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RESEARCH ARTICLE

EFFECTS OF CHEMICAL DEVELOPER DEPLETION ON INSIGHT AND EKTASPEED PLUS FILMS: A SENSITOMETRIC COMPARISON

[1,*]Dr. Vignesswary, A., [2]Dr. Koteeswaran, D. and [3]Dr. Priyanka, S.

[1]Senior Lecturer, Department of Oral Medicine And Radiology, Ultra's Best Dental Science College, Madurai, India
[2]Professor, Department of oral medicine and radiology, Meenakshi Ammal Dental College Chennai, India
[3]Assistant Professor, Department of Dentistry, Meenakshi Medical College and Hospital, Enathur, Kanchipuram, India

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ABSTRACT

Objectives: To compare the sensitometric properties of Insight (F-SPEED) and Ektaspeed Plus radiographic (E-speed) film which was manually and automatically processed using fresh and depleted chemical solutions.

Methods: 8 sets of each type of film were obtained (1set=5films), 4sets being manually processed and 4sets being automatically processed. A total of 80films (40 Ektaspeed Plus and 40 Insight film) were exposed and developed. The first two sets of each film type were developed in fresh chemicals on the first day and the other sets were processed in the same progressively depleted solutions, once a week until the end of experiment within 3weeks. Characteristic curves were constructed to compare the sensitometric properties of the films: contrast, latitude and speed

Results: Results showed that insight film is faster than Ektaspeed plus film under both processing conditions, both in fresh and old chemicals. Depletion occurred faster in automatic processing. Radiographic contrast is higher for both the films, when processed automatically in fresh solution. Contrast of manually processed films showed higher contrast in old chemicals. Insight films are more stable interms of latitude.

Conclusion: Newer insight film can be preferred as it requires only lesser exposure thereby reducing patient radiation exposure to 20%. Chemical depletion in automatic processing was faster than manual condition.

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INTRODUCTION

A major objective of diagnostic radiology is to provide images of optimal quality at radiation doses as low as reasonably achievable (ALARA) (Marcia Spinelli Casanova *et al*., 2006; Geist and Brand, 2001; Syriopoulos *et al*., 1999). The development of dental radiology has been characterised by a progressive increase in x-ray film speed and a consequent reduction in radiation hazards (Maryam Zangouei-Booshehri *et al*., 2011). The image receptor most often used in dental radiography is the x-ray film. X-ray films are classified according to the radiographic speed represented by alphabets (A-F).

One of the most effective ways to reduce patient radiation exposure is that more sensitive films are required to produce an image of less radiation (Maryam Zangouei-Booshehri *et al*., 2011; Stuart, 2009). In 1981, Kodak introduced Ektaspeed, an E-speed film requiring only half the exposure of kodak's version of D-speed film but gained limited clinical acceptance because of poor image quality (Arthur *et al*., 1989; John B Ludlow *et al*., 2001). Kodak refined their technology and launched Ektaspeed plus film to replace Ektaspeed in 1994 to overcome the limitations of the later. It introduced a new T-Mat film emulsion with a flat tabular technology using light-sensitive silver halide grains being flat rather than pebble-shaped and are oriented in a perpendicular fashion to the x-ray. T-Mat technology has not only improved the image resolution, but also has increased the light-gathering ability or speed of ektaspeed plus films (Stuart, 2009; John B Ludlow *et al*., 2001; Lieutenant Gary *et al*., 2003; Wong *et al*., 2002; Kavas *et al*., 1995).

***Corresponding author: Dr. Vignesswary, A.,**
[1]Senior Lecturer, Department of Oral Medicine And Radiology, Ultra's Best Dental Science College, Madurai, India.

