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DEVELOPMENT OF COMPUTATIONAL MODELS FOR THE SIMULATION OF ISODOSE CURVES ON DOSIMETRIC FILMS GENERATED BY IODINE-125 BRACHYTHERAPY SEEDS

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ABSTRACT

The interstitial brachytherapy is one modality of radiotherapy in which radioactive sources are placed directly in the region to be treated or close to it. The seeds that are used in the treatment of prostate cancer are generally cylindrical radioactive sources, consisting of a ceramic or metal matrix, which acts as the carrier of the radionuclide and as the X-ray marker, encapsulated in a sealed titanium tube. This study aimed to develop a computational model to reproduce the film-seed geometry, in order to obtain the spatial regions of the isodose curves produced by the seed when it is put over the film surface. The seed modeled in this work was the OncoSeed 6711, a sealed source of iodine-125, which its isodose curves were obtained experimentally in previous work with the use of dosimetric films. For the films modeling, compositions and densities of the two types of dosimetric films were used: Agfa Personal Monitoring photographic film 2/10, manufactured by Agfa-Geavaert; and the model EBT radiochromic film, by International Specialty Products. The film-seed models were coupled to the Monte Carlo code MCNP5. The results obtained by simulations showed to be in good agreement with experimental results performed in a previous work. This indicates that the computational model can be used in future studies for other seeds models.

1. INTRODUCTION

The interstitial brachytherapy is one modality of radiotherapy in which radioactive sources are placed directly in the region to be treated or close to it. The seeds that are used in the treatment of prostate cancer are generally cylindrical radioactive sources, consisting of a ceramic or metal matrix, which acts as the carrier of the radionuclide and as the X-ray marker, encapsulated in a sealed titanium tube.

The objectives of this work are to develop computational models with geometry composed of a dosimetric film containing a brachytherapy seed on the film surface and to obtain the isodose curves generated by the seed over the film, in a region of interest, through simulations using Monte Carlo method computer codes and compare these results with experimental studies previously obtained [1].

2. MATERIALS AND METHODS

2.1. The Iodine-125 Amersham 6711 seed model

The computational model was based on the source 6711 which consists of a silver rod (ρ = 10.5 g/cm3), covered along its entire length by a radioactive layer composed of a mixture of AgBr and AgI present in the molecular ratio of 2.5:1 with 6.2 g/cm3 density. The whole system is encapsulated by a titanium cylinder (ρ = 4.54 g/cm3). The thickness of the radioactive layer is estimated to be between 1.0 and 2.5 μm [2]. The silver rod, which is the radiographic marker of this seed, is 2.8 mm long and has a radius of 0.25 mm.

The ends of the silver rod are conical sections bevelled at 45 degrees and the end faces of the silver rod have a radius of 0.175 mm. The encapsulation is done by a titanium tube 3.75 mm long, wall thickness of 0.07 mm and outer diameter of 0.8 mm. Due to the different thicknesses shown in the welding of the ends of the seeds [2], their dimensions are given at intervals and the average is a half-sphere with radius 0.375 mm. The inner surface of the welds in this model was considered flat. The total length of the seed is 4.55 mm (Fig. 1).

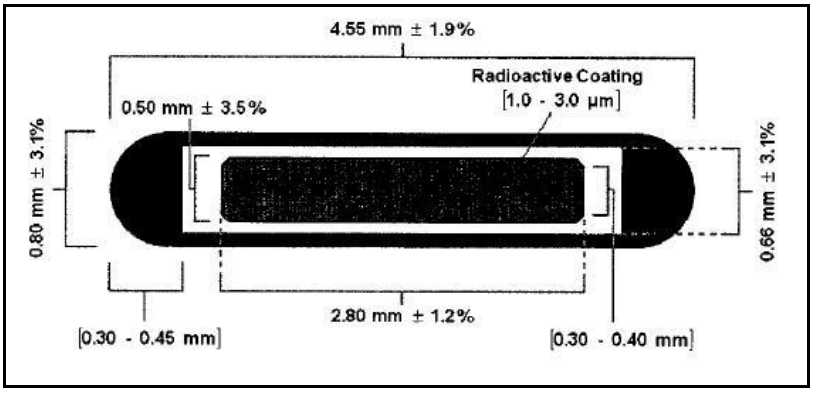


Figure 1. Geometry model of the 6711 seed [2].

