# Image Quality Assessment and Radiation exposure in Intra Oral Dental Radiography

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## Abstract

In this study, an intra oral dental unit (Siemens-70) at King Abdul Aziz University (KAU) Dental Hospital was selected and investigated for visual image quality assessment and radiation protection purposes. Radiation dosimetry for determining the optimum image quality with the lowest radiation exposure to the patient was carried out. A DXTTR dental radiography trainer phantom head and neck, portable survey meter Model RAD EYE-B20, and radiation dosimetry system RADCAL Acuu-pro were used in this study. RADCAL Accu-pro is a non-invasive kV system, reliable instruments to measure and diagnose all X-ray machines including dental units. The radiation exposure to patients in (mGy) was measured using RADCAL ionization chamber Model 10×6-6. The best image quality with the lowest exposure dose was assessed for conventional intraoral X-ray film (Kodak type E) and the digital processing sensor (RVG 5200). Radiation survey level was done during this study for safety and protection purposes.

**Key Words:** Dental radiography Radiation Exposure, Quality control, Image Quality Assessment

## 1. Introduction

Dental radiography especially intra oral radiography (I/O) represents one of the most common types of diagnostic examinations performed recently based on the reports published by United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000. These reports show that, the radiation absorbed dose from all diagnostic examinations including dental radiography contribute with 80-90% from the total absorbed dose arising from man-made radiation sources [1-7]. Radiation protection in dental practice is focused on three basic principles: justification, optimization and dose limitation. These principles imply the definition of selection criteria, methods to reduce radiation dose and education [8]. Dental radiography has relatively low exposure, although the radiation exposure to patient from intraoral dental units is relatively low exposure, there is a need to optimize all exposure parameters in intraoral radiography to minimize the radiation risk to a certain value as mentioned in ALARA principle (As Low As Reasonably Achievable) [2,5,7,9-10]. The majority of dental radiography under investigations is performed in dental clinic in the absence of routine quality assurance and quality control procedures program, also no effective training program was given to the operator. Patients may be subjected to unnecessarily relatively high doses due to lack of maintenance of the used equipment or insufficient techniques where no quality control protocol was not applied [7,11]. Establishing good plan for applying quality control programs including regular checks for all exposure parameters such as dental films processing condition, expiration date for the used chemicals and films, darkroom lighting condition, X-ray unit's constancy, and reproducibility can help keep up high level of radiographic quality and lower exposure to the patient. Quality control test is recommended to achieve on a regular basis to make sure that the radiation exposure to patient is below the international recommended levels. In addition, the image quality as well as the physical exposure parameters were essential for optimization in diagnostic examinations [4,9,12]. These diagnostic examinations must perform under standard protocol to achieve sufficient image quality with the lowest possible absorbed dose to the patient. The important factors that affect the absorbed dose to the patient is the exposure time and the tube voltage [13-14]. The main target is to get an optimal condition between the dose delivered to the patient and the diagnostic physical exposure parameters accuracy and reproducibility with an analogue film technique at certain tube potential and time. The absorbed dose to the patient in dental intraoral units can control by adjusting the exposure time and the tube potential [13]. Significant decreases in radiation dose of dental radiography occur with the use of faster image receptors, intra-oral film holders, rectangular collimation for bitewing radiography, and also use of long, rectangular position indicating devices. Moreover, some radiation protection tools must be used such as leaded aprons and thyroid collars shield to decrease the exposure to different parts of the body [4,9]. Introduction of double-sided emulsion in1924 and progressive increases in film speed over the years have resulted in lower radiation doses while maintaining image quality at an acceptable level. The film remains still a cheap and reliable method of recording images in dental radiography. The radiation absorbed dose to the patient can be reduced by using the preferred faster films type such as E or F-speed dental film. E-speed film has twice the sensitivity of D-speed film by a percentage value of 40% [15]. The aim of the present study was to assess the best image quality in conventional intraoral X-ray film and digital dental radiography with the lowest radiation exposure to patient for dental intraoral premolar and bitewing projection for Siemens-70 dental unit at KAU dental hospital.