In April 2000, Eastman Kodak announced the introduction of newer Insight film, classified as an E/F-speed intraoral film, depending on the processing conditions (Wong, 2002). This new film was classified as F-speed film, according to the ISO standards when processed in roller-transport automatic dental processors. A modest decrease in film speed occurs in absence of this mechanical activation. While an increase in film speed implies further dose reduction for the patient. This newer film requires 60% less exposure time than D-speed film and 20% less than Ektaspeed plus (Marcia Spinelli Casanova, 2006; Arthur *et al*., 1989; John B Ludlow, 2001; James R Geist *et al*., 2003; Ludlow *et al*., 2001). The image quality is also influenced by film processing method (Ghazikhanlou Sani, 2010). Different combinations of films and processing methods, temperature and developer depletion can result in films with different density (Marcia Spinelli Casanova, 2006; Stuart, 2009). All the processing solutions deteriorate as a result of continued use and exposure to air. Use of exhausted developing solutions shows reduced density and contrast. It has been observed that depletion of chemicals can have a deleterious effect on image quality (Marcia Spinelli Casanova, 2006; Ghazikhanlou Sani, 2010). A new dental x-ray film should have better or comparable sensitometric properties to the radiographic film in current use. Exposure time and processing procedures are among the factors determining the radiographic standards (Olaf E Langland *et al*., 1995). It is important to examine image characteristics of E-speed and F-speed film, their behaviour under different processing methods and their performance over time. Therefore the aim of the present study is to compare the sensitometric properties of Insight and Ektaspeed plus radiographic films manually and automatically processed using fresh and depleted chemical solutions.

MATERIALS AND METHODS

The films examined were Ektaspeed Plus film (Kodak Eastman Co, Rochester, NY, USA) and the Insight IP-21(Kodak Eastman Co, Rochester, NY, USA) were evaluated. The films were exposed using a Blue-X Dental X-ray equipment (70kvp/ 8mA). The study was conducted in the department of Oral Medicine and Radiology in Meenakshi Ammal Dental College at Chennai, India. Patients are not included in this particular invitro study. A total of 80 dental x-ray films i.e., 40(E) Ektaspeed plus and 40(F) Insight dental films are included in this study. Ten sets of each film type (E/F) is taken. Each set consists of four films which will be exposed plus one radiographic film which will be unexposed (The unexposed films are used to determine the base-plus fog density). Together each set consists of 5x-ray films which are coded by exposure time using a system of lead letters placed at the film periphery. The codings of 1,2,3,4 is used for films to be manually processed and 5,6,7,8 is used for films to be automatically processed. The exposures are made in four increments:1,10,60 and 180 impulses. Film exposures will be made with a standard source –film distance of 30cm. Among the 8 sets of each type of radiographic film, 4sets being manually processed and 4sets being automatically processed. Among the 4 sets, the first sets of each film will be processed in fresh chemicals (one set is manually processed and the other set is automatically processed) on the first day of the experiment. The other sets will be processed in progressively depleted solutions in subsequent days as mentioned: 5th day, 12th day and 19th day. The above mentioned days are considered as the processing days and the study will be completed in 3weeks period. Velopex automatic processor (90s/30 degree Celsius) was used for automatic processing with Photon DK-38developing kit. The manual processing was performed with Photon DD & FD Manual processing solution. After processing, the film densities will be compared using a digital densitometer (OPTEL, TRANS-4, Pulseecho systems, SION, Bombay) with a 2mm aperture. Optical density will be measured at 5different points across the surface of each degree of density. An average density is determined for each film. Characteristic curves for each film, processing system and processing day are constructed by plotting the optical density against the exposure of film. The characteristic curves are drawn to calculate film speed, inherent contrast and exposure latitude of both manually and automatically processed films which are processed using fresh and depleted chemical solutions. Film speed was calculated as the exposure time (in seconds). Film latitude is the measure of the range of exposures. Contrast was determined for each film type and processing condition using the formula mentioned in appendix (Stuart, 2009; Koji Hashimoto *et al*., 1991).

