Absorbed dose distribution visualization for superficial treatments through the Fricke Xylenol Gel dosimeter (FXG)

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Abstract. Electrons, orthovoltage X-rays and betas are used for superficial treatments. It has been shown that it is practical to measure these three types of radiation using gel dosimetry, which is an accurate dosimetric tool, from which one can infer the absorbed dose. The Fricke Xylenol Gel (FXG) dosimeter has presented adequate results due to its spatial resolution, effective atomic number and density that are near to those of soft tissue. The aim of this work is to compare three types of radiation for skin treatments like orthovoltage (X-rays), brachytherapy (beta rays) and megavoltage (electrons) using the FXG-CCD dosimetric system to determine the calibration curves (CC), beam profiles (BP) and percentage depth dose curves (PDD), evidencing why for clinical applications a specific type of radiation is selected for superficial treatment. From the results obtained we can infer that the FXG-CCD system is adequate for linear, area and volume measurements.

1. Introduction

Radiotherapy commonly has three modalities of dose delivery for superficial treatments: orthovoltage, brachytherapy and megavoltage electrons.

Gel based dosimetry has been widely investigated in some hospitals and research centers for quality control in radiotherapy, once it allows to verify the dose distributions, due to its capacity of detecting high dose gradients with high spatial resolution [1-3]. The FXG dosimeter demonstrated to be adequate for radiotherapy, because its effective atomic number (7.75) and density (1.05 g/cm³) are equivalent to those of the soft tissue (7.42) and (1.04 g/cm³), respectively [4,5].

In this work was shown the absorbed dose distributions from X-rays (80 keV), beta (⁹⁰Sr) and 5 MeV electrons. Calibration measurements, beam profiles and percentage depth dose were registered by the images through CCD detector to obtain respectively the CC, BP and PDD curves. The curves were analyzed through practical measurements done which FXG-CCD [6], using the FXG capacity to be spatially read at once. From obtained results, one can show that the FXG is appropriate for these types of measurements, which confirms that beta and electrons are better than orthovoltage for superficial irradiation.
2. Materials and methods
The measurements were done using three cuvettes for each absorbed dose value, depth and lateral distance. The FXG dosimeter was inserted in PPMA cuvettes (standard, 4.5 x 1 x 1 cm³, and specially manufactured ones of 21 x 6 x 1 cm³, 5 x 5 x 1 cm³ and 7 x 5 x 1 cm³) respectively for CC, BP and PDD measurements. From all values obtained for these measurements the average values from the non-irradiated cuvettes were subtracted.

An in-house scanner was developed to obtain FXG-CCD optical absorbance images, where all images captured with a CCD camera (NIKON/D40) were processed in a developed program with Matlab®, using the pixels intensities, to provide the absorbance values for all samples [6].

For orthovoltage measurements was used the Siemens/Stabilipan II/th. (H 250/300kV), with 80 kV and dose rate of 77.59 cGy/min. Square ⁹⁰Sr/⁹⁰Y planar source (Amersham England), was used for beta measurements with active area of 2 x 2 cm² and surface dose rate of 2.94 cGy.s⁻¹. The FXG dosimeter was irradiated with 5 MeV electron beams from a LINAC (Siemens/Mevatron/6MD). All field sizes were equal to 2 x 2 cm² for all types of radiation. To obtain the CC measurements were applied absorbed doses of 1 up to 5 Gy and for BP and PDD was applied an absorbed dose of 5 Gy, always using a 2 x 2 cm² field size.

For the beam profile using the FXG, an absorbed dose of 5 Gy was given at 1mm depth for ⁹⁰Sr/⁹⁰Y sources [7] and orthovoltage, and 5 Gy at 100.1 cm for megavoltage, in the center of the fields.

For the PDD measurements, FXG cuvettes of 7 x 5 x 1 cm³, were positioned with the minor side, perpendicular to the incident beams. The absorbed dose used for beta, X-rays and electron beams was 5 Gy at build-up depth (maximum dose depth).

3. Results and Discussions
The figure 1 shows calibration curves obtained from orthovoltage, beta and electrons sources. The curves show linear dependence with the absorbed dose, with correlation coefficients, R², of 0.999, 0.997 and 0.999 for orthovoltage, ⁹⁰Sr/⁹⁰Y and electrons, respectively. The standard deviations from the average readings (three measurements) for each measured point and energy not exceed 0.27%.

![Figure 1 - Calibration curves obtained from x-rays (o), beta sources (□) and electrons (Δ)](image-url)

The figure 2a) shows the beam profiles measured through FXG-CCD for X-rays, beta and electrons beams along perpendicular lines crossing the center of each radiation field. From the curves, one can see that the profiles are different due to the type of radiation and irradiation geometry, for example, the penumbra is higher for beta than for X-rays and the top of electron curve is more squared.
than the others, because for small field size using bigger SSD, the profiles are modified near to a Gaussian curve. Although the differences between the curves, the FWHMs are the same.

The figure 2b) shows the PDDs obtained with the FXG-CCD system for X-rays, beta and electron beams. From it one can visualize different behaviors, for example: beta shows the highest gradient, from which only very superficial lesions could be treated; orthovoltage X-rays and 5 MeV electrons could treat deeper lesions, but the electrons give homogeneous absorbed dose even for deeper distances from the surface, once the electrons have a range they would not irradiate health tissue, as do the X-rays. The FXG-CCD system permitted to evaluate how different types of radiation for superficial irradiation are selected through their absorbed dose distribution behaviors.

![Figure 2](image_url)

Figure 2- (a) Beam profiles obtained from X-rays (o), beta sources (□) and electrons (▲) for a 2 x 2 cm^2 field size and (b) Percentage depth dose obtained from X-rays (o), beta sources (□) and electrons (▲).

4. Conclusions
In this work, the FXG-CCD system was used for X-rays, beta and electron radiations to evaluate the behaviours of their absorbed dose distributions (calibration curve, beam profile and percentage depth dose). All calibration curves show adequate linearity with the absorbed dose, R^2 ≈ 1). The beam profiles showed similar FWHM for all types of radiation and energy used and the PDDs showed very different absorbed dose curves, from which one can decide which type of radiation to use for a specific superficial treatment. From the results obtained we can infer that the FXG-CCD system is an adequate dosimeter for linear, area and volume measurements.

References
[1] Baldock C, Burford R P, Billinghan N C, Wagner G S, Patval S, Badawi R D and Keevil S F 1998 Phys. Med. Biol. 43 695-702
[2] De Deene Y, Hurley C, Venning A, Vergote K, Mather M, Healy B J and Baldock C 2002 Phys. Med. and Biol. 47 3441-63
[3] Gustavsson H, Karlsson A, Back S A J, Olsson L E, Haraldsson P, Engstrom P and Nystrom H 2003 Med. Phys. 30 1264-71
[4] Calcina C S G, De Oliveira L N, De Almeida C E, De Almeida 2007 Phys. Med. Biol. 52 1431
[5] De Oliveira L N, Zimmerman R L, Moreira M V, Ila D and De Almeida 2009 Surf. Coating. Tech. 203 2367-69
[6] Sato R, De Almeida A, Moreira M V 2009 Nu. Ins. Meth. Phys. R. B 267 842-5
[7] ICRU 2004 Dosimetry of Beta Rays and Low-Energy Photons for Brachytherapy with Sealed Sources ICRU Report 72 (Bethesda, MD: International Comission on Radiation Units and Measurements)