Response evaluation of $CaSO_4$:Dy; LiF:Mg,Ti and LiF:Mg,Ti microdosimeters using liquid water phantom for clinical photon beams dosimetry

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Abstract. In the area of clinical dosimetry, an efficient and accurate calibration of the radiation beam ensures knowledge of the radiation dose delivered to the patient, allowing thus the success of radiotherapy. This study aimed to evaluate the thermoluminescent (TL) response of $CaSO_4$:Dy produced by IPEN and LiF:Mg,Ti and LiF:Mg,Ti microdosimeters produced by Harshaw Chemical Company to be applied in clinical photon beams (6 and 15 MV) dosimetry using liquid water phantom. Initially, the dose-response curves were obtained for irradiation with cobalt-60 gamma radiation source in air (PMMA plates) and under electronic equilibrium conditions and for clinical photons beams of the Clinac model 2100C accelerators from the two hospitals evaluated: Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo and Hospital Albert Einstein. The TL sensitivities of the dosimeters were also evaluated and the values of their reproducibilities were determined for the response to different energies of radiation.

1 Introduction

The quality control in radiation therapy techniques includes procedures that ensure consistent and safe performance of the dose prescription to the target volume with minimal dose to normal tissues and for workers involved in the process [1]. A quality assurance program is necessary because of the importance of precision of the dose distribution in radiation therapy. In some cases, the isodose curve in radiation therapy is quite steep, therefore, there is evidence that a change in dose from 7 to 10% can be crucial in the probability of tumor control [1].

Thermoluminescent dosimetry (TLD) features many advantages such as small detector size and close tissue equivalence that make it useful for a variety of applications in medicine. The technique has matured and plays an important role in routine clinical dosimetry. Its importance is illustrated for example in a "radiotherapy patterns of care" study by Smith et al who investigated treatment planning in the United States. It was found that 90% of all academic institutions and 50% of other hospitals used TLD for *in vivo* dosimetry [2].

The two main objectives of dosimetry in a clinical environment are typically radiation protection (patients and clinical staff) and quality assurance. It is essential to assess radiation doses to patients in medical procedures to estimate the risk associated with the exposure. In radiotherapy the aim of dosimetry is to make sure that the dose to the target volume is as prescribed while minimising the dose to the surrounding normal tissue.

This study aimed to evaluate the thermoluminescent response of calcium sulphate doped with dysprosium ($CaSO_4$:Dy) dosimeters produced by IPEN and LiF:Mg,Ti and LiF:Mg,Ti microdosimeters produced by Harshaw Chemical Company in clinical electron beams (6 and 9 MeV) dosimetry using liquid water phantom. Initially, the dose-response curves were obtained for irradiation with cobalt-60 gamma radiation source in air (PMMA plates) and under electronic equilibrium conditions and for clinical electron beams of the Clinac model 2100C accelerators from Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo (HC-FMUSP) and Sociedade Beneficente Israelita Brasileira – Hospital Albert Einstein (HAE). The sensitivities of the dosimeters were also evaluated and the values of their reproducibilities were determined for the response to different energies of radiation.

2 Materials and Methods

2.1 Dosimetric TL materials

- 200 $CaSO_4$:Dy thermoluminescent dosimeters (TLDs) produced by IPEN;
- 200 LiF:Mg,Ti (TLD-100) produced by *Harshaw Chemical Company*;
- 105 microLiF:Mg,Ti (TLD-100) produced by *Harshaw Chemical Company*.

2.2 Irradiation systems

- ^{60}Co gamma source from Laboratory of Dosimetric Materials/IPEN (A=0,953 GBq on 11/11/2009).
- Linear accelerators *VARIAN* model Clinac 2100C from Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo (HC-FMUSP) and Hospital Albert Einstein (HAE).

2.3 Equipments

- Cubic liquid water Phantom 30 x 30 x 30 cm^3 filled with distilled water;
- Furnace *Vulcan* model 3-550 PD;
- Surgical heater *Fanem* modelo 315-IEA 11200;
- TL Reader *Harshaw* model 3500.

