RESEARCH

Effects of developer exhaustion on DFL Contrast FV-58 and Kodak Insight dental films

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Objectives: The aim of this study was to compare the properties of the DFL Contrast FV-58 F-speed film (DFL Co., Rio de Janeiro, Brazil) with the Kodak Insight E/F speed film (Eastman Kodak, Rochester, NY) in fresh and exhausted processing solutions. The parameters studied were the speed, average gradient and latitude.

Methods: Five samples of each type of film were exposed under standardized conditions over 5 weeks. The films were developed in fresh and progressively exhausted processing solutions. Characteristic curves were constructed from values of optical density and radiation dose and were used to calculate the parameters. An analysis of variance was performed separately for film type and time.

Results: DFL Contrast FV-58 film has a speed and average gradient that is significantly higher than Insight film, whereas the values of latitude are lower. Exhausted processing solutions were not significant in the parameters studied.

Conclusion: DFL Contrast FV-58 film has stable properties when exhausted manual processing solutions are used and can be recommended for use in dental practice, contributing to dose reduction.

Dentomaxillofacial Radiology (2011) 40, 358–361. doi: 10.1259/dmfr/81585198

Keywords: radiography, dental; X-ray film; diagnostic imaging; radiology

Introduction

Dental radiology has evolved to reduce the radiation dose that reaches the patient. The method used by manufacturers is to produce more sensitive films. Thus, the technology used in X-ray films intends to increase its sensitivity so that it reduces the risk of radiation. The increased sensitivity should not diminish the quality of the image obtained, according to the principle of “as low as reasonably achievable” (ALARA).^{1–4}

The advances in digital systems have made dentists move into this technology. Despite the proven quality of digital intraoral systems, the price and access to technology means that the X-ray film still remains as the main receptor in dental radiography in developing countries.

It is known that different combinations of film and processing methods, temperature and degradation can

result in differences in the density of the films.^{1,4–8} The changes in density can affect the image quality and diagnostic accuracy.^{9,10}

Recently, a Brazilian company released the intraoral DFL Contrast FV-58 F-speed film (DFL Co., Rio de Janeiro, Brazil) into the domestic market. There is no report in the literature about its behaviour when processed in exhausted solutions. The aim of this study was to evaluate the speed, average gradient and latitude of the DFL Contrast FV-58 film and to compare it with the Kodak Insight film (Eastman Kodak Co., Rochester, NY) in fresh and exhausted solutions.

Materials and methods

The following intraoral film types were evaluated: Contrast FV-58 speed group F (batch expiry date October 2009) and the speed group E/F Insight (batch expiry date February 2010). All samples of each type of film were obtained from the same batch.

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Received 26 April 2010; revised 14 July 2010; accepted 18 July 2010

Film exposures were made with a Timex 70 dental X-ray unit (Gnatus Co., São Paulo, Brazil) operating at 70 kVp and 7 mA, with 2.5 mm aluminium equivalence of filtration. The unit was previously evaluated for accuracy of kilovoltage, linearity of timing and half-value layer. A source-film distance of 30 cm was set for all exposures by mounting the X-ray tube head in a jig that provided rigid orientation of the central ray with respect to a fixed film positioning platform.

Preliminary tests were performed to determine the exposure times needed to produce an optical density near to 1.0 on the image of the fourth step (8 mm thick), equivalent to that of the dentine of a mandibular first molar measured at the junction of the distal and occlusal surfaces. Chosen exposure times were 0.32 s for FV-58 and 0.40 s for Insight film.

All exposures were made using an 8-step aluminium stepwedge which ranged from 2 mm to 16 mm in thickness in 2 mm increments. Also, a small square of each film was completely shielded from direct radiation by placing a 5 mm thick lead block on each film. This area was used to measure the base-plus-fog density. The films were coded by type and week of experiment with a system of lead letters that were placed at the periphery of each film.

Five samples of each brand of film were exposed in the beginning of the experiment. A total of ten films were exposed on the first day.

The exposed films were manually developed, using Kodak GBX chemicals (Eastman Kodak Co.). The volume of the developing tank was 9 L. All films were processed within 24 h with development for 2.5 min at 27°C followed by fixation and washing using the manufacturer's instructions. All films were processed in complete darkness and hot air dried.