2.2. Dosimetric Films models

2.2.1. Radiochromic Film model

The radiochromic film modeled in this work is GAFCHROMICs® EBT type, with a density that approaches human tissue.

This type of film dispenses development, thus avoiding the production of chemical waste. It can be handled in bright environments, but direct exposure to sunlight should be avoided. It is recommended by the manufacturer that the film is handled in ambient temperatures between 20 and 25 degrees C. It responds to a dose range from 1 cGy to 8 Gy and has low energy dependence in the range of keV to MeV [3]. A representation of this film is illustrated in Fig. 2. Table 1 lists the densities and compositions used in this model.

Table 1. Composition of the radiochromic film model.

Element	Density (ρ =6.473 g/cm3)	Composition
Silver Bromide (Active Layer)	6.473	Br (42.55%), Ag(57.45%)
Polyethylene Terephthalate (Clear Polyester)	1.38	H (4.2%), C (62.5%), O (33.3%).

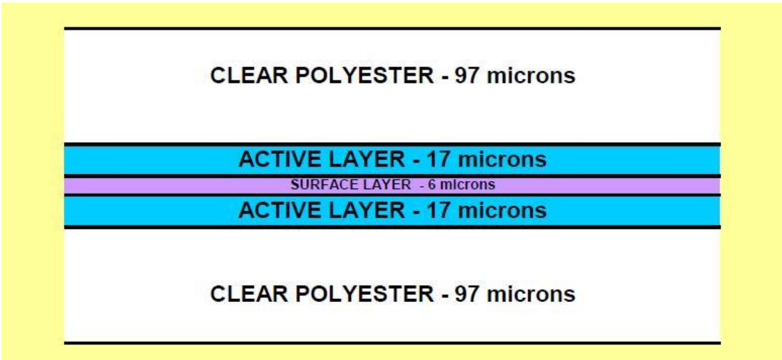


Figure 2. Representation of the GAFCHROMICs® EBT radiochromic films [3].

2.2.2. Photographic Film model

The modeling of the photographic film was developed from geometric information of the Agfa Personal Monitoring 2 / 10 model, manufactured by Agfa-Geavaert. This film has two kinds of photographic emulsions (Fig. 3), the first has high sensitivity and the second has low sensitivity to ionizing radiation [4]. Table 2 lists the densities and compositions used in this model.

Table 2. Composition of the photographic film model.

Element	Density (ρ = 6.473 g/cm3)	Composition
Silver Bromide (Emulsion)	6.473	Br (42.55%), Ag(57.45%)
Polyethylene Terephthalate (Base)	1.38	H (4.2%), C (62.5%), O (33.3%).

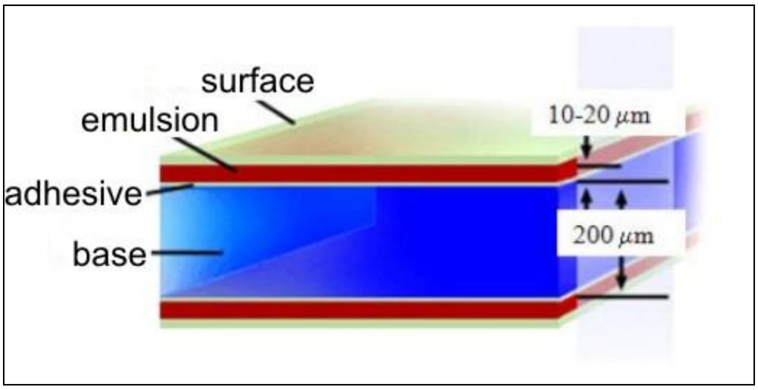


Figure 3. Representation of the AGFA Personal Monitoring 2/10 photographic films [4].

