TL and OSL techniques for calibration of ^{90}Sr+^{90}Y clinical applicators

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Abstract

The ^{90}Sr+^{90}Y clinical applicators are beta sources used in brachytherapy in the treatment of superficial injuries of eyes and skin. According to international recommendations, these applicators must be calibrated periodically. Thermoluminescent dosimetry (TLD) may be used for the calibration of these sources. However, the optically stimulated luminescence (OSL) technique has been already demonstrated as useful for beta dosimetry. In this work, thermoluminescent pellets of $CaSO_4$:Dy and Al_2O_3:C nanodot OSL detectors were utilized for the calibration of some clinical applicators. Both kinds of dosimeters were exposed to different dermatological applicators for the calibration procedure. The results obtained from both luminescent techniques were compared, and agreement was achieved.

Introduction

The thermoluminescent phenomenon is a luminescent dosimetric technique that has been used for many applications for several decades. Due to its advantages (Olko 2010), it presents applications in a large field of research, including individual, environmental and spatial dosimetry. Furthermore, the use of thermoluminescent dosimeters (TLDs) has been applied with success in the calibration and dosimetry of ^{90}Sr+^{90}Y sources used in brachytherapy, called clinical applicators (Oliveira and Caldas 2007; Holmes et al. 2009; Soares et al. 2009).

According to Holmes et al. (2009) and to international recommendations (IAEA 2002; ICRU 2004), clinical applicators should be calibrated to assure: that a quality control program has been applied, that the sources are used correctly and that the treatments of the patients are consistent. Furthermore, it is necessary that each source has a calibration certificate traceable to a primary standard whenever possible (Holmes et al. 2009).

TLDs are recommended for the calibration of beta radiation sources (Oliveira and Caldas 2007; Soares et al. 2009) due to their small dimensions and easy handling. $CaSO_4$:Dy + Teflon pellets were studied and presented efficiency in the detection of beta radiation of ^{90}Sr+^{90}Y sources (Campos and Lima 1987; Oliveira and Caldas 2007).

The optically stimulated luminescence (OSL) technique has been actively utilized as a dosimetry method for archaeological and geological dating. In the present days, the OSL technique has shown usefulness for personal dosimetry too (Botter-Jensen et al. 2003).

The OSL phenomenon is based on the luminescence emitted from an irradiated insulator or semiconductor as a result of light stimulation.

Since the development of this technique, its use is restricted because of the lack of a good luminescent material presenting high sensitivity to radiation and optical stimulation efficiency, a low atomic effective number and adequate fading characteristics (Akselrod and McKeever 1999). The Al_2O_3:C detector is a very good luminescent material for OSL dosimetry, because it presents excellent dosimetric characteristics. It was the first material introduced commercially for personal monitoring based on an OSL reader system from Landauer (McKeever et al. 2004).

The OSL technique has several advantages over the thermoluminescence (TL) technique: the readout method is optical, requiring no heating of the samples; the measurement is less destructive and potentially more sensitive than TL; and the response may be evaluated several times on the same sample (Akselrod and McKeever 1999; McKeever 2001; Akselrod 2000).

The objective of this work was to compare the absorbed dose rates obtained as result of the calibration of $^{90}Sr+^{90}Y$ dermatological applicators using two luminescence techniques: thermoluminescence and optically stimulated luminescence.

Materials and methods

Initially, the TL and OSL detectors were studied in relation to the response reproducibility, and the lower detection limits were determined. For the reproducibility study of the $CaSO_4$:Dy dosimeters, the pellets were exposed to a $^{90}Sr+^{90}Y$ standard source (1850 MBq, 1981), Buchler GmbH & Co., model BSS1, Germany, at 11 cm (dose of 1 Gy). For the reproducibility study of the OSL dosimeters, the samples were irradiated with a $^{90}Sr+^{90}Y$ standard source (460 MBq, 2004), Isotrak, model BSS2, Germany, at 30 cm (dose of 6 mGy).

In this work, a $^{90}Sr+^{90}Y$ clinical applicator (called NIST applicator), calibrated at the primary standard laboratory of the National Institute of Standards and Technology, USA, was utilized as reference system in the calibration of three $^{90}Sr+^{90}Y$ plane dermatological applicators. Two of them (A1 and A3) have calibration certificates from Amersham, and A2 applicator does not have any calibration certificate. The main characteristics of these applicators can be observed in Table 1.

For this work, $CaSO_4$:Dy thin pellets, with dimensions of 0.2 mm of thickness and 6.0 mm of diameter, were utilized. These pellets were mixed with Teflon, and they were produced at the Dosimetric Materials Laboratory of IPEN.

