ORIGINAL

COPPER FILTER FOR DENTAL RADIOGRAPHY: EVALUATION OF RADIOGRAPHIC CONTRAST

FILTRO DE COBRE PARA RADIOGRAFIAS ODONTOLÓGICAS: AVALIAÇÃO DO CONTRASTE RADIOGRÁFICO

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A B S T R A C T

Objective

To study the effects of alternative copper filtration in a dental X-ray machine and evaluate possible changes in radiographic contrast.

Methods

An aluminum step-wedge was radiographed using aluminum (1.5mm) and copper (0.1mm) filters. Physical radiation factors (exposure time, kilovoltage and air-kerma rate) were controlled. After processing, the densitometer readings of the step-wedge step images were measured. For each radiograph, optical density and contrast curves were determined. The values of the areas under the contrast curves for the two groups (aluminum and copper filters) were compared by the two-tailed Mann-Whitney test, with a level of significance of 0.05.

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Results

The mean areas under the contrast curves were -1.956 and -2.115 for the aluminum and copper filters respectively. According to the statistical test, these values were significantly different: copper filtration yielded better contrast.

Conclusion

The use of copper filter requires longer exposure times; it reduces the air-kerma rate and results in higher contrast values than those obtained with aluminum filter.

Indexing terms: aluminum; copper; filtration; X-rays.

RESUMO

Objetivo

Estudar o efeito da filtração alternativa de cobre em um aparelho de raios X odontológico e avaliar as possíveis alterações no contraste radiográfico.

Métodos

Uma escala de densidade de alumínio foi radiografada utilizando-se filtros de alumínio (1,5mm) e cobre (0,1mm). Os fatores físicos da radiação (tempo de exposição, quilovoltagem e taxa de kerma no ar) foram controlados. Após o processamento radiográfico, foram realizadas as leituras densitométricas das imagens dos degraus da escala de densidade. Para cada radiografia, foram determinadas as curvas de densidade óptica e de contraste. Os valores das áreas sob as curvas de contraste para os dois grupos (filtros de alumínio e cobre) foram comparados pelo teste bicaudal de Mann-Withney, com nível de significância de 0,05.

Resultados

A média das áreas sob as curvas de contraste foram: -1,956 e -2,115, para os filtros de alumínio e cobre, respectivamente. Esses valores, quando comparados por teste estatístico, apresentaram diferença estatisticamente significativa, com o maior contraste para as imagens obtidas com o filtro de cobre.

Conclusão

O uso do filtro de cobre requer maiores tempos de exposição, reduz a taxa de kerma no ar e determina maiores valores de contraste do que aqueles obtidos com o filtro de alumínio.

***Termos de Indexação**: alumínio; cobre; filtração; raios X.*

INTRODUCTION

The radiograph is an essential instrument in dental practice. Diagnosis, planning, follow-up and prevention of diseases cannot be done without the information obtained by interpreting radiographic images.

Much clinical and laboratory research has been done with the objective of increasing the efficiency of X-rays for diagnosis, either in an attempt to reach the ALARA principle (“As Low As Reasonably Achievable”), or to produce a good image quality with the lowest radiation dose possible[1-7].

The X-ray beam possesses photons of energy varying from 0 to peak kilovoltage (kVp). Photons in the central portion of this spectrum are much more efficient in producing a radiographic image than photons on either side, when they coincide with the energy range in which dental film emulsions are most sensitive[8]. Low-energy X-rays contribute very little to radiographic image formation because they are largely absorbed by the patient's soft tissues. High-energy photons produce low image contrast and contribute to scattered radiation that degrades the image[1].

Therefore, the ideal filter is one that attenuates both extremes, in contrast to the commonly used aluminum filters, which absorb most strongly in the maximum film sensitivity energy region[7].

One way to optimize the radiation beam is to use additional filtration in X-ray machines, either by substituting the conventional aluminum filter or by associating it with filters of elements that have other atomic numbers in order to produce changes in the energy composition of the radiation beam and improve the quality of radiographic images.

In literature, some authors investigated the use of copper filters in association or not with aluminum filters. Since 1952, Trout et al.[9] have been using aluminum and copper filters to reduce exposure of the skin to radiation, recommending a 0.25mm thick copper sheet for kilovoltages above 100kVp. In 1978, with the objective of evaluating the beam energy, Cho et al.[10] measured the energy spectrum of a dental X-ray machine with added filtration of 0.1mm thick copper or 2mm thick aluminum sheets. They found that attenuation of low-energy photons by the added filters was greater than that obtained with conventional filtration and observed a hardening of the X-ray beam, which means the production of a bundle of X-rays with higher energy photons that are, consequently, more penetrating.