2.4 Dose-response curves to ^{60}Co gamma radiation

The pre-irradiation heat treatments used were:

- $CaSO_4$:Dy - 300ºC/3 h;
- LiF:Mg,Ti and LiF:Mg,Ti microdosimeters - 400ºC/1 h + 100ºC/2 h.

The dose-response curves to ^{60}Co gamma radiation were obtained in air and under electronic equilibrium conditions (PMMA plates). After TL responses evaluation the dosimeters were selected and divided in the groups according to their sensitivities (± 5%) and was obtained dose-response curve for ^{60}Co gamma radiation. To protect the dosimeters irradiated in the liquid water phantom it were packed in plastic films and positioned at depth of maximum dose.

For irradiations in clinical photon beams the TLDs selected were positioned at depths of maximum dose and irradiated in photon beams (6 and 15 MV) of the two hospitals evaluated: HC-FMUSP and HAE. The specifications followed for irradiation parameters were that recommended by the Technical Reports Series No. 398 (TRS 398) from International Atomic Energy Agency (IAEA): field size - 10 x 10 cm^2; TLDs-source distance - 100 cm. The depths of maximum dose for TLDs irradiation are presented in Table 1.

Table 1: Depth of maximum dose (cm) used for the TLDs irradiation.

Radiation beam		**Depth of maximum dose (cm)**	
		HC-FMUSP	**HAE**
Photon	6 MV	1,5	1,5
	15 MV	2,9	2,8

2.5 TL readings

To obtain the dose-response curves for ^{60}Co gamma radiation the TLDs were irradiated with the following doses: 0.5, 1, 10, 50, 100 and 500 mGy and 1, 5 and 10 Gy. The TL responses were evaluated and the dose-response curves of each dosimeter type and its individual sensitivities were obtained to 6 and 15 MV radiation doses: 0.1, 0.5, 1.0; 5.0 and 10.0 Gy. Each presented value represents the average of 10 TL responses and the error bars the standard deviation of the mean (1σ) with a confidence interval of 95%.

3 Results

Figures 1, 2 and 3 show the dose-response curves of the three types of TLDs to ^{60}Co gamma radiation in air and under electronic equilibrium conditions. Figures 4, 5 and 6 show the dose-response curves for clinical photon beams (6 and 15 MV), respectively.

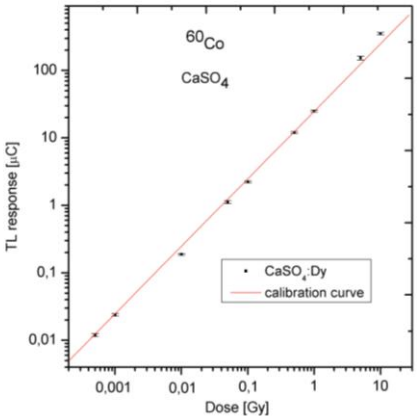

Fig. 1. Dose-response curve of $CaSO_4$:Dy to ^{60}Co gamma radiation in air and under electronic equilibrium conditions

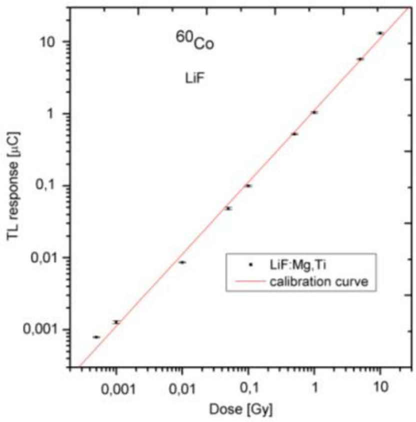

Fig. 2. Dose-response curve of LiF:Mg,Ti to ^{60}Co gamma radiation in air and under electronic equilibrium conditions

