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Patient radiation doses in intraoral and panoramic X-ray examinations in Sudan

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ABSTRACT

Radiation doses were measured for the first time in intraoral and panoramic dental radiology at Sudanese hospitals. Doses were determined using various exposure settings for adults and children in 8 intraoral and 6 panoramic X-ray devices. The study sample was equally divided between devices using a digital image receptor (DR) and those using conventional screen film (SF). Radiation doses are reported in terms of incident air kerma (IAK) (intraoral radiology) and kerma area product (P_{KA}) (panoramic radiology). IAK values in intraoral radiology were: 1.45 mGy (DR), 4.45 mGy (SF), and 3.01 mGy (combined). For panoramic radiology, P_{KA} values ranged: from 35.8 to 103.2 mGy cm^2 (average: 70.4 mGy cm^2) for children and from 65.7 to 151.4 mGy cm^2 (average: 103.4 mGy cm^2) for adults. The results showed that the downward trend in patient doses can be achieved using digital imaging. The study revealed important concerns surrounding radiation protection, such as the lack of regular quality assurance programs and the use of circular collimators.

1. Introduction

Medical X-rays play an important role in the treatment of patients requiring dental implants. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) classified dental radiography as one of the most frequently performed radiological procedures [1]. According to the linear-no-threshold model [2], the radiation risk from low-dose diagnostic radiological procedures is expected to be small, but greater than zero. The associated radiation health effects are stochastic in nature, as demonstrated by the increased probability of carcinogenic radiation with absorbed doses. Accurate dose estimates are therefore essential for enhanced protection of the patient receiving dental radiology, as well as for those undergoing other medical procedures utilizing ionizing radiation.

International organizations and advisory bodies require that the typical radiation doses for patients undergoing common procedures are measured at approved intervals and compared with the diagnostic reference levels (DRLs) [2–4] for diagnostic radiological procedures. The results are used to determine whether measures used to ensure patient protection and safety are optimized and adequate. Corrective action may be required if typical doses exceed or fall substantially below the relevant DRL. In the first situation, patients receive an unnecessary radiation dose, while in the case of lower doses; the exposure levels might not provide useful diagnostic information.

To compare patient doses with the DRLs, radiation doses used in certain radiological procedures should be measured using a simple and easily measurable dose quantity. Consequently, patient doses in intraoral X-ray radiography are measured in terms of incident air kerma (IAK) expressed in mGy. On the other hand, patient doses in panoramic radiography are measured in terms of air kerma-area product (P_{KA}), expressed in mGy.cm^2 [4,5]. In panoramic radiography, a collimated X-ray beam is emitted in a continuous motion around the patient. The use of a P_{KA} meter for dose measurements can eliminate the potential problems that are associated with the special characteristics of panoramic X-ray units [4].

Recently, several dosimetric studies were carried out, primarily in developed countries [6–8], with the aim of increasing radiation protection awareness in dental radiology. Similar dose surveys were performed in Sudan in areas other than dental radiology [9,10]. As a continuation of these efforts, the current dose survey is being conducted and extended in the field of dental radiology.

This study aims to measure patient radiation doses in intraoral and panoramic dental radiography. The results are anticipated to provide the first detailed account of Sudanese radiation exposure levels in

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dental radiography. This is significant in two ways: first, the results may be used as baseline data for future comparisons of dose data; second, the results provide patient dose data that will help in the development of national DRLs.

2. Materials and methods

Measurements were performed to estimate patient radiation doses in 14 dental X-ray units, including 6 panoramic and 8 intraoral devices in Khartoum State, Sudan. The study sample comprises 7 devices using digital image receptors (DRs) (3 panoramic and 4 intraoral), in addition to a similar number of devices based conventional screen film (SF) (3 panoramic and 4 intraoral). Radiation doses were measured for intraoral dental devices using a Piranha Multimeter (RTI Electronics AB, Molndal, Sweden). For panoramic dental devices, doses were measured in terms of P_{KA} using a 3 cc pencil-type ionization chamber (Radcal Corporation, Monrovia, CA, USA). Measurements were made according to the procedures detailed in the International Atomic Energy Agency (IAEA) protocol for dosimetry in diagnostic radiology, as summarized below [11].