## 2. Materials and methods

The study performed to assess, the best image quality with the lowest radiation exposure for dental radiography unit at KAU dental hospital. A 70 kVp,7 mA Siemens intra oral unit, dental phantom (DXTRR phantom) as a substitute for the patient, Dental X-ray film (Kodak type E), RVG 5200 digital imaging sensor, Radcal Acuu pro radiation measurements dosimetry system, and a radiation survey meter Model RAD EYE B20 were used in this study. The experimental set up and the used devices were shown in Figure 1(A-F). The measurements of the physical parameters such as kvp, exposure time, output radiation exposure in mGy were performed using Radcal Accu Pro radiation measurements system manufactured by Radcal Corporation USA as shown in Figure1-A. Radcal Accu Pro has both kvp divider and ionization chamber Model 10×6-6 connected with an electrometer as shown in Figure 1B. The radiation levels in μSv/hr were measured using a survey meter Model RAD-EYE B20 as shown in Figure 1C. To determine the optimum radiation dose for acceptable image quality in two dental examinations (premolar and bitewing), an adult DXTRR phantom dental X-ray trainer was used with the conventional intraoral X-ray film and RVG 5200 digital imaging sensor. For conventional intraoral X-ray film processing (manual processing) dental film type E, the positioning of the film was done using a film holder as shown in Figure 1D. The dental films were developed at the dark room of the university dental hospital training unit. All exposure settings are done at constant tube voltage and tube current (70 kV and 7mA) respectively, with varying exposure time and source to image distance settings (SID). Due to the variation in choosing the exposure parameters from the technicians especially the exposure time and the SID, This work concentrated on varying the exposure time and the source to image distance at constant tube potential and tube current as a trial and error method to get high-quality radiograph with lowest radiation exposure. Several exposures (about 25) conventional intraoral X-ray dental film type E were analyzed and investigated statistically by the author and visually by the technician to get the best image quality with the optimum radiation dose. Also, For digital imaging process, an RVG 5200 digital imaging sensor was used as shown in Figure 1-F. About 20 digital imaging radiography films were taken and investigated by the author and the technician to get the best image with the lowest radiation dose. The radiation safety policy and the radiation protection rules instructions considered in this study according to the university safety and radiation protection policy. The policy recommends using a TLD badge for measuring the personal dose equivalent during this work and found a background level.

| | |
|---|---|
|  A |  B |
|  |  |
| C | D |

| | |
|---|---|
|  |  |
| E | F |

Figure 1: photograph of the quality control test tools and phantom used to measure radiation exposure and image quality; X-ray test device Radcal-Acuu-pro (A); Intra oral dental unit (Siemens) with Radcal ion chamber (B); Radiation survey meter Model RAD EYE-B20 (C); Film positioning holder in DXTRR phantom (D). Positioning of RVG 5200 digital imaging sensor (E); Set up for Radcal ion chamber for measuring entrance surface exposure at different SID (F).

## 3. Results and Discussions

### *3.1. Radiation Survey level*

The radiation leakage from the X-ray machine was checked during the production of the X-ray beam. A radiological survey was done outside the X-ray room at the operator control panel position. The radiation survey levels ranged from 0.06 to1.49 $\mu S_v$/hr with an average value of 0.13 $\mu S_v$/hr and show an acceptable value of background level. The obtained results for all processed dental radiography (conventional X-ray film and digital processing using RVG 5200 sensor) for the radiation level were found below the recommended dose limit. The international recommended dose limit for operators in the field of dental and diagnostic radiology is10µSv/hr as mentioned in International Atomic Energy Agency (IAEA) standard guides: IAEA Safety Series No.115 [16].

### *3.2. Accuracy measurements in exposure time*

The relation between the nominal exposure time and the measured value listed in Tables 1-3. The value of the selected exposure time covered the clinical value by which the patient undergoes radiography. The exposure time range from the lowest value of 0.08 sec to the highest value of 0.64 sec. The measured value for the exposure at different station from the nominal value show acceptable deviation not exceed 1.75%. The acceptability limit for exposure time is 10% deviation from the nominal value.

