PROPOSED VALUES FOR DIAGNOSTIC REFERENCE LEVELS IN INTRAORAL DENTAL RADIOGRAPHY IN SERBIA

by

Zoran M. MIRKOV [1*]***, Nebojša T. MILOŠEVIĆ*** [2]***, and Dario FAJ*** [3,4]

[1] Serbian Institute of Occupational Health Dr Dragomir Karajović, Belgrade, Serbia
[2] Department of Biophysics, Medical Faculty, University of Belgrade, Belgrade, Serbia
[3] Faculty of Medicine, University of Osijek, Osijek, Croatia
[4] Faculty of Dental Medicine and Health, University of Osijek, Osijek, Croatia

Scientific paper
https://doi.org/10.2298/NTRP2401066M

Values for diagnostic reference levels are proposed for intraoral dental radiography in the Republic of Serbia. Proposed numbers for diagnostic reference levels were based on measurements on 119 intraoral units in clinical settings for an adult posterior bitewing X-ray. Values of 3.17 mGy, 3.11 mGy, and 1.58 mGy incident air kerma were found for image receptors film E class, charge-coupled device, and photostimulable phosphor plate, respectively. Similarly, 89.6 mGycm^2, 88 mGycm^2, and 44.6 mGycm^2 air kerma-area products were found for the same detectors. All values are greater than those published in several other similar studies. This is especially true for charge-coupled device image receptors since this technology enables lower patient doses as reported before. This calls for urgent action to optimize intraoral dental imaging, so we present the radiographic techniques used and equipment description to help guide optimization actions.

Key words: dental radiography, radiation protection, diagnostic reference level

INTRODUCTION

It is well-known that the X-ray radiation used in medicine is the largest source of artificial ionizing radiation to the human population. In the Republic of Serbia, more than a quarter of the X-ray sources used in radiology are used in dental medicine. This is consistent with the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) report where more than 25 % of all radiology procedures are dental radiology procedures [1]. Among all dental X-ray devices, intraoral X-ray devices make up the vast majority. Although radiation doses received by patients during exposure of this type are low [1], improper use can still cause unwanted effects (risk) to the patients and professionally exposed workers.

There is a legal obligation to carry out regular quality control (QC) of the mentioned devices annually [2]. The QC can be performed only by authorized legal entities, among which is the Serbian Institute of Occupational Health *Dr. Dragomir Karajovic*. Regular annual QC of intraoral devices during a period from the year 2018 to 2023 enabled the collection of data related to patient doses, as well as other relevant information on radiation protection optimization [3]. A sufficient number of data collected in a large number of institutions enabled the establishment of the empirical formula for calculating the incident air kerma ($K_{a,i}$) in intraoral radiographic imaging [4]. The formula provides information on patient doses based on acquisition parameters which is useful on devices that do not indicate patient doses. The diagnostic reference levels (DRL) [5] are one of the tools that have proven to be very useful in optimizing protection during the medical exposure of patients in diagnostic and interventional radiology (according to the experiences of neighboring countries and many other countries, including the countries of the EU, Japan, Korea, and America [6, 7]). The DRL are defined as *a level used in medical imaging to indicate whether, in routine conditions, the dose to the patient or the amount of radiopharmaceuticals administered in a specified radiological procedure for medical imaging is unusually high or unusually low for that procedure* [6]. Measurements of $K_{a,i}$ at the cone tip (the point at which X-rays are incident on the skin), using standard settings as in clinical practice is a convenient method for setting The DRL values for dental radiography [6]. DRL should be established separately for adults and children [6].

This paper presents the methodology and results of the proposed values for establishing national DRL for adult patients in intraoral dental radiography in the

* Corresponding author, e-mail: kiza.mirkov@gmail.com

Table 1. List of examined intraoral dental X-ray devices and their basic technical characteristics

Number of units	Model (Manufacturer)	Nominal X-ray tube potential [kV]	X-ray tube current [mA]	The source-skin distance [cm]	Collimators with a diameter of [cm]	Total filtration [mm Al]
1	FIAD (Trophy)	70	7	20	6	1.5
3	Heliodent Plus (Sirona)	70	7	20	6	1.5
9	Heliodent Vario (Sirona)	70	7	20	6	1.5
2	Heliodent DS (Sirona)	60	3.5	20	6	1.5
6	Vario DG (Sirona)	70	7	20	6	1.5
3	Xgenus (De Götzen)	70	8	20	6	1.5
7	Gnatus	70	7	20	6	1.5
1	EZ (Vatech)	70	7	20	6	2
1	CS 2100 (CARESTREAM)	60	7	20	6	2
2	CS 2200 (CARESTREAM)	70	7	20	6	2
13	Focus (Kavo)	70	7	22.3	6	2
19	Minray (Soredex)	70	7	20	6	2
3	Leadex 70 (Ritter)	70	7	20	6	1.5
3	ELITYS (Trophy)	60	7	20	6	2.0
2	Heliodent Vario DG (Sirona)	70	3.5	20	6	1.5
1	Imago	70	8	20	6	2
1	FUTUR X 2500 (New Life)	70	8	20	6	1.5
2	Heliodent 70 (Siemens)	70	7	20	6	1.5
3	CCX Digital (Trophy) Trex	70	8	20	6	2.5
10	Expert DC (Gendex)	65	7	20	6	2
1	Endos	65/70	5	20	6	2
5	Pro X (Planmeca)	60	8	20	6	2
1	RXDC (Myray)	60	7	20	6	2.0
1	RXDC extend (Myray)	70	7	20	6	2.0
3	Intra (Planmeca)	63	8	20	6	1.5
2	XDC (Fona)	70	7	20	6	1.5
1	SRL (Fona)	70	7	20	6	1.5
1	ANTHOS AC	70	7	20	6	1.5
2	Satelec X Mind	70	8	20	6	2
10	Dent (Ei Niš)	50	10	10	5	1.5

