# OSL and TL response characterization of microLiF:Mg,Ti dosimeters to be applied to VMAT quality assurance

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## Abstract

VMAT Rapid Arc is a new method of treatment responsible for a change in the setting of radiotherapy, bringing benefits and allowing a lower toxicity in the treatment of patients. With this treatment is possible to minimize the radiation dose to the healthy tissues and escalate the dose to the target volume (tumor) (Hall, 1998; Mundt, 2005; Bortfeld, 2006). The quality assurance is essential to verify the operation of all components involved in the process of treatment planning and dose delivery. Several organizations recommended the verification of patient dose for quality improvement in radiotherapy and the recommended maximum values for the uncertainty in the dose range of ± 5% (ICRU, 1976, AAPM, 1983). This paper aims to evaluate the feasibility of applying LiF:Mg,Ti microdosimeters as a new method of dosimetry to VMAT Rapid Arc.

***Keywords***: Thermoluminescence; Optically Stimulated Luminescence; Lithium Fluoride; Photons Beam; VMAT Rapid Arc.

# 1.- INTRODUCTION

The optically stimulated luminescence (OSL) is a luminescent signal emitted by a semiconductor or an insulator previously irradiated when exposed to light. The intensity of OSL signal is a function of radiation dose absorbed by the material. The process is similar to the thermoluminescence (TL), but differs in the stimulation: instead of thermal stimulation, in OSL defects in the detector are stimulated by optical means [Botter-Jensen et al, 2003].

The TL dosimeters are popular in many hospitals for external dosimetry during radiotherapy treatment but the use of OSL is growing and OSL dosimeters have recently been studied and investigated for medical dosimetry applications [Yukihara and McKeever, 2011].

The dosimetry of ionizing radiation is essential for the radiological protection programs for quality assurance and licensing of equipment. The conventional IMRT – Intensity Modulated Radiation Therapy and VMAT – Volumetric Modulatet Arc Therapy are new techniques responsible for a change in the setting of radiotherapy, bringing benefits and allowing a lower toxicity in the treatment of patients [Hall, 1998; Mundt, 2005; Bortfeld, 2006].

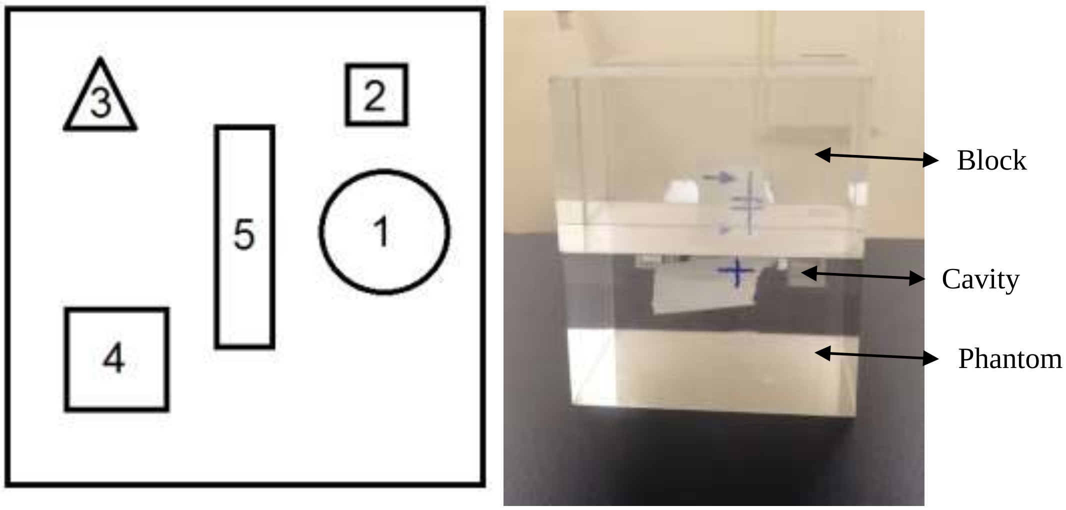
Until recently, few methods of quality assurance are well established techniques for IMRT. To guarantee that the IMRT services accord the highest clinical standards, each institution should invest in a quality assurance program for treatment planning and dose absorbed [Palta et al, 2008]. As the deployment of equipment VMAT is still at the beginning is important to optimize and facilitate quality control mechanisms to ensure that tests are performed in order to preserve above all the patient but also the equipment itself [Hancock, 2008]. This paper aims to compare the behavior of the TL and OSL response of microLiF:Mg,Ti dosimeters to photon clinical beams and evaluate the feasibility of applying this technique in a new method of dosimetry to VMAT Rapid Arc. The TL sensitivity relative to $^{60}$Co, lower limit detection (LLD) and dose-response curves are analyzed.