The TLDs were exposed to the clinical applicators at null distance between source and dosimeter. The TL measurements were taken immediately after each irradiation, using a Harshaw TLD Reader, model 3500, with a linear heating rate of $10ºC.s^{-1}$ and a constant flux of N_2 of $5.0\ l.min^{-1}$. The light emission was integrated in the temperature interval between 180ºC and 350ºC. After the irradiations, the pellets were thermally treated at 300ºC during 3 hours, for reutilization.

Table 1. Characteristics of the ^{90}Sr+^{90}Y NIST, A1, A2 and A3 dermatological applicators.

^{90}Sr+^{90}Y applicator	Manufacturer and model	Nominal absorbed dose rate (Gy/s)	Calibrated by	Calibration date
NIST	Atlantic Research Corporation / B-1 S/N 233	0.40 ± 0.02	NIST	28.01.2003
A1	Amersham / SIQ 18	0.056 ± 0.011	Amersham	08.11.1968
A2	No information	——	——	——
A3	Amersham / SIQ 21	0.053*	Amersham	17.09.1986

*No uncertainty provided in its calibration certificate

Fig. 1. ^{90}Sr+^{90}Y NIST applicator (plane/dermatological source) used in this work as reference in the calibration of the other applicators.

The Landauer Al_2O_3:C nanodot dosimeter is a layer of Al_2O_3:C sandwiched between two layers of polyester for a total of 0.3 mm of thickness and 7.0 mm of diameter. These detectors were exposed to the three applicators under the same conditions that the TLDs. The OSL dosimeters were optically treated at 26x10^3 lux during one hour prior each utilization. A Delta OHM radiometer, model D09721, LUX LP 9021PHOT sensor, was utilized to determine the light level. The Landauer microStar reader and software were utilized to evaluate the OSL detector response. The measurements were taken immediately after irradiation.

Results

Initially, the TL and OSL samples were studied in relation to their response reproducibility and lower detection limit. Dose-response curves were obtained for both materials using the NIST applicator and, finally, the absorbed dose rates were obtained for the A1, A2 and A3 applicators.

Reproducibility study of the dosimeters

The reproducibility of the TL response of $CaSO_4$:Dy samples was obtained after five series of irradiations (1 Gy), measurements and thermal treatments. The maximum perceptual deviation obtained was equal to 7.1 %, and the associated uncertainty was 8.7 %.

The reproducibility of the OSL response, using ten Al_2O_3:C detectors, ten times irradiated (6 mGy), measured and optically treated, was already determined as 4.9 % (Pinto and Caldas 2009), and the associated uncertainty was 2.8 %.

Lower detection limit

The lower detection limit was obtained by the variability of the TL response of non-irradiated $CaSO_4$:Dy samples. The limit obtained for the TLDs pellets was 56 µGy, presenting the same order of magnitude of the results obtained for this material ($CaSO_4$:Dy) by Campos and Lima (1987).

In the case of OSL detectors, the lower detection limit was determined graphically. The Al_2O_3:C were irradiated with the source of ^{90}Sr+^{90}Y of the BSS2 beta secondary standard system in a dose interval from 0.05 to 10 mGy. A dose-response curve was obtained and presented linear behaviour between 0.2 and 10 Gy.

The lower detection limit was obtained extrapolating the dose-response curve of 0.05 to $1x10^{-2}$ mGy (Figure 2), to compare it with the detection limit presented by the manufacturer (Landauer), of 0.2 mGy to beta radiation. In this work, the value obtained was 0.13 mGy.

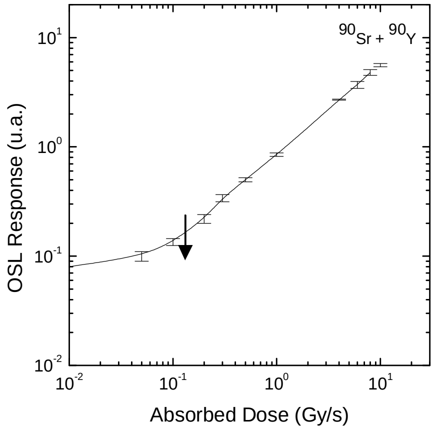

Fig. 2. Dose-response curve of the Al_2O_3:C detectors to ^{90}Sr+^{90}Y (BSS2), using the OSL technique, and utilized in the determination of the lower detection limit of the OSL response of Al_2O_3:C nanodot samples.