Republic of Serbia. The results were also analyzed for every image receptor separately and compared to the previously published values. In addition to DRL establishment, data on personnel training, QC, and maintenance of the units are collected and presented.

METHODS AND MATERIALS

According to the data received by the regulatory body Serbian Radiation and Nuclear Safety and Security Directorate, there are about 300 intraoral dental units in the Republic of Serbia. This paper includes the results of testing 119 intraoral dental units in Serbia. A list of dental X-ray units is given in tab. 1. The devices given in the table show diversity in terms of architecture. The most important difference is in the architecture of devices produced in Serbia (Dent Ei Niš) which are single-phase, and all others are high frequency. Another weak point of these units is using fixed 50 kV (60 kV to 70 kV is recommended for dental intraoral X-ray sets equipment) [8] and a short focus-to-skin distance (FSD) of 10 cm while a minimum FSD of 20 cm has been recommended [8]. The aforementioned devices can be found in public institutions only. Due to their outdated architecture (more than 30 years old), they are expected to be replaced soon. Interestingly, 90 % of all intraoral devices are owned by the private sector.

The measurement was done for an adult man (70 10) kg, in standard clinical settings for molars of the upper jaw. The parameters that were evaluated were collected from 2018-2023. The parameters that are examined, according to the regulations [2], are given in tab. 2.

The measurements are performed using a regularly calibrated multimeter with a semiconductor detector, MPD Barracuda (RTI Electronics AB, Sweden). The established measurement uncertainty for $K_{a,i}$ measurement is 7 %. Calibration of the unit is performed in the Secondary Standard Dosimetry Laboratory (SSDL) Vinca Institute of Nuclear Sciences, Radiation and Environment Protection Department, Belgrade, Serbia. Each measurement, for each measured parameter, is repeated at least five times.

The KAP values are obtained by calculating the multiplication of $K_{a,i}$ values with the area of the tube opening [9]. KAP values are given (along with quality control results) for each of the image receptors (Class E film, CCD (charge-coupled device), and PSP (photostimulable phos-

Table 2. Performance testing of the dental X-ray units

Quantity tested	Parameter tested	Allowed tolerance limits	Probation periods
X-ray tube voltage	Repeatability	10 %	Annually
	Accuracy	10 %	Annually
Exposure time	Repeatability	10 %	Annually
	Accuracy	10 %	Annually
	Linearity	10 %	Annually
Output dose at the tube top	Repeatability	10 %	Annually
	Accuracy	10 %	Annually
Attenuation half-thickness	For voltage < 70 kV	1.5 mmAl	Annually
	For voltage > 70 kV	2.5 mmAl	Annually
Field diameter at end of X-ray cylinder		N 6 cm	Annually

phor plate)). It has to be mentioned that as of 2018, class D and F films are not used as image receptors.

During regular QC measurements, a survey was conducted among employees in dental practices. The survey aimed to gain insight into the dental radiology practice using intraoral X-ray units and accompanying equipment. The following questions were asked:
– whether the employees were trained to work with the X-ray units and accompanying equipment,
– whether regular quality control of image processing devices is performed (if the image processing device exists), and
– whether the X-ray units and image processing devices are regularly serviced.

RESULTS

Based on a survey conducted among users of intraoral X-ray devices, it was found that:
– 60 % of users are not adequately or sufficiently trained to work with intraoral dental X-ray devices and image processing devices,
– 70 % of users do not perform regular QC of film and image processing devices, and
– 75 % of users do not have their X-ray units and image processing devices maintained on a regular basis.

The results of KAP measurements for each of the image receptors found are given in tabs. 3-5.

A special group of devices consisted of the mentioned devices of domestic production (production ceased 30 years ago). The results for this group are presented in the tab. 6.

DISCUSSION

This work recommends national DRL (3rd quartile) for intraoral dental radiology when exposing upper jaw molars to an adult. DRL were found to be 88.6 mGycm^2, 89.0 mGycm^2, and 44.6 mGycm^2 for E-class film, CCD, and PSP image receptors, respectively. Tables 3-5 shows that different patient doses are achievable and should be used for different image receptor technologies. This is in line with recent guidelines [5].

