RESEARCH ARTICLE

Assessment of the radiological safety of a Genoray portable dental X-ray unit

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Objectives: The portable dental radiographic systems are generally used in emergency situations (e.g. during natural disasters) for disabled/aged patients and in patient rooms. This study assesses the output exposure of a portable dental radiographic system measured using thermoluminescent dosimeters (TLDs).

Methods: Occupational exposure of the operator was determined when the portable dental unit was used for mandibular and maxillary teeth exposure.

Results: The doses of some critical organs of an operator were measured using TLDs implanted within the Rando phantom.

Conclusions: Considering the annual organ dose limits, the eye lens dose limit is the main factor determining the frequency of system application.

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Introduction

There are different kinds of imaging systems used in dental radiography. The international guidelines on radiation protection define a distance of at least 2 m from the X-ray tube by the operators for stationary tubes.¹

The hand-held battery-operated radiographic systems have been introduced to dentists during the past decade. The portable dental radiographic systems have shown promising outcomes in forensic medicine, humanitarian missions, nursing homes and disabled patients. The operators should hold the unit during the exposure; thus, the occupational exposure risk of such devices may be increased. Few studies have been conducted on the radiation risk associated with portable exposing systems and most of them have been performed by manufacturers.²⁻⁴ Recently, an investigation on radiation

exposure with NOMAD™ portable radiographic system (Aribex Inc., Orem, UT) revealed that the risk is no greater than those of the national standard radiographic units (USA) for patients or operators, while the measured doses are well below the recommended levels.⁴

In this study, first, the isodose lines of the output of a Genoray model of a dental radiographic unit were measured using thermoluminescent dosimeters (TLDs). Second, based upon the International Commission on Radiological Protection (ICRP) criteria,^{5,6} occupational radiological quantities [*i.e.* $H_p(10)$, $H_p(3)$ and $H_p(0.07)$] as well as critical organ doses of the operator in the neck/head area were investigated when the unit was used for mandibular and maxillary teeth exposure.

Methods and materials

A Genoray PORT X II (Genoray, Seongnam City, Korea) portable dental radiographic system was assessed in this

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study.⁷ The exposures were performed at a high voltage of 60 kV with 2 mA current and a maximum total duration time of 2 s per shot.

In the first step, the output exposure was measured using 150 TLD pellets (GR-200 model) placed at different distances in front of the system. All the TLDs were exposed 20 times to increase the accuracy of measurements and then the accumulated thermoluminescence (TL) readings were divided by that number. The quantity of $H^*(10)$ (millisievert per shot) was measured in the experiment.

In the second part of the experiment, a male Rando phantom was used to simulate the operator body. A 30-cm diameter spherical polyethylene phantom on a slab cubic Plexiglas[®] ($30 \times 30 \times 15 \text{ cm}^3$) was applied to simulate the scattering rays of the upper part of the patient body. These tissue-equivalent spherical and slab phantoms simulate the head and trunk of a patient, respectively.

The maxillary and mandibular teeth of patients on the phantom were exposed with and without protective means (lead apron and thyroid shield) during the experiments. Figure 1 shows the experiment set-up of

the patient exposures along with the Rando phantom as the operator. The operator's hands/arms were assumed to be in a close position as much as possible, therefore the Genoray unit was placed near the operator's chest area in all the experiments.

The organ doses in the Rando phantom were measured by at least three TLDs in each organ and type GR-200 pellets already implanted in the phantom. For finger dosimetry, TLDs were placed on the surfaces of two 20-mm rod phantoms at the sides of the unit (hand position of the operator on the unit).

The patient phantom along with the TLDs was exposed by 90 shots in each experiment to increase the accuracy of measurements. Hence, the accumulated readings of TLDs had to be divided by the value to obtain the final results in terms of dose per shot (*e.g.* millisievert per shot). The exposed TLDs were annealed and measured by a Harshaw TLD[™] (Thermo Fisher Scientific, Waltham, MA) reader system.

The mean organ equivalent doses were calculated using Equation (1):^{8,9}

$$\bar{H}_T = \frac{\sum TL_n \times ECC_n}{n} \times CF \times \frac{RL_0}{RL} \times \frac{\left(\frac{\mu_{en}}{\rho}\right)_{\text{Tissue}}}{\left(\frac{\mu_{en}}{\rho}\right)_{\text{Air}}} \quad (1)$$

where TL is the TLD pellet reading value, ECC is the element correction coefficient of each pellet, CF is the conversion factor, n is the number of implanted pellets at each organ, RL is the reference light values of TLD reader and μ_{en}/ρ is the mass energy absorption coefficient at an effective energy of 60 kV of X-ray tube. The operational quantities of $H_p(10)$, $H_p(3)$ and $H_p(0.07)$ were measured to estimate the whole body effective dose, and eye lens and finger doses of the operator, respectively.