# 2.- MATERIALS AND METHODS

The pre irradiation heat treatment used to the LiF:Mg,Ti microdosimeters produced by Hashaw Chemical Company was 400ºC for one hour using a furnace VULCAN model 3-550 PD plus 100ºC for two hours using a furnace FANEN model 315-IEA 11200. The dosimeters were selected with repeatability better than ± 5% and calibrated using $^{60}$Co gamma radiation source of the Centro de Tecnologia das Radiações (CTR-IPEN/CNEN). Three cycles of heat-treatment, irradiation with $^{60}$Co gamma-radiation (656.4 MBq) in air under electronic equilibrium conditions and TL/OSL reading were carried out. The individuals and average thermoluminescent and optically stimulated luminescent responses of the dosimeters were obtained and the microdosimeters were separated into groups of five dosimeters according to their sensitivity.

The dose response curves to 6 MV photons clinical beams were obtained using a linear accelerator Clinac Varian 6EX of the Hospital Israelita Albert Einstein (HIAE) with doses ranging from 30 up to 1400 cGy. The irradiations were carried out using a polymethacrylate (PMMA) phantom with absorbed doses corrected to the maximum dose depth by planning system of the equipment.

To evaluate the viability of application of the LiF:Mg,Ti microdosimeters in the VMAT dosimetry, the microdosimeters were irradiated in the VMAT Varian Rapid Arc of HIAE with 6 MV photons beam. To perform these irradiations a specific PMMA phantom containing five cavities with different geometric shapes was made. The project of this phantom is showed in the Figure 1a. Cavity 5 was defined as target (tumor to be treated) and the others cavities as possible organs at risk. A group of eight microdosimeters were positioned inside the cavities and a PMMA block 10 cm thick was placed on the PMMA phantom (Figure 1b). This PMMA block was used to ensure the backscattered radiation. All cavities were irradiated with homogeneous doses.




a) b)

Figure 1. a) Project of PMMA phantom containing five cavities; b) PMMA block used upon phantom with microdosimeters positioned to irradiation.

The obtained results using the LiF:Mg,Ti microdosimeters were compared with the planning system of the HIAE. The planning has been done so that no isodose line pass through cavities providing a homogeneous dose of radiation inside each cavity. The isodose lines provided by planning system of VMAT Rapid Arc of HIAE are presented in Figure 2.

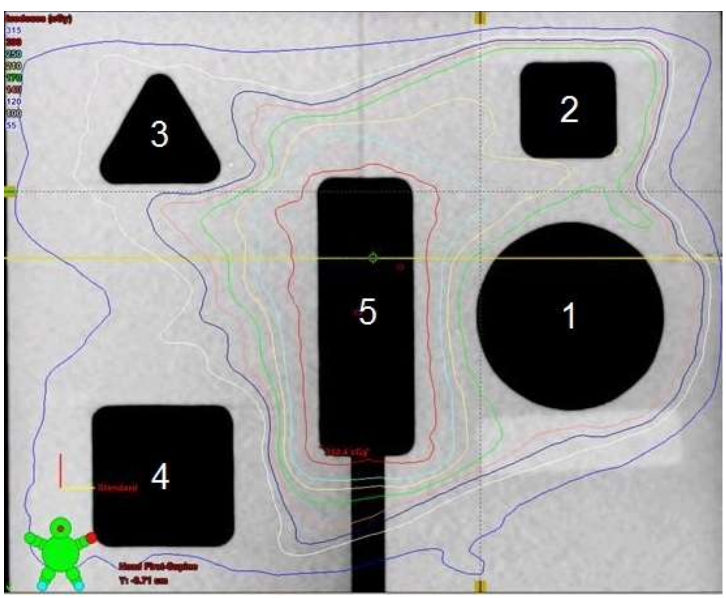



Figure 2. Dose distribution in the phantom with five cavities - isodose lines provided by planning system.

Each presented value of the dose response curves and the phantom irradiation is the average of five and eight measurements of dosimeters of the same sensitivity respectively. The error bars represent the standard deviation of the mean (1σ) with a confidence interval of 95%. The sensitivity (S) and lower limit detection (LLD) were calculated with the respective equations 1 and 2:

$$S(units.Gy^{-1}) = \frac{\overline{R}}{D} \quad (1)$$

$$LLD(Gy) = \overline{R} + 3 \cdot \sigma \quad (2)$$

where: "$\overline{R}$" is the mean of the TL/OSL response of the dosimeters of each group, "D" is the absorbed dose and "σ" is the standard deviation.