RESULTS

The characteristic curves of Ektaspeed plus and Insight films developed in the first and last days of the experiment are shown in Figure 1 and 2. The shift of curves along the x-axis indicates the difference in the speed of the two films.

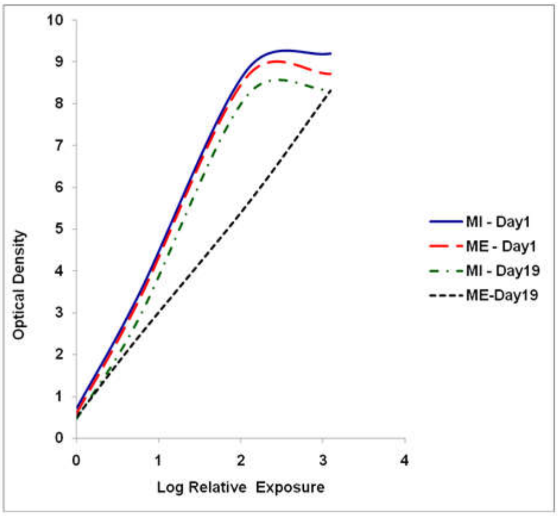

Figure 1. Characteristic curves of Insight and Ektaspeed Plus films using manual processing with fresh and old chemicals

Insight films (curve on the left) is faster than Ektaspeed plus (curve on the right) under both processing conditions because lesser exposure is required to produce the same level of density. This difference is observed in both fresh and old chemicals. The effects of depletion on the characteristic curves are shown in figures 3 to 6 which changed the form of the characteristic curves and is faster under automatic processing. The degradation of chemicals in automatic developing is visually detectable in the characteristic curves at the end of the second week (Figure 5 and 6). Under manual conditions, this effect is only noted at the end of third week (Figure 3 and 4). As the solution gets degraded, the curves of both films are shifted to the right in relation to the previous processing days, which indicates that there is a decrease in film speed as chemical depletion occurs.

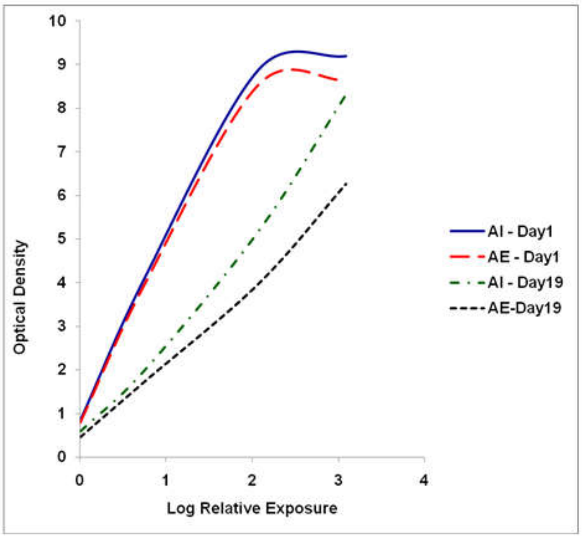

Figure 2. Characteristic curves of Insight and Ektaspeed Plus films using automatic processing with fresh and old chemicals

The base plus fog densities for all combinations of film types, processing techniques and processing days are shown in Table 1. The contrast values are shown in Table 2.

Table 1. Base-plus-Fog density of both films manually and automatically Processed on different days

Day	Manual processing		automatic processing	
	Ektaspeed plus	insight	Ektaspeed plus	Insight
1st	0.19	0.17	0.26	0.19
5th	0.21	0.18	0.20	0.19
12th	0.21	0.17	0.22	0.19
19th	0.19	0.17	0.20	0.20

Table 2. Contrast values for Ektaspeed Plus and Insight films manually and automatically processed on different days

Day	Manual processing		automatic processing	
	Ektaspeed plus	insight	Ektaspeed plus	Insight
1st	4.13	4.24	4.66	4.79
5th	3.89	3.89	1.95	2.18
12th	3.39	3.83	1.9	2.12
19th	2.59	3.74	1.855	2.04