Ponce et al.[11], in 1988, reported that the use of filters like aluminum and copper modifies the beam energy and consequently, modifies the contrast, thus potentially affecting the ability to diagnose by radiographic images. In the same year, Kohn et al.[3] compared the use of aluminum, yttrium and copper filters for extraoral radiographs in relation to the effective energy of the beam, exposure dose, X-ray tube load and quality of the resultant radiographs. Their result showed that the 0.1mm thick copper filter associated with the 2mm thick aluminum filter contributed to a lower incident radiation dose and less increased X-ray tube load. With regard to the quality of the radiographs, all were shown to be acceptable, irrespective of the filter used.

In 1990, Cordt & Engelke[12] compared the effect of adding a niobium filter to another of copper, in relation to the incident radiation dose and obtained lower values when the copper filter was used. In the same year, Jangland & Axelsson[13] compared copper filtration (0.18mm and 0.09mm) added to niobium (50μm), and found a reduction of image contrast and increase of tube load. The authors also commented that these factors must be weighed, considering the benefit of the reduction in the dose absorbed by the patient, when deciding whether or not to use added filtration.

In 1991, Tamburús[14] analyzed the use of aluminum/copper filters and compared them with conventional aluminum filtration to evaluate the quality of the radiographic image and the radiation dose. The results indicated a significant reduction in radiation dose with the use of aluminum/copper filters, but there was a small loss of radiographic image quality. In the same year, McDonnell & Price[15] reported that when a copper filter is added to conventional aluminum filtration, the result is a reduction in exposure of 10-12%.

In 1999, Watanabe[16] considered copper filtration as an alternative to aluminum filtration, by comparatively analyzing the radiographic image quality and the radiation dose obtained with the use of 2mm thick aluminum filter plus 0.08mm and 0.13mm thick copper filter. With the use of cooper filter, he observed a reduction in the exposure to radiation dose and unchanged quality of the radiographic images.

In 2000, Gonçalves[17] studied the effect of alternative aluminum-copper alloy filtration in dental X-ray machines, evaluating the reduction in air-kerma rate, X-ray energy spectrum and alterations in the radiographic image quality. The results showed a hardening of the X-ray beam with a reduction of the air-kerma rate ranging from 4.33 to 47.33% and without alteration in the contrast of the radiographic image. The aim of this study was to evaluate the use of copper filter in a dental X-ray machine and its effect on radiographic contrast.

METHODS

A Heliodent 60B X-ray machine (Siemens, São Paulo, Brazil) was used operating at 60kVp and 10mA. An 8-step aluminum step-wedge, ranging from 2 to 16mm in thickness with 2mm increments, was radiographed. Ektaspeed Plus films (Eastman Kodak Company, Rochester, USA) were used as image receptors. The exposures were made under standard conditions, using a focus-film distance fixing device, allowing a perpendicular incidence of the X-ray beam on object and film. Beyond the step-wedge, a lead foil was placed on the film (3mm thickness) for later evaluation of base density plus fog. A 20mm thick layer of distilled water was interposed in the passage of the X-ray beam to simulate soft tissues. The water was contained in a specific compartment of the device, which allowed the exposures to be standardized.

Radiation beam physical factor measurements (exposure time, kilovoltage, air-kerma rate) were controlled by means of the 6000B NERO monitor (Victoreen Incorporation, Cleveland, USA).

Ten radiographs of the step-wedge were obtained with the radiation beam filtered with 1.5mm thick aluminum filter, and another 10 radiographs with the beam filtered with 0.1mm thick copper filter to replace the conventional aluminum filtration. The X-ray machine used had inherent filtration of 0.5mm thick aluminum equivalent.

Preliminary radiographs of a step-wedge were taken with various exposure times for the aluminum and copper filters. These tests were carried out to determine the exposure time required for producing an optical density of 1.0 (measured with a densitometer) in the 10mm thick step, irrespective of the filter used. Thus, it took twice as long to accomplish the radiographs with the copper filter as it took when using the conventional aluminum filter.

After the exposures, the films were processed manually in a conventional darkroom, using GBX solutions (Eastman Kodak Company, Rochester, USA). The developing time was 5 minutes at a temperature of 20ºC. The radiographs were dried in a hot air dryer.

After processing, the densitometer readings of the step-wedge step images, as well as the base density plus fog for each film were measured, with a 0-424 Digital Densitometer (Victoreen Incorporation, Cleveland, USA).

