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DEPTH DOSE CURVES FROM $^{90}Sr+^{90}Y$ CLINICAL APPLICATORS USING THE THERMOLUMINESCENT TECHNIQUE

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ABSTRACT

The $^{90}Sr+^{90}Y$ beta-ray sources widely used in brachytherapy applications were developed in the 1950's. Many of these sources, called clinical applicators, are still routinely used in several Brazilian radiotherapy clinics for the treatment of superficial lesions in the skin and eyes, although they are not commercialized anymore. These applicators have to be periodically calibrated, according to international recommendations, because these sources have to be very well specified in order to reach the traceability of calibration standards. In the case of beta-ray sources, the recommended quantity is the absorbed dose rate in water at a reference distance from the source. Moreover, there are other important quantities, as the depth dose curves and the source uniformity for beta-ray plaque sources. In this work, depth dose curves were obtained and studied of five dermatological applicators, using thin thermoluminescent dosimeters of $CaSO_4$:Dy and phantoms of PMMA with different thicknesses (between 1.0 mm and 5.0 mm) positioned between each applicator and the TL pellets. The depth dose curves obtained presented the expected attenuation response in PMMA, and the results were compared with data obtained for a $^{90}Sr+^{90}Y$ standard source reported by the IAEA, and they were considered satisfactory.

1. INTRODUCTION

Special $^{90}Sr+^{90}Y$ beta-ray sources, called clinical applicators, are utilized since 1950's when they were developed by Friedell and col. [1]. A previous study showed that in the 90's approximately 10 different manufacturers produced hundreds of these applicators [2]. This medical application of this type of beta sources diffused by all the world. Nowadays, the clinical applicators are not commercialized anymore, but several Brazilian clinics and hospitals still use them.

The $^{90}Sr+^{90}Y$ clinical applicators can be dermatological, when used in treatment of keloids, or ophthalmic, if used in post-operative procedures of pterigya. In the case of brachytherapy, these sources are positioned in contact with the lesioned area. These sources differ from their geometry: dermatological applicators are usually plane and ophthalmic applicators are concave.

According to international recommendations [3,4] and a previous work [5], and quality control programs for brachytherapy dosimetry [3], the clinical applicators have to be calibrated periodically. It is very important, because the brachytherapy sources have to be very well specified in order to reach the traceability of calibration standards. The traceability is the propriety of a result of a measurement by which it can be related to standard references, usually national or international, through comparisons with well established uncertainties [6].

In the case of beta-ray sources, the recommended quantity is the absorbed dose rate in water at a reference distance from the source. Moreover, there are other important quantities, as the depth dose curves and the source uniformity for beta-ray sources. Depth dose curves are very important for therapy dose planning.

Thermoluminescent dosimeters (TLDs) are recommended materials for the calibration of applicators [7] and dosimetry of beta sources [8], due to their low cost and easy handling. In a previous work thin pellets of $CaSO_4$:Dy were demonstrated to be adequate for the calibration of applicators [9]. Extrapolation chambers, radiochromic films, alanine pellets and plastic scintillators are also utilized for the calibration of clinical applicators [10,11].

The main objective of this work was to study the distribution of the dose in depth at water at several thicknesses of PMMA plates, utilizing the thermoluminescent technique.

2. MATERIALS AND METHODS

In this work, a beta radiation source of the beta secondary standard system of Buchler GmbH & Co., Germany (1850 MBq), BSS1, was utilized in the reproducibility study of the TL response. Five ^{90}Sr+^{90}Y dermatological applicators were also utilized to obtain the depth dose curves: applicators NIST, A, B, D and E. The main characteristics of these applicators can be observed in Table 1. The Calibration Laboratory of IPEN (LCI) has three dermatological applicators: the applicator NIST, calibrated at the primary standard laboratory at the National Institute of Standards and Technology, USA; applicator A with a calibration certificate of Amersham, England, and applicator B, without any calibration certificate. The applicators D and E are from a clinic and a research institute respectively.

