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USING SILICONE-BASED RUBBERS AS BOLUS MATERIALS IN RADIOTHERAPY

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Abstract. *In radiotherapy certain types of cancer are encountered that occupy both the surface of the skin and the tissue underneath, which requires the use of attenuation materials in order to ensure correct treatment. Our research aim is to find materials that are more cost effective than the commercially available ones.*

Keywords: *Radiotherapy, bolus, silicone rubber, photon beam, attenuation*

1. Introduction

Radiotherapy has remained a major component of the curative and palliative therapy of cancer and plays a major role in the management of many benign diseases [1]. Radiation therapy is a clinical modality of treating malignant neoplasia with the use of ionizing radiation [2]. The aim of radiotherapy is to deliver a precisely measured dose of radiation with the surrounding healthy tissue receiving a minimal as possible dose, resulting in high quality of life and prolongation of survival or palliation of symptoms at a reasonable cost [3].

Some types of cancers are located in the tissue underneath the skin and on the surface of the skin itself, for example, the cases of patients whose chest wall underwent a mastectomy procedure or the cases of patients that have cancer in the head and neck region [4][5].

The basic linear accelerator used in radiotherapy uses a photon beam with the energy of 6 MV [6]. The dose distribution of a megavoltage photon beam upon entering the body of a patient is presented in Figure 1. The photon beam delivers a certain surface dose D_S which increases with the energy of the photon beam until it reaches the maximum value D_{max} when it starts to decrease until it exits the patient's body as the D_{ex} dose. This region between 0 and z_{max} is referred to as the dose buildup region [7].

The photon beam does not deliver a high-enough radiation dose to the surface of the intended volume of treatment so, by using a tissue-like bolus material, we can ensure the full coverage of the treated area [8].

Our research is focused on using different silicone based rubbers to replace the expensive commercially-available bolus.

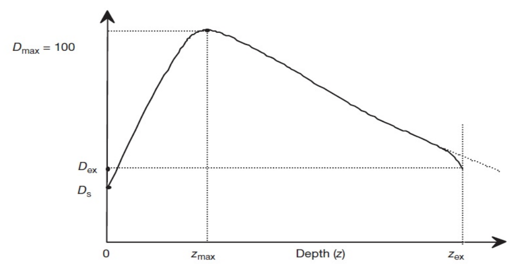

Figure 1. Dose distribution of a photon beam [7]

2. Materials and Methods

Two samples were made for dosimetric measurements. The first sample was made from GS530SP01K1 [9] and the second sample was made from GS528C1G500 [10], both samples were made from silicone based rubbers from Prochimia. For simplification purposes, the first sample was named GS530 and the second GS528. Silicones have the property of vulcanizing at room temperature [11], so the manufacturing stage of pouring the silicone in a template and letting it dry for 24 hours is relatively simple, with the material then being ready for use. Figure 2 presents the created materials: GS530 is white silicone and the GS528 is a transparent.

At the West University of Timisoara, we made a mould with dimensions of 12 cm x 12 cm and a thickness of 0.3 cm, with 6 sheets of each silicone sample being made. The stacking of the slabs allowed us to measure the attenuation of radiation with the variable thickness of the bolus.

The samples were irradiated with a photon beam from a linear accelerator VARIAN UNIQUE with the energy of 6 MV at the OncoHelp Association.

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Radiation quantities were registered with a dosimetric phantom from ArcCheck SUN NUCLEAR that has a total of 1386 radiation detectors and 442 detectors in a 10 x 10 cm field [12].

We measured 5 different samples from the same material and same thickness, and the differences between the measurements were below 0.5%. Then we irradiated the boluses only once for the measurements in which we analyzed the radiation attenuation according to the bolus thickness.