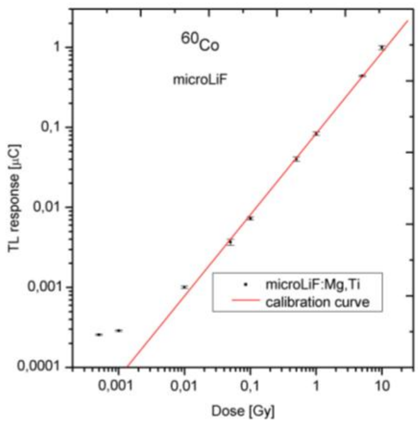

Fig. 3. Dose-response curve of LiF:Mg,Ti microdosimeters to ^{60}Co gamma radiation in air and under electronic equilibrium conditions

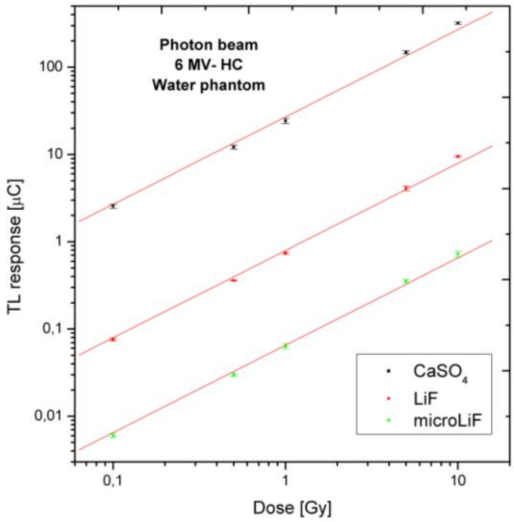

Fig. 4. Dose-response curve of $CaSO_4$:Dy, LiF:Mg,Ti and LiF:Mg,Ti microdosimeters to 6 MV photon beam using liquid water phantom for irradiation in the HC-FMUSP

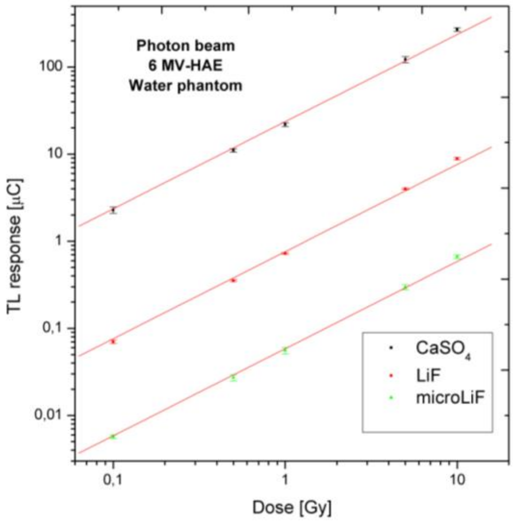

Fig. 5. Dose-response curve of $CaSO_4$:Dy, LiF:Mg,Ti and LiF:Mg,Ti microdosimeters to 6 MV photon beam using liquid water phantom for irradiation in the HAE

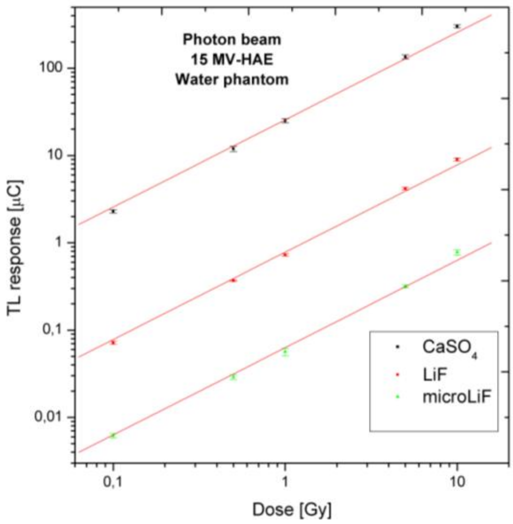

Fig. 6. Dose-response curve of $CaSO_4$:Dy, LiF:Mg,Ti and LiF:Mg,Ti microdosimeters to 15 MV photon beam using liquid water phantom for irradiation in the HAE

The dose-response curves to photon beams (6 and 15 MV) of the studied materials present linear behavior for absorbed doses up to 10 Gy, indicating a tendency to supralinearity for doses higher than 10 Gy.