Table 1. Characteristics of the ^{90}Sr+^{90}Y dermatological applicators

Applicator	Manufacturer and model	Nominal activity (MBq)	Absorbed dose rate (Gy/s)	Calibration date
NIST	*Atlantic Research Corporation* B-1 S/N 233	N.I.	0.40	28.01.2003
A	*Amersham* SIQ 18	1480	0.056	08.11.1968
B	Without calibration certificate			
D	*Amersham* SIQ 21 0266MP	740	0.053	17.09.1986
E	*Amersham* Sr 5072 2096	1850	0.04	14.05.2003

Thin thermoluminescent (TL) $CaSO_4$:Dy pellets were utilized, with dimensions of 6.0 mm of diameter and 0.2 mm of thickness. The pellets were irradiated using the source of the BSS1 system positioned at 11.0 cm of distance using a PMMA support, of BSS1. The pellets were irradiated using the five applicators. Each pellet was positioned on a phantom, allowing a null distance between the applicator and the dosimeter. The TL pellets were thermally treated (300ºC/3h) and cooled (during 15 min) on a rectangular aluminum plaque of $23x19x2.5cm^3$ for their reutilization. The measurements were obtained utilizing a TL reader from Harshaw Nuclear System, model 2000A/B, with a linear heating rate of 10°C/s; the reading cycle was performed within 30s. The light emission was integrated in the temperature interval of 180°C to 350°C, according to Campos et al. (1987).

The depth dose curves were obtained using seven PMMA plaques of 1.0, 1.5, 2.0, 2.5, 3.0, 4.0 and 5.0 mm of thickness and 5.4 cm of diameter. These plaques can be observed in Fig. 1.

Figure 1. PMMA plaques utilized in the study of the distribution of the dose in depth of water.

3. RESULTS

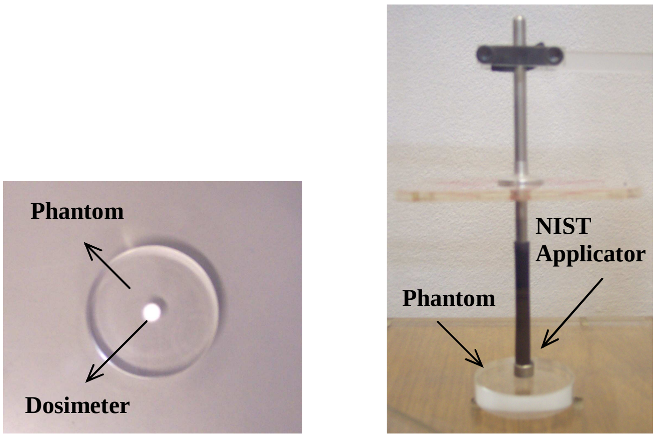
3.1. Characterization of the TL dosimeters

Initially, a reproducibility study of the TL response of the $CaSO_4$:Dy pellets was performed. The dosimeters were irradiated with a dose of 1.0 Gy using a $^{90}Sr+^{90}Y$ source of the BSS1 system. Their TL responses were obtained. Afterwards, the pellets were thermally treated at 300ºC/3h. This cycle was repeated five times. The maximum percentual deviation obtained for the dosimeter response was 4.1%. The associated uncertainty was equal to 10.4%.

For the determination of the lower detection limit, five series of measurements of null dose were obtained. The values of null dose were taken after the thermal treatments, and the TL response was obtained of the non-irradiated pellets. From these results, the lower limit of detection was obtained. This limit is obtained from the sum of the average of the TL readings of the non-irradiated pellets and 3 times the value of the standard deviation of these measurements, multiplied by the calibration factor of the sample. The lower limit of detection obtained for the $CaSO_4$:Dy samples was (77.2 ± 0.23) μGy; this value presented the same order of magnitude of results from Campos and Lima (1987).

3.2. Depth dose curves

The depth dose curves were determined using the $CaSO_4$:Dy pellets. The seven PMMA plaques were utilized. The pellets were positioned on a PMMA phantom shown in Fig. 2a. Each applicator was positioned vertically on the dosimeter during the irradiations, as can be seen in Fig. 2b.



