

DOSIMETRIC COMPARISON OF ELECTRON BEAM AND $^{90}\text{Sr}+^{90}\text{Y}$ APPLICATOR FOR KELOIDS TREATMENT

Talita S. Coelho¹, Ariane Tada¹, Marco A. R. Fernandes², Patrícia L. Antonio¹, and Hélio Yoriyaz¹

¹ Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
tasallesc@usp.br

² Faculdade de Medicina da UNESP de Botucatu – (UNESP-SP)
Departamento de Dermatologia e Radioterapia
Rubião Junior – Distrito de Botucatu
18618-970 - Botucatu, SP
marco@cetea.com.br

ABSTRACT

Studies have been shown that among several methods that have been used for the treatment of keloids the surgical excision followed by the adjuvant radiotherapy presents the lowest relapsed rate of the injury. In this work a comparative dosimetric study has been performed using a 4 MeV electron beam from a Varian Clinac 2100C linear accelerator at the radiotherapy service of the Hospital das Clínicas of UNESP-HC, Botucatu-SP and an Amershan $^{90}\text{Sr}+^{90}\text{Y}$ brachytherapy applicator with 1491 MBq of activity. Percentage depth dose curves from ionization chamber measurements and through Monte Carlo simulation have been obtained and compared. Dose measurements have been obtained using parallel plates ionization chamber (Esradin A12) and extrapolation mini-chamber developed at IPEN. The dose calculations have been obtained using the well-known Monte Carlo radiation transport code MCNP-4C. Maximum dose differences obtained between measured/calculated values for $^{90}\text{Sr}+^{90}\text{Y}$ applicator and for the electron beam were, respectively: 7.8 % and 8.0%. The profiles of the depth and superficial tissue dose distribution produced by the electron beam revealed themselves flatter and more homogeneous than those produced by the $^{90}\text{Sr}+^{90}\text{Y}$ applicator, especially to wider fields, which cannot be obtained with brachytherapy applicators because of their geometric limitations. In conclusion this present work has shown that $^{90}\text{Sr}+^{90}\text{Y}$ applicators could be efficient for small and very superficial lesions but in most cases electron beam sources are more adequate especially for large and deeper lesions.

1. INTRODUCTION

Keloid is a pathology that is characterized by an excessive production of fibrous tissue (fibroblasts) by the skin as a consequence of some coetaneous trauma or surgical excision [1]. Generally, its aspect is like a scar with irregular form and can rise up to 1.0cm above the skin. In the beginning, keloids are reddish-brown acquiring pallid rose tones and eventually whitish afterwards. Anatomically, keloids appear on layer of the derme skin, built up from stable fibers that are predominantly composed by collagen and elastin. Studies indicate that the formation of keloids is pronounced in children and adolescents with more incidences in women than in men and with people of dark skin and eastern descendants [2,3].

The main sites of keloid formation are chest, shoulders, ears, neck and less often in the face and the extremities. For patients, keloids are not only a matter of cosmetic question, but

depending of the body's region, it can cause burning sensation, itching, tingling or pain, and once installed it does not regress spontaneously [4].

The surgical excision has been the most common medical procedure when keloid is diagnosed; however, it has been observed that when only the surgery is performed, the rate of lesion recurrence is of the order of 50-80% [5]. The adjuvant radiotherapy with electron beams and betatherapy have been the most indicated therapeutic modalities to reduce this recurrence rate.

The electron beams used in the radiotherapy are produced by linear accelerator. For specific cases of keloid treatment the energy of the beam varies from 4 MeV to 6 MeV and depends on the morphological conditions, size and geometry of the lesion.

In the present study we used the Varian Clinac 2100C linear accelerator at the radiotherapy service of the Hospital das Clínicas of UNESP-HC, Botucatu-SP. This accelerator can be used for benign or malignant lesion. The accelerator's energy spectra needed for Monte Carlo simulations was determined empirically based on depth dose experimental curve in a water phantom measured with ionization chamber.