Dose-response curves of NIST applicator

The TL response of the $CaSO_4$:Dy samples was obtained in relation to absorbed dose in the air, irradiating the pellets with the NIST applicator in a dose interval from 5 to 20 Gy, at the null distance between dosimeter and source. The dose-response curve obtained can be observed in Figure 3. The TL pellets presented the expected response in the tested dose interval, with linear behaviour up to 10 Gy.

A dose-response curve was obtained for the OSL detectors (Figure 4) using the NIST applicator, under the same conditions of TLDs, but in a dose interval from 3 to 10 Gy. A linear behaviour can be observed.

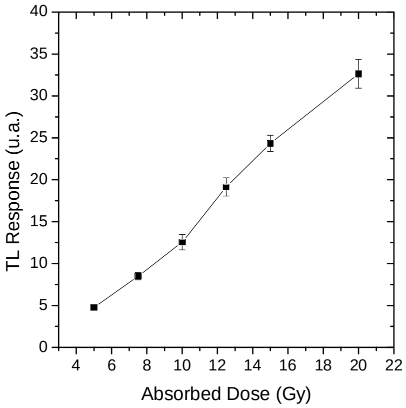

Fig. 3. Dose-response curve of the $CaSO_4$:Dy thin pellets, irradiated with the reference NIST applicator (^{90}Sr+^{90}Y).

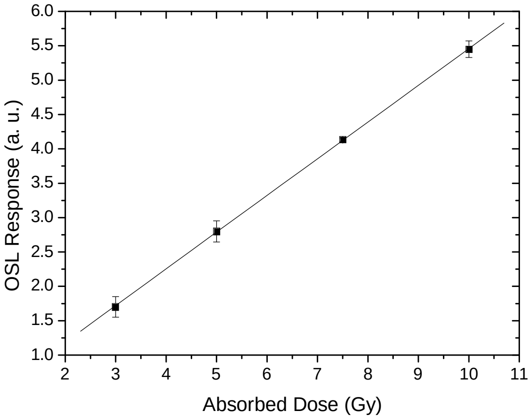

Fig. 4. Dose-response curve obtained of the Al_2O_3:C detectors, irradiated with the reference NIST applicator (^{90}Sr+^{90}Y).

Calibration of the ^{90}Sr+^{90}Y dermatological applicators

Using the dose-response curves of TL and OSL detectors, it was possible to calibrate the A1, A2 and A3 clinical applicators.

The $CaSO_4$:Dy thin dosimeters and the Al_2O_3:C detectors were exposed to each one of the clinical applicators during the irradiation time interval of 330, 330 and 300s, respectively for the A1, A2 and A3 applicators. These time intervals were chosen according to the activity of each source. The null distance between pellets and clinical applicators was always used during these irradiations.

The absorbed dose rates were determined and the results can be observed in Table 2.

Table 2. Absorbed dose rates obtained in this work, using the TL and OSL techniques, of the clinical applicators, in comparison with those provided in their calibration certificates.

^{90}Sr+^{90}Y applicator	Absorbed dose rate (Gy/s)		
	Certificate	TL technique	OSL technique
A1	0.0213 ± 0.0043	0.0254 ± 0.0051	0.0275 ± 0.0055
A2	No certificate	0.0294 ± 0.0060	0.0336 ± 0.0067
A3	0.0299 ± 0.0060	0.0342 ± 0.0068	0.0386 ± 0.0077

The maximum relative uncertainty for the TL measurements was equal to 9.6 % for the A1 applicator. In the case of the OSL measurements, the maximum relative uncertainty was equal to 1.7 % for the A2 applicator.

Discussion

The same procedure was adopted for the calibration of ^{90}Sr+^{90}Y clinical applicators using two techniques: TL and OSL. The usefulness of the TL detectors in the calibration of these applicators was verified in a previous work (Antonio and Caldas 2009), but the TL measurements in this work were taken in another TL reader (Harshaw Nuclear System, model 2000 A/B). These results, using different models of TL readers, are very similar (maximum difference of 16 % for the A3 applicator) demonstrating the efficiency of this kind of calibration method.

Conclusions

The reproducibility study of both TL and OSL detectors showed satisfactory results.

The absorbed dose rates obtained using TL dosimeters of $CaSO_4$:Dy and OSL detectors of Al_2O_3:C, in the calibration of the ^{90}Sr+^{90}Y clinical applicators, in comparison with the values provided in their calibration certificates, presented a maximum difference of 22 % (for the OSL technique and A1 and A3 applicators) between techniques and respective certificates, and of -12 % (A2 applicator) also between the two techniques.

It can be concluded that the OSL technique is as effective as the TL technique for the calibration of dermatological clinical applicators used in brachytherapy procedures.

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