Nevertheless, DRL proposed in this work do not show any advantage in terms of patient doses when CCD are used. Further analyses, using the achievable doses given as median values lead to different conclusions. Achievable doses were found to be 77.7 mGycm^2, 58.0 mGycm^2, and 36.2 mGycm^2 for E-class film, CCD, and PSP image receptors, respectively. It reveals that units with CCD image receptors are not always used in an optimized way and patients would benefit from personnel education and optimizing imaging in dental radiology.

It has to be mentioned that the measurement results of domestically produced devices (EI Niš dent) show almost three times higher KAP values when compared to devices that use PSP as an image receptor, tab. 6. These units are obsolete and their recent removal and replacement with newer ones is foreseen in the near future. This was the reason that the results of domestic devices (EI Niš dent) were not included in the above-established DRL.

We found that films of class D are not in use anymore, tab. 1, as recommended before [8]. Table 1 also shows that only cylindrical collimators are in use for intraoral dental radiology in the Republic of Serbia. This contributes to reducing the patient dose since the dose for patients is lower in the case of rectangular collimators because the exposure field is smaller and diagnostic information is not lost as already shown [10-13].

Table 7 presents a comparison of DRL found before with the results of this work (without EI Niš dent results).

The comparison in tab. 7 reveals that most of the DRL values are greater than those established in several other similar studies. This is especially true for CCD image receptors since this technology enables lower patient doses as reported before [14-16]. A similar conclusion can be drawn from measurements of the incidence air kerma.

During the measurements, we collected information on user opinions of their training. Data collected showed that 60 % of users think that they are not adequately or sufficiently trained to work with intraoral dental X-ray devices and image processing devices. This can be one of the reasons for higher patient dose values found in this study. A positive outcome of measuring campaigns and surveys of patient radiation safety in radiology is building a radiation safety culture [17]. It can be seen in this study also because the results on training, QC, and maintenance of image quality are improved when compared to the study performed before [3].

Table 3. Measurement results of X-ray tube voltage and time compared to nominal values and measurement, film E image receptors, with calculated values for KAP, standard deviation, median, and third quartile