2.1. Radiation dose measurements

For intraoral devices, doses are measured in terms of incident air kerma (IAK), defined as the kerma to air from an incident X-ray beam measured on the central beam axis at the position of the patient or phantom surface without the backscattered radiation [11,12]. Measurements were made using standard settings for tube voltage, tube load, and exposure time at a certain focus-to-detector distance (FDD). IAK was obtained from the measured air kerma free in air, according to Eq. (1):

$$IAK = K_{FDD}\left(\frac{FDD}{FSD}\right)^2 \quad (1)$$

where IAK is the incident air kerma at the typical focus-to-skin distance (FSD), and K_{FDD} is the air kerma measured at the FDD. An FDD of 50 cm was used to simulate the scatter free geometry necessary for IAK measurements.

In radiological procedures (including dental radiology), DRLs are set at the entrance surface dose (ESAK), defined as ($ESAK = IAKxB$), where B is the backscattered radiation that depends on beam quality and radiation field size. Due to the small radiation field size (size of the dental film), values of B on dental X-ray examination are very small; therefore, it was suggested by many authors that the values of IAK and ESAK are almost equal in dental radiology [7,13].

In panoramic dental radiography, dose measurements are reported in terms of $\boldsymbol{P_{KA}}$, defined as the integral of the air kerma over the area of the X-ray beam in a plane perpendicular to the beam axis [11,12]. First, the air kerma-length product ($\boldsymbol{P_{KL}}$) was measured using a calibrated pencil-type computed tomography (CT) ion chamber positioned on the panoramic device in front of the secondary collimator (slit), as well as at the center of the slit and perpendicular to its length direction. Second, $\boldsymbol{P_{KA}}$ is derived from the measured $\boldsymbol{P_{KL}}$ values using Eq. (2) [11,12], where H is the beam height measured using X-ray radiography film:

$$P_{KA} = P_{KL}(\text{mGy. cm}) * H(\text{cm}) \quad (\text{mGy. cm}^2) \quad (2)$$

The setup for the measurement of the kerma area product ($\mathbf{P_{KA}}$) using a pencil-type CT ion chamber is shown in Fig. 1.

3. Results

In Table 1, intraoral equipment information is presented. Eight different types of equipment are studied. All devices used circular collimators instead of rectangular collimators, which are preferred for radiation protection purposes.

Fig. 1. Setup for the measurement of the kerma area product (P_{KA}) using a pencil-type CT ion chamber. Extracted from the IAEA protocol for dosimetry in diagnostic radiology [10].

Table 1
Intraoral equipment information.

Machine Code	Model	Vendor	Country of Origin	Collimator Type	Modality
Intra01	YKY-Y	China Gauze	China	Circular	SF
Intra02	MINRAY®	Soredex	Finland	Circular	SF
Intra03	Myray	Cefla S.C.	Italy	Circular	SF
Intra04	Myray	Cefla S.C.	Italy	Circular	SF
Intra05	ENDOS AC	Villa Sistemi Medicali	Italy	Circular	CR
Intra06	ENDOS AC	Villa Sistemi Medicali	Italy	Circular	CR
Intra07	MR05	Villa Sistemi Medicali	Italy	Circular	CR
Intra08	MR05	Villa Sistemi Medicali	Italy	Circular	CR

Table 2
Tube voltage (kV setting), tube current per time mAs, FSD, and IAK values measured in intraoral examinations among pediatric and adult populations.

Machine Code	Modality	kVp	mAs	FSD (cm)	IAK (mGy)
Intra01	SF	70	4.41	21.0	5.84
Intra02	SF	60	2.24	13.0	3.86
Intra03	SF	70	4.20	6.00	3.60
Intra04	SF	70	3.60	6.00	4.84
Intra05	CR	65	0.45	17.50	1.40
Intra06	CR	65	0.40	17.50	1.31
Intra07	CR	70	0.45	14.00	1.95
Intra08	CR	70	0.40	14.00	1.24

Table 2 presents the tube voltage (kV setting), tube current exposure time product (mAs), FSD, and IAK values for intraoral dental X-ray examinations. The tube voltage ranged from 60 to 70 kV, the tube current ranged from 0.4 to 42 mA, and the FSD ranged from 6 to 21 cm. Using these settings, the IAK ranged from 1.25 to 5.84 mGy (average: 3.0 mGy). Radiation dose distributions in intraoral dental radiology are graphically presented in Fig. 2.

As shown in Table 2, the intraoral radiography units present IAK values ranging from 1.3 to 5.84 mGy with an average IAK of 3.0 mGy. The digital unit (Intra 06) exhibited the lowest IAK, while the conventional film/screen unit (Intra 01) presented the highest IAK