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MEASUREMENT OF RADIATION DOSE IN DENTAL RADIOLOGY

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Patient dose audit is an important tool for quality control and it is important to have a well-defined and easy to use method for dose measurements. In dental radiology, the most commonly used dose parameters for the setting of diagnostic reference levels (DRLs) are the entrance surface air kerma (ESAK) for intraoral examinations and dose width product (DWP) for panoramic examinations. DWP is the air kerma at the front side of the secondary collimator integrated over the collimator width and an exposure cycle. ESAK or DWP is usually measured in the absence of the patient but with the same settings of tube voltage (kV), tube current (mA) and exposure time as with the patient present. Neither of these methods is easy to use, and, in addition, DWP is not a risk related quantity. A better method of monitoring patient dose would be to use a dose area product (DAP) meter for all types of dental examinations. In this study, measurements with a DAP meter are reported for intraoral and panoramic examinations. The DWP is also measured with a pencil ionisation chamber and the product of DWP and the height *H* (DWP × *H*) of the secondary collimator (measured using film) was compared to DAP. The results show that it is feasible to measure DAP using a DAP meter for both intraoral and panoramic examinations. The DAP is therefore recommended for the setting of DRLs.

INTRODUCTION

For dose measurements in diagnostic radiology it is important to have a well-defined and easy-to-use method. The measured dose quantities are normally entrance surface dose (ESD), entrance surface air kerma without backscatter (ESAK) or dose area product (DAP) which measures the air kerma area product (KAP). The ESD, ESAK and DAP are all used for the setting of diagnostic reference levels (DRLs)[1]. Conversion factors from DAP to effective dose (*E*) are available for evaluation of radiation risk, mostly using Monte Carlo generated conversion factors[2]. The radiation risk for different types of examination can then be compared.

In dental radiology, ESAK for intraoral examinations and the dose width product (DWP) for panoramic examinations have been recommended for the setting of DRLs[1,3]. DWP is defined as the air kerma at the front side of the secondary collimator integrated over the collimator width and an exposure cycle. It is usually measured using a stack of thermoluminescence dosemeters or film. Recently, measurements of DWP with a pencil ionisation chamber[4,5] have also been reported. Since fixed settings of tube voltage (kV) and tube load (mA) are normally used in the examinations, ESAK and DWP are measured in the absence of the patient but using the same parameter settings of tube voltage, tube load and exposure time as for the patient present.

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The aim of this study is to show that it is possible and convenient to use a DAP meter to measure patient doses in intraoral and panoramic examinations.

METHODS

A DAP meter consisting of a transmission ionisation chamber with a traceable calibration factor (Doseguard 100, RTI Electronics AB, Sweden) was used to measure DAP for intraoral and panoramic X-ray units. The calibration was performed according to the method of Larsson *et al.*[6], which assures that the calibration factor is independent of the beam geometry[6,7]. The authors have also shown that the variation in sensitivity is negligible over the surface area of the DAP meter.

The DAP ionisation chamber was located at the end of the cone of the intraoral unit with the cone pointing towards the ceiling (Figure 1). In the case of the panoramic unit it was located in front of the first collimator (Figure 2). The measured values were corrected for chamber attenuation and energy dependence. Correction for chamber attenuation is needed since the DAP meter is calibrated to measure KAP at the exit side of the chamber while, in these measurements, the KAP outside the chamber is the quantity of interest. No corrections were made for room temperature and pressure. For measurement of ESAK, tube voltage, total filtration and HVL, a multimeter (Barracuda, RTI Electronics AB, Sweden) with traceable calibration factors was used. Film was used to measure field sizes for the intraoral unit and collimator height was used for the panoramic unit. The DWP was measured using a pencil ionisation chamber with a traceable calibration factor (PTW, Freiburg, Germany). Measured DAP values were compared with calculated values as DAP = ESAK × A (beam area) and DAP = DWP × H (beam height), for the intraoral and panoramic examinations, respectively.

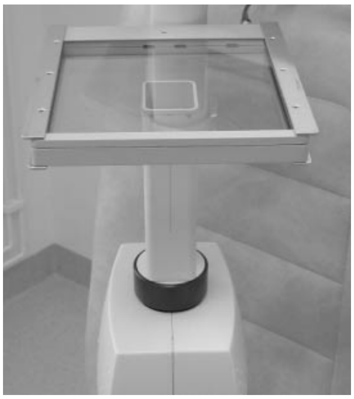

Figure 1. Transmission ionisation chamber for measuring of DAP values in an intraoral unit.

Figure 2. Transmission ionisation chamber for measuring of DAP values in a panoramic unit.

The intraoral measurements were performed using a Gendex Oralix DC unit (7 mA, total filtration 2.8 mm Al, focus cone distance 21.5 cm, rectangular beam 13.5 cm^2) with Kodak Insight film (Eastman Kodak Co., Rochester, NY, USA) as the image receptor. The panoramic unit was a Planmeca PM2002 CC/EC Proline (Planmeca OY, Finland) with a film-screen system of sensitivity 400. Measurements were made for patient exposure settings used at the Department of Oral Radiology, Institute for Postgraduate Dental Education, Jönköping, Sweden (DOR), and surrounding clinics.

RESULTS

Measured DAP values for the intraoral unit are presented in Table 1, together with exposure parameter settings and calculated values. Measured values for patient examinations at DOR are given in Table 2.

Measured DAP values for the panoramic unit for two different examination programmes using different exposure times and beam heights at different tube voltages are shown in Table 3. Programe 1 is generally used for adults and programe 2 is usually used for examination of children. Measured DWP values, beam heights and calculated DAP values are also given. In Table 4, values from panoramic examinations at DOR and surrounding clinics are presented.

