

Assessment of absorbed dose in critical organs in OPG: a phantom study

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ABSTRACT

Orthopantomography is a well-established imaging technique in dental diagnosis. Although its exposure to individuals is relatively low compared to other diagnostic radiology examinations, it is still the most frequent X-ray examination. So it is important to estimate absorbed dose to critical organs in this examination. The present study was designed to determine the radiation doses to eyes, parotid, thyroid, submandibular gland and brain using Gafchromic films in an anthropomorphic head and neck phantom in three imaging centers, one digital and the remainders analogue. The absorbed dose to brain was measured globally with two vertically and horizontally embedded films in the phantom and submandibular, parotid and thyroid glands were also measured at their correct position in the phantom. The dose to the eyes was measured at the surface. Each measurement was triplicated and results were presented as mean (SD). After calibration of the films, they were embedded in the phantom and it was exposed with similar conditions for an adult patient. Absorbed doses were from 0.97-3.12 mGy for brain, 1.23-3.02 mGy for left parotid, 1.19-4.54 mGy for right parotid, 1.27-4.46 mGy left thyroid, 1.56-3.88 mGy for right thyroid, 1.45-2.83 mGy for Submandibular, 1.55-2.38 for right eye and 1.39-3.77 mGy for left eye. Our results showed similar depth and surface doses at all. Due to the direction of X-ray tube rotation, in the analogue devices in which the direction of rotation was right to left, doses of left sided organs were higher, and in the digital device that the direction was left to right, doses of right sided organs were higher. The absorbed doses in digital device were significantly lower than the analogue devices ($p\text{-value} \leq 0.05$).

Keywords: Orthopantomography; Film Dosimetry; Radiation Dosage; Phantom.

INTRODUCTION

Radiography is the greatest man-made source of ionizing radiation to the population. Its role in the cumulative ionizing radiation exposure has been increased from 15% of total annual exposure of population in 1987 to about 50% in 2006 in the US [1-4]. It is one of the most common and useful modalities in medical imaging that play an important role in medical diagnosis. The problem that causes limitation in radiographic studies is direct use of ionizing radiation. Due to the harmful effects of ionizing radiation, correct usage of ionizing radiation is one of the most important concerns among physicians and researchers. So the radiation protection organizations and committees have set some limitations for the clinical use of ionizing radiation. According to the ALARA principle,

radiographers must take radiographs of sufficient quality at the lowest possible radiation dosage to the patient [1, 4-7].

Dental Problems are one of the most common medical problems in societies and medical imaging, especially panoramic imaging (OPG) which is one of the most common and appropriate methods for diagnosis of these problems. In this modality, X-ray tube and image receptor turn in concert around the patient's head and take a panoramic image from patient's teeth. As a large area of the jaw is depicted, OPGs considered to be an appropriate modality for diagnosis of dental problems. An important problem in OPG is the exposure of critical organs such as salivary glands, thyroid and brain in the imaging process. An estimated 62980 new cases of thyroid cancer has been diagnosed in the

US with an estimated 1890 deaths in 2014, with 3 in 4 cases occurring in women. It is the most rapidly increasing cancer in the US and has been increasing worldwide over the past few decades which might be due to increased detection using more sensitive diagnostic procedures. The known risk factors for thyroid cancer include being female, having an enlarged thyroid or thyroid nodules, family history of thyroid cancer and radiation exposure early in life [8]. Also approximately 85% of parotid gland's overall absorbed dose is related to dental radiography [2]. Because of the important role of these organs in the body, and also their significant sensitivity to ionizing radiation, it is necessary that the imaging is performed with lowest radiation dose for attaining images with sufficient quality [5-7]. Many studies about dose reduction in OPG have been performed [6, 7, 9] in which effects of changing exposure parameters such as kV and mA has been discussed. Most of these studies have been performed on patients as entrance dose measurements. These studies represent that reduction in exposure parameters results in a significant reduction of patient's absorbed dose.

There exist different methods for medical dosimetry including TLDs, gels and films [10-12]; films might be the oldest dosimeters with high spatial resolution. Among several available films, Gafchromic films have a spatial resolution of ~25 μm , high sensitivity and uniformity [9, 12-14].

According to Report of UNSCEAR, dental radiography is one of the most frequent types of radiological procedures performed which usage is growing [11]. Unfortunately in our country as many other developing countries, there exists no nuclear guideline for medical exposures [2]; it is therefore essential that some studies be performed on the patient's dose in several imaging studies.