10 extraoral 18 × 24 cm size Kodak T-Mat G films were exposed to light and processed daily for a total of 50 films a week and 200 films in the whole experiment. Each extraoral film corresponds to approximately 36 intraoral films. In order to maximize exhaustion, the extraoral films were exposed to light and the solutions were not replenished during the whole experiment. During the day, while there was no film processing, the solutions maintenance temperature was about 29°C, which was the environment temperature.

At the end of the first week, a second set of ten exposed dental films (five of FV-58 and five of Insight) was processed. The exposures were repeated for 3 more weeks, in a total of 4 weeks of experiment. The process of developing 10 extraoral films daily was repeated in the whole experiment in a total of 200 films.

After processing, film densities were measured with a MRA digital densitometer (MRA Company, Ribeirão Preto, SP, Brazil) with a 2-mm aperture. Optical density was measured at three points across the surface of each step of the stepwedge and lead block images. An average density was determined for each step.

The radiation dose of each step of the stepwedge was measured by thermoluminescent dosimeters (TLDs).

Pre-calibrated TLD-100 lithium fluoride chips were supplied and analysed by the Laboratory for Metrology of Ionizing Radiation at the Federal University of Pernambuco (LMRI/DEN-UFPE).

Pairs of TLDs were exposed under identical settings (peak kilovoltage, milliamperes and distance) that were used on films at the time of 0.32 s and 0.4 s. The first pair of TLDs was directly exposed and measured the incident beam intensity. 2 mm aluminum plates were then used to expose other pairs of TLDs in order to measure the dose that reached each step of the stepwedge. Two TLDs were used to measure background radiation.

Before the study, LMRI/DEN-UFPE calibrated all dosimeters using the same type and range of radiation that would be used during the experiments. All TLDs were read after exposure using a Victoreen (2800M; Victoreen Instrument Co., Cleveland, OH) TLD reader at LMRI/DEN-UFPE. The dose values were calculated from calibration curves previously obtained, taking into account the contribution of background radiation.

The dose values were used to construct the characteristic curves in fresh and exhausted chemicals for each film type. The dose values were plotted against the density values measured behind the aluminum steps. A power curve was fitted in the plotted points and used to calculate, for each week, the film speed, average gradient and latitude.

The film speed was calculated as the reciprocal of the exposure required (in Roentgen) to produce a density of 1.0 above base plus fog. The average gradient and the latitude were calculated in the net density range of 0.25–2.00 above base plus fog. The average gradient was calculated as the difference in density (1.75) divided by the difference in the logarithm of the dose in Gy required to produce these densities.

Data were analysed using the statistical package R (<http://www.r-project.org/>). In order to examine the response of each film type in relation to the exhaustion of the processing solution, analysis of variance (ANOVA) was performed. ANOVA was used to assess the outcome variables of speed, average gradient and latitude. The software Microsoft Excel 2007 (Home and Student; Microsoft Corp., Redmond, WA) was used to graph the data.

Results

The film speed, average gradient and latitude values are shown in Table 1.

The results of the statistical analysis over the whole study period are summarised in Table 2.

Different behaviours were found for each studied variable over the study period. However, no significant influence of the exhaustion on the sensitometric properties was found ($P > 0.05$). All variables demonstrated significant differences according to film type ($P < 0.05$).

Figures 1–3 illustrate the effect of progressive exhaustion on speed, average gradient and latitude.

