Dosimetric evaluation using 3D printed anthropomorphic skull phantom for small field dosimetry using thermoluminescent dosimeters

Almeida SB[1]., Cunha APV[2]., Campos LL[1].
(1) Radiation Metrology Center, Instituto de Pesquisas Energéticas e Nucleares, Av. Prof. Lineu Prestes, 2242 – Cidade Universitária, São Paulo – SP, Brazil
(2) Radiation Therapy Department. Hospital das Clínicas de São Paulo – HC, Av. Dr. Enéas Carvalho de Aguiar, 255 - CerqueiraCésar, São Paulo - SP, 05403-000
Email address: sbipen@usp.br

Abstract: The usability of phantoms plays a critical role in commissioning and quality assurance programs in radiotherapy departments as they improve patient care setup with greater precision between personalized treatment planning and irradiation setup uncertainties. With the emergence of these new radiotherapy modalities, it became necessary to apply relatively small fields that are dynamic or static. The use of these field sizes can cause uncertainty in dosimetry, requiring special attention in small field dosimetry. TLDs have advantages for having characteristics such as high spatial resolution and dose response, offering a promising opportunity to measure the absorbed dose in a small field. As a result, we can conclude that the use of the 3D phantom with thermoluminescent dosimeters proved to be very useful in the application of small field dosimetry, enabling a more accurate investigation in quality controls involving treatments whose doses are relatively high in radiosurgery techniques that require more accurate and reliable measurements in dose delivery.
Keywords: *Medical physics; Radiation oncology; Small field, Dosimeters thermoluminescent; 3D print*

Introduction: Phantom are artificial representations of anatomical structures of the human body in terms of size, shape, and functions, consisting of structures with tissue equivalent material and considered an extremely important factor in radiotherapy, as any radiological inconsistency between the phantom and the patient can affect results in patient treatment, leading to an unsatisfactory outcome (Babaloui, 2020).

Recently, interest in the application 3D printing has increased in several studies that demonstrate a realistic production of phantom that can be filled with solutions such as: water, dosimetric gels and epoxy resin (Gallas, 2015) or 3D printed phantom that are built completely solid (Priece, 2019; Babaloui, 2020). Several studies have shown the advantages of 3D printed phantoms for use in radiotherapy due to the freedom of printing to create prototypes that allow simulating independent anatomical regions, such as: liver, kidneys, and spleen (Price, 2019).

The TLDs present conditions of great precision in measurements performed in the radiotherapy sectors and have already proven to be quite useful in several clinical applications. The objective of this work is to perform a small field dosimetry using a skull phantom employing thermoluminescent dosimeters for the application of clinical photon beams.

Method: For this study, LiF:Mg,Ti. µLiF:Mg,Ti, CaSO:Dy dosimeters were used and for the irradiation system, the 6EX linear accelerator from Varian belonging to Hospital da Clinicas from São Paulo was used. The phantom was submitted to real conditions of a radiotherapy treatment, where the phantom and planning was performed first, then the phantom was submitted to irradiation with a dose of 7 Gy, using the 3D dynamic arc radiosurgery technique. The phantom was positioned as planned and placed on the thermoplastic mask for immobilization. For the irradiation fields, radiographic images were taken using Excatrac®. To reduce the statistical variation, the treatment phantom procedure was performed three times for each group of detectors. The irradiation parameters are described in table 1.

Table 1. Phantom irradiation parameters

	Table angle	Start of gantry [°]	End of gantry [°]	Collimator angle[°]	X1 [mm]	X2 [mm]	Y1 [mm]	Y2 [mm]	MU/min
Arc dinâm. 1	70	30	150	270	14	14	16	16	302
Arc dinâm. 2	30	150	30	270	14	14	16	16	310
Arc dinâm. 3	330	330	210	270	14	14	16	16	311
Arc dinâm. 3	290	210	330	270	14	14	16	16	300

Fonte: O autor (2022).

Results: Clinical applications were performed according to the radiosurgery treatment protocol. The phantom was positioned as planned and an X-ray image was taken for each field to verify possible positioning corrections. The results obtained are described in tables 2, 3 and 4.

Table 2. (CaSO4:Dy) Doses evaluated in the 3D printed skull phantom compared to the planning system.

Point	TL Resp. (μC)	Fcal. Rel. 0,8Gy (Gy/μC)	Evaluated dose (Gy)	Planned dose (Gy)	MSD (Gy)	CV%	Dif. %
1	2,45	0,151	0,37	0,44	0,01	2,7	6,7
2	9,74	0,151	1,47	1,62	0,01	0,7	13,4
4	8,77	0,151	1,32	1,80	0,03	2,3	46,3
5	59,67	0,137	8,20	8,12	0,04	0,5	0,1

Fonte: O autor (2022).

Table 3. (LiF:Mg,Ti) Doses evaluated in the 3D printed skull phantom compared to the planning system.

Point	TL Resp. (Cont)	Fcal. Rel. 0,8Gy (Gy/μC)	Evaluated dose (Gy)	Planned dose (Gy)	MSD (Gy)	CV%	Dif. %
9	46110	1,212	0,55	0,57	0,01	2,6	1,4
8	88916	1,212	1,08	1,34	0,03	2,6	24,9
6	100956	1,212	1,22	1,78	0,04	3,6	54,8
5	720287	0,114	8,22	8,12	0,15	1,8	1,9

Fonte: O autor (2022).

Table 4. µLiF:Mg,Ti) Doses evaluated in the 3D printed skull phantom compared to the planning system.

Point	TL Resp. (Cont)	Fcal. Rel. 0,8Gy (Gy/μC)	Evaluated dose (Gy)	Planned dose (Gy)	MSD (Gy)	CV%	Dif. %
1	66280	0,526	0,35	0,39	0,01	3,5	3,6
2	183436	0,526	0,96	1,00	0,02	2,1	3,0
5	1713373	0,048	7,92	7,89	0,02	0,003	4,8

Fonte: O autor (2022).

Discussion and Conclusion: The results obtained demonstrated the viability of TLDs for clinical applications of photon beams for small fields. The values described in the tables above show agreement in percentage terms below +5% as recommended by the ICRU. The largest percentage difference found was 4.8% (µLiF:Mg,Ti) in relation to the planning system. All thermoluminescent dosimeters showed a relatively low uncertainty, with good stability and reproducibility in all measurements.

Reference:

1. Hendee WR, Mower HW. A time of opportunity in the education of medical physicists: Report of a multi-organizational summit on the education of medical physicists. Med Phys. 2006; 33(9):3327-32.
2. Krummer SC, Giulkiani ER, Susin LO, Folleto JL, Lermen NR, Wu VY, et al. Evolução do padrão de aleitamento materno. Rev Saúde Pública. 2000;34(2):143-8.
3. Naisman HA, Kerr GR. Fetal growth and development. New York: Mc Graw-Hill; 1970.
4. Kimura J, Shibasaki H, editors. Recent advances in clinical neurophysiology. Proceedings of the 10th International Congress of EMG and Clinical Neurophysiology; 1995; Kyoto; Japan. Amsterdam: Elsevier; 1996.
5. Instituto da Criança. Hospital das Clínicas. Faculdade de Medicina da Universidade de São Paulo. Relatório Anual de atividades, 1993. São Paulo:1994.