The aims of this study was to measure surface and depth doses of critical organs in head and neck in OPG imaging, and to compare findings with reference values presented by the international radiation protection organizations.

MATERIALS AND METHODS

Dosimeter Selection and Calibration

The selected dosimeter used was Gafchromic XR QA2 films (Radiation Products Design, Inc., USA) which are designed for quality control in diagnostic radiology. To do so, films were cut to 2x2 cm pieces and were exposed to radiation with same energy used in OPG (70 kV). To obtain calibration curve, 7 badges of films (3 piece of film/badge) were provided. Each badge was exposed to a dose in the range of 0-7 mGy which was monitored simultaneously by a real-time dose monitor device (Pehamed, Germany). After exposing the films and reading the dose values from dose monitor device, the following equation (Eq. 1) was used to obtain the net optical density (NOD) to find out the calibration curve and calibration:

$$\text{NOD} = \log_{10}(I_o/I_e) - \log_{10}(I_o/I_u) = \log_{10}(I_u/I_e) \quad \text{Eq. 1}$$

In which I_o is the red channel of reference light intensity, I_e is the red channel of reflected light intensity from exposed films and I_u is the red channel of reflected light intensity from unexposed films. The films were read out with a scanner (Canon commercial scanner, Lide 90, 600 dpi) which was performed after a certain time to warm up (with 5 repeated scans with 600 dpi before reading the films) the scanner lamp. The films were placed in same position each time the scan was repeated and the red channel of scanned films was extracted using Matlab (version 7.8, Mathworks, USA). Calibration curve was obtained as the best curve fitted on the experimental data using Excel (version 2010, Microsoft office, USA) and calibration equation was the related polynomial equation.

Anthropomorphic Phantom

The anthropomorphic phantom used in this study (Fig 1) was constructed from humanoid skull and paraffin wax with different amounts of NaCl as impurity was used for bone, soft tissue and fat, respectively. Paraffin wax was selected from suggested materials by White for soft tissue which has general formula of C_nH_{2n+2} and average density of 0.9 gr/cm^3 [15]. Using the following relationship (Eq. 2):

$$\rho_e = \rho_m \cdot N_A \cdot \sum a_i \cdot (Z_i/A_i) \quad \text{Eq. 2}$$

Electron density of soft tissue was calculated. In this equation, N_A is the Avogadro number, a_i is weighting fraction of material with atomic number of Z_i and mass number of A_i [16]. In the constructed phantom there exist two hollow plastic tubes to mimic trachea and esophagus and a hollow plastic box to mimic the mouth cavity; two cylinders placed vertically and horizontally from the upper limit of skull downwards and from left parotid to right parotid on the base of skull to place films for brain dose estimation.

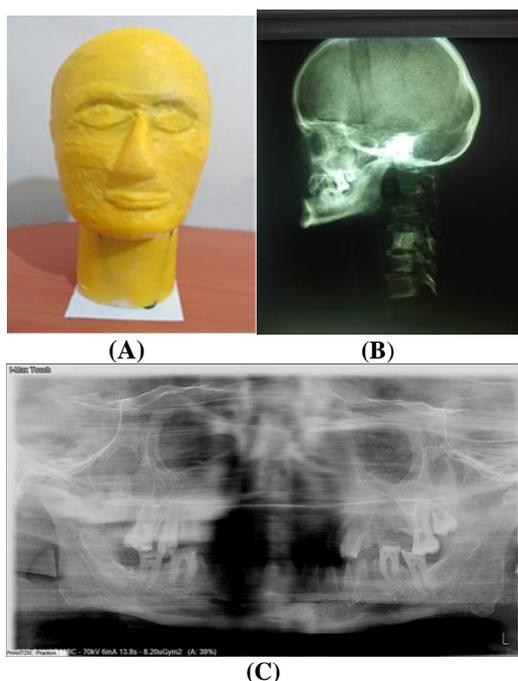


Figure 1: Anthropomorphic Head and neck phantom (A) and its lateral radiograph (B) and its panoramic radiograph (C)

The left and right extremes of the later were used to estimate parotid dose. Besides, there exist two cylinders at side lobes of thyroid in order to measure thyroid dose. Radiation dose to eye was measured at the surface.

Absorbed Dose Measurements

Three units (one digital and two analogues) that was located in three different imaging centers was considered in this study. Phantom exposure parameters were the same as adults with approximately same head size as the phantom (table 1). Direction of tube rotation was right to left in analogue devices and left to right in the digital device.

