Comparative study of different phantoms in 12 MeV clinical electron beam dosimetry

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Abstract

This paper aims to compare the thermoluminescent response of LiF:Mg,Ti microdosimeters and $CaSO_4$:Dy dosimeters for PMMA, solid water and liquid water phantoms, irradiated in 12 MeV clinical electron beam. Regarding the dose-response curves, there were no significant differences in the response of both dosimeters for three different phantoms. The LiF:Mg,Ti microdosimeters reproducibility ranged from 1.9% to the liquid water and solid water phantoms and 2.4% to the PMMA phantom. The $CaSO_4$:Dy dosimeters reproducibility ranged from 0,66% to the liquid water, 0,67% to the solid water and 1,6% to PMMA phantom. The intrinsic efficiency obtained for the LiF:Mg,Ti microdosimeters was 0.056±0.006 $\mu C.Gy^{-1}.mg^{-1}$, 0.058±0.006 $\mu C.Gy^{-1}.mg^{-1}$ e 0.061±0.006 $\mu C.Gy^{-1}.mg^{-1}$ for solid water, PMMA and liquid water phantoms respectively. For $CaSO_4$:Dy dosimeters, the intrinsic efficiency obtained was 0.96±0.09 $\mu C.Gy^{-1}.mg^{-1}$, 0.99±0.09 $\mu C.Gy^{-1}.mg^{-1}$ e 1.1±0.1 $\mu C.Gy^{-1}.mg^{-1}$ for solid water, liquid water and PMMA phantoms respectively. With these results it can be stated that the three phantoms showed no significant difference between their TL responses for both dosimeters and energy used. For the three phantoms studied, the dose-response curves presented a linear behavior for dose up to 5Gy with supra-linear tendency for doses above this value. All reproducibility values are better than the recommended limit of ± 5% and the difference between the values obtained for intrinsic efficiency of the three phantoms is almost negligible for both dosimeters, LiF:Mg,Ti e $CaSO_4$:Dy. Thus, the phantom material doesn't alter significantly the results of the 12 MeV clinical electron beam dosimetry using LiF:Mg,Ti e $CaSO_4$:Dy as thermoluminescent detector.

1. INTRODUCTION

Thermoluminescence is a phenomenon of the visible photons released by thermal means. In 1950's, Daniels and his co-works made the first applications of TL to dosimetry when they used lithium fluoride (LiF) to made radiation measurements after bomb test (Cameron, 1968). With the advancements in the use of nuclear technology for medical purpose, there was a major concern related to the detection and evaluation of radiation dose for control (Oberhofer e Scharmann, 1979).

In radiotherapy treatments is necessary to be sure that the patient is receiving the correct dose prescribed. The main objective of radiotherapy dosimetry is to determine with great precise the dose absorbed to the tumor. The clinical dosimetry main objectives are to promote the radiation protection of individuals (patients and staff) and establish a radiation beam quality control (Oberhofer e Scharmann, 1979). The high energy electron beams have broad application in medicine, especially in the treatment of various cancers. Several organizations recommended the verification of patient dose for quality improvement in radiotherapy and the International Committee of Radiation Units and Measurements (ICRU) establish, in 1976, that "*all procedures involved in planning and execution of radiotherapy may contribute to a significant uncertainty in the dose administered to the patient"*. The recommended maximum values for the uncertainty in the dose range of ± 5% (ICRU, 1976).

The thermoluminescent dosimeters have a long history of ionizing radiation dosimetry in radiotherapy and, in this area, most measurements have been done with lithium fluoride doped with magnesium and titanium (LiF:Mg,Ti). However, another thermoluminescent material, calcium sulfate doped with dysprosium ($CaSO_4$:Dy), has been studied for application in the same area

(Robar et al, 1996; Nunes, 2008; Matsushima, 2010; Bravim, 2011). The $CaSO_4$:Dy is produced and marketed by Laboratory of Dosimetric Materials of th Instituto de Pesquisas Energéticas e Nucleares – IPEN/CNEN.

The different phantom materials can also alter the dosimeters response to different radiation types, so these facts should be considered in dosimetry. This paper aims to compare the thermoluminescent response of LiF:Mg,Ti microdosimeters and $CaSO_4$:Dy dosimeters for PMMA, solid water and liquid water phantoms, irradiated in 12 MeV clinical electron beam.