Results

Figure 2 shows the isodose lines of the output system obtained by means of TLDs. The output dose of the system has a conical shape, which approximately follows the distance inverse square law (*i.e.* isodose lines of A–D), and is compatible with the shape of the output reported by the manufacturer.⁷ The doses outside the conical main beam (*e.g.* E–G lines) are owing to the main beam scattering from the air that have significantly smaller values in comparison with that of the main beam. Moreover, the dose values at the back and sides of the unit (*i.e.* the tails of isodose lines “F” and “G” where the fingers of the operator may be exposed) are generally negligible. That is, the shielding of the housing tube designed by the manufacturer completely protects the operator against the leakage radiation in X-rays.

The results of the organ doses of the operator in various exposure conditions are presented in Table 1.

Figure 1 Configuration of experiments in the assessment of occupational exposures with and without shields by a Genoray portable radiographic unit: (a) exposure of mandibular teeth and (b) exposure of maxillary teeth.

Figure 2 Isodose output lines of a Genoray portable radiographic unit (in millisievert per shot): A, 4.82; B, 2.61; C, 1.30; D, 0.96; E, 0.06; F, 0.015; G, 0.008; H, 0.005.

Discussion

The measured values in Table 1 show the scatterings from the head/neck/body of the patient that have the most contribution in the organ dose of the operator in such a system.

The fingers of the operator are directly exposed only to similar scattering rays from the spherical head phantom. Thus, it is expected to obtain the same finger dose values from both mandibular and maxillary exposures.

Table 2 Maximum number of shots per year (N_y) values that can be used by an operator of a Genoray portable dental unit

Organ	ICRP reference	
	ICRP-60	ICRP-118
Whole body (maxillary teeth)	210	210
Fingers	357	357
Eye lenses (maxillary teeth)	1350	180

ICRP, International Commission on Radiological Protection.

Since the positions of the other organs of the operator are farther from the scattering areas of the patient, the different scattering solid angles lead to different organ doses for the operator.

The ICRP-60 recommends an annual dose limit of 20 mSv (averaged over 5 years) owing to the occupational exposure of the whole body, 500 mSv for hand dose and 150 mSv for the eye lenses.⁵

Recently, the ICRP recommends an annual dose limit of 20 mSv for the eye lenses of the operators.⁶

The total dose was measured to be 95 μ Sv per shot in a closed hand/arm situation of the operator when maxillary teeth of the patient were exposed. Also, eye lenses and finger doses were measured as 0.111 and 1.410 mSv per shot, respectively.

The maximum number of shots per year, N_y , can be calculated as follows:

$$N_y = \frac{H_{\max}}{H_T} \quad (2)$$

where $H_{\max}$ is the related recommended annual dose limit and H_T is the value from Table 1, which has been calculated from Equation (1).

The calculated maximum N_y values for the whole body, fingers and eye lenses are presented in Table 2 with the assumption of ICRP dose recommendations. Thus, the new dose limit may refer to the main restriction of applying the system to the eye lens doses (*i.e.* 180 shots per year). N_y values may be increased by decreasing exposure times to

Table 1 The measured values of organ doses (in microsievert or microgray per shot) in two different kinds of examinations (the dose values are the mean values of the thermoluminescent dosimeters in each organ with related standard deviations)

Organ dose of operator	Exposed area of patient	Type of cover	
		Without lead shields	With lead shields (apron/thyroid shields)
Whole body	Maxillary teeth	95 (± 14)	0.154 (± 0.020)
	Mandibular teeth	28 (± 9)	0.086 (± 0.014)
Fingers	Maxillary teeth	1410 (± 200)	
	Mandibular teeth		
Eye lenses	Maxillary teeth	111 (± 6.2)	
	Mandibular teeth	19 (± 2)	
Thyroid gland	Maxillary teeth	53 (± 3)	0.26 (± 0.03)
	Mandibular teeth	10 (± 0.6)	0.12 (± 0.02)
Salivary gland	Maxillary teeth	46 (± 7.3)	
	Mandibular teeth	6 (± 1.5)	
Parathyroid gland	Maxillary teeth	8 (± 1.1)	Negligible
	Mandibular teeth	2 (± 0.2)	Negligible
Cheekbone	Maxillary teeth	5 (± 1)	
	Mandibular teeth	1 (± 0.3)	
Gonads	Maxillary teeth	2.7 (± 2)	Negligible
	Mandibular teeth	2 (± 1)	Negligible

less than 2 s. Also, the dose values in Table 1 show that the use of shields, lead apron or thyroid shield (and possibly lead eye glass) may significantly decrease the operator dose values and consequently increase the related N_y values.

Conclusion

This study determined the output exposure of a Genoray portable dental radiographic unit. Also, the occupational exposure of the system under mandibular and maxillary bone exposure was determined. Shielding of the housing tube completely protects the operator against the leakage radiation in X-rays. However, the operator can be highly

exposed by the back-scattered radiations from the patient during the imaging process.

The frequency of application of the system is limited by the workload, averaged exposure duration and annual dose limit of the eye lens. Total effective dose as well as organ doses in the neck area can be reduced using shield devices such as lead aprons or thyroid shields.

Considering critical organs and total effective doses, our findings show that the portable dental radiographic unit is a safe device for operators. However, according to the as low as reasonably achievable principles, as well as the objectives of portable dental radiographic systems, the efficacy of them should be evaluated against the stationary dental radiographic units.

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