Iran. J. Radiat. Res., 2006; 4 (2): 81-86

A study of densitometry comparison among three radiographic processing solutions

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Background: The radiographic image accuracy depends on the X-ray film information visibility. Good visibility is found by good contrast. Radiation exposure parameters (kVp, mAs) and film processing conditions have impact on contrast. In dentistry radiography machines, exposure time and processing procedure are set by radiographer. No optimized exposure time and processing conditions may lead to incorrect diagnosis and re-exposure of the patient. Therefore, we studied the performance of the three different available processing solutions with dental X-ray film. ***Materials and Methods:*** Dental intraoral E-speed films, size 2 (Kodak company, USA) were used in this study. These films were developed in a manual processor using three different brands of processing solution: 1) Taifsaz (Iran), 2) Darutasvir (Iran) and 3) Agfa (Germany) for temperatures of 25°C, 28°C and 30°C at the three different exposure times, 0.2 s, 0.25 s and 0.35 s. Performance was evaluated with respect to base plus fog, relative contrast and relative speed. ***Results:*** Darutasvir processing solution as the cheapest one showed higher base plus fog density at 25°C and 30°C than that of Taifsaz and Agfa solutions. Also, Darutasvir solution was found to have better relative contrast than that of the others, except for 30°C at 0.25 s. Relative speed was higher in Darutsavir solution than Agfa for 25°C at three exposure times used in this study, for 28°C at 0.2 s and for 30°C at 0.35 s. Taifsaz Processing solution was in the second order with respect to tested conditions. ***Conclusion:*** Comparison among available X-ray film processing solutions for different temperatures at different exposure times can help to maintain image quality while patient exposure and film cost are kept considerably low. **Iran. J. Radiat. Res., 2006; 4 (2): 81-86**

Keywords: *Radiographic image, dental X-ray film, processing solution .*

INTRODUCTION

The radiographic image accuracy depends on the X-ray film information visibility. Good visibility is found by good contrast. The image information is a pattern of the X-ray beam intensities caused by the subject as its different attenuating materials. For example bone and soft tissues pass different beam intensities which results in an image contrast [1]. It was shown that the energy of the X-ray beam may be used to produce a visible pattern of black metallic silver on the X-ray film [2-4]. The measurement of film blackness is called "photographic density" defined by:

$$D = \log \frac{I_0}{I} \qquad (1)$$

Where D = density, I_0 = light incident on a film and It = light transmitted by the film.

The simple definition of contrast is the difference in density existing between various regions on the film [3]. Radiographic contrast depends on subject contrast and on film contrast. Subject contrast depends on the thickness, density and atomic number of the subject, the radiation energy (kVp), contrast materials and scatter radiation. Film contrast depends on four factors: film characteristic curve, film density, screen or direct X-ray exposure and film processing. Akdeniz and Lomcali did densitometry evaluation of four radiographic processing solutions. They found that depending on the processor and processing solutions in use, exposure time and processing temperature could have been modified, while maintaining the image quality [1].

Using an optimized mAs (production of mA and exposure time), causes the sufficient X-ray beam to get optimized image density and contrast on the processed film. In dentistry

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radiography machines exposure time and processing procedure are under radiographer control and are among the factors determining radiographic standards [5]. No optimized exposure time and processing conditions may lead to incorrect diagnosis and re-exposure of the patient. Therefore, we studied the performance of the three different available processing solutions with dental X-ray film, since there has been published data on the issue.

MATERIALS AND METHODS

Dental intraoral E-speed films, size 2 (Kodak Co., USA) were used in this study. All films were irradiated by an X-ray tube (Toshiba D082 B 3M 61113, Italy) at 70 kVp and 8 mA with 20 cm target film distance and 2 mm Al total filtration. The test object was a step wedge made of commercially pure aluminum (99.36% Al, 0.35% Fe, 0.1% Cu, 0.02% Mn and 0.2% Si) and consisted of ten steps from 1 to 10 mm in thickness. All films were developed in a manual processor.