(a) (b)

Figure 2. Set-up utilized to obtain the depth dose curves: (a) Dosimeter positioned on the phantom and (b) applicator NIST irradiating the dosimeter of $CaSO_4$:Dy.

The results obtained in air were normalized to water equivalent thickness of 1.0 mm, as recommended by the IAEA standard (2002). The PMMA thickness utilized during the measurements were converted to water equivalent thickness through:

$$\rho_{water} \,.\, d_{water} = \rho_{acrylic} \,.\, d_{acrylic} \qquad (1)$$

where:

- ρ_{water} is the volumetric density of the water (1.0 g/cm^3);
- d_{water} is the thickness of water equivalent material;
- $\rho_{acrylic}$ is the volumetric density of the acrylic (1.15 g/cm^3);
- $d_{acrylic}$ is the PMMA thickness.

The depth dose curves obtained for all applicators, with the normalization of the measurements for 1.0 mm depth, can be observed in Fig. 3.

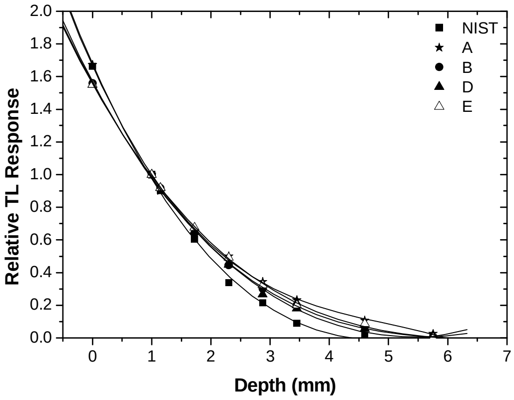


Figure 3. Depth dose curves for the five $CaSO_4$:Dy dermatological applicators: NIST, A, B, D and E.

The values of the relative TL response were obtained for different water depths utilized by the IAEA standard (2002), and the results can be observed in Table 2.

Table 2. Depth doses for the dermatological applicators NIST, A, B, D and E normalized to 1.0 mm of water depth.

Depth in water (mm)	IAEA Report (2002)	Relative TL Response				
		NIST	A	B	D	E
0	*1.752*	1.665	1.669	1.559	1.552	1.555
0.5	*1.342*	1.311	1.291	1.260	1.263	1.259
1.0	*1.000*	1.000	1.000	1.000	1.000	1.000
1.5	*0.734*	0.712	0.756	0.754	0.757	0.771
2.0	*0.533*	0.480	0.568	0.552	0.549	0.575
3.0	*0.272*	0.167	0.318	0.270	0.251	0.297
4.0	*0.127*	0.039	0.165	0.122	0.104	0.137
5.0	*0.052*	0.019	0.071	0.051	0.041	0.055
6.0	*0.018*	0.002	0.020	0.018	0.005	0.006

The difference between the value obtained from each applicator in this work and the value of the IAEA standard, at null depth, presented a variation from 4.7% (applicator NIST) and 11.0% (applicator B). For the interval of 0 mm to 1.0 mm thickness, the maximum variation was 12.9% (applicator D). For the interval of 0 mm to 3.0 mm thickness, the maximum variation was 38.6% (applicator NIST). At thicknesses above 4.0 mm of PMMA or water depth, the variations were even greater. The maximum percentual deviation of all results obtained was 33.4%.

4. CONCLUSIONS

The reproducibility study of the TL response and the lower detection limit showed satisfactory results. Depth dose curves were obtained for all dermatological applicators, presenting similar results when compared to the international recommendations of IAEA (2002). Therefore, the $CaSO_4$:Dy thin pellets are adequate for calibration and dosimetry of ^{90}Sr+^{90}Y applicators. The differences presented in the results probably occur due to the high uncertainties of the absorbed dose rates of the calibration certificates of the sources and to the lack of uniformity of the radioactive material of the applicators.

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