In Brazil the most common applicators are $^{90}\text{Sr}+^{90}\text{Y}$ emitters. They have a half life of 28.5 years and emit particles with a maximum energy of 0.546 MeV. ^{90}Sr decays in ^{90}Y which half life is 64.1 hours with a energy of 2.279 MeV (99.99% of transactions) and 0.519 MeV (0.01%), that by turn decays in ^{90}Zr which is stable [6].

These applicators are used to prevention of treatment of skin diseases such as keloids and some very superficial lesions of the skin, and eye diseases as the pterygium. The objective is to prevent the formation of new keloids by the inhibition of fibroblast. The applicators have a primary barrier of low atomic number plastic with approximately 10.0 mm of thickness for protection during handling. The face of the plate in contact with the skin is covered by a 0.5 mm thick polyethylene plastic to absorb low energy electrons generated in the decay of the ^{90}Sr [7].

The utilization and handling of these applicators in radiotherapy services are limited by the data provided by international manufactures, which in certain situations compromise the treatment's quality and flexibility.

This work presents a comparative study of the dosimetric characteristics between 4 MeV electron beam and a $^{90}\text{Sr}+^{90}\text{Y}$ applicator for skin treatment using the MCNP Monte Carlo code and ionization chamber.

2. MATERIALS AND METHODS

The Monte Carlo code was applied to simulate the curves of percentages depth dose, using a applicator of $^{90}\text{Sr}+^{90}\text{Y}$ of the brand Amershan and a 4 MeV electron beam from a Varian Clinac 2100C linear accelerator at the radiotherapy service of the Hospital das Clínicas of UNESP-HC, Botucatu-SP. The response of these calculations were validated through of experiments, using chambers of ionization.

2.1. Dosimetry of the applicator of $^{90}\text{Sr}+^{90}\text{Y}$

The dose calculation has been performed in a phantom composed by a cylinder of water of radius of 4.5 mm, with 14 slices of 0.6 mm of thickness, representing the layers of the skin. The source was modeled as a plane-circular plate of $^{90}\text{Sr}+^{90}\text{Y}$, representing an applicator of betatherapy, that has a diameter of 9.0 mm. The activity of the source is 1491 MBq (2009). The applicator is placed in contact with the skin and covered by 1.0 mm of polyethylene plastic which act barring the low energy electrons generated from the decay of ^{90}Sr , as showed the figure 1.