2. MATERIALS AND METHODS

Before irradiation the dosimeters were heat-treated with conditions: microLiF:Mg,Ti - 400ºC/1 h using a furnace VULCAN model 3-550 PD plus 100ºC/2 h using a furnace FANEN model 315-IEA 11200; CaSO4:Dy - 300ºC/3 h using a furnace VULCAN model 3-550 PD. 15 dosimeters of each, microLiF:Mg,Ti and $CaSO_4$:Dy, were irradiated in air under electronic equilibrium conditions with a ^{60}Co gamma source (Activity: 656.4MBq). After the TL reading were performed and the individuals and average TL responses of the dosimeters obtained, they were separated into 6 groups of 5 detectors each according to their sensitivity (3 groups of microLiF:Mg,Ti and 3 groups of $CaSO_4$:Dy). The TL readings were performed using a TL reader Harshaw model QS 3500.

Fig. 1: PMMA phantom and TLDs electron beam irradiation set up.

To perform the irradiations in the clinical electron beam (12 MeV) using a linear accelerator Varian Clinac 2100C the groups of dosimeters were positioned at the PMMA, solid water and liquid water phantom at the depth of maximum dose, 2.4 cm. The figure 1 shows the phantom and TLD electron beam The PMMA and solid water phantoms consist of 30x30 cm^2 plates of different thickness and the water liquid phantom is a PMMA cubic box with dimensions 40.0x40.0x40.0 cm^3 filled with distilled water. To ensure the adequate backscatter of the beam, 5 cm of the simulator material were used. The radiation field size applied was 10x10 cm^2 with a source-detector distance of 100 cm.

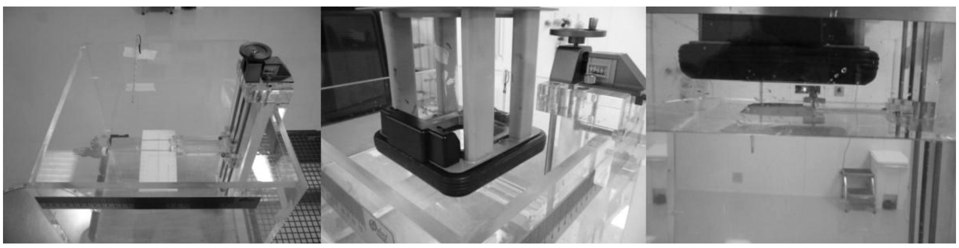

Fig. 2: Liquid water Phantom (a); electron beam irradiation of TL dosimeters in liquid water phantom (b) and (c).

3. RESULTS AND DISCUSSION

Figure 3 shows the dose-response curves of microLiF:Mg,Ti and $CaSO_4$:Dy to liquid water, solid water and PMMA phantoms. There were no significant differences in the response of both dosimeters for three different phantoms.

The intrinsic efficiency obtained for the LiF:Mg,Ti microdosimeters was 0.056±0.006 $\mu C.Gy^{-1}.mg^{-1}$, 0.058±0.006 $\mu C.Gy^{-1}.mg^{-1}$ e 0.061±0.006 $\mu C.Gy^{-1}.mg^{-1}$ for solid water, PMMA and liquid water phantoms respectively. For $CaSO_4$:Dy dosimeters, the intrinsic efficiency obtained was 0.96±0.09 $\mu C.Gy^{-1}.mg^{-1}$, 0.99±0.09 $\mu C.Gy^{-1}.mg^{-1}$ e 1.1±0.1 $\mu C.Gy^{-1}.mg^{-1}$ or solid water, liquid water and PMMA phantoms respectively.

