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Measurements of radiation exposure of dentistry students during their radiological training using thermoluminescent dosimetry

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HIGHLIGHTS

- Dose of training dentistry students was estimated with LiF:Mg,Cu,P+PTFE dosimeters.
- The average effective dose of students in the role of patient was also estimated.
- The sum of organ doses from TL measurements is considered as the whole body dose.
- The uncertainty in the results was less than 2%.

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ABSTRACT

Exposure among dentistry students has not been assessed or regulated in Mexico. This work assessed the average exposure of 35 dentistry students during their training with the aid of LiF:Mg,Cu,P+PTFE thermoluminescent dosimeters. For the students in the roles of dentist and observers, maximum accumulated equivalent dose obtained was 2.59 ± 0.11 and 4.64 ± 0.39 mSv, respectively. Students in the role as patients received a maximum accumulated effective dose of 28.41 ± 0.31 mSv. If compared to occupational dose limits, this latter value is 56% of the recommended value of 50 mSv in any year. It was found that in all cases, values of equivalent dose to the women breasts were equal to the background dose. Results are discussed and compared to previous published work. Suggested recommendations were given to authorities in order to minimize exposure of the students in the role as patients.

1. Introduction

Medicine is among the main application areas related to the peaceful uses of ionizing radiation, however, it represents the second major source of human exposure to radiation, after the environmental radiation. For this reason, radiation dosimetry is a fundamental need in medical applications of radiation. Thermoluminiscence dosimetry (TLD) has proved to be a very important tool in clinical, personal and environmental monitoring of ionizing radiation.

The dentist's daily activity is related to the use of X-rays for intra-oral and panoramic radiographies, both the patient's and dentist's protection are considered on the ICRP recommendations (ICRP, 1991, 2007, 2007b). The dentist's responsibility regarding radiation protection comprehends minimizing the patient's exposure and his/her own by implementing optimal operating procedures, equipment performances and facility designs. An overview on diagnostic reference levels (Vassileva and Rehani, 2015) has been published recently. This article makes emphasis on the variation of radiation dose imparted to patient undergoing radiological examinations in different hospitals, both in studies performed in the United Kingdom and in different parts of the world (Muhogora et al., 2008; European Commission, 1999; Shrimpton et al., 1991; ICRP, 1996). Variations by a factor of 20 or more have been reported in the United Kingdom, and these were even higher in European surveys performed in 1987–88 and 1991 (European Commission, 1999). National reference doses for some common

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radiographic examinations were first suggested for the United Kingdom in 1989(NRPB, 1990).

The International Commission on Radiologic Protection (ICRP) introduced diagnostic reference levels in 1990 (ICRP,1991) and further developed the concept in publication 73, ICRP Supporting Guidance 2 and ICRP publications 103 and 105 (ICRP, 1996, 2001, 2007, 2007b); specifically, ICRP defines a diagnostic reference level as “a form of investigation level, applied to an easily measured quantity, usually the absorbed dose in air, or in a tissue-equivalent material at the surface of a simple standard phantom or representative patient”.

In particular, in dentistry training, the use of X-rays poses a physical risk that would become greater when not recognized as such. In this scenario, at a professional level and because of the prominence of the dentist's private practice, the professional would not be provided with the appropriate protection and the exposure would continue indefinitely. Several publications provide information related to patient dose measurements in dental radiology (Kaugars et al., 1985; Price, 1986; Adams, 1988; Maccia, et al., 1988; Goren, et al. 1989; Carvalho et al., 1992; Bohay et al., 1994; Lecomber and Faulkner, 1998; Yakoumakis et al., 1998; González et al., 2001; Ogundare et al., 2002; Pauwels et al., 2012), however, there are few reports of dose measurements in students involved in radiological training, where in many cases, the students play three roles; dentist, observer and patient.

There is little information about students' exposure and their possible risks, especially in developing countries where labor protection measures do not cover students. Substitute procedures on the patients' roles called ‘simulators’ or ‘phantoms’ have been introduced for some decades with the purpose of avoiding unnecessary exposure among students (Jameson and Alcox, 1968). However, their current use is far from being general in developing countries. In 1986 there were still educational institutions in the USA that did not work with the new resources (Farman and Hines, 1986). In this paper the values of equivalent dose that students in the role of dentist and observer would receive as well as the effective dose that students in the role of patient would receive were estimated from TLD measurements.

The aim of this study was to establish the magnitude of the doses received by dentistry students in order to prevent possible future radiological risks by suggesting the introduction of new practices and subjects in radiological training.