Figure 2 shows the phantom on the OPG units. Dosimetric measurements were performed for brain, left and right parotid (depth dose at depth of parotid), lens of eye (surface dose) and thyroid (depth dose at depth of thyroid) using XR-QA films on an anthropomorphic head phantom. It is notable that to measure brain dose, two perpendicular directions was selected and the average dose was measured. Besides, using similar applicators, parotid and thyroid depth dose at both sides was measured.

The exposed films were read-out using the above mentioned scanner and the related dose was obtained from the obtained calibration equation. It is notable that to increase reproducibility, each measurement was repeated 3 times. To analyze differences between groups, ANOVA test was used at a significant level of 0.05 (p-value<0.05).



Figure 2. Phantom placement in analogue (left) and digital (right) devices

Table 1. Technical characteristics and exposure parameters of each OPG unit

	kVp	mA	Exposure Time	Type
Center A	70 kV	10 mA	16 s	Analogue
Center B	70 kV	6 mA	14 s	Digital
Center C	66 kV	9 mA	18 s	Analogue

RESULTS

Figure 3 shows the calibration curve for the Gafchromic XR-QA films. In this graph, the horizontal axis shows the net optical density (NOD) as described before and the vertical axis shows dose values in mGy. Table 2 shows the

measured doses to considered organs in the assessed centers presented as Mean (SD). As it is observed, the highest values are corresponded to parotid and the lowest value is the estimated brain dose between all centers.

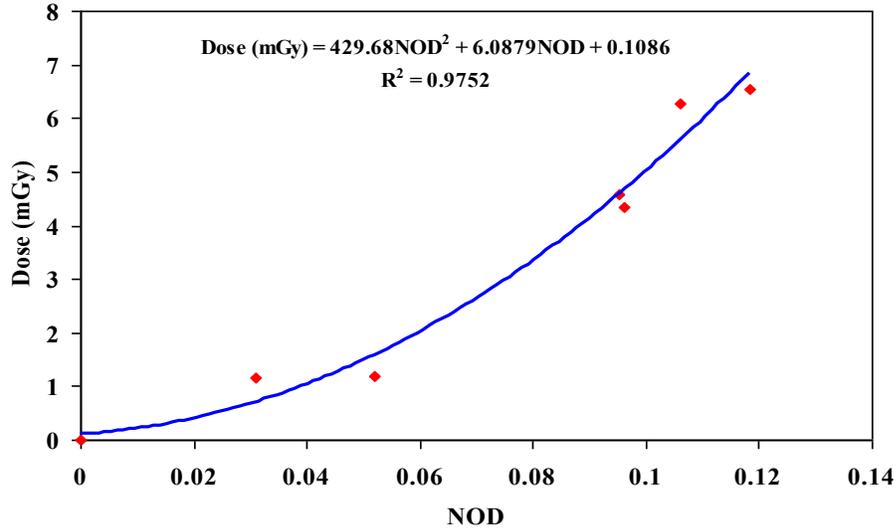


Figure 3. Calibration curve for films used with the calibration equation

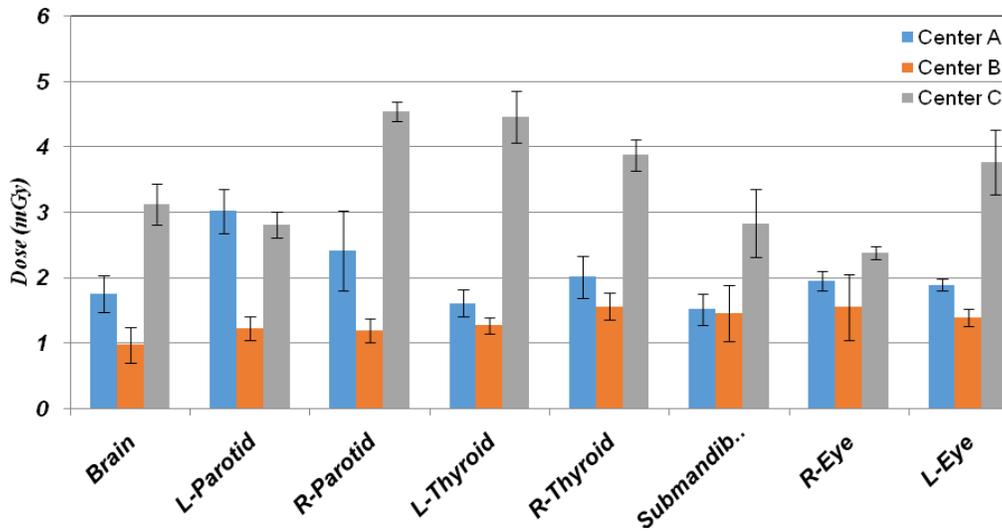


Figure 4. Mean absorbed dose to critical organs in three centers, A and C analogue and B digital

