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Comparative Study on the Surface Dose of Some Bolus Materials

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Abstract

In order to investigate the possibility of using different materials as bolus in radiotherapy, five samples denoted by S2 - S6 were prepared and analyzed by comparison with one available commercial bolus denoted by S1. Sample S1 was a thermoplastic material from Qfix; S2 was a moldable silicon rubber (RTV-530 from Prochima); S3 and S4 were obtained by adding micrometric particles of Al and Cu respectively (at the same mass concentration of 5.5%); S5 was another moldable silicon rubber (GSP400 from Prochima) and S6 was a mixture of GSP400 and micrometric particles of Cu (at the mass concentration of 5.5%). The measurements of normalized transmitted dose as a function of sample thickness were performed for all samples (S1 - S6) at two values of electron beam energy (6 and 9 MeV) produced by a linear accelerator VARIAN 2100SC. The results showed that the maximum of the normalized transmitted dose of manufactured samples (S2 - S6) is registered at smaller sample thicknesses than for the analyzed commercial bolus (sample S1). The smallest sample thickness corresponding to normalized maximum point dose is obtained for sample S2 (RTV-530). Measurements performed for electron beam energy of 6 and 9 MeV have proven the possibility of using the manufactured samples as bolus in radiotherapy.

Keywords

Bolus Materials, Surface Dose, Build-Up Region, Moldable Silicon Rubber, Electron Beams

1. Introduction

Radiation therapy uses ionizing radiation to deliver the desired dose in a defined target volume, but with special care on the protection of healthy tissues. In cases where the target volume is located on skin surface, the use of

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low energy photon and electron beams, in combination with absorbent materials called boluses, is a common practice [1]-[4]. The conventional method for increasing the surface dose is by adding layers of tissue equivalent bolus, whose thickness varies depending on the beam energy. Materials used in the clinical environment as a bolus must be non-toxic, easy to produce, durable, inexpensive and flexible. In addition, the bolus must provide a homogenous dose distribution in target volume. Bolus materials which are commercially available are paraffin, gels, Aquaplast (Qfix, Orfit) or Superflab [5]-[9].

Searching for different absorbent materials which could be used in radiotherapy as compensating materials (bolus) for a better distribution of doses in the targeted volume needs further special attention [10]-[12]. The basic conditions of these new materials, besides the mandatory radiation protection are: lower production costs; easy to produce and easy to design in the geometry of individual treatment; flexible and nontoxic.

Every practitioner in radiotherapy knows the necessity to protect the organs adjacent to tumors and the search of materials with this aim is a constant demand.

In this paper we present a comparative study on the transmitted dose through a commercial bolus (Aquaplast from Qfix) and five laboratory made bolus samples.

2. Materials and Methods

Six samples, denoted by S1 - S6, were subjected to dosimetry measurements. The sample S1 was a commercial thermoplastic material produced by Qfix [9]. The sample denoted by S2 was a moldable silicone, with a commercial name RTV-530, produced by Prochima [13]. Aluminum is known as electron absorber [14] [15]. We tried to combine the flexibility and the ability to mold of silicon rubber with the absorbing properties of aluminum. The sample denoted by S3 was a composite material consisting of Al particles dispersed in RTV-530, with mass concentration of Al equal to 5.5%. The sample denoted by S4 was also a composite material consisting of Cu particles dispersed in RTV-530, with mass concentration of Cu equal to 5.5%. The sample denoted by S5 was a moldable silicone with the commercial name GSP400, produced by Prochima [16]. Sample S6 was obtained by combining moldable silicon GSP400 with Cu particles, with the mass concentration of Cu equal to 5.5%.

Moldable silicones chosen for the obtaining of samples present the necessary condition to be used as a bolus, being non-toxic and do not irritate the skin when touched.

All samples were produced at the Faculty of Physics in West University of Timisoara. For each sample 10 identical slabs, with the thickness of 3 mm were made. The dimensions of each slab were 12 cm × 12 cm. Overlaying of slabs allowed us to investigate the transmitted dose as function of sample thickness (from 3 mm to 30 mm). Dosimetry measurements were performed using electron beams produced by a linear accelerator VARIAN 2100SC at the High Energy Radiotherapy Center Timisoara.

3. Experimental Set-Up

A picture of the experimental setup is presented in **Figure 1**. All measurements were performed at a standard source surface distance (SSD) of 100 cm using an electron applicator of 10 cm × 10 cm. The transmitted dose has been measured with a Markus ionization chamber (type 23343) placed on the inner surface of samples. In order to eliminate the backscatter electrons from the measurement table, 15 cm of standard acrylic phantom (type 2967 from PTW-Freiburg, Germany) was placed between Markus chamber and the measurement table (see **Figure 1**). The electric charge collected by the ionization chamber was measured using an UNIDOS electrometer.