For each radiograph, the optical density and contrast curves were determined, as well as the areas under the contrast curves, based on the methodology described by Tamburús & Lavrador[18]. The values of the areas under the contrast curves for the two groups (aluminum and copper filters) were compared by means of the two-tailed Mann-Whitney test, with a level of significance of 0.05.

RESULTS

The mean density values and standard deviation for the images obtained using aluminum and copper filters are presented in Table 1.

From the optical density values of all the relative repetitions for each type of filter, the overall density curves were obtained, being: density = 0.373

Table 1. Mean optical density and standard deviation (s.d.) of the images obtained with aluminum and copper filters for each step of a step-wedge.

	Aluminum	Copper
0 mm	2.41 (0.02)	2.57 (0.03)
2 mm	1.72 (0.00)	1.89 (0.02)
4 mm	1.27 (0.01)	1.40 (0.02)
6 mm	0.97 (0.00)	1.09 (0.01)
8 mm	0.78 (0.01)	0.85 (0.01)
10 mm	0.66 (0.01)	0.70 (0.00)
12 mm	0.56 (0.01)	0.59 (0.01)
14 mm	0.48 (0.00)	0.50 (0.00)
16 mm	0.44 (0.00)	0.45 (0.00)
Db + fog*	0.28 (0.01)	0.29 (0.01)

* Db + fog: mean value of the base density and fog for each tested filter.

$+ e^{0.711 - 0.202x}$ for the aluminum filter and density = $0.340 + e^{0.804 - 0.183x}$ for the copper filter. These curves are illustrated in Figure 1.

The overall contrast curves for each type of filter were also obtained, which were: contrast = $- 0.202 + e^{0.711 - 0.202x}$ for the aluminum filter and contrast = $- 0.183 + e^{0.804 - 0.183x}$ for the copper filter; the mean areas under the curves were: -1.956 and -2.115 for the aluminum and copper filter, respectively. These contrast curves are illustrated in Figure 2. Please note the fact that the negative sign attributed to the contrast values is owing to the location of the curves below the abscissa axis.

The frequency distributions of the areas for the individual curves, for each type of filter, are shown in Figure 3.

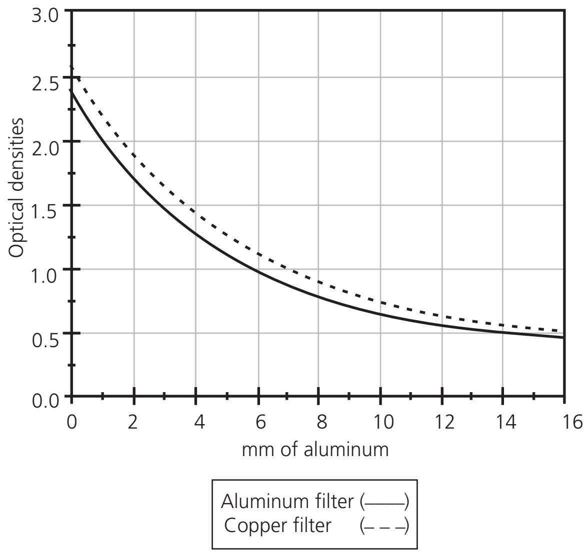

Figure 1. Curves associating optical density values and step-wedge thicknesses (mm of aluminum) for the aluminum and copper filters.

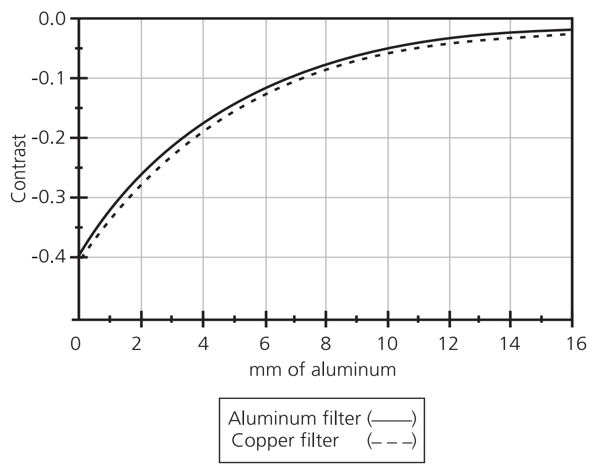

Figure 2. Curves associating contrast values and step-wedge thicknesses (mm of aluminum) for the aluminum and copper filters.