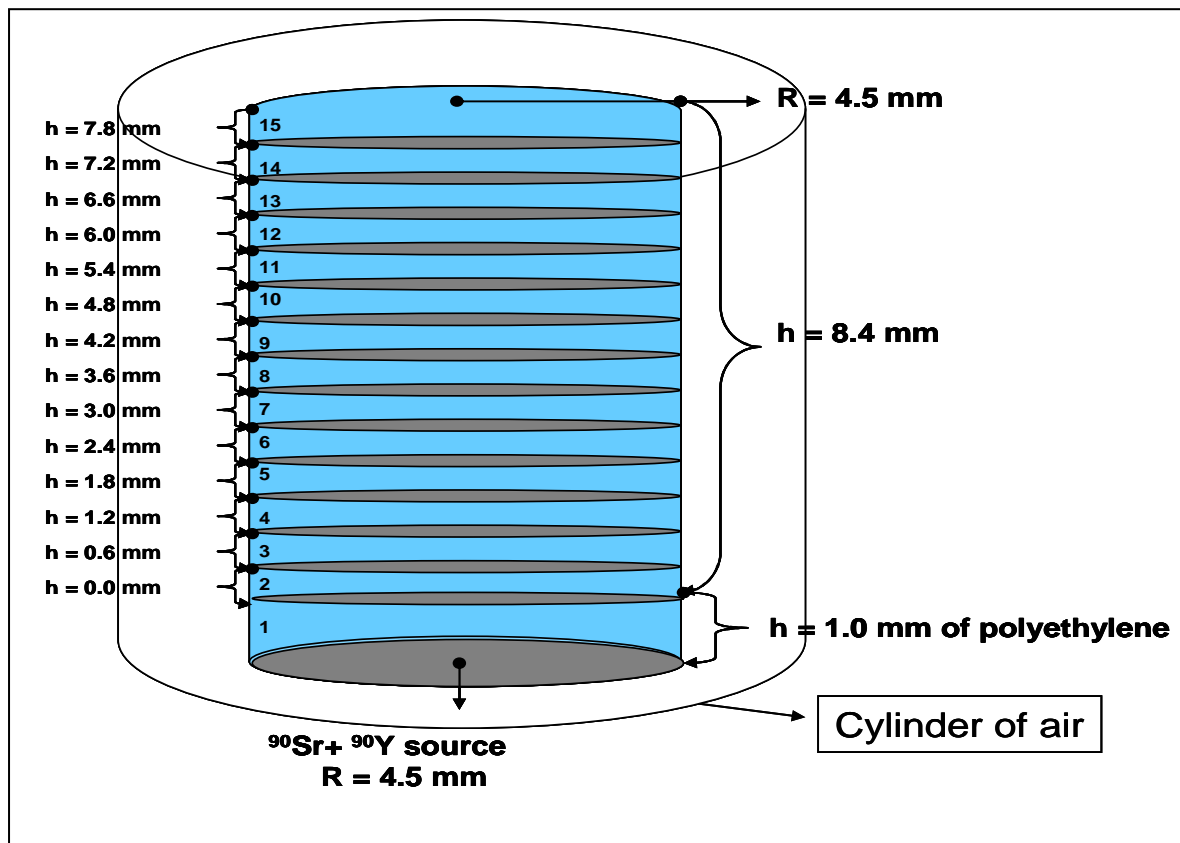


Figure 1. Simulation's geometric of applicator de $^{90}\text{Sr}+^{90}\text{Y}$.

Both the skin and the applicator were placed inside a cylinder of air. The figure 2 showed the spectrum used is made up from the characteristic energy of ^{90}Sr and ^{90}Y weighted by their decay probabilities.

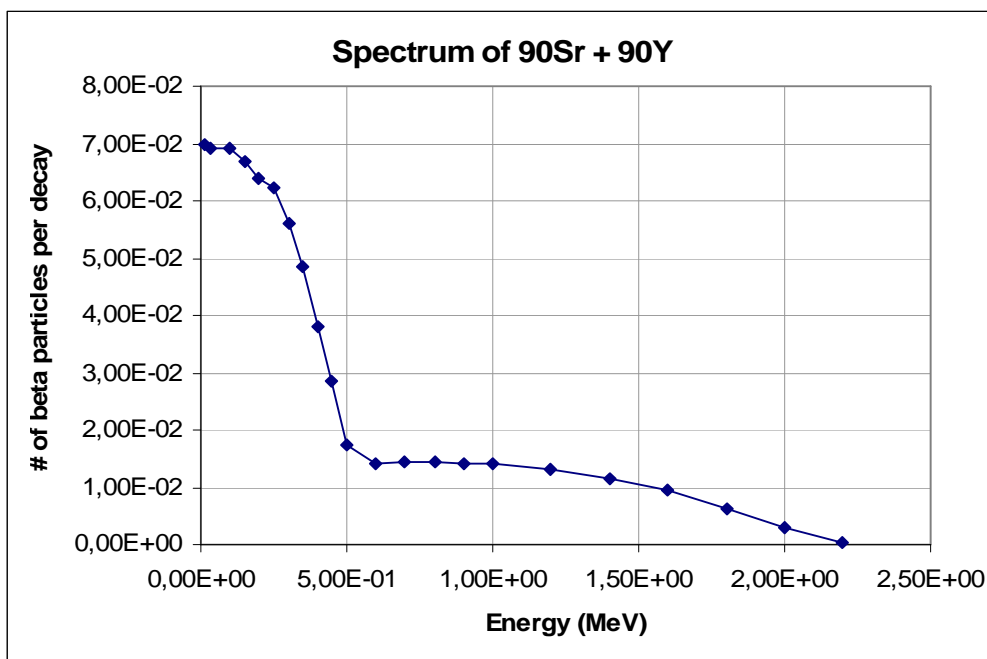


Figure 2. Spectrum of energy of $^{90}\text{Sr}+^{90}\text{Y}$.