### *3.3. Variation in measuring output radiation exposure*

Figure 2 and Table1 show that the relation between the values of the output radiation exposure in mGy with the exposure time in sec. A linear relation was found between the measured exposure time and the measured output exposure with very strong linear correlation coefficient of 1. Considerable variations were found in measuring the output radiation exposure with respect to SID where the SID varies from 40 to 60 cm. The output radiation exposure ranged from the lowest value 0.532 mGy to the highest value 3.46 mGy. Table 2 show the relation between the measured output exposures with the exposure time at distance 50 cm from the surface of the patient. Tables 3 show the same relation at different distance (60 cm). The measured output radiation exposure ranged from 0.24 mGy to 0.98 mGy although for increasing the SID the output radiation exposure decreases according to the inverse square law ad of course the resolution of the image quality decreases. The results show that the best distance at which the patient undergoes dental radiography about 50 cm based on the clinical choice for the physical parameters from the technician.

### *3.4. Image quality assessment*

The output radiation exposure and the exposure time was measured and registered for each film at the different setting of exposure time including the clinical settings. The reading was repeated at different value of SID. The image quality assessed based on the criteria (pass/fail) from the opinion of the author and the technician. Figure 3 and 4 shows the developed dental film in case of manual processing and digital processing radiography.

All the developed intra-oral conventional dental films were investigated and assessed visually by arranging these films on a light source view box. Also the same analyses were done for the digital radiography images using computer software. The author and the technician commented on these developed films and on the digital constructed dental films and made conclusion based on the visual assessment of the image quality and the value of the output radiation exposure to get the best image quality in both cases. After evaluation and interpretation of the results, the best image quality was determined (arrow in Figure 2) for manual processing at 0.2 sec, 50 SID, and the registered corresponding radiation exposure is 1.08 mGy. For digital processing radiography, the best image was assessed and recorded for 0.16 sec exposure time at source to skin distance of 50 cm and the corresponding output radiation exposure is 0.86 mGy as shown in Figure 4 (film number 16).