Table 2. Absorbed Dose to critical organs in three OPG units as Mean (SD) in mGy

	Brain	L-Parotid	R-Parotid	L-Thyroid	R-Thyroid	Submandibular	R-Eye	L-Eye
Center A	1.76(0.28)	3.02(0.34)	2.42(0.61)	1.61(0.21)	2.01(0.32)	1.52(0.24)	1.95(0.15)	1.89(0.09)
Center B	0.97(0.27)	1.23(0.18)	1.19(0.18)	1.27(0.12)	1.56(0.21)	1.45(0.43)	1.55(0.5)	1.39(0.13)
Center C	3.12(0.31)	2.81(0.19)	4.54(0.15)	4.46(0.40)	3.88(0.24)	2.83(0.52)	2.38(0.10)	3.77(0.49)

Besides, absorbed doses to critical organs were drawn in fig 4 in three centers as Mean (SD). The difference between analogue and digital centers as seen on graph is significant (p -value <0.05).

DISCUSSION

There exist several parameters including kVp, mA, and exposure time which affect absorbed dose to critical organs in OPG. As expected, there were differences in absorbed doses of the same organs resulting from different devices. It seems that this difference is mainly due to different exposure parameters used in different devices. As it is observed from table 1, the exposure parameters in the digital device is much lower than the analogue devices, due to the higher sensitivity of digital detectors compared with the screen-film systems; so it is expected that the absorbed doses from digital device be significantly lower than the other analogue devices.

Besides, we realize that the direction of tube rotation also affects the absorbed dose; in analogue devices, the direction of rotation was from right to left and accordingly, doses of left sided organs were higher, and in the digital device the direction of rotation was from left to right and so doses of right sided organs were higher. There exist several studies in the literature which assessed doses in OPG. In one study, the doses to radiosensitive organs in OPG were estimated pediatric head phantom and the effectiveness of a short collimator in reducing dose was studied. It was shown that the short collimator reduced the dose to the brain and the eyes by 57% and 41%, respectively and doses to the submandibular and sublingual glands increased by 32% and 20%, respectively, when using a program with a narrower focal trough intended for a small jaw. The effective dose measured with the short collimator was 7.7 μ Sv and dose to the lens of eye was 17 μ Gy [7].

Our measured dose values although differences between digital and analogue devices, but are significantly higher than the values they obtained which might be due to the differences in OPG units used. In another study, the shielding effect of thyroid collar for digital panoramic radiography was evaluated. They measured

average tissue-absorbed doses using TLD chips in an anthropomorphic phantom and effective organ and total effective doses were derived according to the ICRP 2007 recommendations. The effective thyroid doses obtained were from 1.12-2.71 μ Sv when no thyroid collar was used. When 1 collar was used in front of the neck, the effective thyroid doses reduced from 9.6% up to 22.7%. When using two collars, the effective thyroid doses were also significantly reduced for the two machines and it was found that using a thyroid collar is helpful in direct digital OPG systems whereas for the indirect digital OPG systems, the thyroid collar had no extra protective effect on the thyroid [5]. Another study has been performed to provide comparative measurements of the effective doses from direct and indirect digital OPG units in a head phantom representing an average man using TLD chips. The effective doses of the 4 digital OPG units ranged from 8.9-37.8 μ Sv. Besides, it was founded that the effective doses from the direct digital OPG units were higher than the indirect units [6]. In a study on the effective dose from three cone beam CT (CBCT) units in a head and neck tissue-equivalent human phantom, the doses from three common dental clinical situations was compared and the feasibility of Gafchromic XR-QA2 as a dosimeter was assessed. The effective dose of a CBCT unit was from 10-129 μ Sv. The range of effective doses for digital panoramic machines measured was 8-14 μ Sv [17].

We showed that the Gafchromic films are good candidates for such measurements and the dose values obtained are near to the results of this study.

CONCLUSION

In conclusion, as the phantom was made from standard tissue substitute material, the results show nearly real clinical doses in OPG studies for selected organs. However, to obtain more accurate results, we offer some further dosimetric studies on patients including adults and children.

ACKNOWLEDGMENT

This work was made possible with a research grant of student research committee of Semnan University of Medical Sciences.

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