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Verification of Dose Assessment for 3D Printed Plastic Scintillator

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1. Introduction

A typical method for verifying the treatment plan is to scan the film or ionization chamber. It is a method to confirm dose by measuring dose at specific reference position or viewing 2D distribution [1]. There are some studies to verify dose with plastic scintillators, but most of them use scintillators of very small volume [2].

We are trying to measure the total dose absorbed into brain tumors by making a scintillator in the shape of a tumor with a 3D printer. In order to verify that the 3D printing plastic scintillator we developed is suitable for dose measurement, we made a scintillator dosimeter with the same shape as the farmer type ionization chamber and compared the doses [3].

2. Methods and Results

2.1 Dosimeter

The dosimeter used to measure the reference dose is a farmer type ionization chamber with a cavity volume of 0.6 cc (PTW30001). The scintillators used in the measurements were made from self-developed 3D printed scintillator resin [3]. The kits, which have the same shape as the ionization chamber, were made using commercial 3D printer resin (Fast BLK, Carima). The scintillators and kits were made with two DLP 3D printers (Pico2 HD, Asiga; custum order, Carima). A kit surrounding the scintillator (Kit1) and a kit surrounding the optical fiber (FP200URT, Thorlabs) (Kit2) were prepared separately. They were designed to connect Kit1 and Kit2 in the same format as plastic bottle cap. Three identical scintillator samples were made and reflective paint (EJ-510, Eljen Technology) was applied to increase the amount of light and then placed in Kit1. Fig. 1 and Fig. 2 show the actual scintillator dosimeter and its configuration.

2.2 Experimental Setup

PMT (H10721-20, Hamamatsu) was used to measure scintillation light and the current signal was recorded with an electrometer (6517B, Keithley). Dosimetries were conducted at Korea Institute of Radiological & Medical Sciences (KIRAMS) and Seoul National University Hospital (SNUH) Gamma Knife Center.

In KIRAMS, the ionization chamber and the scintillation dosimeter were placed in waterproof sleeve and doses were measured, respectively, in a 30 × 30 × 30 cm water phantom (100 cm SSD, 10 × 10 cm field Co60 beam for calibration). A black waterproof sleeve was made to minimize the background signal of the scintillation dosimeter. Ionization chamber was measured in PMMA waterproof sleeve and black waterproof sleeve respectively, and the scintillation dosimeter was measured in black waterproof sleeve.

In SNUH Gamma Knife Center, doses were measured in solid water phantom with three types of beams respectively (4, 8 and 16 mm collimators, Leksell Gamma Knife Icon).

Fig. 1. Photograph of the ionization chamber, the scintillation dosimeter and its components.

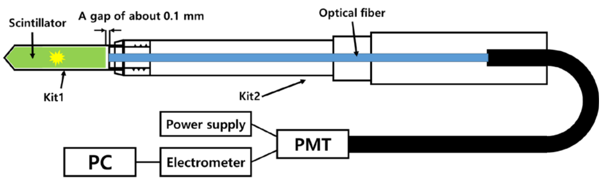

Fig. 2. Schematic diagram of experimental setup of the scintillation dosimeter system.

2.3 Dose Measurements

In KIRAMS, the ionization chamber with PMMA waterproof sleeve was measured ten times in 100 seconds, and black waterproof sleeve was measured three times in 100 seconds. The scintillation dosimeter was measured three times in 100 seconds for each of the three samples. The Cherenkov light was measured by connecting a kit1 composed of black resin only. In SNUH Gamma Knife Center, the ionization chamber and the scintillation dosimeter were measured three times in 100 seconds each.

The dose conversion factor (K_c) was obtained from the known dose rate of the KIRAMS calibration beam and the measured current value. The conversion factor for black waterproof sleeve (K_b) was also obtained. The doses (D) were calculated by applying the factors to the current value (I) measured by the gamma knife beams. The formula is as follow:

$$D = K_c \times I \times (K_b) \quad [Gy] \tag{1}$$

The dose values obtained are shown in Table I. For each Co60 beam, linear fitting was performed with dose values of the ionization chamber and the scintillation dosimeter. As a result of the linear fitting, adj. R-square values were 0.99522, 0.99629 and 0.99146 for samples 1, 2 and 3, respectively. The result for Sample1 is shown in Fig. 3.