Model	X-ray tube voltage [kV]		Set *it* [mAs]	Set *t* [s]	Measure *t* [s]	Measure $K_{a,i}$ [Gy]	Half value layer (HVL) measured [mm Al]	Measured total filtration [mm Al]	The source-skin distance [cm]	Tube opening [cm^2]	KAP [mGycm^2]	Film development
	Set	Measured										
FIAD (TROPHY)	70	70.18	2.24	0.28	0.282	845.59	2.65	1.5	20	28.26	23.9	Manually
Heliodent Plus (Sirona)	70	70	0.56	0.08	0.08	869.94	1.77	1.4	20	28.26	24.6	Automatic
Heliodent Vario (Sirona)	70	66.11	3.5	0.5	0.484	880.77	1.69	1.3	20	28.26	24.9	Manually
Heliodent Vario (Sirona)	70	67.56	3.5	0.5	0.46	880.77	1.69	1.3	20	28.26	24.9	Manually
RXDC Extend (Myray)	70	69.19	1.4	0.2	0.2	1000	1.99	1.82	20	28.26	28.3	Automatic
Xgenus (De Götzen)	70	68.25	2.56	0.32	0.304	1010.94	1.74	1.6	30	28.26	28.6	Automatic
Gnatus	70	66.6	2.24	0.32	0.32	1037.96	1.7	1.4	20	28.26	29.3	Automatic
Xgenus (De Götzen)	70	68.98	2.8	0.35	0.323	1085.39	2.01	1.9	30	28.26	30.7	Manually
EZ (Vatech)	70	68.51	1.4	0.2	0.2	1200	2.2	2.19	20	28.26	33.9	Automatic
CS 2100 (CARESTREAM)	60	62.47	1.75	0.25	0.25	1558.97	1.57	1.4	20	28.26	44.1	Automatic
Focus (Kavo)	70	70.13	1.4	0.2	0.2	1570	2.12	2	23	28.26	44.4	Automatic
Minray (Soredex)	70	71.09	1.4	0.2	0.2	1580	1.96	1.68	23	28.26	44.7	Automatic
Heliodent Vario (Sirona)	70	69.87	3.5	0.5	0.5	1601.4	2.5	1.8	20	28.26	45.3	Manually
Xgenus (De Götzen)	70	69.84	4	0.8	0.83	1703.2	1.91	1.7	31	28.26	48.1	Manually
Leadex 70 (Ritter)	70	69.54	3.5	0.4	0.343	2057.78	2.28	1.2	20	28.26	58.2	Manually
Heliodent Vario (Sirona)	70	74	2.8	0.4	0.41	2176.16	1.58	1.3	20	28.26	61.5	Automatic
Gnatus	70	66.6	2.24	0.32	0.32	2192.51	1.72	1.6	20	28.26	62	Manually
Heliodent Plus (Sirona)	70	72.75	1.4	0.2	0.2	2200	1.68	1.18	20	28.26	62.2	Automatic
ELITYS (Trophy)	70	71.76	2.43	0.347	0.348	2334.4	1.9	1.6	20	28.26	66	Automatic
Vario DG (Sirona)	70	66.62	3.5	0.5	0.5	2371.39	1.82	1.8	20	28.26	67	Manually
IMAGO	70	64.17	4	0.5	0.47	2417	1.81	2.2	20	28.26	68.3	Manually
FUTUR X 2500 (New Life)	70	68.62	4	0.5	0.49	2737.18	2.23	2.23	20	28.26	77.4	Manually
Heliodent 70 (Siemens)	70	66.71	3.5	0.5	0.503	2761.36	2.07	2	20	28.26	78	Automatic
Gnatus	70	64	7	1	0.91	2786.7	2.5	1.9	20	28.26	78.8	Manually
Heliodent Vario (Sirona)	70	65.13	3.5	0.5	0.48	2845	1.59	1.3	20	28.26	80.4	Manually
Heliodent 70 (Siemens)	70	68.59	3.5	0.5	0.452	3029.2	1.88	1.8	20	28.26	85.6	Automatic
Vario DG (Sirona)	70	65.29	3.5	0.5	0.5	3056.2	1,89	1,7	20	28.26	86.4	Manually
CCX Digital (Trophy) Trex	70	63.43	4	0.5	0.47	3077.84	1.6	1.4	20	28.26	87	Manually
Heliodent Vario (Sirona)	70	68.07	3.5	0.5	0.5	3125.78	2,24	1,5	20	28.26	88.3	Automatic
Minray (Soredex)	70	70.22	3.5	0.5	0.5	3129	2	1.8	20	28.26	88.4	Automatic
Leadex 70 (Ritter)	70	70.54	4	0.5	0.48	3137.4	1.91	2.1	20	28.26	88.7	Manually
Gnatus	70	67.03	7	1	0.923	3143	1.73	1.8	20	28.26	88.8	Manually
Heliodent Vario (Sirona)	70	63.12	4.41	0.63	0.584	3155.8	1.54	1.3	20	28.26	89.2	Manually
Heliodent Vario (Sirona)	70	66.11	3.5	0.5	0.484	3220.56	2.51	1.2	20	28.26	91	Automatic
Expert DC (Gendex)	65	66.01	2.8	0.4	0.397	3391.92	1.68	1.5	20	28.26	95.9	Automatic
Endos	70	67.56	4	0.5	0.51	3492.8	1.82	1.7	20	28.26	98.7	Automatic
Gnatus	70	67.83	7			3756	1.96	2.4	20	28.26	106.1	Manually
Leadex 70 (Ritter)	70	69.46	5.04	0.63	0.584	3855.9	1.82	1.5	20	28.26	109	Manually
Minray (Soredex)	70	69.58	3.5	0.5	0.497	3956.05	2.02	1.8	20	28.26	111.8	Automatic
Minray (Soredex)	70	70.36	3.5	0.5	0.5	4070.99	1.96	1.8	20	28.26	115	Automatic
VARIO DG (Sirona)	70	3.5				4377.94	2,56	2,56	20	28.26	123.7	Manually
CS 2200 (Carestream)	70	71.58	4.41	0.63	0.63	5701.69	2.05	1.8	20	28.26	161.1	Automatic
Gnatus	70	63.85	7	1	0.93	5739.3	1.9	2.08	20	28.26	162.2	Manually
Pro X (Planmeca)	70	69.16	4	0.5	0.5	5852.16	2.48	2.7	20	28.26	165.4	Manually
Standard deviation											37.0	
Median											77.7	
3rd quartile											89.6	

CONCLUSIONS

We suggest the following values for national DRL in intraoral dental radiology when exposing upper jaw molars, for an adult: Class *E* film – 89.6 mGycm^2, CCD devices – 88.0 mGycm^2, PSP devices – 44.6 mGycm^2.

All values are greater than those established in several other similar studies. This is especially true for CCD image receptors since this technology enables lower patient doses as reported before [10, 13, 19]. A similar conclusion can be drawn from measurements of the incidence air kerma. The results show that there is room for improvements in optimization, but also in staff training to improve awareness of patient radiation safety in dental radiology. This can be achieved by involving medical physicists, or technical licensed institutions more closely in dental radiology clinical practice. Also, additional education and training in medical exposure are specially designed for this group of workers professionally exposed to ionizing radiation.