Table 1 Speed, average gradient and latitude of FV-58 and Insight films after exhaustion of processing solutions

	Speed ^a		Average gradient ^b		Latitude ^c	
	FV-58	Insight	FV-58	Insight	FV-58	Insight
Week 0	105.80	65.92	1.10	0.95	1.59	1.84
Week 1	89.81	51.93	1.11	0.99	1.58	1.77
Week 2	78.59	44.91	1.10	1.00	1.60	1.75
Week 3	71.04	48.39	1.08	1.00	1.62	1.75
Week 4	83.23	56.58	1.08	0.98	1.61	1.79

^aInverse of the exposure necessary for a density of 1 (note: calculations of speed used non-logarithmic numbers exposure time)

^b $(2.0 - 0.25) / \{\text{Log}(10) \text{ exposure for density of } 2.0 - \text{Log}(10) \text{ exposure for density of } 0.25\}$

^c $\{\text{Log}(10) \text{ exposure for density of } 2.0 - \text{Log}(10) \text{ exposure for density of } 0.25\}$

Table 2 *P*-values for the study variables during the 4-week period

Evaluation	Sensitometric properties		
	Speed	Average gradient	Latitude
Film type*	0.000862	$3.41 \cdot 10^{-5}$	$3.38 \cdot 10^{-5}$
Week	0.073655	1	0.777967

Analysis of variance was run for each variable by using a model that incorporated week of processing and film-type factors

*Statistical significant at $\alpha = 0.05$

Figure 1 Changes in speed of two film types with exhaustion of the chemicals from week 0 (fresh chemicals) to week 4

Discussion

This study reports film speed, average gradient and latitude and its response to processing solution exhaustion of Contrast FV-58 intraoral film in comparison with Kodak Insight film.

The specified exposure conditions required from the International Organization for Standardization (ISO) standard for photography are unobtainable by anything other than medical X-ray units.^{3,11} However, this study used a conventional dental X-ray source to generate characteristic curves because these conditions are more representative of actual radiographic practice.

Figure 2 Changes in average gradient of two film types with exhaustion of the chemicals from week 0 (fresh chemicals) to week 4 **Figure 3** Changes in latitude of two film types with exhaustion of the chemicals from week 0 (fresh chemicals) to week 4

In Brazil, the DFL company has released the Contrast FV-58 F-speed film. This film seems to be a Brazilian version of the American brand Flow FV-58 (Flow X-Ray, West Hempstead, NY), since the first samples also contained, on its surface, the word "FLOW". This information, however, was never confirmed by the DFL. The film Flow FV-58 had its prototype tested by Farman and Farman,¹ and demonstrated that it could reduce the radiation dose without loss of image quality.

In this study, the exhaustion of the processing solutions was accelerated by developing 18×24 cm extraoral films with maximum exposure.⁶ As a result, loss of solution level was observed. The number of films processed in a week had to be limited so that the solutions did not deplete excessively in a few days.

As the processing solutions became progressively exhausted, both films lost speed. In fresh and in exhausted solutions, FV-58 film had the highest speed. The FV-58 progressively lost its speed value until the end of third week and increased on the fourth. The Insight lost speed until the end of second week and increased on the third and fourth weeks. This behavior probably occurred as a result of to the "chemical fog" caused by the

developing action of non-exposed crystals. As seen in other studies, the combination of film processing can increase or decrease the sensitivity, even to the point of moving them between categories of different sensitivities.^{1,12} Each film showed a distinct average gradient behaviour during the experiment. Over the course of 3 weeks, while the FV-58 decreased the average gradient values, the Insight increased. At the end of the third week, their behaviour reversed and the FV-58 increased the average gradient while the Insight decreased.

In this experiment, latitude was calculated from the same density range of average gradient and the results were inversely proportional to it. As average gradient increases the angle of the sensitometric curve, the latitude decreases the exposure range of the film; that is, the film reaches higher densities with less exposure. The Contrast FV-58 latitude values were significantly lower than the Insight film.

Insight film latitude tended to decrease until the end of the second week of exhaustion and presented an increase in the fourth and fifth weeks. Contrast FV-58 latitude values decreased slightly from the beginning of the experiment until the end of the first week of exhaustion. From that point on, latitude increased until the third week and then decreased in the last week of the study.

The results of this study show that differences in processing chemicals affect the characteristics of the X-ray films and different film types respond differently to depletion of chemicals.

In conclusion, the Contrast FV-58 F-speed film's properties are consistent with the manufacturer's claims. The highest speed and average gradient of the film are stable, even when exhausted manual processing solutions are used. Contrast FV-58 F-speed film is an alternative to obtain images with lower radiation doses and acceptable standard of quality.

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