Three different processing solutions were evaluated: 1) Taifsaz (Iran), 2) Darutasvir (Iran) and 3) Agfa (Germany). X-ray tube, films and step wedge were placed in the same fixed positions for all exposures. Films were exposed at 0.2 s, 0.25 s and 0.35 s and processed at three different temperatures (25°C, 28°C and 30°C). 81 films were exposed for each solution, 27 for each exposure time and solution temperature combination, plus 27 films for base and fog at three different temperatures. Each set of films was processed simultaneously in fresh solutions, and new chemicals were used for each cycle.

Radiographic densities were measured with a digital densitometer (Gammasonic, Institute for Medical Research LTD, Australia) for the steps of the wedge on each exposed and unexposed film using a 3 mm aperture and a light source of 5W. The average of 9 consecutive measurements was obtained for each step which was corrected for the base plus fog density.

Relative speed was evaluated as the average density of the 6th step base minus plus and fog. Relative contrast was defined as the 4th step density subtracted from that of the 10th step. Processing time 18s was used for all films. General Linear Model analysis was used as the statistical method.

RESULTS

Table 1 show the base plus fog density for each solution at three different temperatures

Table 1. Base plus fog density for each solution at the three different temperature, 25°C, 28°C and 30°C.

Name	Temperature	N	Density mean	Std. Deviation	95% Confidence level	
					Lower level	Upper level
	25					
Darutasvir		27	.2133	.00480	.2114	.2152
Taifsaz		27	.2067	.02148	.1982	.2152
Agfa		27	.1811	.00577	.1788	.1834
	28					
Darutasvir		27	.2344	.00698	.2317	.2372
Taifsaz		27	.2389	.00577	.2366	.2412
Agfa		27	.2011	.00320	.1998	.2024
	30					
Darutasvir		27	.2556	.04191	.2390	.2721
Taifsaz		27	.2500	.01271	.2450	.2550
Agfa		27	.2156	.00506	.2136	.2176

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(25°C, 28°C and 30°C). For Darutasvir solution mean value of the base plus fog density at 25°C and 30°C were greater than that of the others. Taifsaz solution showed greater mean base plus fog density value at 28°C than that of the others; however there were no significant mean differences between Darutasvir and Taifsaz solutions at the three temperatures under examination (P> 0.05, CL = 95%). There was a significant difference of Darutasvir and Agfa solutions (P< 0.05, CI = 95%) and also those of Taifsaz and Agfa solutions (P<0.05, CL = 95%) at the temperatures under examination (25°C, 28°C and 30°C).

Tables 2, 3 and 4 compare relative contrast among the three different solutions used in this study (25°C, 28°C and 30°C). For 25°C Darutasvir solution showed better contrast than the others at the three different exposure times, 0.2 s, 0.25 s and 0.35 s; however there were significant differences between Darutasvir and Agfa solutions at all

Table 2. Relative contrast among the three different solutions used in this study at 25°C, at the three different exposure times, 0.2 s, 0.25 s and 0.35 s.

Name	Exposure time (sec)	N	Contrast mean	Std. Deviation	95% Confidence level	
					Lower level	Upper level
	0.20					
Darutasvir		9	-.4478	.01922	-.4626	-.4330
Taifsaz		9	-.3644	.04667	-.4003	-.3286
Agfa		9	-.3544	.02698	-.3752	-.3337
	0.25					
Darutasvir		9	-.6856	.04065	-.7168	-.6543
Taifsaz		9	-.5478	.11798	-.6385	-.4571
Agfa		9	-.4500	.05545	-.4926	-.4074
	0.35					
Darutasvir		9	-.7611	.03371	-.7870	-.7352
Taifsaz		9	-.7300	.19013	-.8761	-.5839
Agfa		9	-.5211	.06051	-.5676	-.4746

Table 3. Relative contrast among the three different solutions used in this study at 28°C, at the three different exposure times, 0.2 s, 0.25 s and 0.35 s.