To validate the calculations, experimental measurements were obtained using the same applicator of the simulations. The detector was a mini-extrapolation chamber of plane window, developed at the Laboratory of Calibrations and Instruments of IPEN, connected to the PTW electrometer model UNIDOS 10001, that allows a tension of $\pm 50\text{V}$. The mini-chamber was stabilized 1 hour before the beginning of the measurements and its sensitive volume remained fixed at 1.0 mm.

The source-detector distance had been modified using polystyrene plates of different thickness, from 0.6 mm to 5.4 mm with increments of 0.6 mm. The first measure was taken without plate in such a way that the source was in contact with the detector. All the measurements were done inside a special acrylic box designed to guarantee the proper protection for the operator and the adequate position of the source and the mini-chamber, as showed the figure 3.

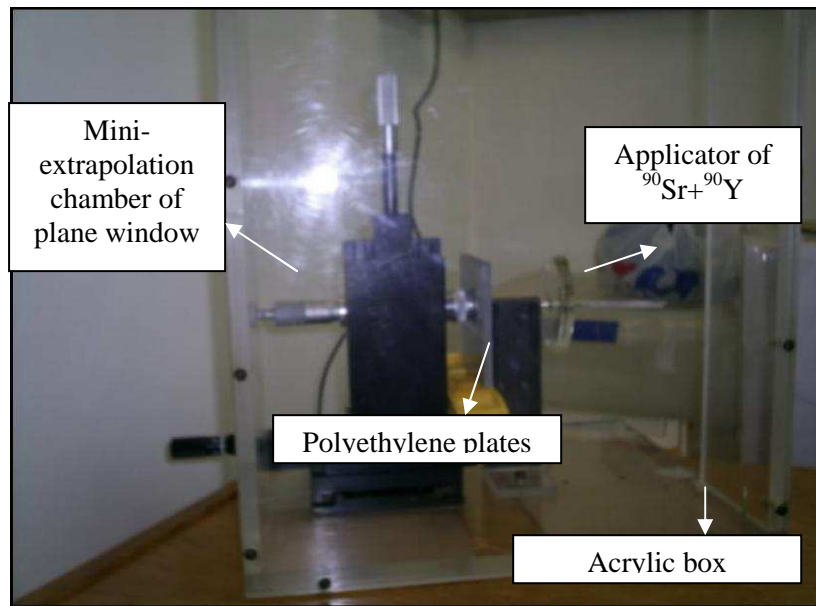


Figure 3. Experimental measurement arrangement using mini-extrapolation chamber of plane window.

The charge measurements were taken in intervals of 60 s totalizing 6 measures for each source-detector distance being 3 at positive polarity and the other 3 at negative polarity. After the charge measurements being transformed to current and corrected to normal conditions of temperature and pressure, the average of the measurements for each distance was calculated.

2.2. Dosimetry of the 4 MeV electron beam

For the experimental measurements with the electron beam it was used the linear accelerator Varian model Clinac 2100C, of the Radiotherapy Service from the Hospital das Clínicas of the Faculdade de Medicina of UNESP Botucatu-SP. The detector used to measure the electron beam was the waterproof parallel plate ionization chamber Exradin A12 calibrated in electrons beams and coupled to its electrometer (Standar Imaging CDX-20000B-JO10553). The simulator object (phantom Oxford) had 30 cm x 30 cm x 30 cm³ of dimensions and the material of its walls and of the support of ionization chamber was acrylic. As showed figure 4.