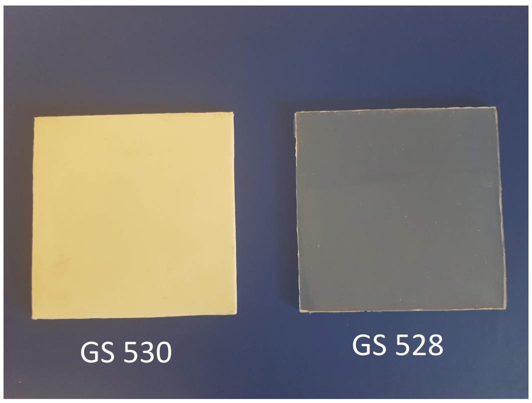

Figure 2. GS530 is on the left side and the GS528 is on the right side

3. Experimental Set-up

The experimental set-up is presented in Figure 3. We used photon fields from a VARIAN UNIQUE linear accelerator with energy of 6 MV and a size of 10 x 10 cm.

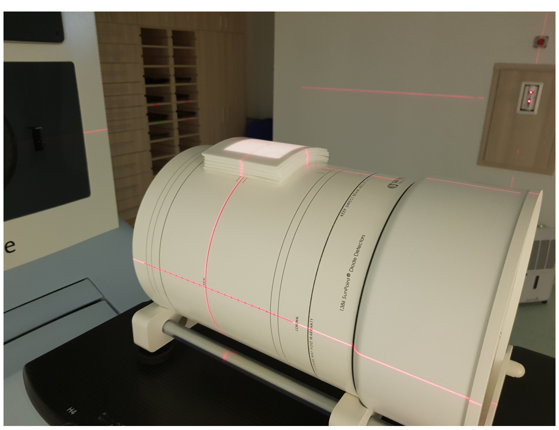

Figure 3. The stack of sheets of bolus with the ArcCheck

All of the measurements were performed by placing the ArcCheck in the mechanic isocenter of the linear accelerator, the phantom is placed using the lasers in the treatment room and the slabs were placed on the top of the phantom.

The measurements points used in our experiments are in the surface diodes of the ArcCheck that are at 89.8 cm from the radiation source of the accelerator.

The dosimetric readouts were interpreted by the SNC Patient software and the measured value is given in cGy. The ArcCheck and SNC Patient are products are made by SUN NUCLEAR.

The sheets were stacked one by one and irradiated with 200 MU and the measurements were compared with baseline measurements obtained without any slabs.

All the bolus sheets were irradiated with 5000 MU. The distance between the couch of the accelerator and the source of the radiation was 100 cm, as seen in Figure 4.

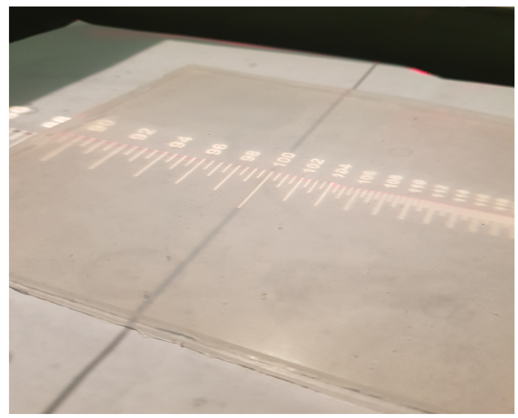

Figure 4. Distance between the source of the linear accelerator and the treatment couch

The radiation attenuation was remeasured and checks were performed to see whether there were any differences before and after the application of the 5000 MU.

4. Experiment results and Discussion

The experimental results of the attenuation of the silicone based bolus are presented in the figures below.

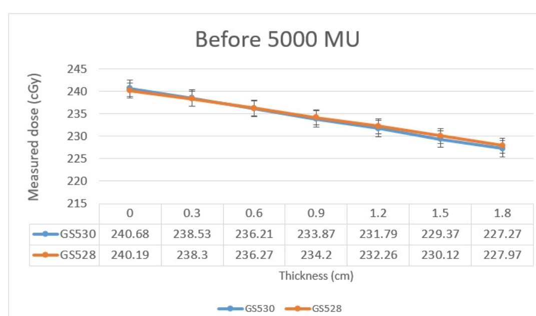

Figure 5. Comparison between the two materials before 50 Gy

In Figure 5, the two samples of bolus were compared before 5000 MU was applied using different thicknesses to observe which is better at dose attenuation. Both materials attenuate around the same amount of radiation.