Current results refer to adult patients, while data for pediatric patients are missing. Since pediatric patients are a more sensitive group of patients it is important to establish pediatric DRL as well. Furthermore,

Table 4. Measurement results of X-ray tube voltage and time compared to nominal values and measurement, CCD (digital) image receptors, with calculated values for KAP, standard deviation, median, and third quartile

Model	X-ray tube voltage [kV]		Set *it* [mAs]	Set *t* [s]	Measured *t* [s]	Measured $K_{a,i}$ [Gy]	HVL Measured [mm Al]	Measured total filtration [mm Al]	The source-skin distance [cm]	Tube opening [cm^2]	KAP [mGycm^2]
	Set	Measured									
Pro X (Planmeca)	63	63	1	0.125	0.125	1181.00	2.26	2.7	20	28.26	33.4
Heliodent Vario (Sirona)	70	66.43	2.24	0.32	0.305	1307.71	1.81	1.7	20	28.26	37.0
Heliodent DS (Sirona)	60	61.77	1.75	0.25	0.247	1361.85	1.67	1.6	20	28.26	38.5
CCX Digital (Trophy) Trex	70	66.36	1.6	0.2	0.18	1607.65	2.1	1.7	20	28.26	45.4
XDC (Fona)	60	59.2	1.4	0.2	0.2	1670.00	1.79	1.98	20	28.26	47.2
Vario DG (Sirona)	70		2.24			1848.57	1.57	1.2	20	28.26	52.2
ANTHOS AC	70	70.43	2	0.25	0.28	1927.00	1.63	1.2	20	28.26	54.5
Minray (Soredex)	70	70	1.75	0.25	0.25	1991.39	2.02	1.8	20	28.26	56.3
EXPERT DC (Gendex)	65	66.84	1.75	0.25	0.245	2028.18	1.69	1.5	20	28.26	57.3
XDC (Fona)	70	70.2	2.52	0.36	0.361	2053.25	2.56	3	20	28.26	58.0
Heliodent Plus (Sirona)	70	70.53	1.4	0.2	0.2	2400.00	1.82	1.49	20	28.26	67.8
Heliodent DS (Sirona)	60	61.98	2.8	0.4	0.4	2609.99	1.9	2	20	28.26	73.8
Intra (Planmeca)	70	69.67	1.6	0.2	0.2	2927.85	2.19	2.1	20	28.26	82.7
SRL (Fona)	70	67.16	2	0.285	0.283	3093.80	2.1	2.06	20	28.26	87.4
Intra Prostyle (Planmeca)	63	63	2	0.25	0.25	3137.00	1.71	1.7	20	28.26	88.7
Minray (Soredex)	70	71.5	2.8	0.4	0.4	3164.56	2.11	1.9	20	28.26	89.4
Intra promax (Planmeca)	70	69.18	1.4	0.2	0.2	3180.00	1.78	1.47	20	28.26	89.9
Gnatus	70		3.5			3271.10	1.6	1.78	20	28.26	92.4
Minray (Soredex)	70	71.05	2.8	0.4	0.4	3360.67	2	1.7	20	28.26	95.0
Standard deviation											21.0
Median											58.0
3rd quartile											88.0

intraoral radiography is a low-dose procedure when compared to panoramic and especially CBCT devices. Establishing DRL in these procedures is of paramount importance to help in further optimization of these procedures as well.

AUTHORS' CONTRIBUTIONS

The manuscript was prepared by Z. M. Mirkov. All authors analyzed and discussed the results and reviewed the manuscript. D. Faj supervised and edited the paper.

ORCID NO

Z. M. Mirkov: 0000-0001-7579-8019
N. T. Milošević: 0000-0002-0589-1848
D. Faj: 0000-0002-4111-5459

REFERENCES

[1] ***, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources, Effects and Risks of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2020/2021 Report, Volume I. UN, 2022

[2] ***, Rulebook on Application of the Radiation Sources in Medicine (Official Gazette RS 1/12 from 11.01.2012), Belgrade, Serbia, 2012

[3] Mirkov, Z., Determination of Dose for Patients in Intraoral Dental Radiology in the Republic of Serbia, M. Sc., University of Novi Sad, Association of Centers for Interdisciplinary and Multidisciplinary Studies and Research, Novi Sad, Serbia, 2016

[4] Mirkov, Z., *et al*., The Empirical Formula for Calculating the Incident air Kerma in Intraoral Radiographic Imaging, *Dentomaxillofac Radiol* (2021), 50: 20210117

[5] ***, ICRP, 201, Diagnostic Reference Levels in Medical Imaging, ICRP Publication 135. Ann. ICRP 46(1)

[6] Ciraj, B. O., *et al.*, Radiation Protection of Patients in Diagnostic Radiology: Status of Practice in Five Eastern-European Countries, Based on IAEA Project // *European Journal of Radiology, 79* (2011), 2, pp. e70-e73

[7] Faj, D., *et al.*, Patient Dosimetry in Interventional Cardiology at the University Hospital of Osijek // *Radiation Protection Dosimetry, 128* (2008), 4, pp. 485-490

[8] ***, European Commission, European Guidelines on Radiation Protection in Dental Radiology, RP 136, Luxembourg, 2004

[9] Helmrot, E., Alm Carlsson, G., Measurement of Radiation Dose in Dental Radiology, *Radiat Prot Dosimetry 114* (2005), 1-3, pp. 168-171

[10] Horton, P. S., *et al*., A Comparison of Rectangular and Cylindrical Collimation for Intraoral Radiographs, *J Dent Educ., 47* (1993), 12, pp. 771-773