Table 3. Speed for Ektaspeed Plus and Insight films manually and Automatically processed on different days

Day	Manual processing		Automatic processing	
	Ektaspeed plus	Insight	Ektaspeed plus	Insight
1st	1.15	1.12	1.02	0.99
5th	1.22	1.22	2.43	2.18
12th	1.4	1.24	2.5	2.24
19th	1.83	1.27	2.56	2.33

In 0.25 to 5 density ranges, the average gradient for Insight film is higher than Ektaspeed plus film on the first day of processing. In the beginning the contrast in both the films is higher when automatically processed. Regardless of the processing condition, the contrast values of both the films decreased secondary to solution depletion. Contrast of manually processed films of both types showed slightly greater contrast values in old solutions when compared to automatic processing. Table 3 shows the speed of both types of films processed both manually and automatically.

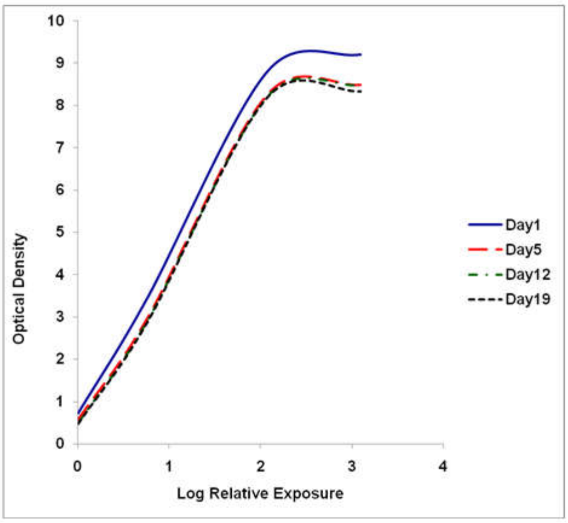

Figure 3. Effects of solution depletion on characteristic curves of manually processed Insight film

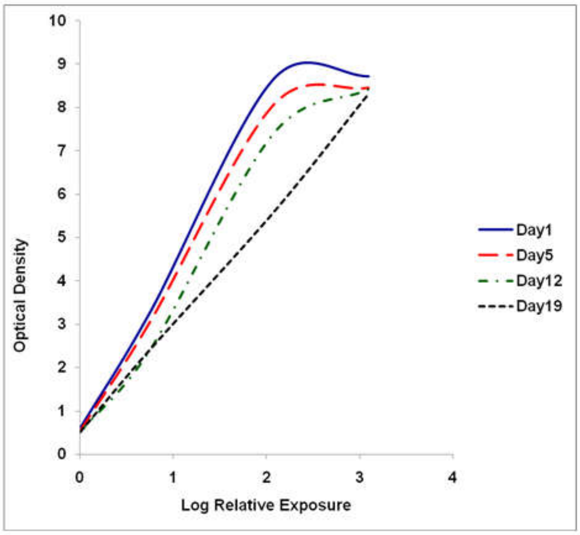

Figure 4. Effects of solution depletion on characteristic curves of manually processed Ektaspeed Plus film

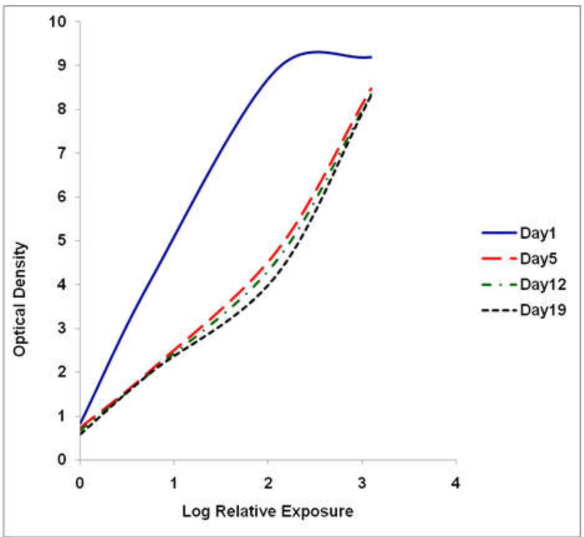

Figure 5. Effects of solution depletion on characteristic curves of automatically processed Insight film