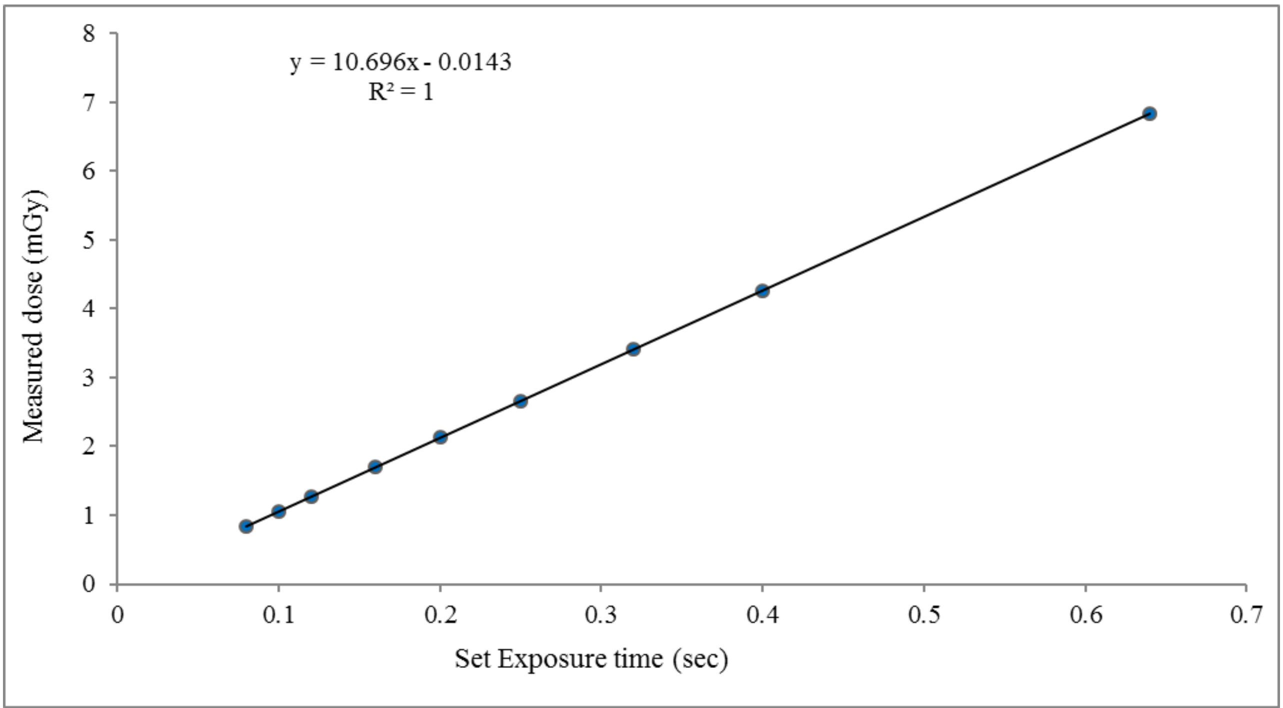


**Figure 2. Measured dose with the exposure time at constant 70 kVp ,7mA and 40 SID.**

**Table 1. Radiation absorbed dose, nominal exposure time and the measured value of exposure time at 40 cm SID.**

| Film No. | Radiation Dose (mGy) | Set Exposure Time (sec) | Measured Exposure Time (sec) | deviation% |
|---|---|---|---|---|
| 1 | 0.8394 | 0.08 | 0.0802 | 0.25 |
| 2 | 1.0708 | 0.10 | 0. 0991 | 0.90 |
| 3 | 1.2680 | 0.12 | 0.1190 | 0.83 |
| 4 | 1.6950 | 0.16 | 0.1590 | 0.60 |
| 5 | 2.1250 | 0.20 | 0.1990 | 0.50 |
| 6 | 2.6610 | 0.25 | 0.2490 | 0.40 |
| 7 | 3.4090 | 0.32 | 0.3190 | 0.30 |
| 8 | 4.2600 | 0.40 | 0.3990 | 0.25 |
| 9 | 6.8330 | 0.64 | 0.6390 | 0.16 |

Exposure parameter: 70 kVp, 7 mA, and 40 cm SID: Source to image distance

**Table 2. Radiation absorbed dose, nominal exposure time and the measured value of exposure time at 50 cm SID.**

| Film No. | Radiation Dose (mGy) | Set Exposure Time (sec) | Measured Exposure Time (sec) | deviation% |
|---|---|---|---|---|
| 1 | 0.4225 | 0.08 | 0.0796 | 0.50 |
| 2 | 0.5316 | 0.10 | 0.0998 | 0.20 |
| 3 | 0.6412 | 0.12 | 0.1190 | 0.83 |
| 4 | 0.8569 | 0.16 | 0.1590 | 0.63 |
| 5 | 1.0750 | 0.20 | 0.2000 | 0 |
| 6 | 1.3470 | 0.25 | 0.2490 | 0.40 |
| 7 | 1.7260 | 0.32 | 0.3190 | 0.31 |
| 8 | 2.1610 | 0.40 | 0.4000 | 0 |
| 9 | 3.4570 | 0.64 | 0.6390 | 0.16 |

Exposure parameter: 70 kVp, 7 mA, and 50 cm SID: Source to image distance

**Table 3. Radiation absorbed dose, nominal exposure time and the measured value of exposure time at 60 cm SID.**

| Film No. | Radiation Dose (mGy) | Set Exposure Time (sec) | Measured Exposure Time (sec) | deviation% |
|---|---|---|---|---|
| 1 | 0.2410 | 0.08 | 0.0786 | 1.75 |
| 2 | 0.3031 | 0.10 | 0.0992 | 0.80 |
| 3 | 0.3654 | 0.12 | 0.119 | 0.83 |
| 4 | 0.4893 | 0.16 | 0.159 | 0.63 |
| 5 | 0.6135 | 0.20 | 0.198 | 1.00 |
| 6 | 0.7663 | 0.25 | 0.249 | 0.40 |
| 7 | 0.9835 | 0.32 | 0.319 | 0.31 |
| 8 | 1.232 | 0.40 | 0.400 | 0 |
| 9 | 1.975 | 0.64 | 0.639 | 0.16 |