2.3. Computational Model

For this work two computational models were developed, both with ~~a~~ geometries that consist of a brachytherapy seed on a film, as illustrated in Fig. 4. The model 01 used the geometry of a radiochromic film (Fig. 2), with 3.5 cm wide and 4 cm long; and the model 02 used the geometry of a photographic film (Fig. 3), with 3 cm wide and 4 cm long. In Fig. 5 and 6 the seed-film geometries on a large scale are illustrated.

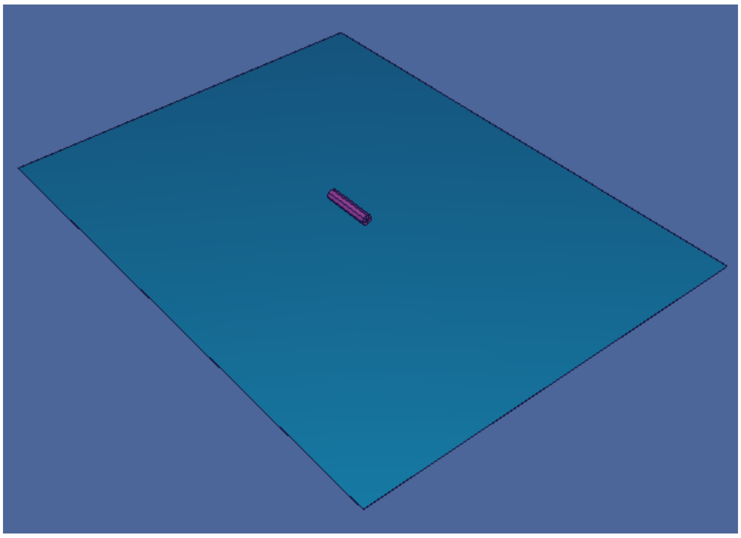


Figure 4. 3D view of the geometry: seed + film.

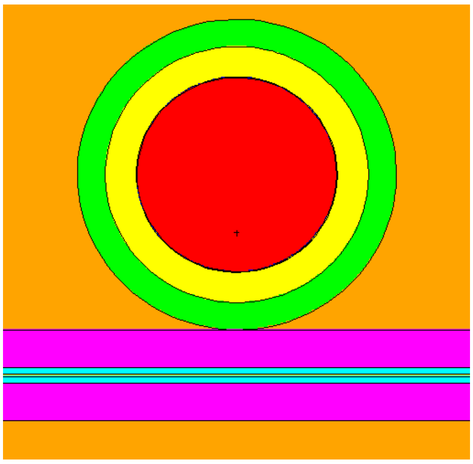


Figure 5. Extended view of the model: seed + radiochromic film.

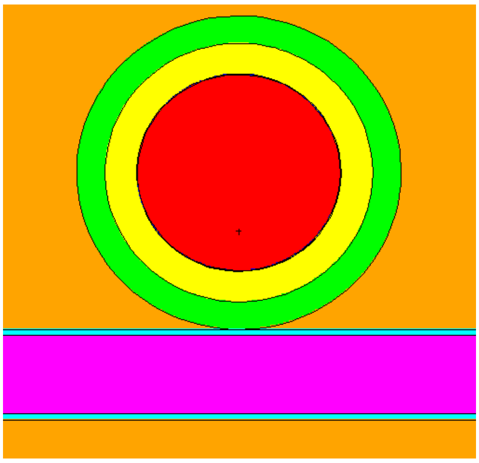
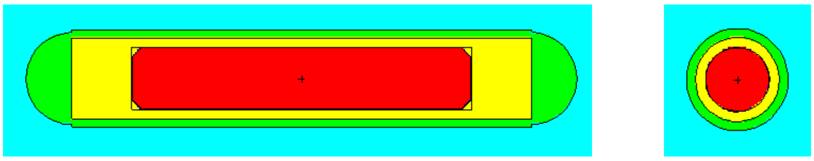


Figure 6. Extended view of the model: seed + photographic film.