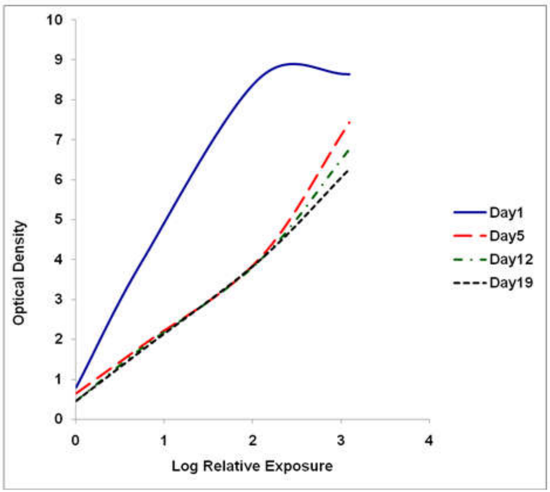

Figure 6. Effects of solution depletion on characteristic curves of automatically processed Ektaspeed Plus film

Insight film is faster than Ektaspeed plus film in both types of processing conditions. As the processing solutions are increasingly depleted, both films lose their speed. Insight film lose less speed in both processing conditions.

DISCUSSION

When a series of films are exposed under similar conditions, the relationship is conventionally done by plotting the optical density on the Y-axis and logarithm of relative exposure on the X-axis and the curve so obtained is known as the "Characteristic curve" or "H and D curve" for the film which was named after F.Hurter and V.C.Driffield in 1890 (Stuart, 2009; Thomas *et al*., 1990). By film exposure, it is refered to the product of the intensity of the exposure (milliamperes of x-ray tube current) and time of exposure (in seconds). Thus exposure is expressed in terms of milliampere-seconds abbreviated as mAs. As the exposure of the film increases, its optical density also increases (Stuart, 2009; Thomas *et al*., 1990). As such the overall degree of darkening of an exposed film is refered to as radiographic density, which is measured as the optical density of an area of a film using a digital densitometer. The optical density of the film relative to the exposure can be altered by changing the developing temperature and developing time. This can be measured as mentioned in appendix (Stuart, 2009). Analysis of the characteristic curve of a particular film provides information about the contrast, speed (sensitivity) and latitude of the film. There is a flat portion of the curve where the exposure and density values are both low which corresponds to the base and fog of the film and is in an area where by small exposures have little or no measurable effects on film. If an unexposed film is processed there will always be a measurable density on the film. This density is made up of two components i.e., inherent density of the base as it is customary for manufacturers to tint the plastics base slightly so that a more esthetically acceptable radiograph is obtained and secondly, because of the fog due to the development of unexposed silver halide crystals. This tinting, usually blue, adds slightly to the density. This is called base-plus fog or gross fog density (Smith, 1970). Generally it is in the range of 0.2-0.3 (Stuart, 2009). There is then a "toe" region which leads into the steeply rising portion of the graph. The steeply rising portion of the graph then leads to shoulder part which comes the next where the curve flatten out and the curve again becomes horizontal. Further exposures will not increase the density at this point, because virtually all of the silver halide crystals have already been exposed. The important part of the characteristic curve is between the toe and shoulder and in this region the curve is almost a straight line. The position of the characteristic curve on such a graph can be altered by two main factors, the conditions under which the film is processed and the quality of the radiation to which it is exposed (Smith, 1970).