Exposure parameter: 70 kVp, 7 mA, and 60 cm SID: Source to image distance

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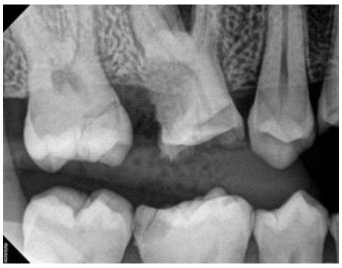
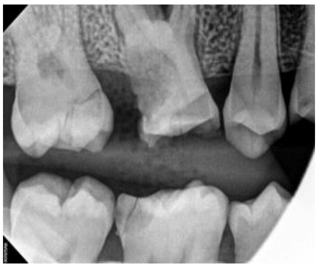
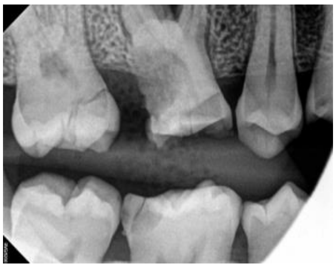
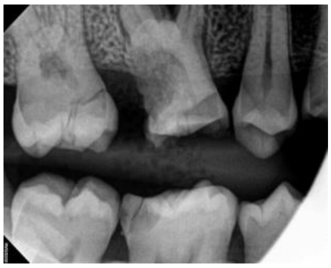
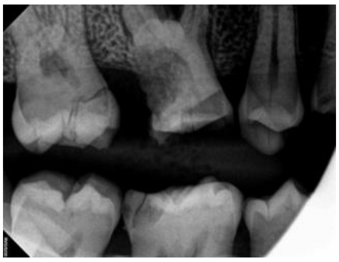
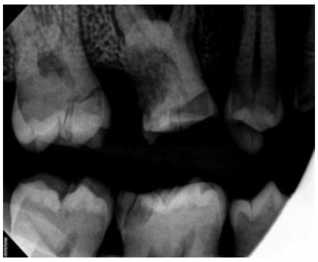
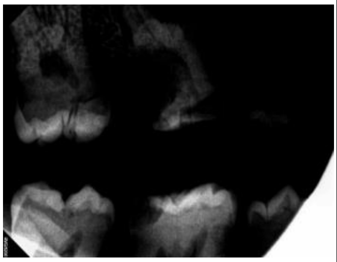
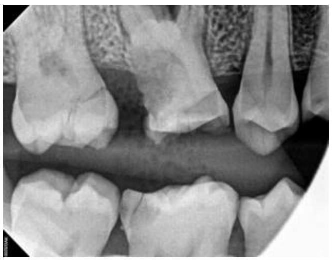
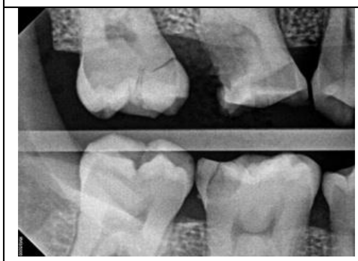
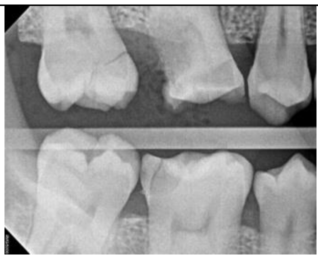
|---|---|---|---|
|  |  |  |  |
| # 1 at 0.2 sec | # 2 at 0.12 sec | # 3 at 0.16 sec | # 4 at 0.25 sec |
|  |  |  |  |
| #5 at 0.32 sec | #6 at 0.4 sec | #7 at 0.64 sec | # 8 at 0.08 sec |
|  |  |  |  |
| # 9 at 0.1 sec | # 10 at 0.06 sec | # 11 at 0.5 sec | # 12 at 0.05 sec |

**Figure 3. Image quality assessment has taken at different exposure time's and40 cm SID using RVG 5200 sensor for bitewing projection.**