Name	Exposure time (sec)	N	Contrast mean	Std. Deviation	95% Confidence level	
					Lower level	Upper level
	0.20					
Darutasvir		9	-.6100	.05852	-.6550	-.5650
Taifsaz		9	-.5367	.05679	-.5803	-.4930
Agfa		9	-.5111	.05231	-.5513	-.4709
	0.25					
Darutasvir		9	-.9778	.07120	-1.0325	-.9230
Taifsaz		9	-.7456	.12431	-.8411	-.6500
Agfa		9	-.6644	.06710	-.7160	-.6129
	0.35					
Darutasvir		9	-1.1067	.08916	-1.1752	-1.0381
Taifsaz		9	-.8967	.13454	-1.0001	-.7933
Agfa		9	-.8622	.10604	-.9437	-.7807

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Table 4. Relative contrast among the three different solutions used in this study at 30°C, at the three different exposure times, 0.2 s, 0.25 s and 0.35 s.

Name	Exposure time	N	Contrast mean	Std. Deviation	95% Confidence level	
					Lower level	Upper level
	0.20					
Darutasvir		9	-.6456	.04746	-.6820	-.6091
Taifsaz		9	-.3644	.04667	-.4003	-.3286
Agfa		9	-.5356	.06167	-.5830	-.4882
	0.25					
Darutasvir		9	-.7933	.36073	-1.0706	-.5161
Taifsaz		9	-.8411	.14547	-.9529	-.7293
Agfa		9	-.7200	.05958	-.7658	-.6742
	0.35					
Darutasvir		9	-1.1733	.18138	-1.3128	-1.0339
Taifsaz		9	-.9044	.18915	-1.0498	-.7591
Agfa		9	-.9222	.06160	-.9696	-.8749

the above mentioned exposure times, and between Darutasvir and Taifsaz solutions, only at 0.2 s significant difference was observed ($p<0.05$, CL = 95%). The same results were found for 28°C, except that there was no significant difference between Darutasvir and Taifsaz solutions at 0.2 s too. For 30°C there were significant differences among Darutasvir, Taifsaz and Agfa processing solutions (sorted according to better contrast) at the exposure time of 0.2 s ($p<0.05$, CL = 95%). No significant differences was observed among them at 0.25 s exposure time ($p<0.05$, CL = 95%). Darutasvir solution had better contrast than Agfa solution with significant difference at 0.35 s exposure time ($p < 0.05$, CL = 95%).

Tables 5, 6 and 7 compare relative speeds among these solutions at three different exposure times, 0.2 s, 0.25 s and 0.35 s for the fixed temperatures of 25°C, 28°C, and 30°C. For 30°C, there was significant differences in relative speed between Taifsaz and Agfa solutions at 0.25 s and between Darutasvir

Table 5. Relative speeds among three different solutions at the three different exposure times, 0.2 s, 0.25 s and 0.35 s for the fixed temperatures of 25°C.

Name	Exposure time	N	Speed mean	Std. Deviation	95% Confidence level	
					Lower level	Upper level
	0.20					
Darutasvir		9	.4967	.02958	.4739	.5194
Taifsaz		9	.4511	.08565	.3853	.5169
Agfa		9	.4200	.03391	.3939	.4461
	0.25					
Darutasvir		9	.8200	.08703	.7531	.8869
Taifsaz		9	.6911	.11858	.6000	.7823
Agfa		9	.6056	.07248	.5498	.6613
	0.35					
Darutasvir		9	.9878	.06797	.9355	1.0400
Taifsaz		9	.9544	.26773	.7487	1.1602
Agfa		9	.7367	.06225	.6888	.7845

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Table 6. Relative speeds among three different solutions at the three different exposure times, 0.2 s, 0.25 s and 0.35 s for the fixed temperatures of 28°C.

Name	Exposure time	N	Speed mean	Std. Deviation	95% Confidence level	
					Lower level	Upper level
	0.20					
Darutasvir		9	.6744	.07248	.6187	.7302
Taifsaz		9	.6033	.08396	.5388	.6679
Agfa		9	.5567	.05268	.5162	.5972
	0.25					
Darutasvir		9	1.1344	.09748	1.0595	1.2094
Taifsaz		9	.9122	.10628	.8305	.9939
Agfa		9	.7644	.09671	.6901	.8388
	0.35					
Darutasvir		9	1.3500	.08185	1.2871	1.4129
Taifsaz		9	1.1711	.15608	1.0511	1.2911
Agfa		9	1.1089	.22430	.9365	1.2813

Table 7. Relative speeds among three different solutions at the three different exposure times, 0.2 s, 0.25 s and 0.35 s for the fixed temperatures of 30°C.

