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Patient Protection in Dental Radiology: Influence of Exposure Time on Patient Dose*

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Abstract: This paper shows the results of dose assessment for dental radiographic procedures. Entrance surface doses for 5 different procedures were assessed. More than 15 hospitals, twenty X-ray units in total, were encompassed in this research. Patient doses were estimated based on results of X-ray tube output measurements. Finally, doses were compared with Reference levels. Higher dose values were observed for X-ray units with 50 kVp. In comparison with digital units, doses from other procedures are significantly higher.

Keywords: Dental radiology, Patient doses, Tube voltage, Exposure time.

1 Introduction

Dental radiography is one of the most valuable tools used in modern dental health care. It makes possible the detection of physical conditions that would otherwise be difficult to identify and its judicious use is of considerable benefit to the patient. However, the use of dental radiological procedures must be carefully managed, because x-rays can damage healthy cells and tissues [1]. In general, doses incurred during dental examinations are relatively low. However, dental radiology accounts for nearly 25% of the total number of radiological examinations in the European Union [2, 3]. Moreover, a large part of dental radiography is carried out on children and young adults, for whom the risk from exposure to x-rays is up to 3 times higher. In addition to that, many patients in general dental practice may be subjected to unnecessarily high radiation doses due to unsatisfactory equipment and outdated techniques [4]. The interest in dental radiology is therefore very high because of the large amount of equipment and the large number of persons exposed.

2 Methods

The investigation was performed during regular quality control in dental x-ray units in use in public and private sector in 2008. Data were collected in 15

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hospitals, with 20 x-ray units investigated in total. The units can be divided in 3 groups according to the nominal value of their tube voltage (50, 65 and 70 kV), while each group consisted of 5 units of the same manufacturer. The fourth group was made of digital x-ray units. According to the Serbian quality control protocol, x-ray equipment performances were analyzed in terms of: kVp accuracy, exposure time accuracy and reproducibility, and entrance surface dose reproducibility. Dental x-ray units do not offer the possibility to adjust either tube voltage or current; therefore only the exposure time is considered as a potential for reducing the patient dose. Human jaw normally consists of 32 teeth divided into incisors (1, 2), fangs (3), premolars (4, 5) and molars (6, 7 and 8). Depending on the region of interest that is exposed to x-rays, different exposure times are used. Moreover, the selected exposure time depends also on the person taking radiographs. Therefore the data of exposure techniques were collected in a conversation with the staff during quality control procedures. All measurements were carried out with a properly calibrated Barracuda dosimeter R-100 (RTI Electronics AB, Sweden).

Results of the quality control of the equipment covered in this survey are given in **Tables 1**, **2**, **3** and **4**. Most of the devices fully meet the criteria of acceptability according to the current standard. Although the acceptability limit for tube voltage is 10% deviation from the nominal value, this is considered too severe due to the lack of auto-transformer in the construction of dental X-ray unit, which could compensate variations of high voltage on the device caused by voltage drops in the power grid. Regarding the exposure time, the accepted criterion is 10 %. According to recent recommendations, the acceptability criterion of 20%, either for tube voltage or exposure time, are to be also applied [5, 6].

Table 1

Quality control results for x-ray unit type Dent Ei Nis, 50 kV, 10 mA.

x-ray unit	tube voltage nominal value [kV]	tube voltage measured value [kV]	deviation [%]	tube current [mA]	time [s]	measured time [s]	deviation [%]	ESD [mGy]
1	**50**	54.9	10	**10**	1	0.775	22	3.2
2	**50**	51.5	3	**10**	1	0.992	1	3.3
3	**50**	47.8	4	**10**	0.8	0.836	5	6.0
4	**50**	42	16	**10**	1	0.987	1	6.4
5	**50**	56.3	13	**10**	0.5	0.512	2	1.59

Table 2

Quality control results for x-ray unit type Oralix 65 Philips, 65 kV, 7.5 mA.

x-ray unit	tube voltage nominal value [kV]	tube voltage measured value [kV]	deviation [%]	tube current [mA]	time [s]	measured time [s]	deviation [%]	ESD [mGy]
1	**65**	67	3	**7.5**	0.54	0.54	0	2.0
2	**65**	64	2	**7.5**	0.2	0.139	30	0.76
3	**65**	70.4	8	**7.5**	0.64	0.648	1	2.2
4	**65**	63.4	2	**7.5**	0.8	0.8	0	1.8
5	**65**	71.5	10	**7.5**	0.5	0.532	6	2.0

Table 3

Quality control results for x-ray unit type Sirona Heliodent, 70 kV, 7 mA.

x-ray unit	tube voltage nominal value [kV]	tube voltage measured value [kV]	deviation [%]	tube current [mA]	time [s]	measured time [s]	deviation [%]	ESD [mGy]
1	**70**	73.8	5	**7**	0.5	0.508	2	0.59
2	**70**	73.4	5	**7**	0.5	0.512	2	0.79
3	**70**	63.56	9	**7**	0.5	0.444	11	2.6
4	**70**	78.9	13	**7**	1	0.972	3	2.0
5	**70**	74.8	7	**7**	0.5	0.5	0	0.47

Table 4

Quality control results for digital x-ray units.

x-ray unit	tube voltage nominal value [kV]	tube voltage measured value [kV]	deviation [%]	tube current [mA]	time [s]	measured time [s]	deviation [%]	ESD [mGy]
1	**60**	59.7	0	**7**	0.5	0.503	1	0.32
2	**70**	71.00	1	**7**	0.5	0.497	1	0.57
3	**70**	88.20	26	**7**	0.50	0.50	0	1.9
4	**65**	63.40	2	**7.5**	0.50	0.53	6	1.8
5	**70**	77.50	11	**7**	0.50	0.50	0	1.4

3 Results and Disscusion

The results of this investigation are presented in **Tables 5** and **6**. Values obtained differ by a factor of up to 10. Comparing x-ray units with nominal voltage of 50 kV with digital devices, the difference in exposure time is up to 10 times for each group of teeth, while the doses differ by up to 3 times. The minimum dose value is on digital units in the case of incisors, while the maximum value is on the x-ray devices with 50 kV nominal voltage value.