The thermoluminescent and optically stimulated luminescent responses were obtained using TL reader Harshaw model QS 3500 and OSL reader Risø model TL/OSL-DA-20 respectively. To OSL measurement of the microdosimeters were stimulated with Blue Led NICHIA - NSPB-500AS (470 nm) to OSL signal readings and for this measurement was used the Hoya U-340 filter.

# 3.- RESULTS

The TL and OSL dose-response curves of microLiF:Mg,Ti dosimeters to 6 MV photons beam to the absorbed dose range studied (30 – 1400 cGy) are presented in Figure 3.

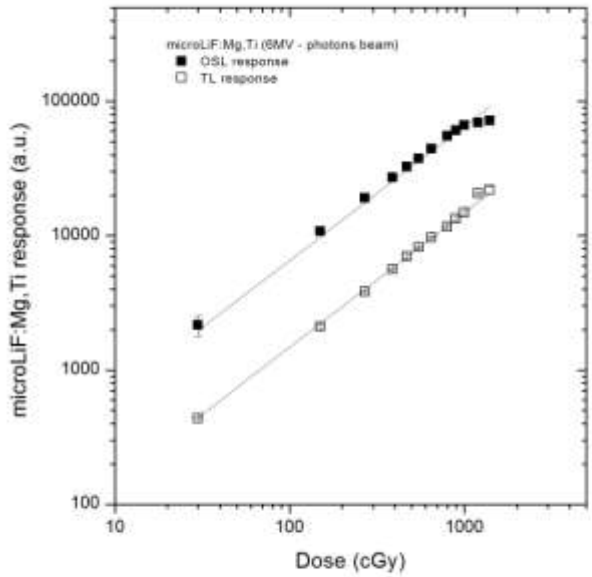



Figure 3. OSL and TL dose-response curves of microLiF:Mg,Ti to 6 MV photons beam from linear accelerator Varian 6EX of HIAE.

The TL sensitivity to 6 MV photons beam relative to $^{60}Co$ ($S_{6MV}/S_{60Co}$) and the LLD of LiF:Mg,Ti microdosimeters obtained to 6 MV photons beam are showed in the table 1. The minimum, maximum and average absorbed doses evaluated by the LiF:Mg,Ti microdosimeters and the average dose given by the planning system of HIAE to VMAT Varian Rapid Arc are showed in the table 2.

Table 1. TL and OSL sensitivity to 6 MV photons beam relative to $^{60}Co$ and LLD of LiF:Mg,Ti microdosimeters to 6MV photons beam.

| | OSL | TL |
|---|---|---|
| $S_{6MV}/S_{60Co}$ | 0.06778 | 1.019 |
| LLD [Gy] | $5.2x10^{-2}$ | $4.7x10^{-4}$ |

Table 2. Minimum, maximum and average absorbed doses obtained by LiF:Mg,Ti microdosimeters and the average dose given by the planning system of HIAE to VMAT Varian Rapid Arc.

| | OSL | | | TL | | | Planning system |
|---|---|---|---|---|---|---|---|
| Cavities at phantom | Absorbed doses (cGy) | | | | | | |
| | $D_{min}$ | $D_{max}$ | $\overline{D}$ | $D_{min}$ | $D_{max}$ | $\overline{D}$ | $\overline{D}$ |
| 5 (target) | 299.9 | 303.9 | 301.8±1.4 | 296.3 | 303.6 | 300.5±2.2 | 300.0 |
| 1 | 149.5 | 153.0 | 151.0±1.4 | 147.8 | 152.6 | 150.4±1.5 | 150.0 |
| 2 | 197.9 | 203.2 | 200.5±1.9 | 198.4 | 203.5 | 201.0±2.0 | 200.0 |
| 3 | 99.90 | 103.7 | 101.8±1.2 | 97.96 | 101.9 | 99.86±1.47 | 100.0 |
| 4 | 49.61 | 54.14 | 51.6±1.3 | 47.79 | 52.02 | 49.79±1.76 | 50.00 |

The agreement between absorbed dose given by the planning system and obtained with the microLiF:Mg,Ti are showed in the Figures 4a and 4b.

