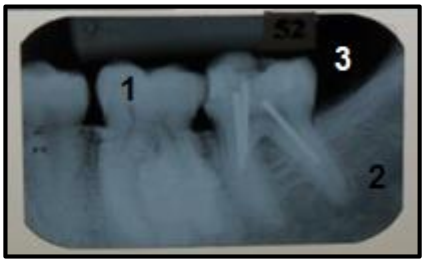

**Figure 7: Periapical radiograph of molars, showing the crown of the tooth 37 (1), the alveolar region of the tooth next 38 (2) and dark (3) region.**

For radiographs of incisors the regions were: tooth crown 31, the dark region of the upper left corner of the tooth 31 and the alveolar region between the apices of the roots of the teeth 31 and 41, as shown in Figure 8.

**Figure 8: Periapical radiograph of incisors, showing the region of the tooth crown 31 (1), alveolar region (2) and dark (3) region.**

As a complement to the results obtained by densitometer, radiographs were subjected to subjective evaluation by two dental radiologists. The regions analyzed by them are described below: molars - tooth crown 37 (cementum - enamel junction) and alveolar region near the root of the tooth 38; incisors - tooth crown 31 (cementum - enamel junction) and alveolar region between the apexes of the roots of the teeth 31 and 41. The evaluation criteria followed the scores shown in Table 1.

**Table 1: Table with the criteria for subjective evaluation of optical densities.**

| Optical Density | Value |
|---|---|
| **Too light** | **-2** |
| **Unclear** | **-1** |
| **Ideal** | **0** |
| **Darker** | **1** |
| **Too dark** | **2** |

# 4. RESULTS

The elemental alloy composition of the filters was evaluated by EDXRF techniques and the example spectrum shown in Figure 9.

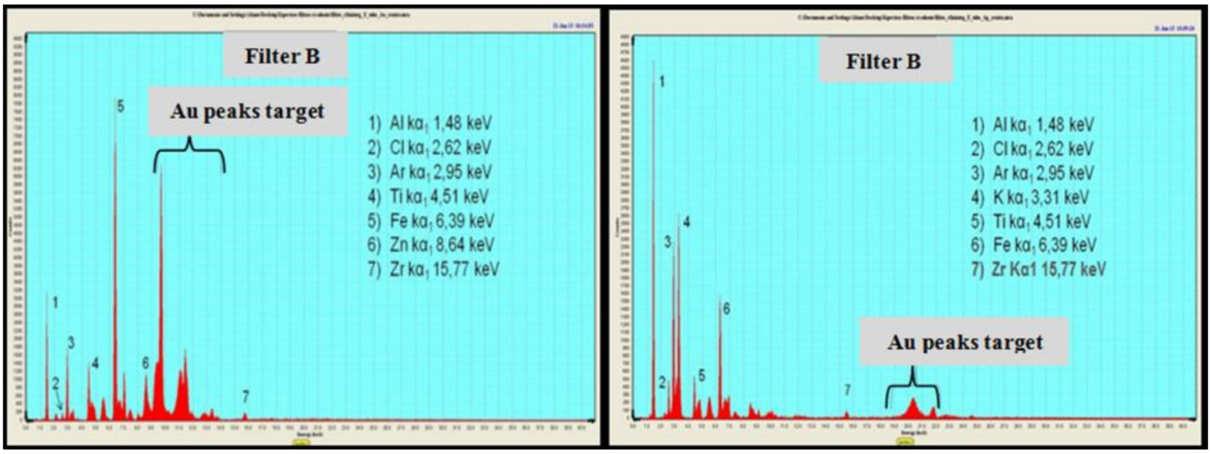

**Figure 9: Spectrum obtained by irradiating the filter B.**

The elements which were determined by the EDXRF technique are shown in Table 2.

**Table 2: Elements found in filters A to J.**

| Filter | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| Al | x | x | x | x | x | x | x | x | x | x |
| Cl |  | x |  | x |  |  |  |  |  |  |
| Co |  |  |  |  |  |  |  |  |  |  |
| Cu |  |  |  | x | x | x | x | x | x | x |
| K |  |  |  | x |  |  |  |  |  |  |
| Fe | x | x | x | x | x | x | x | x | x | x |
| Mn | x |  |  | x | x |  |  |  |  |  |
| S |  |  |  | x |  |  |  |  |  |  |
| Ti |  | x |  |  |  |  |  |  |  |  |
| Zn |  | x | x |  |  |  |  |  |  |  |
| Zr |  | x |  |  |  |  |  |  |  |  |

Radiographs 20A, 20F, 20G and 20J were classified as unclear regarding the subjective analysis. Radiographs 20B, 20C, 20D, 20E, 20H and 20I were classified as ideal (Table 3).