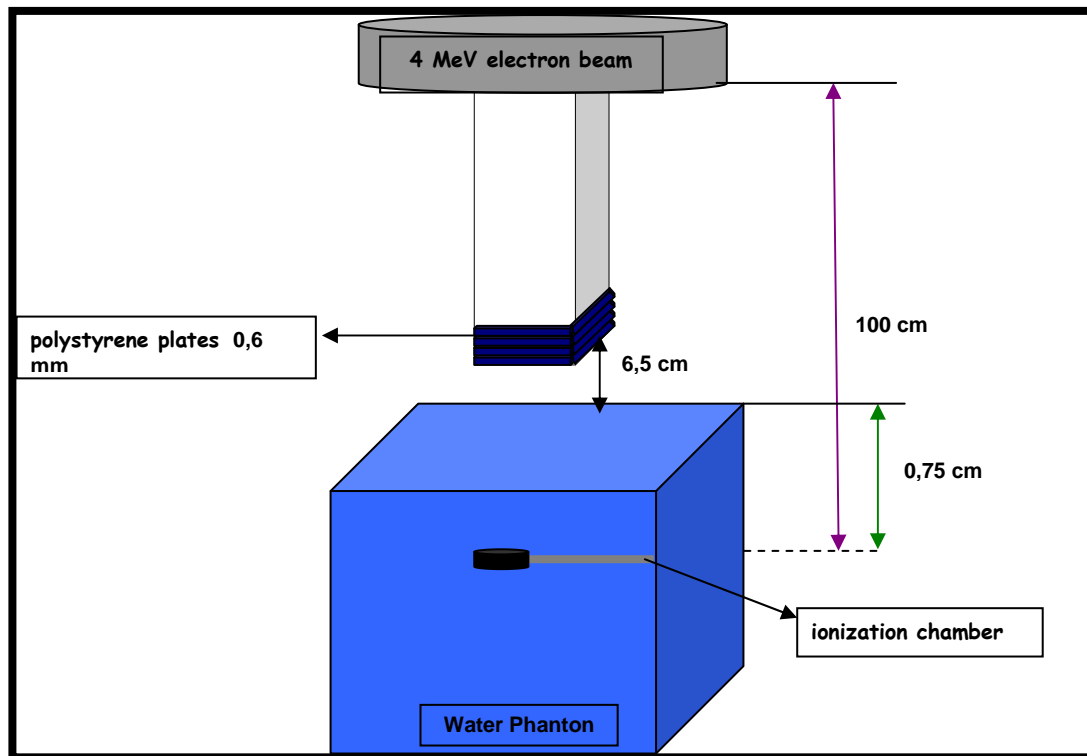


Figure 4. Experimental measurement arrangement using ionization chamber.

To simulate the skin layers, 10 polystyrene plates, material equivalent to the human tissue, with 0.6 mm were used. Before beginning the measures, the PDD curve had to be estimated to get the electron spectrum of the linear accelerator and to verify at which position the maximum dose had occurred. The surface of the ionization chamber was placed Z_{ref} at 0.75 cm from the phantom surface where the maximum dose region were identified. The first irradiation was without any plate and one plate per time was added for each subsequent irradiation.

For the MCNP simulations, a water cube representing the phantom was modeled. Inside this cube there were 26 ellipsoids where 14 of them located at the build-up region. The distances between the ellipsoid centers are exactly the thickness of the polystyrene plates used in the experiment, i.e., 0.06 cm. The environment around the phantom was simulated as a cylinder of air as showed the figure 5.