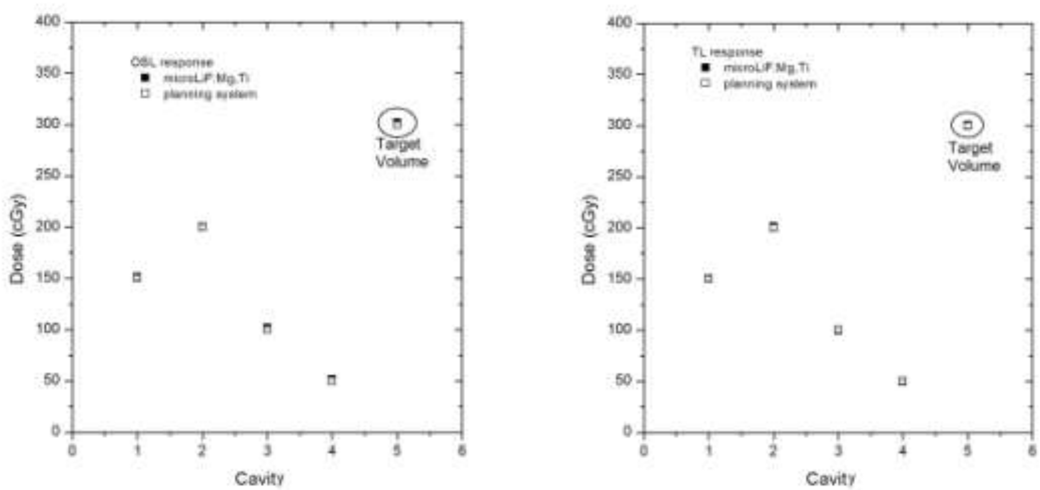



Figure 4. Average absorbed doses measured by microLiF:Mg,Ti with a) OSL and b) TL techniques and provided by the planning system.

# 4.- DISCUSSION

It can be observed a linear behavior from 30 up to 1000 cGy and a saturation of the OSL and TL response for doses above 1000 cGy.

Considering the results of OSL measures using microLiF:Mg,Ti the absorbed dose ranged from 299.91 cGy up to 303.94 cGy to cavity 5 - target (0.0300%); from149.49 cGy up to 153.02 cGy for the cavity 1 (0.340%), from 197.95 cGy up to 203.20 cGy up to cavity 2 (2.02%), from 99.90 cGy up to 103.72 cGy to cavity 3 (0.100%) and from 49.61 cGy up to 54.14 cGy to cavity 4 (0.780%) concerning to the minimum and maximum doses obtained in the cavities 1 to 5.

Regarding the average dose inside each cavity measured with the microLiF:Mg,Ti compared with the absorbed dose given by the planning system can be observed a variation of 0.720%, 0.250%, 0.790%, 3.18% and 0.620% in the cavities 1 to 5 respectively.

For TL measures of microLiF:Mg,Ti the absorbed dose ranged from 296.37 cGy up to 303.65 cGy for cavity 5 (1.21%), from 147.78 cGy up to 152,57 cGy for cavity 1 (1.48%), from 198.41 cGy up to 203.47 cGy for cavity 2 (0.79%), from 97.96 cGy up to 101.87 cGy for cavity 3 (2.04%) and from 47.79 cGy up to 52.02 cGy for cavity 4 (4.42%). The variation of the average absorbed dose inside each cavity measured with the microLiF:Mg,Ti compared with the absorbed dose given by the planning system observed is 0.26%, 0.51%, 0.14%, 0.42% and 0.16% in the cavities 1 to 5 respectively.

In all cases the TL and OSL experimental results agree with the absorbed doses provided by the planning system of VMAT Varian Rapid Arc as can be seen in Figures 4a and 4b.

# 5.- CONCLUSIONS

The LiF:Mg,Ti microdosimeters presented linear dose-response curve up to 1000 cGy for OSL and TL techniques. Experimental results obtained using microLiF:Mg,Ti showed maximum variation of punctual absorbed dose of 4.32% and 4.42% referring cavity 4 (50 cGy) using microLiF:Mg,Ti as OSL and TL dosimeter respectively.

Regarding the average absorbed dose of dosimeters batch inside each cavity, the maximum variation was 3.18% and 0.51% using OSL and TL techniques respectively. To both techniques, OSL and TL, LiF:Mg,Ti microdosimeters presented results according with the maximum variation acceptable in radiation therapy, 5% [ICRU, 1973; AAPM, 1983].
These results of LiF:Mg,Ti microdosimeters are previous but presented great performance to determine with precision the absorbed dose in VMAT using OSL and TL techniques and PMMA phantom. To add more reliability further studies will be done to analyze the isodose lines with heterogeneous dose inside the cavities. So, OSL and TL dosimetry using microLiF:Mg,Ti promise to be an alternative to assure the quality control for the absorbed dose by VMAT Varian Rapid Arc technique.

## Acknowledgments

The authors are thankful to grant #2010/16437-0, São Paulo Research Foundation (FAPESP); CNPq, CAPES and INCT - Metrology of Radiation in Medicine for the partial financial support and to the Radiation Therapy staff of the Hospital Israelita Albert Einstein for the photons irradiations.

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