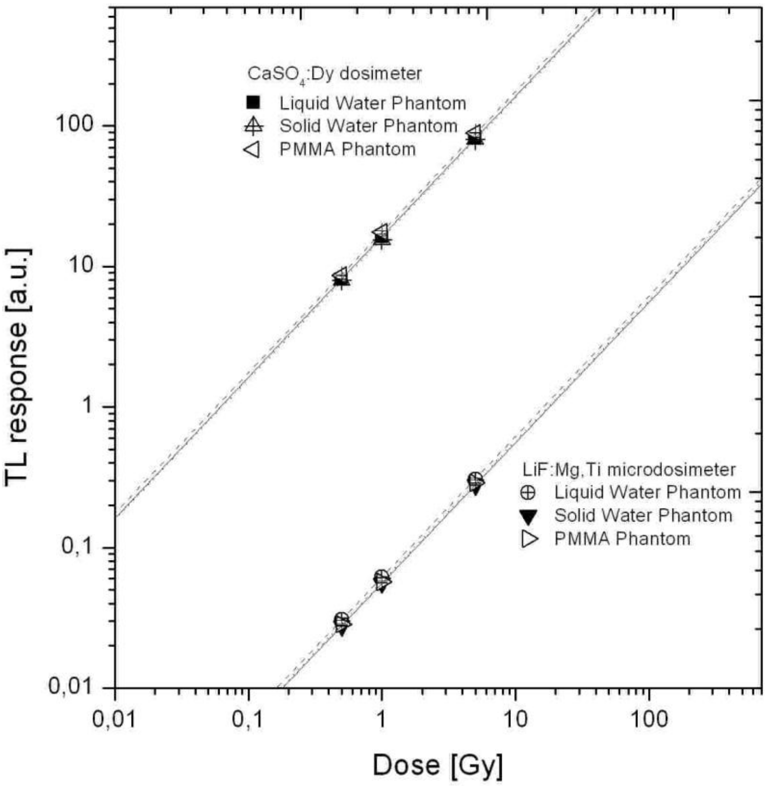

Fig. 3: Dose-response curves of microLiF:Mg,Ti and $CaSO_4$:Dy for liquid water, solid water and PMMA phantoms.

As can be seen at the table 1, the LiF:Mg,Ti microdosimeters reproducibility ranged from 1.9% to the liquid water and solid water phantoms and 2.4% to the PMMA phantom. The $CaSO_4$:Dy dosimeters reproducibility ranged from 0.66% to the liquid water, 1.3% to the solid water and 1.5% to PMMA phantom.

TABLE 1 Individual sensitivity, average sensitivity and reproducibility of microLiF:Mg,Ti and $CaSO_4$:Dy for liquid water, solid water and PMMA phantoms.

	Sensitivity to ^{60}Co					
	Water		Solid water		PMMA	
	$CaSO_4$:Dy	μLiF:Mg,Ti	$CaSO_4$:Dy	μLiF:Mg,Ti	$CaSO_4$:Dy	μLiF:Mg,Ti
	0,90	0,77	0,85	0,70	0,96	0,72

Individual sensitivity	0,87	0,76	0,87	0,69	0,98	0,70
	0,87	0,70	0,81	0,63	0,90	0,64
	0,89	0,71	0,82	0,65	0,95	0,65
	0,87	0,75	0,86	0,69	0,97	0,72
average sensitivity	0,88	0,74	0,84	0,67	0,95	0,69
deviation	0,010	0,030	0,020	0,030	0,030	0,040
reproducibility	0,71	1,9	1,3	1,9	1,5	2,4

4. CONCLUSION

With these results it can be stated that the three phantoms showed no significant difference between their TL responses for both dosimeters and energy used. For the three phantoms studied, the dose-response curves presented a linear behavior for dose up to 5Gy with supra-linear tendency for doses above this value. All reproducibility values are better than the recommended limit of ± 5% and the difference between the values obtained for intrinsic efficiency of the three phantoms is almost negligible for both dosimeters, microLiF:Mg,Ti e $CaSO_4$:Dy. Thus, the phantom material doesn't alter significantly the results of the 12 MeV clinical electron beam dosimetry using microLiF:Mg,Ti e $CaSO_4$:Dy as thermoluminescent detector.

5. REFERENCES

Bravim, A., Sakuraba, R.K., Cruz, J.C., Campos, L.L. 2011. Study of LiF:Mg,Ti and $CaSO_4$:Dy dosimeters TL response to electron beams of 6MeV applied to radiotherapy using PMMA and solid water phantoms. Radiat. Meas., 46 (12) 1979-1981.

Cameron, J.R.; Suntharalingam, N.; Kenney, G.N. 1968. Thermoluminescent dosimetry. Londres: The Colonial Press.

International Commission On Radiation Units And Measurements - ICRU 1976. Report 24: Determination of Absorbed Dose in a Patient Irradiated by Beams of X or Gamma Rays in Radiotherapy Procedures. Bethesd, Maryland: ICRU Publications.

Matsushima, L.C., 2010. Avaliação da Resposta de Detectores Termoluminescentes na Dosimetria de Feixes Clínicos Utilizando Diferentes Simuladores. Dissertação (Mestrado)–Instituto de Pesquisas Energéticas e Nucleares, São Paulo.

Nunes, M.G., Campos,L.L., 2008. Study of $CaSO_4$:Dy and LiF:Mg,Ti detectors TL response to electron radiation using a SW Solid Water phantom. Radiat. Meas. 49, 459–462.

Oberhofer, M.; Scharmann, A. 1979. Applied Thermoluminescence dosimetry. Ispra, Itália: Adam Hilger Ltd (Commission of the European Communities).

Robar, V.; Zankowski, C.; Olivares, M.P.; Podgorsak, E.B., 1996. Thermoluminescence dosimetry in electron beams: Energy dependence. Med. Phys. v. 23, n. 5, p. 667-673.