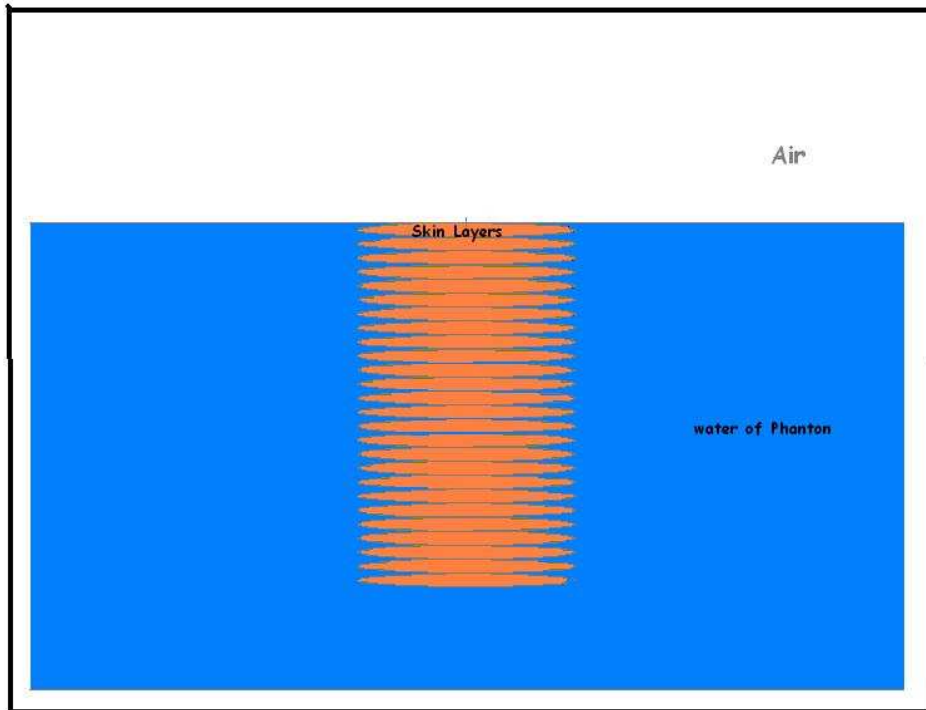


Figure 5. Simulation's Geometry of 4MeV electron beam.

The reconstruction of the electron energy spectrum was made from the PDD obtained experimentally with the ionization chamber. The advantage of this process of reconstruction is that it does not need the knowledge of the accelerator's composition and geometry. If we consider a mono-energetic beam at the MCNP simulation, then a divergence between the experimental and the simulated results might be from 11% up to 106%. By using the spectral reconstruction technique, the maximum deviation is 2% at the deepest points.

3. RESULTS

3.1. Dosimetric analysis of $^{90}\text{Sr}+^{90}\text{Y}$ applicator and 4 MeV electron beam

Figure 6 shows the curve of percentage depth dose calculated with MCNP and the one obtained with the mini-extrapolation chamber. The maximum variation between the calculated and the experimental curves is of 7.71% and occurs at the distance of 5.4 mm. The behavior of this source reveals a great ionization power and a short tissue range, i. e., the maximum radiation dose occur at the tissue surface (0.0 mm of depth) and at 3.0 mm of depth there is around 15% of the maximum dose. Both experimental and simulated one showed deviation below 2.0%. From these results, both dosimetry methods are satisfactory as they present equivalent curves.