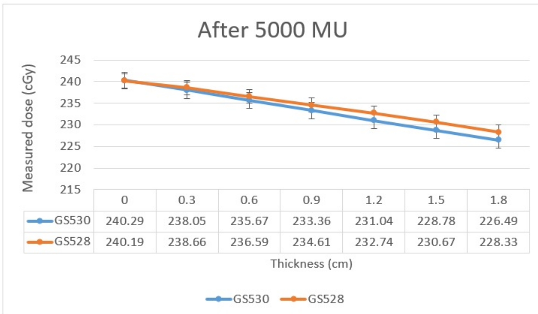

Figure 6. Comparison of the two bolus after 50 Gy

Figure 6 presents the dosimetric measurements of samples irradiated with 5000 MU. GS530 attenuates a higher dose after the thickness of 0.6 cm with the difference being around 1%.

The stability of the silicone rubbers is very good for its use as a bolus material as dose attenuation did not change after the 5000 MU were administrated and the flexibly of the sheets remained unchanged.

We used ArcCheck detectors to measure and verify that the created sheets were homogenous and that the dose attenuation did not change after 5000 MU; for this test the dose profiles on the longitudinal axis were used.

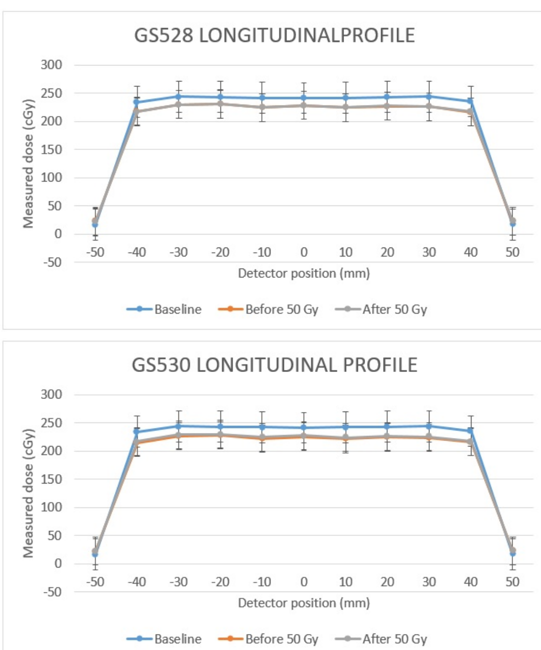

Figure 7. Longitudinal profiles of the samples irradiated before and after 50 Gy compared with a baseline

Figure 7 compares dose attenuation at 1.8 cm thickness for each material separately before and after the 5000 MU was applied with a baseline provided by measurements obtained without any bolus material placed on the ArcCheck.

The silicone rubbers used for the experiments are stable with the delivered dose attenuating in the same manner after the 5000 MU was delivered to the sheets of bolus. We did not see any major differences in the profile depending on the dose.

5. Conclusion

Either one of the proposed silicone based rubbers is good substitute for the commercially-available bolus. GS528C1G500 is more useful in day-to-day practice because it is transparent allowing the scar tissue to be observed while covered with the bolus.

Silicone rubbers are cheap and they can be easily made to accommodate the needs of individual patients.

Following the experiments, we observed that the boluses used maintained their dosimetric attenuation even after the 5000 MU delivered, the difference between measurements being 1%, which does not negatively influence a possible use of the materials for treating cancer patients.

Further studies are needed in the future to see the compatibility of these silicone rubbers with the skin of the patients undergoing radiotherapy to prevent unwanted side effects.

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