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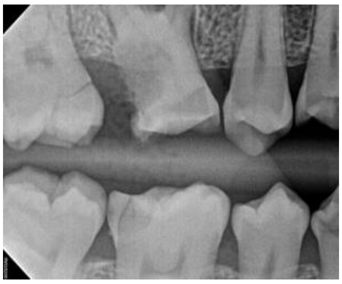
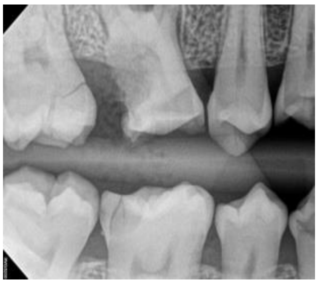
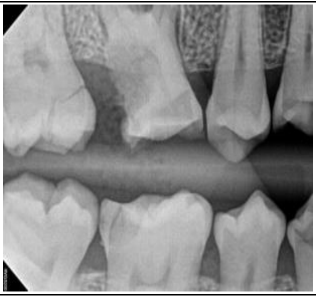
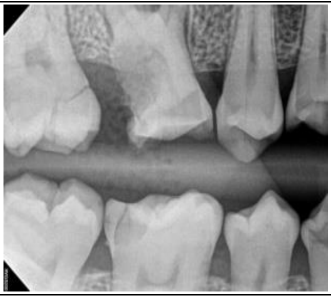
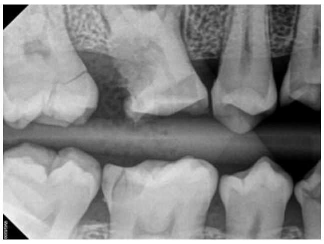
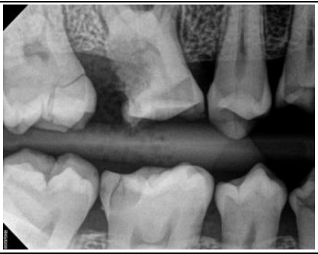
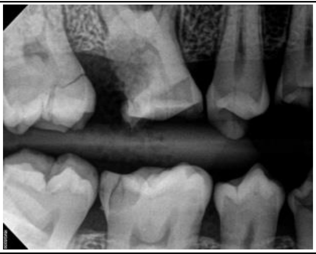
|---|---|---|---|
|  |  |  |  |
| # 13 at 0.08 sec | # 14 at 0.2 | # 15 at 0.12 sec | # 16 at 0.16 sec |
|  |  |  |  |
| # 17 at 0.25 sec | # 18 at 0.32 sec | # 19 at 0.4 sec | # 20 at 0.64 sec |

**Figure 4. Image quality assessment has taken at different exposure time's and50 cm SID using RVG 5200 sensor for bitewing projection.**

From the obtained results the majority of the registered digital processing films gave acceptable image quality for diagnostic purposes and the main factor for choice the best image quality is the value of the absorbed dose given to the patient.  For conventional dental film (manual processing) the best image recorded by the arrow shows that in Figure 2. It seems that the manual processing of the dental film cannot be used in the assessment process due to many factors found in this study such as the variation in choosing the physical parameters by the technicians especially for the exposure time and the distance between the collimator of the dental tube and the patient, film sensitivity, the dark room condition, condition of chemical solution such as fixer and developer and finally the handling and skills of the technician about the variation in the time for developing the dental film.

**Figure 5: Photograph showing the best image quality assessed (arrow shape) in conventional X-ray film processing for premolar projection.**

**4. Conclusion**

1) The image quality is essential for the diagnostic process; there are considerable variations between conventional and digital processing about radiation exposure and exposure time.

2) There are many factors that affect on the conventional processing such as human handling and skills, quality of chemicals, the film sensitivity, and repeat film rate.

3) The radiation survey shows background level and the radiation protection rules applied correctly at the hospital.

4) The exposure time represents the most important physical parameter that affects patient exposure and image quality in digital processing. The measured exposure time was found accurate for the examined dental unit.

5) The Entrance surface exposure depended on the exposure time and found linear at all examined station of exposure time.

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