[11] Richard, E. C., *et al*., Comparison of Technical Errors in Pediatric Bitewing Radiographs Acquired with Round *vs*. Rectangular Collimation, Oral Surgery, Oral Medicine, *Oral Pathology and Oral Radiology, 133* (2022), 3, pp. 333-342

[12] Parrott, L. A., Ng, S. Y., A Comparison Between Bitewing Radiographs Taken with Rectangular and Circular Collimators in UK Military Dental Practices:

Table 5. Measurement results of X-ray tube voltage and time compared to nominal values and measurement, PSP (digital) image receptors, with calculated values for KAP, standard deviation, median, and third quartile

Model	X-ray tube voltage [kV]		Set *it* [mAs]	Set *t* [s]	Measured *t* [s]	Measured $K_{a,i}$ [Gy]	HVL measured [mm Al]	Measured total filtration [mm Al]	The source-skin distance [cm]	Tube opening [cm^2]	KAP [$mGycm^2$]
	Set	Measured									
RXDC (Myray)	60	61.58	1.4	0.2	0.2	1247.18	1.71	1.7	20	28.26	35.2
RXDC (Myray)	60	62.45	0.7	0.1	0.1	238.80	1.54	1.4	20	28.26	6.7
Pro x (Planmeca)	60	58.61	1	/	/	17.40	2.22	3	20	28.26	0.5
Elitys (Trophy)	60	60.76	4.41	0.63	0.633	3730.81	1.69	1.7	20	28.26	105.4
Intra (Planmeca)	63	60.25	2	0.25	0.25	1261.60	1.86	1.8	20	28.26	35.7
Expert DC (Gendex)	65	65.31	1.12	0.16	0.16	1196.25	1.78	1.5	20	28.26	33.8
Expert DC (Gendex)	65	65	1.12	0.16	0.16	1212.00	1.83	1.7	20	28.26	34.3
Expert DC (Gendex)	65	64.1	1.12	0.16	0.16	1195.64	1.75	1.6	20	28.26	33.8
Expert DC (Gendex)	65	65	1.12	0.16	0.16	1213.21	1.64	1.5	20	28.26	34.3
RXDC (Myray)	65	61.19	3.5	0.5	0.5	1780.52	1.77	1.8	20	28.26	50.3
Expert DC (Gendex)	65	65.12	2.24	0.32	0.316	2462.41	2	1.94	20	28.26	69.6
Expert DC (Gendex)	65	65	2.24	0.32	0.32	2445.81	1.81	1.7	20	28.26	69.1
Expert DC (Gendex)	65	65	2.24	0.32	0.32	2426.41	1.86	1.9	20	28.26	68.6
Vatech	65	64.79	2.1	0.3	0.3	902.71	1.77	1.7	20	28.26	25.5
Satelec X Mind	70	69.79	1.6	0.2	0.2	982.98	2.01	1.8	20	28.26	27.8
Focus (Kavo)	70	69.99	0.875	0.125	0.124	958.93	2.15	2.1	23	28.26	27.1
XDG (Fona)	70	74.49	0.84	0.24	0.244	1233.40	1.81	1.3	20	28.26	34.9
Vario DG (Sirona)	70	/	1.12	/	/	1178.82	1.8	1.8	20	28.26	33.3
Focus (Kavo)	70	70.58	1.12	0.16	0.16	1285.40	2.07	1.9	23	28.26	36.3
Focus (Kavo)	70	70.27	1.12	0.16	0.16	1313.31	1.93	1.6	23	28.26	37.1
Focus (Kavo)	70	70	1.12	0.16	0.16	1265.73	2	1.8	23	28.26	35.8
Minray (Soredex)	70	70	1.12	0.16	0.16	1256.60	2.03	1.8	20	28.26	35.5
Minray (Soredex)	70	70	1.12	0.16	0.16	1292.79	2.5	2.5	20	28.26	36.5
Minray (Soredex)	70	70	1.12	0.16	0.16	1161.96	2.1	1.9	20	28.26	32.8
Extend (Myray)	70	68.99	1.28	0.16	0.159	826.27	2.01	1.9	20	28.26	23.4
Pro X (Planmeca)	70	70	1.4	0.2	0.2	1991.64	2.4	2.6	20	28.26	56.3
Minray (Soredex)	70	70	1.4	0.2	0.2	1522.40	2.09	1.9	20	28.26	43.0
Satelec X Mind	70	70.22	1	0.125	0.122	623.86	2.16	2.1	20	28.26	17.6
Minray (Soredex)	70	70.59	0.7	0.1	0.1	759.92	2.01	1.8	20	28.26	21.5
ELITYS (Trophy)	70	70.59	0.812	0.203	0.201	1381.42	2.16	2	20	28.26	39.0
Focus (Kavo)	70	69.34	1.4	0.2	0.2	1570.00	2.04	1.9	23	28.26	44.4
Focus (Kavo)	70	70.57	1.4	0.2	0.2	1270.00	2.04	1.83	23	28.26	35.9
Focus (Kavo)	70	71.08	0.7	0.1	0.1	790.00	2.01	1.76	23	28.26	22.3
Focus (Kavo)	70	69.74	1.4	0.2	0.2	1534.00	2.06	1.91	23	28.26	43.4
Focus (Kavo)	70	69.27	1.6	0.2	0.2	1290.00	2.07	1.96	23	28.26	36.5
XDC (Fona)	70	68.33	1.4	0.2	0.2	2355.00	2.11	2.07	20	28.26	66.6
Expert DC (Gendex)	70	70.04	1.12	0.16	0.16	1280.00	2.05	1.88	23	28.26	36.2
Focus (Kavo)	70	69.94	1.4	0.2	0.2	1620.00	2.09	1.96	23	28.26	45.8
Minray (Soredex)	70	71.20	1.4	0.2	0.2	1500.00	2.05	1.83	23	28.26	42.4
Pro X (Planmeca)	70	70.82	1.4	0.2	0.2	2230.00	2.60	2.84	20	28.26	63.0
Minray (Soredex)	70	69.45	1.12	0.16	0.16	1260.00	2.04	1.91	23	28.26	35.6
Minray (Soredex)	70	70.22	1.12	0.16	0.16	1280.00	2.02	1.82	23	28.26	36.2
Minray (Soredex)	70	71.09	1.4	0.2	0.2	1580.00	1.96	1.68	23	28.26	44.7
Minray (Soredex)	70	70.56	1.4	0.2	0.2	1570.00	2	1.77	23	28.26	44.4
Minray (Soredex)	70	72.53	1.4	0.2	0.2	1637.00	1.79	1.85	23	28.26	46.3
CS 2200 (Carestream)	70	70.87	1.4	0.2	0.201	1730.00	2.1	1.92	20	28.26	48.9
Standard deviation											17.5
Median											36.2
3rd quartile											44.6