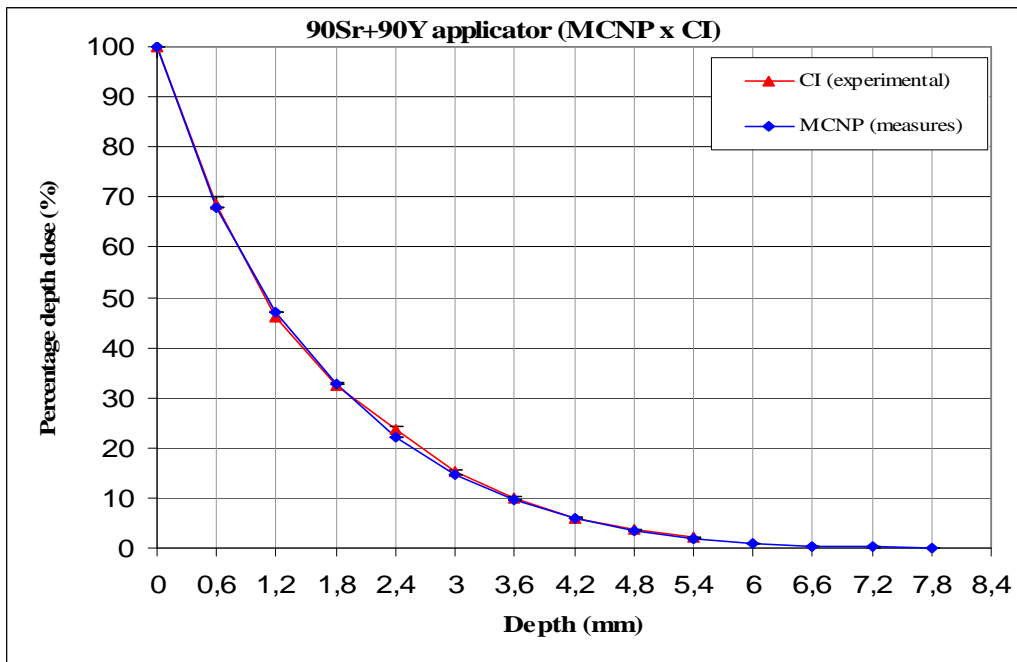


Figure 6. Curve of percentage depth dose measure and experimental of the applicator of $^{90}\text{Sr}+^{90}\text{Y}$.

Figure 7 shows a comparison between the curve of percentage depth dose obtained with the parallel plate ionization chamber and the one calculated with the Monte Carlo method. For the first two points, the calculated Monte Carlo results show a variance of 0.5% from the expected value. For the other points, the difference between the experimental and the simulated results are between 1% and 8%. Both experimental and simulated one showed deviation below 1.0%. The simulated result was satisfactory once it has presented the same behavior as the experimental one.

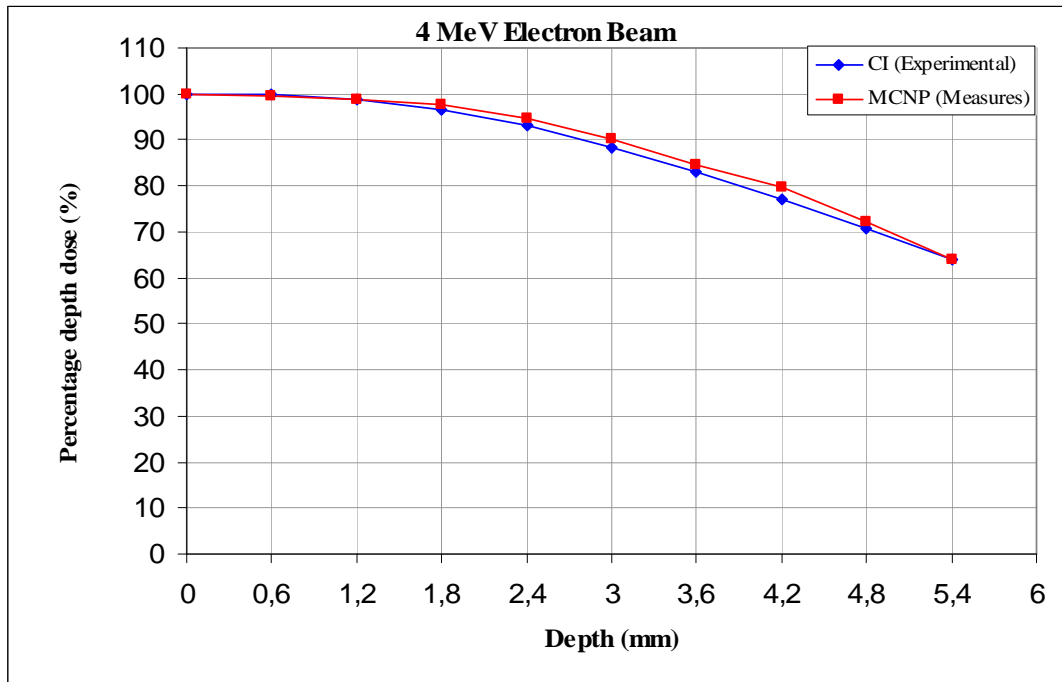


Figure 7. Curve of percentage depth dose measure and experimental of the 4 MeV electron beam.