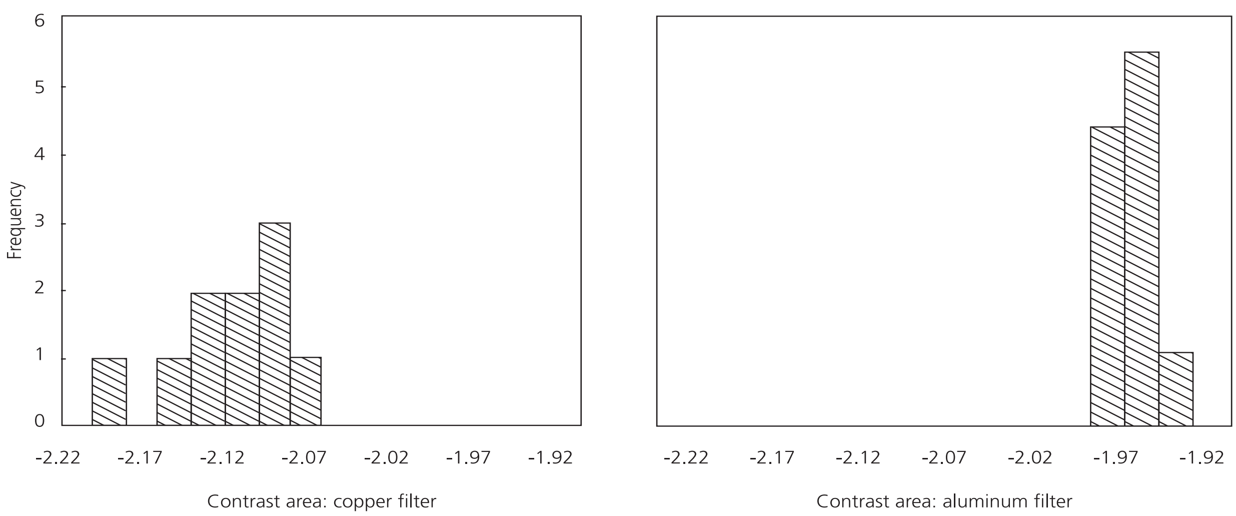

Figure 3. Distribution of the frequencies of the contrast areas for the copper and aluminum filters, respectively.

Next, the values of the areas under the contrast curves for the two groups (aluminum and copper filters) were compared with the Mann-Whitney test. This test detected significant differences between the two filters, observing a greater contrast for the images obtained with copper filtration.

The mean value of the base density plus fog was 0.28 for the aluminum filter, and 0.29 for the copper filter.

With regard to the air-kerma rate, which was monitored by the NERO device, a reduction of this value was observed when the copper filter was used.

DISCUSSION

This study found that the use of copper filter instead of conventional aluminum filter caused a change in the contrast of the radiographic image, showing greater values to those obtained with the conventional filter. However, these results differ from those of Jangland & Axelsson[13], who observed a reduction of image contrast and increase in tube load with the use of added copper filtration. On the other hand, Watanabe[16] observed that radiographs obtained with a copper filter presented similar contrast to those obtained with an aluminum filter. This result was also found by Gonçalves[17] who studied the effect of the alternative aluminum-copper alloy filtration in dental X-ray machines and did not observe alteration in the contrast of the radiographic image.

The preference for radiographs with a greater or lower degree of contrast is extremely subjective and depends on the objective of the diagnosis; for images of bone or soft tissue, low contrast is desirable; for examinations of denser structures, like enamel, high contrast is desirable. Ponce et al.[19] and Ponce et al.[11], when comparing radiographs presenting different contrasts, observed that the examiners generally showed a preference for those with higher contrast, although all had been considered acceptable for diagnosis.

With regard to radiation dose (expressed as air-kerma rate) they found a reduction in the values of this rate when the radiographs were taken with a copper filter. This result agreed with those of Konh et al.[3], Cordt & Engelke[12], Tamburús[14], Watanabe[16] & Gonçalves[17]. However, in spite of the exposure dose being reduced, it is necessary to increase the exposure time, which would consequently cause an overload of the X-rays tube. But although this time is longer, with the current, sufficiently sensitive films (group of sensitivity F) it still is practicable.

Another advantage of associating the copper filter with the group F films would be the fact that these faster films, according to some authors[20], present a slightly lower inherent contrast when compared with the films of other sensitivity groups, which could be compensated for the images of greater contrast produced with the use of the copper filter. This fact, as well as the reduction in the patient's exposure dose, validates the use of the copper filter in dental X-rays machines and shows the need for further studies about associating the copper filter with group F films.

Based on the methodology used, the copper filter is a possible alternative for dental X-ray machines to replace the conventional aluminum filter.

CONCLUSION

Copper filters require longer exposure times but result in less air-kerma rate and more contrast than aluminum filters.

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Received on: 9/1/2007
Final version resubmitted on: 2/5/2007
Aproved on: 26/6/2007