The ratios of the scintillation dosimeter dose to the ionization chamber dose were also obtained (Fig. 4, Table II). All three samples showed similar trends. For a 4 mm collimator beam, the doses of the scintillator samples were measured slightly higher than the reference, and less and less for the 8 mm and 16 mm collimator beams. When the beam size is large, it is considered that the dose is less measured because the probability that the scintillation light generated at the beam edge enters the optical fiber is relatively small. Judging from a consistent trend of the ratios and the adj. R-square values shown above, it is believed that dose assessment can be performed with this scintillator.

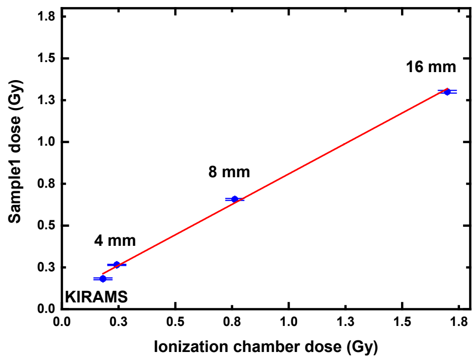

Fig. 3. Dose values and linear fitting of the ionization chamber and the scintillation dosimeter (Sample1) for each Co60 beam.

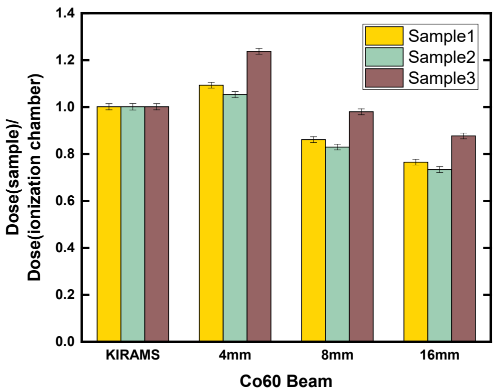

Fig. 4. Ratios of the dose values of the ionization chamber to the scintillation dosimeter for each Co60 beam.

Table I: Dose values measured for each Co60 beam (Gy)

	KIRAMS	Gamma Knife		
		4 mm	8 mm	16 mm
Ionization chamber	0.18132 ±0.00034	0.24230 ±0.00976	0.76224 ±0.01030	1.69916 ±0.01047
Sample1	0.18156 ±0.00550	0.26485 ±0.00343	0.65658 ±0.00574	1.30047 ±0.00816
Sample2	0.18156 ±0.00589	0.25529 ±0.00360	0.63238 ±0.00567	1.24671 ±0.00796
Sample3	0.18156 ±0.00549	0.29977 ±0.00367	0.74685 ±0.00612	1.49020 ±0.00819

Table II: Ratios of the scintillation dosimeter dose to the ionization chamber dose

	KIRAMS	Gamma Knife		
		4 mm	8 mm	16 mm
Sample1	1.00132 ±0.01292	1.09307 ±0.01199	0.86138 ±0.01222	0.76536 ±0.01220
Sample2	1.00132 ±0.01384	1.05361 ±0.01220	0.82963 ±0.01218	0.73372 ±0.01212
Sample3	1.00132 ±0.01290	1.23719 ±0.01228	0.97981 ±0.01246	0.87702 ±0.01221

3. Conclusions

In order to verify the dose assessment using the 3D printed plastic scintillator, we compared the doses of the ionization chamber and the scintillation dosimeter under various irradiation conditions. The adj. R-square values of the linear fitting between the ionization chamber dose and the scintillation dosimeter dose was over 0.99. The ratio of the scintillator dosimeter dose to the ionization chamber dose showed a tendency to decrease as the beam size increased. We plan to get more accurate results with PMT which maintains the temperature, and later we plan to create a tumor-shaped scintillator and conduct a dose assessment.

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