Transmission through the sample is obtained by measuring the dose (electric charge) with and without sample in the same geometry (SSD = 100 cm), using the equation:

$$\text{Transmission}_{\text{sample}}(\%) = 100 \times \left(\text{dose}_{\text{sample}} / \text{dose}_{\text{open field}}\right) \tag{1}$$

The dosimetry measurements were performed with a linear accelerator (VARIAN 2100SC) at the High Energy Radiotherapy Center Timisoara at two electron beam energy values, namely 6 MeV and 9 MeV.

4. Experimental Results and Discussion

Experimental results of the transmitted dose through the investigated samples are presented in **Figure 2** and **Figure 3**. All values of the transmitted dose were normalized to the maximum value of each sample.

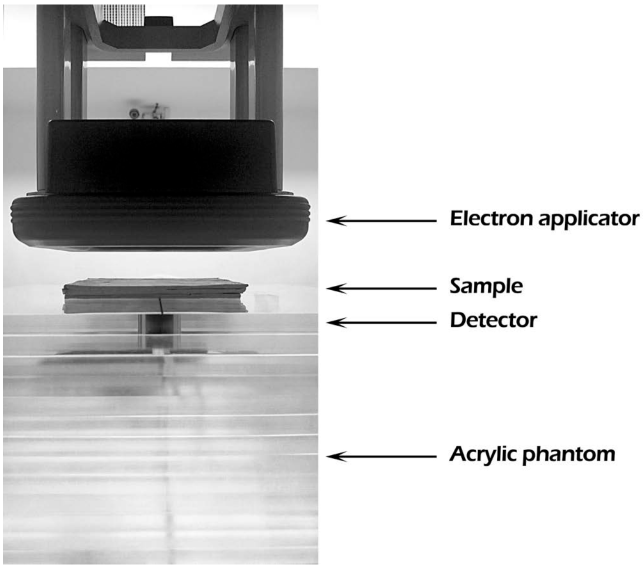

Figure 1. Experimental setup for transmitted dose measurements.

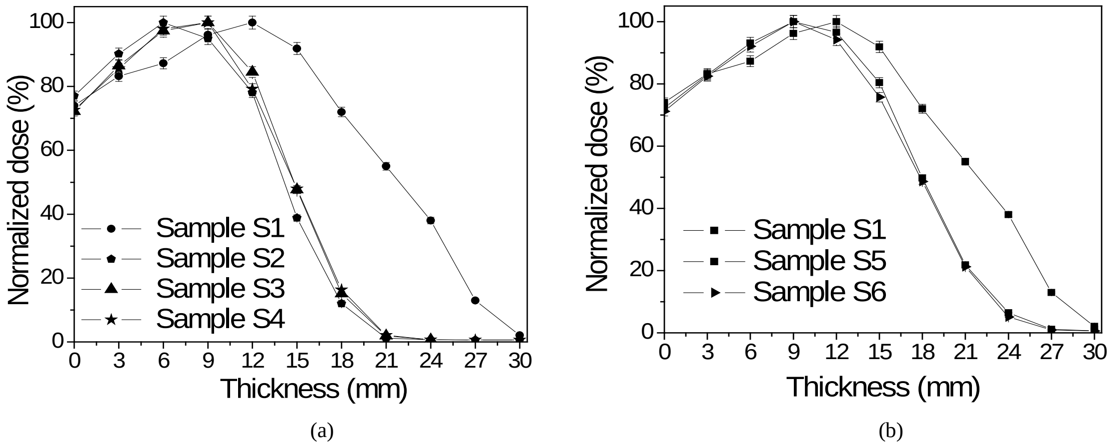

Figure 2. Normalized dose distribution versus sample thickness for 6 MeV electron beam: (a) thermoplastic material (S1) and RTV-530 based samples (S2-S4); (b) thermoplastic material (S1) and GSP400 based samples (S5, S6).