The modeling of the seeds (Fig. 7) was done through the use of geometric information of Amersham 6711 commercial seed and was prepared using the software Visual Editor, which is part of the installation package of MCNP5 Monte Carlo code. For validation, comparisons were made between simulations performed by MCNP5 and EGSnrc Monte Carlo codes. The tests showed differences less than 3% and 10% for the radial dose and anisotropy functions [5].



(a) **(b)**

Figure 7. Views of the brachytherapy seed model based on AMERSHAM 6711 [5].

3. RESULTS AND DISCUSSION

The simulations of computational models "Film + seed" developed for this study were performed using the MCNP5 code, in an average computational time of 3 ½ hours, for 10^9 histories. The number of histories was enough to get $R \leq 0.05$, as suggested in the MCNP5 manual. These simulations were performed on a computer with an Intel ® Corel ™ 2 Duo, CPU E6750 @2.66GHz, 1.99 GB of RAM and Microsoft Windows XP operating system, version 2002 service pack 3.

The isodose curves obtained in the simulations for the second emulsion in photographic film are shown in Fig. 8. This emulsion shows more accurate results because it is furthest from the seed. Figure 10 shows the simulation results to the isodose curves for the radiochromic film model.

These results were compared with those from the experimental measurements [1].

The curves obtained in the second emulsion of photographic film, calibrated in the range of 0 to 18 mGy and irradiated for 2 min are shown in Fig. 9.

The curves obtained in the radiochromic film, calibrated in the range of 0 to 400 mGy and irradiated for 1 h are shown in Fig. 11.

The curves shown in Figs 8 to 11 are quantified by statistical weights, calculated for the maximum dose (weight 1.00), depending on the dose range used in each of the dosimetric film.

In the photographic film computational model for the second emulsion (Fig. 8), the isodose curve with the 0.34 factor of the maximum dose has a range with a radius of approximately 1.25 mm and the curve with the 0.20 factor, a range of approximately 1.75 mm. The curves of the experimental results (Fig. 9) that are closer to these chosen factors are: the curve of the 0.36 factor with a range of approximately 1.5 mm and the curve of the 0.23 factor with a range of approximately 2.5 mm.

To the radiochromic film computational model, the curves with the factors 0.33, 0.22 and 0.11 of the maximum dose (Fig. 10) had approximate ranges of 0.85 mm, 1.25 mm and 1.9 mm. The experimental curves with values closer to these factors are: 0.38, 0.25 and 0.13 with ranges of 1.25 mm, 2.00 mm and 2.25 mm.

These results were obtained with the first versions of the computer models "Film + seed" and showed average errors of 25%. In the next phase of this study refinements will be made in the models with the aim of creating an auxiliary tool to estimate the extent of the isodose curves in regions of interest.

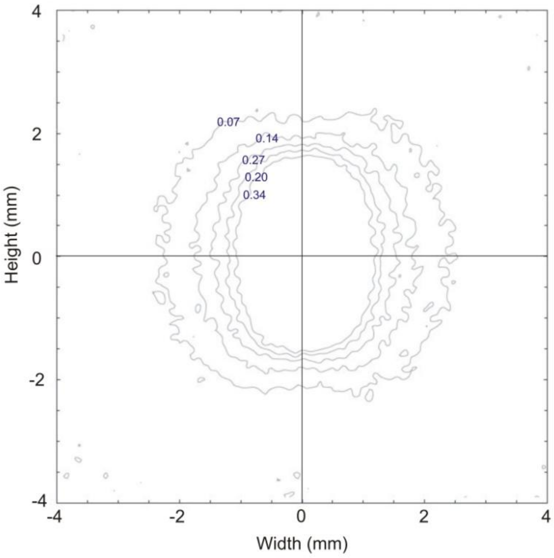


Figure 8. Simulated curves with the computational model for the less sensitive emulsion (photographic film).