a Retrospective Study, *Dentomaxillofacial Radiology, 40* (2011), 2, pp. 102-109

[13] Björn, S., Arne, P., Questionnaire Survey on the Use of Dental X-Ray Film and Equipment Among General Practitioners in the Swedish Public Dental Health Service, *Acta Odontologica Scandinavica, 53* (2009), 4, pp. 230-235

[14] Praskalo, J., *et al*., Intraoral Dental X-Ray Radiography in Bosnia and Herzegovina: Study for Revising Diagnostic Reference Level Value, *Radiat Prot Dosimetry, 190* (2020), 1, pp. 90-9

[15] Suliman, I. I., Abdelgadir, A. H., Patient Radiation Doses in Intraoral and Panoramic X-Ray Examinations in Sudan, Phys Medica [Internet], 2018;46(February):148-52. Available from: https://doi.org/10.1016/j.ejmp.2018.01.017

[16] Storm, C., Nezich, R., Establishment of a Local Diagnostic Reference Level for Dental Intraoral Bitewing X-Rays, *Phys Eng Sci Med., 46* (2023), 2, pp. 747-751

[17] Faj, D., *et al*., Establishment and Utilization of Diagnostic Reference Levels in Medical Imaging: Results from a Survey and Consultation Under the IAEA

Table 6. Measurement results (Dent Ei Niš) of X-ray tube voltage and time compared to nominal values and measurement, film *E* image receptors, with calculated values for KAP, standard deviation, median, and third quartile

X-ray tube voltage [kV]		Set *it* [mAs]	Set *t* [s]	Measured *t* [s]	Measured $K_{a,i}$ [Gy]	HVL Measured [mm Al]	Measured total filtration [mm Al]	The source-skin distance [cm]	Tube opening [cm^2]	KAP [mGycm^2]	Film development
Set	Measured										
50	48.27	5	0.5	0.48	4837.60	1.03	1	10	19.625	94.9	Manually
50	47.74	5	0.5	0.47	3047.40	1.6	1.5	10	19.625	59.8	Automatic
50	47.7	5	0.5	0.49	5426.80	1.69	1	10	19.625	106.5	Manually
50	50.84	8	0.8	0.87	5884.80	1.4	1.6	10	19.625	115.5	Manually
50	47.6	8	0.8	0.77	6365.28	1.79	3.7	10	19.625	124.9	Manually
50	47.7	8	0.8	0.82	4252.32	1.79	3.6	10	19.625	83.5	Automatic
50	42.1	8	0.8	0.8	4472.64	1.65	2.6	10	19.625	87.8	Manually
50	45.39	5	0.5	0.52	5715.60	1.54	1.6	10	19.625	112.2	Manually
50	52.12	5	1	1.13	7550.80	1.52		10	19.625	148.2	Manually
50	46.95	10	1	0.95	10380	1.68		10	19.625	203.7	Manually
Standard deviation										39.9	
Median										109.3	
3rd quartile										122.6	

Table 7. Comparative results of research in intraoral dental radiology with the results of this study without EI Niš dent results