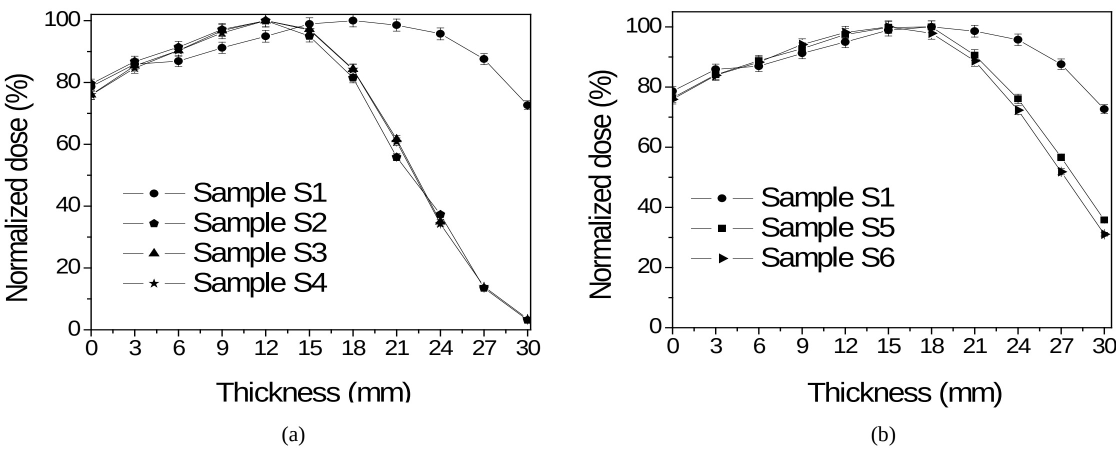

Figure 3. Normalized dose distribution versus sample thickness for 9 MeV electron beam: (a) thermoplastic material (S1) and RTV-530 based samples (S2 - S4); (b) thermoplastic material (S1) and GSP400 based samples (S5, S6).

Figure 2(a) presents comparative results of the normalized transmitted dose of the commercial bolus (sample S1) and our manufactured samples (S2 - S4), at electron beam energy of 6 MeV. As can be observed from **Figure 2(a)** the position of maximum dose point of sample S1 is located at the sample thickness of 12 mm. For sample S2, the sample thickness corresponding to the maximum dose point is 6 mm. In the case of samples S3 and S4 the sample thickness corresponding to the maximum dose point is 9 mm.

Bearing in mind that the aim of using bolus is to shift the maximum dose point towards the skin surface, we may assert that adding Al or Cu particles in RTV-530 moldable silicon is benefic with respect to the commercial bolus (Qfix) but the best result is obtained by simply using of RTV-530.

Figure 2(b) presents the dependence of normalized transmitted dose on the sample thickness for commercial bolus (sample S1) and our manufactured samples (S5 and S6), at electron beam energy of 6MeV. Results show that the sample thickness corresponding to the maximum point dose of samples S5 and S6 is smaller than in the case of commercial bolus. Also, one can observe from **Figure 2(b)** that adding Cu particles to GSP400 moldable silicon does not change the position of the maximum point dose.

In other order of ideas, as can be observed from **Figure 2(a)**, at a sample thickness equal to 18 mm, the value of the normalized transmission through commercial sample S1 is 67%, whilst at the same thickness of the samples produced by us (S2, S3 and S4) the normalized transmission is smaller than 15 %. Therefore the samples S2-S4 can also be used as protective materials (shields).

From **Figure 2(b)** one can observe that the protective characteristics of samples S5 and S6 are not so important as those of samples S2-S4 at the same thickness.

Figure 3 presents results of measurements at electron beam energy of 9 MeV regarding the dependence of normalized transmitted dose on the sample thickness for a commercial bolus (sample S1) and our manufactured samples. As can be observed from **Figure 3(a)**, the position of maximum dose point of sample S1 is placed at the sample thickness of 18 mm, whilst for samples S2, S3 and S4 the sample thickness corresponding to the maximum dose point is 12 mm, being irrespective of sample composition. Similar behavior is obtained in the case of samples S5 and S6, for which adding Cu particles to GSP400 brings no shift of the normalized maximum point dose.

5. Conclusions

Bolus properties of five manufactured samples consisting of moldable silicon rubber and micrometric aluminum and copper particles have been investigated and compared with a commercial thermoplastic bolus from Qfix. The study was performed by measurements of normalized transmitted dose as a function of sample thickness.

The experimental results obtained for electron beam energy of 6 MeV have shown that, by adding Al or Cu particles in RTV-530 moldable silicon, the maximum point dose shifts with respect to the commercial bolus (Qfix) but the best result is obtained by simply using of RTV-530. Also samples S2 - S4 can be used as protective materials even at small thickness.

Measurements performed for electron beam energy of 9 MeV have shown a shift of the maximum point dose in the case of samples S5 and S6 with respect to the commercial bolus. Adding copper particles to GSP400 (sample S6) does not change the position of the maximum point dose compared to sample S5 (which consists of moldable silicon rubber GSP400).

In conclusion, the experimental results prove the possibility of using the investigated samples as boluses in radiotherapy.

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