Radiographic contrast is a general term used to describe the range of densities on a radiograph which is usually measured as the steepness or average slope of the diagnostically useful portion of the curve. Greater the slope of the curve, greater is the contrast. Film processing also influences contrast (Thomas *et al*., 1990). Film contrast is inturn maximised by optimal film processing conditions. This can be calculated by the formula as mentioned in appendix (Koji Hashimoto *et al*., 1991). The slope (gradient) of a straight line joining two points of specified density on the characteristic curve is called average gradient (Koji Hashimoto *et al*., 1991; Thomas *et al*., 1990; Smith, 1970). The reciprocal of the value of the exposure required to produce a certain density above base plus fog defines the speed of the film (Stuart, 2009; Koji Hashimoto, 1991). The results of this study showed that different film types and processing conditions respond differently to depletion, which is in agreement with the previous investigations (Marcia Spinelli Casanova, 2006; Syriopoulos *et al*., 1999; John B Ludlow, 2001; Syriopoulos *et al*., 2001). The depletion causes a change in the form of the characteristic curves. In manual processing this change is observed only at the end of last week, while in automatic it occurred at the end of the second week. This shows that the developing solution depletion occurs faster in automatic processors than in manual conditions due to the higher temperature of the chemicals in the automatically processed solutions. When the chemicals are fresh, the highest contrast values are found in automatic processing, whereas manual processing provided higher contrasts when solution gets depleted which is also consistent with those of previous studies (Syriopoulos *et al*., 2001; Joanne Catandella Fletcher, 1987). In this study, insight films yielded a higher contrast values than ektaspeed plus as reported by Ludlow *et al*. Contrast values are decreased secondary to chemical depletion which is also reported by previous investigators (Syriopoulos *et al*., 1999; Thunthy and Weinberg, 1995). The findings of our study showed that ektaspeed plus films are more affected by processing conditions than insight films which is also reported previously (Marcia Spinelli Casanova *et al*., 2006). Film latitude is a measure of range of the exposures that can be recorded as distinguishable densities on a film. A film is optimised to show a wide latitude with a long straight-line portion and a shallow slope. Interms of latitude, insight films are more stable than ektaspeed plus films on either processing conditions. Films with narrow latitude show higher contrast. The outcome of this study shows that the newer insight film is faster than ektaspeed plus film. As the processing solution depletes, both films lose their speed. Insight films lose much lesser speed when compared to ektaspeed plus and the smaller reduction of speed suggests that this film is more resistant than ektaspeed plus films to the effects of chemical depletion as previously reported by Geist and Brand (White and Yoon, 1997).

Conclusion

Chemical depletion in automatic film processing is faster than in manual processing. In depleted chemicals, both film types had an increase in latitude values and a decrease in speed and contrast. Insight film is more resistant than ektaspeed plus film to decrease in film speed and latitude when processed in older chemicals, whereas contrast in ektaspeed plus film is comparatively more stable. Based on these, the use of the newer insight dental film can be preferred as it requires only lesser exposure to produce the same level of density when compared to the ektaspeed plus film, thereby reducing the patient exposure to radiation. Although film speed can be increased slightly by using different processing techniques at a higher temperature, this is achieved only at the expense of the increased film fog and graininess. Thus processing in depleted solutions can lower the effective speed. It is always preferable to use fresh processing solutions and follow the recommended processing time and temperature with adequate replenishment of the solution. The study also confirms that the choice of the processing solutions also have an important impact on the quality of the resulting radiographs (Stuart, 2009; Farman and Farman, 2000). The results obtained from previous investigations in a 4week period can be obtained in a period of 3weeks itself in our study.

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Appendix:

1. Optical density=$\log_{10} [I_o/I_t]$
   I_o=intensity of the incidental light
   I_t=intensity of the transmitted light
2. Contrast = (D2-D1)/(Log E_2- Log E_1)
   D1,D2=difference in densities
   E1,E2=the corresponding exposures in relation to the average gradient of the characteristic curve.

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