Dose measurements in intraoral radiography using thermoluminescent dosimeters

C Azorin¹, J Azorin², F Aguirre² and T Rivera¹
¹Centro de Investigación en Ciencia Aplicada y Tecnología Avanzada-Legaria Instituto Politécnico Nacional, México, D.F., México
²Università Autónoma Metropolitana-Iztapalapa, México, D.F., México
E-mail: cazorin@ipn.mx

Abstract. The use of X-ray in medicine demands to expose the patient and the professional to the lowest radiation doses available in agreement with ALARA philosophy. The reference level for intraoral dental radiography is 7 mGy and, in Mexico, a number of examinations of this type are performed annually. It is considered that approximately 25% of all the X-rays examinations carried out in our country correspond to intraoral radiographies. In other hand, most of the intraoral X-ray equipment correspond to conventional radiological systems using film, which are developed as much manual as automatically.

In this work the results of determining the doses received by the patients in intraoral radiological examinations made with different radiological systems using LiF:Mg,Cu,P+PTFE thermoluminescent dosimeters are presented.

In some conventional radiological systems using film, when films are developed manual or automatically, incident kerma up to 10.61 ± 0.74 mGv were determined. These values exceed that reference level suggested by the IAEA and in the Mexican standards for intraoral examinations.

1. Introduction

Medical applications represent the most important source of population exposure to radiation; among these, dental radiology is the most common radiological examination type used in industrialized countries¹, being intraoral radiography one of the X ray examinations most used in human beings². One of the techniques used in intraoral radiography is periapical radiography.

The intraoral radiography is an exploratory technique that consists in placing within the mouth of the patient radiography films of different sizes that are exposed from the outside by a X-ray machine. Intraoral periapical radiography serves to explore two to four teeth, from the crown to the apex, the periodontal space and the surrounding bone tissue.

The measurement of the dose received by patients is considered as an important factor in the quality control in medical radiology, so it is important to expose the patient to radiation doses as low as possible, according to the ALARA principle. One of the most important parameters in diagnostic radiology is the surface entrance dose³, so it is important to determine the entrance dose received by patients in intraoral radiographic examinations performed with different imaging systems.
The reference level for a periapical dental radiography proposed by the International Atomic Energy Agency (IAEA) and adopted by Mexico in the Mexican Official Standard NOM-229-SSA1-2002, is 7 mGy. In Mexico, a lot of annual examinations of this type are performed, it is estimated that approximately 25% of all radiographs made in our country are for intraoral radiographs. In addition to most dental radiography systems correspond to conventional periapical radiographic film systems whose development is done either manually or automatically.

The entrance surface dose (ESD) is a measure of the dose absorbed by the skin at the point of entrance of the X-ray beam. The ESD may be determined directly or indirectly due to that is proportional to factors such as the current, the exposure time the kilovoltage, the filtration and the beam collimation; This determination could be made by direct measurement using thermoluminescent dosimeters (TLD) or ionization chambers or calculated indirectly. The method recommended for measuring entrance dose is thermoluminescent dosimetry due to the specific characteristics of this type of dosimeters.

1. Materials and methods

The study was performed on 60 patients in several dental radiology installations of the city of Leon, Guanajuato, Mexico. Twelve X-ray dental systems of different brands were considered, setting the voltage and current in the range of 60 to 70 kVp and 5 to 10 mA respectively. The exposure time was varied between 0.2 and 0.5 s for lower right first premolar and left first molar respectively with a total filtration of 2 mm Al. All patients were studied only during their prescribed examinations, so they were not submitted to any extra examination or any unnecessary exposure to radiation.

The dosimetric control was performed on dental patients previously having their informed consent. Thermoluminescent dosimeters (TLD) of LiF:Mg,Cu,P + PTFE of national manufacturing were used. These TLDs were wrapped and sealed in black plastic previously cleansed with alcohol. The DTLs were placed in the center of the radiation beam on the skin of the patient without interfering with the image. For each measurements were used three DTLs by taking the average of the dose measured by each of these three dosimeters. TLDs were read at the end of the workday using a Harshaw 3500 TL reader; subsequently they were thermally erased to be reused subsequently.

The preparation method of the LiF:Mg,Cu,P + PTFE has been described in the previous work. The characterization of the TLDs was performed as follows: from a batch of 500 TLDs, those showing linearity in the dose range 1 to 10 mGy and repeatability of ± 5% were selected. For calibration of the dosimeters a 55 keV X-ray beam was used. Average absorbed dose was checked with an ionization chamber within a standard deviation of 2%. The thermoluminescent response of the dosimeters was converted to air kerma using the calibration equation as in (1) and subsequently to dose equivalent by applying the appropriate weighting factor which in this case is equal to the unit due that radiation are X-rays. Calibration curve obtained was the following:

\[ D(\text{mGy}) = 49.15L - 29.231 \]  

Where L is the readout in nC.