Table 5
Exposure times applied, for different regions of interest.

x-ray units	Exposure time [s]				
	Incisors	Fangs	Premolars	Molars	Molars (8)
	Mean value ± standard deviation (min – max)				
Dent Ei Niš (50 kV, 10 mA)	0.64 ± 0.04 (0.6 – 0.7)	0.64 ± 0.04 (0.6 - 0.7)	0.74 ± 0.08 (0.64 – 0.8)	0.88 ± 0.10 (0.8 – 1.0)	0.88 ± 0.10 (0.8 – 1.0)
Oralix 65 Philips (65 kV, 7.5 mA)	0.23 ± 0.07 (0.2 – 0.35)	0.26 ± 0.05 (0.2 – 0.3)	0.28 ± 0.04 (0.2 – 0.3)	0.36 ± 0.04 0.3 – 0.4	0.37 ± 0.04 (0.3 – 0.4)
Sirona Heliodent Vario (70 kV, 7 mA)	0.28 ± 0.09 (0.17 – 0.40)	0.32 ± 0.08 (0.25 – 0.40)	0.37 ± 0.8 (0.3 – 0.5)	0.47 ± 0.10 (0.4 – 0.63)	0.49 ± 0.09 (0.4 – 0.63)
Gendex Oralix AC (65 kV, 7.5 mA, digital)	0.06 ± 0.02 (0.04 – 0.08)	0.06 ± 0.02 (0.04 – 0.08)	0.06 ± 0.02 (0.04 – 0.08)	0.08 ± 0.01 (0.06 – 0.09)	0.08 ± 0.01 (0.06 – 0.09)

Table 6
Entrance surface doses for different regions of interest.

x-ray units	ESD [mGy]				
	Incisors	Fangs	Premolars	Molars	Molars (8)
	Mean value ± standard deviation (min – max)				
Dent Ei Niš (50 kV, 10 mA)	3.06 ± 0.99 (1.86 – 4.33)	3.06 ± 0.99 (1.86 – 4.33)	3.54 ± 1.26 (2.48 – 5.77)	4.14 ± 1.10 (3.11 – 5.77)	4.14 ± 1.10 (3.11 – 5.77)
Oralix 65 Philips (65 kV, 7.5 mA)	0.90 ± 0.58 (0.44 – 1.91)	0.96 ± 0.29 (0.44 – 1.13)	1.03 ± 0.39 (0.66 – 1.64)	1.31 ± 0.38 (0.88 – 1.91)	1.35 ± 0.39 (0.88 – 1.91)
Sirona Heliodent Vario (70 kV, 7 mA)	0.70 ± 0.69 (0.20 – 1.84)	0.83 ± 0.85 (0.24 – 2.30)	0.90 ± 0.84 (0.30 – 2.30)	1.13 ± 1.04 (0.38 – 2.87)	1.15 ± 1.03 (0.46 – 2.87)
Gendex Oralix AC (65 kV, 7.5 mA, digital)	0.16 ± 0.12 (0.03 – 0.27)	0.16 ± 0.12 (0.03 – 0.27)	0.16 ± 0.12 (0.04 – 0.27)	0.19 ± 0.13 (0.05 – 0.35)	0.19 ± 0.13 (0.05 – 0.35)

Bearing in mind that different groups of teeth need different exposure times for obtaining quality diagnostic information, the range of values observed in this investigation for each type of device is as expected. Doses on the devices with nominal voltage values of 65 and 70 kV are slightly different. According to the current Law on the use of sources of ionizing radiation in medicine [7], the reference value of ESD in intraoral dental radiology is 6 mGy. The values obtained in this paper are far below this threshold for all 4 types of devices. **Table 7** shows the Canadian reference values of ESD for intraoral examinations. Compared with those, the values obtained in this study in case of x-ray-device with nominal voltage of 50 kV are higher, and twice as high for the premolars and molars.

Table 7
Reference levels for ESD, *film speed* E [2].

voltage [kV]	ESD_{min} [mGy]	ESD_{max} [mGy]
50	1.92	2.44
65	1.27	1.66
70	1.09	1.44

4 Conclusion

Presented results show high doses on x-ray units with the nominal voltage value of 50 kV, and a wide range of doses for the same group of teeth and different values of kV. Possible causes of this can be the characteristics of x-ray device, inadequate film processing conditions and outdated techniques used. Regular quality control of dental x-ray units can eliminate deficiencies related to equipment. Inadequat technique is a more significant problem, because dentists and radiology technicians are insufficiently educated in the field of radiation protection. Efficient implementation of the basic principles of radiation protection, particularly that of practice optimization through the quality assurance program, is the only adequate way of reducing the patient dose while preserving the quality of diagnostic information. Therefore, further research should be directed towards the effective implementation of this program in dental x-ray cabinets in Serbia.

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