Name	Exposure time	N	Speed mean	Std. Deviation	95% Confidence level	
					Lower level	Upper level
	0.20					
Darutasvir		9	.7622	.08511	.6968	.8276
Taifsaz		9	.4078	.07513	.3500	.4655
Agfa		9	.5867	.05568	.5439	.6295
	0.25					
Darutasvir		9	1.0700	.43497	.7357	1.4043
Taifsaz		9	1.0567	.17321	.9235	1.1898
Agfa		9	.8378	.09176	.7672	.9083
	0.35					
Darutasvir		9	1.5389	.08403	1.4743	1.6035
Taifsaz		9	1.1789	.23587	.9976	1.3602
Agfa		9	1.1322	.05932	1.0866	1.1778

and Agfa solutions at 0.35 s ($p< 0.05$, CL = 95%). For 28°C, there was significant differences between Darutasvir and Agfa at 0.2 s, and between Taifsaz and Agfa at 0.25 s ($p< 0.05$, CL = 95%). Finally, for 25°C, there were significant differences in relative speeds between Darutasvir and Agfa at the three different exposure times used in this study ($p< 0.05$, CL = 95%).

DISCUSSION

Base plus fog density for Darutasvir and Taifsaz processing solutions were higher than Agfa ($p< 0.05$, CL = 95%). This may indicate that these solutions have less potassium bromide as restainer than Agfa. Higher base plus fog values indicate that an X-ray examination can be carried out with a lower

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exposure without loss of image quality in the resulting radiograph [2]. Darutasvir processing solution had the best contrast at the three different exposure times 0.2 s, 0.25 s and 0.35 s for the fixed temperatures of 25°C, 28°C and 30°C. Therefore, using this solution can cause good visibility and better accuracy than those of the others. By having good contrast it will not be necessary to use longer exposure times, and the patient dose can be reduced consequently. Taifsaz solution holds the second order, except for 30°C at 0.2 s that Agfa processing solution kept the second position. Relative speeds in Darutasvir and Taifsaz processing solutions were higher than that of Agfa processing solution. The use of processing solutions with higher speeds indicates that the X-ray examination may be carried out at a lower exposure without image quality loss.

In this study, we found an economic advantage since Darutasvir processing solution as the cheapest solution gave the best results. Akdeniz and Lomcali [1] did densitometry evaluation of four radiographic processing solutions. The present observation similar to other reports [1] showed that exposure time and processing temperature can be modified while maintaining image quality. However, the solutions examined by Akdeniz and Lomcali were different from ours. There is little published data on this subject, so it isn't possible to compare the results with other studies. It would be suggested to do these types of studies in different countries to find out if the environment and climate will affect the results.

In conclusion in this study Darutasvir processing solution was found as the cheapest one showing higher base plus fog density at 25°C and 30°C than those of Taifsaz and Agfa solutions. Also, for temperatures of 25°C, 28°C and 30°C at three different exposure times, 0.2 s, 0.25 s and 0.35 s, Darutasvir solution showed a better relative contrast than that of the other ones, except for 30°C at 0.25 s according to the present research. Relative speed was higher in Darutsavir solution than Agfa for 25°C at three exposure times used in this study and for 28°C at 0.2 s and for 30°C at 0.35 s. Higher relative speed causes patient dose reduction. On the whole, Taifsaz Processing solution was the second in ranking as for the tested conditions. Finally, it was found that comparison of the available X-ray film processing solutions at different temperatures and at different exposure times can help to maintain image quality, while the patient exposure and film cost are kept considerably low.

ACKNOWLEDGMENT

This study has been supported by Tehran University of Medical Sciences.

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