3.2. Dosimetric Comparison between the 4 MeV electron beam and the applicator of $^{90}\text{Sr}+^{90}\text{Y}$

Figure 8 shows the curve of percentage depth dose (PDD) obtained with the ionization chamber, the applicator of $^{90}\text{Sr}+^{90}\text{Y}$, and the 4 MeV electron beam. From this Figure comes out that from 0.0 mm to 2.0 mm of thickness there is a variation of less than 10% of the maximum dose using the electron beam while using the applicator the $^{90}\text{Sr}+^{90}\text{Y}$, the variation is 70% of the maximum dose. So, as the human skin (dermis and epidermis) at the thorax region varies from 1.439 mm to 2.062 mm of thickness [3], for these depths there is a better dose distribution at the tissue after the treatment with the 4 MeV electron beam, which may contribute to decrease the relapsed rate of the injury [8].

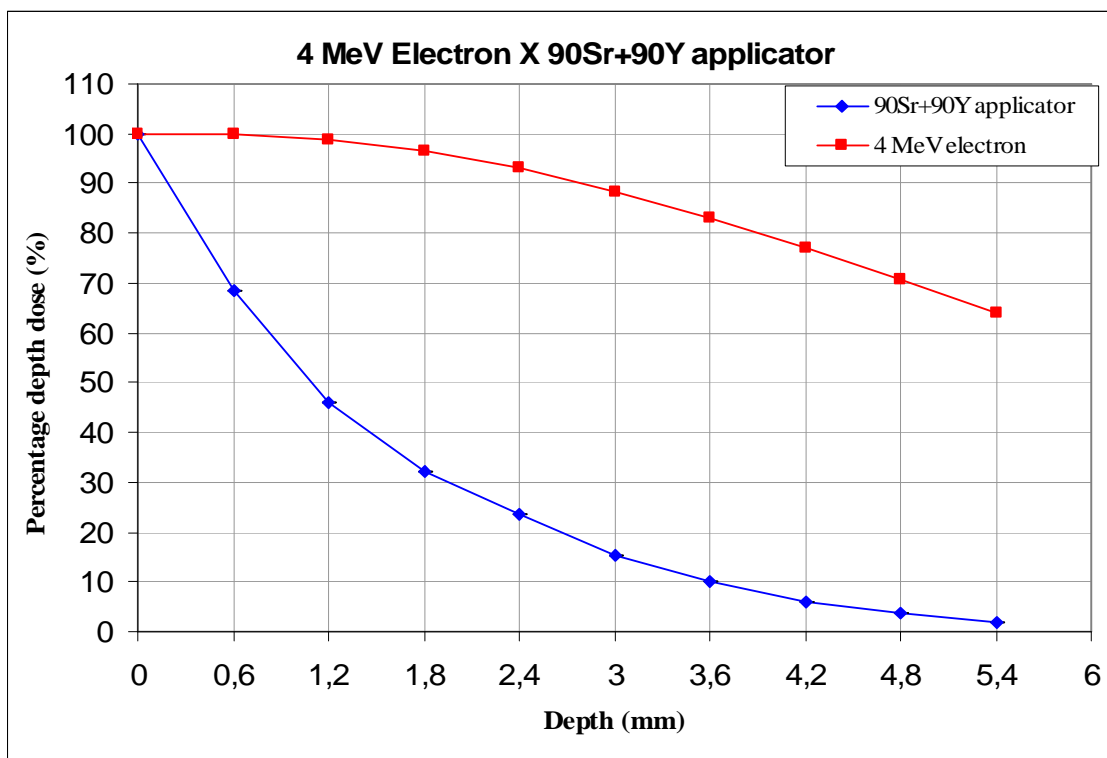


Figure 8. Dosimetric comparison of the applicator of ⁹⁰Sr+⁹⁰Y and of the 4 MeV electron beam.

4. CONCLUSION

The analysis of percentage depth dose curves that were obtained from the ionization chambers and the MCNP-4C simulations have shown that both dosimetry methods are satisfactory once they present equivalent curves for the 4 MeV electron beam and also for the applicator of ⁹⁰Sr+⁹⁰Y. The dosimetric comparison between these two types of radiation sources illustrates that the 4 MeV electron beam puts up a better dose distribution at the tissue. This result summed to the fact that electron beams from linear accelerators might have several dimensions and might be wider than the beta ray of the applicators of ⁹⁰Sr+⁹⁰Y, indicate a greater efficacy of the therapy with the electron beams.

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