All radiographs from group 30 were classified as too light (Table 4), due to exposure time be short (0.2 s). In group 40, all radiographs were classified as unclear (Table 5) except 40C and 40D which were classified as ideal.

**Table 3: Classification of group 20 shown optical densities.**

| Molars | OD crown region | OD alveolar region | OD dar region |
|---|---|---|---|
| 20A | 0.43 | 0.54 | 1.52 |
| **20B** | **0.42** | **0.63** | **1.48** |
| **20C** | **0.40** | **0.61** | **1.53** |
| **20D** | **0.41** | **0.48** | **1.50** |
| **20E** | **0.43** | **0.65** | **1.52** |
| 20F | 0.43 | 0.59 | 1.49 |
| 20G | 0.42 | 0.59 | 1.47 |
| **20H** | **0.42** | **0.65** | **1.51** |
| **20I** | **0.43** | **0.61** | **1.48** |
| 20J | 0.43 | 0.65 | 1.48 |

**Table 4: Classification of group 30 shown optical densities.**

| Incisors | OD crown region | OD alveolar region | OD dar region |
|---|---|---|---|
| 30A | 0.58 | 0.51 | 0.76 |
| 30B | 0.60 | 0.51 | 0.71 |
| 30C | 0.57 | 0.48 | 1.05 |
| 30D | 0.62 | 0.54 | 1.08 |
| 30E | 0.67 | 0.55 | 1.28 |
| 30F | - | - | - |
| 30G | 0.57 | 0.51 | 1.02 |
| 30H | 0.58 | 0.49 | 1.51 |
| 30I | 0.43 | 0.60 | 1.48 |
| 30J | 0.43 | 0.65 | 1.48 |

**Table 5: Classification of group 40 shown optical densities.**

| Incisors | OD crown region | OD alveolar region | OD dar region |
|---|---|---|---|
| 40A | 0.71 | 0.61 | 1.13 |
| 40B | 0.70 | 0.60 | 1.22 |
| **40C** | **0.70** | **0.59** | **1.21** |
| **40D** | **0.73** | **0.62** | **1.23** |
| 40E | 0.72 | 0.58 | 1.07 |
| 40F | 0.68 | 0.60 | 1.37 |
| 40G | 0.74 | 0.59 | 1.28 |
| 40H | 0.71 | 0.63 | 1.30 |
| 40I | 0.74 | 0.60 | 1.10 |
| 40J | 0.70 | 0.60 | 1.09 |

## 5. DISCUSSION AND CONCLUSIONS

In comparison with Mauriello et al’s study which evaluated filtering efects with Al and rare earth elements in image contrast, in the present study rare earth elements were not found in the spectra of the filters assessed. Regarding Aluminium, which was presented in all filters evaluated on this research, it was observed good acceptance of the evaluators for the three groups of X-rays as the quality of image.

The 1989 study [7] showed that the evaluators prefere Al conventional filtering instead of Yttrium-Aluminum filtering. In the current study, the presence of Al in all alloy filters evaluated also reflected a high acceptance of radiographs. The element yttrium was not found in the spectra obtained.

Image quality obtained in the study [8] was not modified when the radiographs made using Al and Al-Cu filters were compared. In this study, aluminium was presented in all filters and in filters A, B, C and E copper was not appeared. In the other filters was observed the presence of Al and Cu and all radiographs were considered acceptable by the evaluators.

By analyzing effects of Cu alternative filtration about radiographic contrast, the research [8] concluded that the use of this filter, although require longer exposure, reduces Kerma rate in air and leads values of contrast greater than obtained with the Al filter. In this study, the exposure factor was not analyzed. However, it was observed that the Cu presence in alloy filtration evaluated resulted in no loss in image quality, but it was not possible to infer its relationship with increased contrast.

Image quality of radiographs made using Al-Zn filters (with different Zn concentrations) and Al filter, at work [9], was compared and the results showed no significant difference according to the evaluators, which agrees with this paper. In this study the presence of Zn in the radiographs group assessed has not represented a loss in image quality.

From the results obtained it was concluded that both unclear radiographs and ideal radiographs were produced by using filters of elementary common. Therefore, conventional filters evaluated were an acceptable option to produce quality images in dental radiology, despite differences in the composition of the alloys.

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