Figures 7, 8 and 9 show the average sensitivity of the three types of TLDs according to the dose and Hospital irradiation.

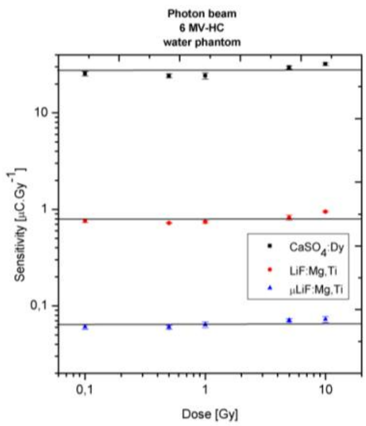

Fig. 7. Average sensitivity of the TLDs to 6 MV photons using a liquid water phantom for irradiation in the HC-FMUSP

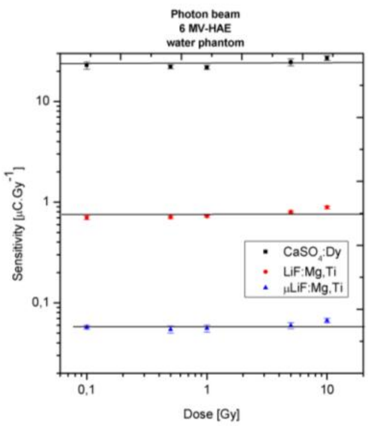

Fig. 8. Average sensitivity of the TLDs to 6 MV photons using a liquid water phantom for irradiation in the HAE

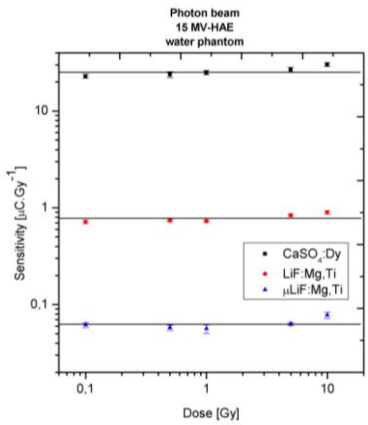

Fig. 9. Average sensitivity of the TLDs to 15 MV photons using a liquid water phantom for irradiation in the HAE

Analyzing the TL sensitivities can be observed that the $CaSO_4$:Dy dosimeters present TL sensitivity approximately 28 and 334 times higher than LiF:Mg,Ti and microLiF:Mg,Ti dosimeters, respectively. The analysis of Fig. 9 confirms the tendency of supralinear behavior for doses higher than 10 Gy.

The values of the reproducibility of TL response calculated according to the hospitals evaluated and the energy of the radiation beam are shown in Table 2.

Table 2: Average reproducibilities of the TL response of dosimeters.

Hospital	Photon beam	$CaSO_4$:Dy	LiF:Mg,Ti	microLiF:Mg,Ti
HC-FMUSP	6 MV	4,34	1,21	2,23
HAE	6 MV	1,67	1,18	2,57
	15 MV	0,653	0,872	2,37

The TL response reproducibility varies from 0.653 to 4.34% for photon beams (6 and 15 MV) and liquid water phantom.

4 Conclusions

The dose-response curves obtained for the irradiation of the TLDs to ^{60}Co source and to clinical photon beams (6 and 15 MV) presented linear behavior over the dose range studied (0.1 to 10 Gy).

The average TL sensitivity calculated for each dose shows little variation, mainly for the two varieties of LiF: Mg, Ti. For doses higher than 5 Gy was observed the beginning of the supralinearity behavior.

The TLD of $CaSO_4$:Dy showed a greater variation in average sensitivity, a result that was expected because the thermoluminescence is an effect dependent on the mass and area of the dosimeter and also by a sensitivity higher than the other dosimeters.

Analyzing the TL sensitivities can also conclude that the three types of TLDs showed no energy dependence in the energy range studied.

The TL response reproducibility is better than ± 4.34% for both 6 and 15 MV in accordance with the references found in literature [6, 7].

The results indicate that TLDs of CaSO4:Dy can be used in photon dosimetry applied to radiotherapy using liquid water phantom.

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