As shown in Tables 1 and 3 the deviation between measured and calculated DAP values is less than 5–7%. This indicates that measurements with a DAP meter gives results which agree with those calculated from ESAK or DWP.

RISK CALCULATIONS

Calculation of risk is uncertain, in particular, for dental applications[(8)]. Factors that convert DAP to

Table 1. Tube voltage (kV setting), exposure time, ESAK, measured and calculated DAP-values and deviation for intraoral exposure settings.

Tube voltage (kV)	Exposure time (s)	Measured ESAK (mGy)	Measured DAP value (Gy cm^2)	Calculated DAP value (Gy cm^2)	Deviation (%)
60	0.5	2.52	0.033	0.034	−4.2
60	0.25	1.26	0.016	0.017	−4.4
60	0.1	0.49	0.006	0.007	−2.2
70	0.16	1.09	0.014	0.015	−4.6
70	0.1	0.68	0.009	0.009	−4.5

Gendex Oralix DC, 7 mA, total filtration 2.8 mm Al, focus cone distance 21.5 cm, rectangular beam 13.5 cm^2

effective dose (E) are useful for comparison of the risk between different types of examination[2,9]. Williams and Montgomery[4] derived a conversion factor of 0.06 mSv per Gy cm^2 for panoramic radiography using calculated DAP values and with E-values from White[10]. Stenström *et al.*[11] and Helmrot[12] derived, including the salivary glands, a conversion factor E/DAP in a two-step process using conversion factors between DAP and the energy imparted to the patient (ε) from Alm Carlsson *et al.*[13]: $E/\text{DAP} = [\varepsilon/\text{DAP}] \times [E/\varepsilon]$. Conversion factors found were 0.06–0.07 mSv per Gy cm^2 for intraoral radiography depending on tube voltage (60–70 kV) and 0.08 mSv per Gy cm^2 for panoramic radiography for the most commonly used kV settings.

Table 2. Type of examination, tube voltage (kV setting), exposure time, ESAK, DAP-values for intraoral radiograph at DOR.

Type of examination	Tube voltage (kV)	Exposure time (s)	ESAK (mGy)	DAP value (Gy cm^2)
Molar upper jaw	60	0.5	2.52	0.034
BTW molar, molar lower jaw	60	0.32	1.61	0.022
BTW premolar, canine	60	0.25	1.26	0.017
Incisive	60	0.2	1.00	0.014

Gendex Oralix DC, 7 mA, total filtration 2.8 mm Al, focus cone distance 21.5 cm, rectangular beam 13.5 cm^2. Film Kodak Insight

DISCUSSION

A DAP ionisation chamber is easy to use for the measurement of patient dose in dental radiography applications. The DAP values can therefore be used for setting DRLs, as has also been suggested by Williams and Montgomery[4]. They calculated the DAP values from measurements of the DWP and collimator height and reported that for an average standard adult panoramic examination DAP = 0.113 Gy cm^2. The corresponding figure for intraoral radiography was 0.093 Gy cm^2. This study shows lower values depending on the use of another type of unit for panoramic examinations and rectangular collimation and Kodak Insight film for intraoral examinations. Circular collimation and probably another type of film were used by Williams and Montgomery[4].

The introduction of DRLs has lead to DAP meters being installed as an integral part in present-day radiology equipment used for the automatic registration of patient dose. This could also be a possibility for panoramic units. With the advent of digital radiography and the use of automatic exposure control for these examinations, such equipments would allow easy monitoring and follow-up of individual patient doses.

CONCLUSIONS

It has been shown that the use of a DAP meter for determining patient doses in intraoral and panoramic examinations is feasible. The DAP meter is a

Table 3. Tube voltage (kV setting), tube current, exposure time, measured DAP values, DWP values, beam heights, calculated DAP values and deviation.

Programme number	Tube voltage (Kv)	Tube current (mA)	Exposure time (s)	Measured DAP value (Gy cm^2)	Measured DWP value (mGy mm)	Beam height (cm)	Calculated DAP value (Gy cm^2)	Deviation (%)
1	74	6	18.4	0.092	70.4	13.3	0.094	2
1	72	6	18.4	0.087	67.8	13.3	0.090	3
1	70	6	18.4	0.083	62.0	13.3	0.082	0
2	70	6	15.4	0.060	55.1	11.3	0.062	4
1	68	4	18.4	0.052	39.5	13.3	0.053	1
2	68	4	15.4	0.038	33.3	11.3	0.038	−1
1	66	4	18.4	0.048	38.8	13.3	0.052	7
2	66	4	15.4	0.035	32.7	11.3	0.037	5
1	64	5	18.4	0.057	43.3	13.3	0.058	1
2	64	5	15.4	0.040	36.4	11.3	0.041	3
1	62	8	18.4	0.085	67.2	13.3	0.089	5
2	62	8	15.4	0.061	56.9	11.3	0.064	5
1	60	8	18.4	0.078	62.5	13.3	0.083	6
2	60	8	15.4	0.057	53.5	11.3	0.060	6

Planmeca PM2002 CC Proline, total filtration 3.0 mm Al.

Table 4. DAP values for patient examinations at DOR.

Type of examination	Tube voltage (kV)	Tube current (mA)	Average measured DAP value (Gy cm^2)
Adult big man	70	9	0.100
Adult normal man	68	7–8	0.073
Adult woman	64	6–7	0.058
Children 7–12 y	62	4–6	0.035
Children <6 y	60–62	4–5	0.027

Film-screen sensitivity equal to 400. Planmeca PM 2002 CC/EC Proline, total filtration 3.0 mm Al

useful tool in quality control programmes and DAP is an important parameter in optimising the exposure parameter settings of an examination since it is related to radiation risk. Hence is recommended for setting of DRLs in dental radiology.

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