Researcher (country and year)	Teeth (upper or lower jaw)	Values (KAP in mGycm^2 or $K_{a,I}$ in mGy)		
Looe *et al*. (Germany 2005) [20]	Upper jaw, molars	48.8 mGy cm^2		
Poppe *et al*. (Germany 2007) [21]	Upper jaw, molars	61.5 mGy cm^2		
KFDA report (Korea, 2009) [22]	Lower jaw, molars	59.4 mGy cm^2		
Han S, *et al*. (Koreja, 2011) [23]	Upper jaw, molars Upper jaw, premolars Upper jaw, incisors	55.5 mGy cm^2 46 mGy cm^2 36.5 mGy cm^2		
Manousaridis *et al*. (Greece 2013) [24]	Upper jaw, molars	2.9 mGy		
Praskalo *et al*. (Bosnia and Herzegovina 2020) [14]	Upper jaw, molars	DRL for the film-screen system (3.5 mGy) and for digital receivers (1.2 mGy)		
Izawa *et al*. (Japan 2017) [18]	Upper jaw, molars	Local DRL Film-screen 1.59 0.20 mGy		
Suliman, Abdelgadir (Sudan 2018) [15]	Upper jaw, molars	1.45 mGy (DR), 4.45 mGy (film-screen) and 3.01 mGy (combined)		
Christofides *et al*. (Cyprus 2016) [19]	Upper jaw, molars	7.23 mGy		
Storm *et al*. (Australia 2023) [16]	Upper jaw, molars	2 mGy, 57 mGycm^2		
Z. Mirkov (2023) (present work)	Upper jaw, molars	Film E	3.17 mGy	89.6 mGycm^2
		CCD	3.11 mGy	88.0 mGycm^2
		PSP	1.58 mGy	44.6 mGycm^2

Technical Cooperation Programme in Europe and Central Asia, *Physica Medica, 108* (2023), 102565, https://doi.org/10.1016/j.ejmp.2023.102565.

[18] Izawa, M., *et al*., Establishment of Local Diagnostic Reference Levels for Quality Control in Intraoral Radiography, *Oral Radiol., 33* (2017), 1, pp. 38-44

[19] Christofides, S., *et al*., Local Diagnostic Reference Levels for Intraoral Dental Radiography in the Public Hospitals of Cyprus, Phys Medica [Internet], 32 (2016), 11, pp. 1437-43, Available from: http://dx.doi.org/10.1016/j.ejmp.2016.10.014

[20] Looe, H. K., *et al*., Conversion Coefficients for the Estimation of Effective Doses Intraoral and Panoramic Dental Radiology from Dose-Area Product Values, *Radiation Protection Dosimetry, 131* (2008), 3, pp. 365-373

[21] Poppe, B., *et al*., Radiation Exposure and Dose Evaluation in Intraoral Dental Radiology, *Radiat Prot Dosimetry, 123* (2007), 2

[22] ***, Korea Food and Drug Administration Report, Development of Diagnostic Reference Level in Dental X-Ray Examination in Korea, 2009, Available on http://rnd.kfda.go.kr.

[23] Han, S., *et al*., Dose Area Product Measurement for Diagnostic Reference Levels and Analysis of Patient Dose in Dental Radiography, *Radiat Prot Dosimetry, 150* (2012), 4, pp. 523-531

[24] Manousaridis, G., *et al*., Establishment of Diagnostic Reference Levels for Dental Intraoral Radiography, *Radiation Protection Dosimetry, 156* (2013), 4, pp. 455-457

Received on March 6, 2024
Accepted on April 24, 2024

Зоран М. МИРКОВ, Небојша Т. МИЛОШЕВИЋ, Дарио ФАЈ

ПРЕДЛОЖЕНЕ ВРЕДНОСТИ ЗА ДИЈАГНОСТИЧКЕ РЕФЕРЕНТНЕ НИВОЕ У ИНТРАОРАЛНОЈ СТОМАТОЛОШКОЈ РАДИОЛОГИЈИ У СРБИЈИ

У Републици Србији успостављени су дијагностички референтни нивои за интраоралну стоматолошку радиографију. Дијагностички референтни нивои постављени су на основу мерења на 119 интраоралних рендген апарата у клиничким условима за рендгенске снимке задњег угриза одрасле особе. Вредности од 3.17 mGy, 3.11 mGy, и 1.58 mGy керме у ваздуху нађене су за филм рецептора слике Е класе, CCD сензор и фотостимулабилну фосфорну плочу, респективно. Слично, производ керме и површине пронађен је за исте детекторе, као 89.6 $mGycm^2$, 88 $mGycm^2$, и 44.6 $mGycm^2$. Све вредности веће су од оних утврђених у неколико других сличних студија. Ово посебно важи за CCD сензор рецепторе за слику јер ова технологија омогућава ниже дозе за пацијенте као што је раније објављено. Ово захтева хитну акцију за оптимизацију интраоралног снимања зуба, тако да представљамо коришћене радиографске технике и опис опреме како бисмо помогли у пружању смерница за даљу оптимизацију.

Кључне речи: дентална радиографија, заштита од зрачења, дијагностички референтни ниво