For clarity and completeness a brief account of the relevant quantities “Equivalent dose” and “Effective dose” (ICRP, 1991; Hughes, 1991, ICRP, 2007) is presented:

The equivalent dose, $H_{T,R}$, in an organ or tissue, T, due to a given type of radiation, R, is given by Eq. (1):

$$H_{T,R} = w_R D_{T,R} \quad (1)$$

Where: w_R is the radiation weighting factor and $D_{T,R}$ is the average absorbed dose in the organ or tissue, T, from radiation, R.

The effective dose is a measure of the combined effect on the body of the doses to several different organs or tissues in the body. The relationship between the probability of a stochastic effect and the equivalent dose received varies with the organ or tissue irradiated. The equivalent dose is therefore modified by the tissue weighting factor w_T, dependent on the organ or tissue irradiated. It is not dependent on the energy of radiation.

The effective dose, E, is a doubly weighted average absorbed dose Eq. (2):

$$E = \sum_T w_T H_T = \sum_T w_T \sum_R w_R D_{T,R} \quad (2)$$

where: w_T is the tissue or organ weighting factor; w_R is the radiation weighting factor and $D_{T,R}$ is the average absorbed dose in the organ or tissue, T, from radiation, R.

The Unit for equivalent dose and effective dose is the Sievert (Sv).

2. Materials and methods

2.1. X-ray equipment

A 50 kV voltage X-ray source with a 1.5 mm Al window from the Equipment Trophy Trex ETX Dental X-Ray & Electronic, Timer Controller Type 1R1X70E was used by the students during their training. An effective energy equal to 24 keV was obtained with the aid of the absorption coefficient tables for Al and W from the National Institute of Standards and Technology (NIST) (Hubbell and Seltzer, 1995).

2.2. TL measurements and radiation dose

The measurement of radiation dose was performed using high sensitivity LiF:Mg,Cu,P+PTFE TL dosimeters developed at Instituto Nacional de Investigaciones Nucleares (ININ), México (González et al., 2007). These detectors have been characterized and optimized delivering a TL signal 25–35 times greater than that of TLD-100 (Thermofisher Scientific, Inc.). Their relative X-ray to ^{137}Cs gamma TL response was measured leading to a correction factor of 0.95 for 24 keV X-rays (González et al., 2007) necessary to estimate the correct dose. See Fig. 1.

The LiF:Mg,Cu,P+PTFE TL dosimeters are 5 mm diameter discs of 0.6 mm thickness with an average TL mass equal to 8.0 ± 0.4 mg. Before any irradiation, TL dosimeters were annealed at 240 °C during 10 min, followed by a second annealing at 100 °C during 2 h. Calibration measurements were performed exposing the thermally treated dosimeters to gamma radiation from a JL Shepherd and Associates, Mod. 28–6B ^{137}Cs (E=662 keV) Irradiator, property of “Comisión Nacional de Seguridad Nuclear y Salvaguardas (CNSNS)”, México; at a dose rate of 2.5 mGy/h. Three dosimeters were exposed at a 1 m distance from the source for each calibration dose in the range from 0.05 to 10 mGy. The precise dose values were previously verified with the aid of an ionization chamber.

The irradiated TLD's (both under gamma and dental X-ray shots) were read out using a 4000 Harshaw TL reader. The TL signal was digitalized by a RC232C interface and integrated from

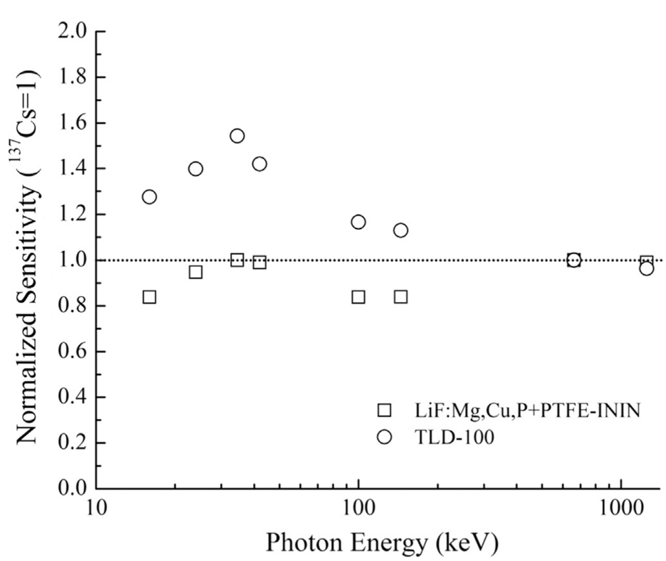

Fig. 1. Normalized (to ^{137}Cs) sensitivities of TL phosphors as a function of photon energy.