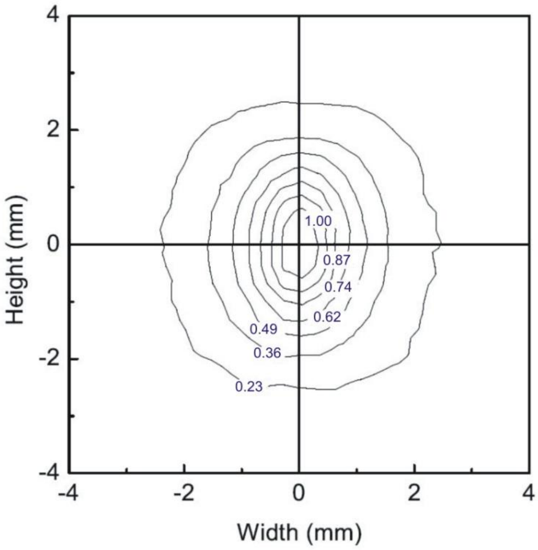


Figure 9. Isodose curves obtained experimentally in the less sensitive emulsion (photographic film).

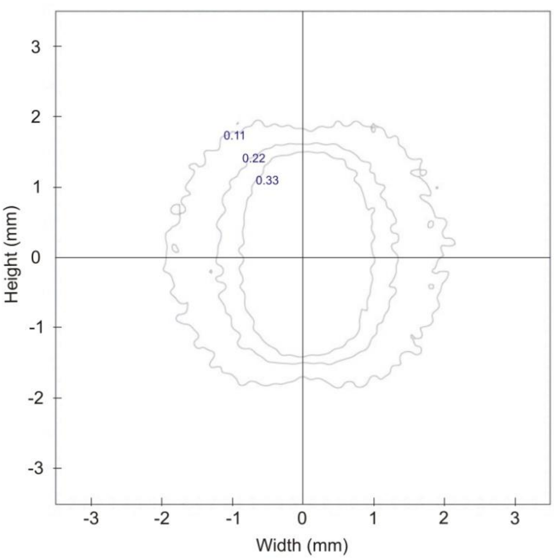


Figure 10. Simulated curves with the computational model for the radiochromic film.

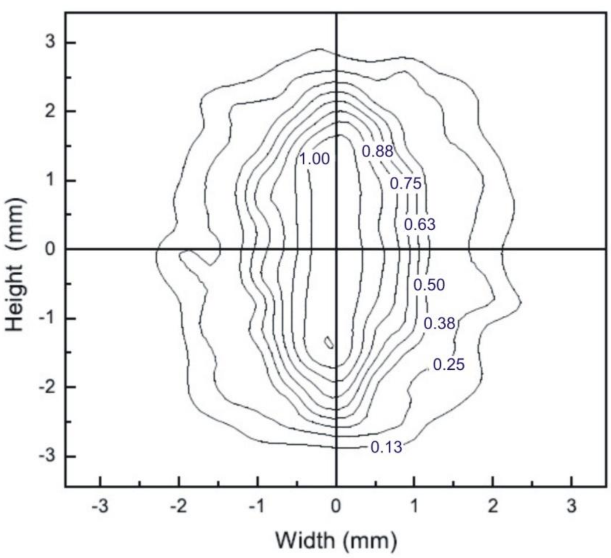


Figure 11. Isodose curves obtained experimentally for the radiochromic film.

4. CONCLUSIONS

The computer models created in this first stage of the study showed satisfactory results when compared to the experimental results. As perspectives of this study, computer models are refined so that they can be used as auxiliary tools in estimating the extent of isodose curves in regions of interest, both in films or in other dosimetric mediums.

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