2. Results

This study included a total of 60 adult patients (33 women and 27 men). Table 1 summarizes the basic information about patients and exposure parameters. The average age of the patients was 36.9 ± 0.5 years being statistically significant the difference between the ages of women and men. The purpose of the examinations was: periapical diagnosis 45%, treatment 28%, surgery 15% and other reasons 12%. The average exposure time was 0.303 s without statistical significance between exposure times for men and women.
Table 1. Basic information about patient age, purpose of the examination and exposure time.

| Basic information | Women (N = 33) | Men (N = 27) | Total (N = 60) |
|-------------------|----------------|--------------|---------------|
| Age (years)       | 36.7 ± 0.5     | 37.2 ± 0.5   | 36.9 ± 0.5    |
| purpose of the examination |                |              |               |
| a) Diagnosis      | 25%            | 20%          | 45%           |
| b) Treatment      | 15%            | 13%          | 28%           |
| c) Surgery        | 8%             | 7%           | 15%           |
| d) Other          | 7%             | 5%           | 12%           |
| Exposure time (s) | 0.293 ± 0.118  | 0.314 ± 0.116| 0.303 ± 0.121 |

Table 2 shows the values obtained for the incident air kerma measured at the center of the beam in periapical radiography examinations. The average kerma for radiography of molar teeth was 6.1 ± 1.3 mGy. The highest kerma values obtained were 10.6 ± 0.8 mGy and 9.2 ± 1.4 mGy for first molar teeth right and left respectively. While the lowest kerma value (3.2 ± 0.9 mGy) was measured for the upper right first premolar.

Table 2. Incident kerma values measured at the center of the beam in periapical radiography examinations.

| Average value of the surface incident kerma (mGy) | Women (N = 33) | Men (N = 27) | Average |
|-------------------------------------------------|----------------|--------------|---------|
| a) Pre-molar                                    | 5.7 ± 1.0      | 5.7 ± 1.1    | 5.7 ± 1.1 |
| b) Molar                                        | 6.3 ± 1.4      | 6.5 ± 1.5    | 6.4 ± 1.5 |
| c) Incisor                                      | 6.0 ± 1.3      | 6.1 ± 1.9    | 6.1 ± 1.3 |

3. Discussion
Cases where kerma values higher than the reference level (7 mGy) were obtained, may be due that these X rays systems are short cone in which the focus-skin distance is 5.0 cm, obtaining dispersion higher than that obtained in the long cone X ray equipment and also due that some dental installations does not have a Quality Assurance Program.

TLD-100 were used for dental dosimetry because they fulfill with the characteristics of a good dosimeter for this purpose: small size, tissue equivalence, independence of radiation energy.

It is recommended to make known these results to dentists for creating awareness about the fact that they there should not be indiscriminate use of X-rays and they must have a quality assurance program.

For further studies, we suggest taking into account the physical characteristics of the patient, such as thickness of the cheek, and molar size, in order to relate with the factor causing of the increase the dose in molar radiography.
4. Conclusions
The results of this study show that exposure of patients undergoing periapical examinations, on average, do not exceed the dose reference levels specified in the standard (7 mGy); however, in some cases if these levels (10.6 ± 0.7 mGy and 9.2 ± 1.4 mGy) for right and left first molar teeth respectively these levels were exceeded.

It was learned that it is necessary to do quality control to those X-ray systems that exceeded the limit.

Results obtained are useful and important to propose modifications to the standard (NOM-229-SSA1-2002) to include periapical dental X-ray equipment, due to that this standard currently only takes into account to the dental panoramic systems.

5. References
[1] Horner K 1994 Radiation protection in dental radiology. British Journal of Radiology 67 1041-1049
[2] Kalinowski P, Kalinowski P, Rozylo-Kalinowska I, Rozylo T K 2001 Demographic structure of patients taking dental X-rays in the Lublin region. Annals of University Mariae Curie Sklodowska [Med.] 56 431-435
[3] Williams J R and Montgomery A 2000 Measurement of dose in panoramic dental radiodiology. British Journal of Radiology; 73 1002-1006
[4] González L, Vano E, Fernández R 2001 Reference doses in dental radiodiagnostic facilities. British Journal of Radiology 74 153-156
[5] NORMA Oficial Mexicana NOM-229-SSA1-2002 Salud ambiental. Requisitos técnicos para las instalaciones, responsabilidades sanitarias, especificaciones técnicas para los equipos y protección radiológica en establecimientos. Diario Oficial de la Federación, septiembre de 2006
[6] Azorín J. 1990 Luminescence Dosimetry. Theory and Applications. Ediciones Técnico-Científicas. México, D.F.
[7] González P R, Quiroz M C, Azorín J, Furetta C and Ávila O 2005 Improvement in the preparation method of LiF:Mg,Cu,P thermoluminescent phosphor. Journal of Applied Science 5(8) 1408-1411
[8] Azorín J, Furetta C and Scacco A 1993 Preparation and properties of thermoluminescent materials. Physica Status Solidi A. 138(1) 9-47