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Feasibility study of 3D-printed scintillation detector for quality assurance

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INTRODUCTION / PURPOSE

Three-dimensional printing technology has made rapid progress in recent years and is widely used in the field of radiology. The advantage of using a 3D printer is its fabrication capability, which is expected to reduce the uncertainty through dose verification by patient-specific phantoms [1]. In patient-specific quality assurance (QA) for radiotherapy, it is of high interest to perform 3D measurements of the dose distribution. A system for verifying dose distribution in three dimensions is also awaited in radiotherapy. However, currently, even if a 3D printer is used to create a patient-specific phantom, it is possible to measure a point [2] or a 2D dose [3] and not a 3D measurement.

Our research group focused on multifunctional materials for 3D printer and developed radiation-sensitive materials. This material is a highly transparent material to which a scintillation substance is added to make it luminescent in response to radiation. A test case is shown in Fig. 1. In the figure, In the figure 1, it can be seen that test cube reacts to ultraviolet light and emits light. The purpose of this study was to investigate the feasibility of a 3D-printed scintillation detector for quality assurance in radiotherapy.

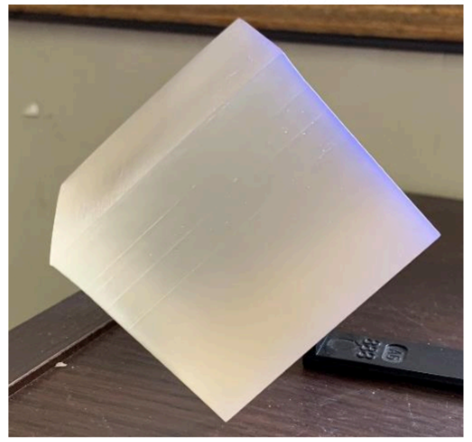

Fig.1 A cube scintillation detector formed using a 3D printer. The phantom is visible as a blue glow in response to ultraviolet rays.

METHOD

The 3D-printed scintillation detector was formed using photopolymer resins and constructed by stereolithography 3D printer (Phrozen shuffle XL; Phrozen Tech Co. Ltd.). We developed a new resin that emits light in response to radiation. The emission from the scintillator was detected by a Charge-Coupled Device (CCD) camera (BU-50LN; BITRAN). The energies of the electron beam were 6 MeV and 9 MeV from Varian TreuBeam linear accelerator, and the dose linearity of the emission quantity was verified. The depth dose curves obtained by the 3D-printed scintillation detector were compared with that obtained by the ionization chamber (Roos Electron Chamber; PTW-Freiburg) to verify the feasibility of a 3D-printed scintillation detector.

RESULTS

The 3D-printed scintillation detector showed good dose linearity for 6 and 9 MeV therapeutic electron beam. The determination coefficient (R2) value was 0.994 between 0 and 300 MU (Fig. 2). In the PDD comparison, the 50% dose depth was 23.5 mm and 35.2 mm at 6 MeV and 9 MeV, respectively. The difference between the 50% dose depth obtained by the ionization chamber measurement was -0.2 mm and -0.8 mm (Fig. 3). On the other hand, there was an increase in the surface dose, which is most likely caused by surface reflection.

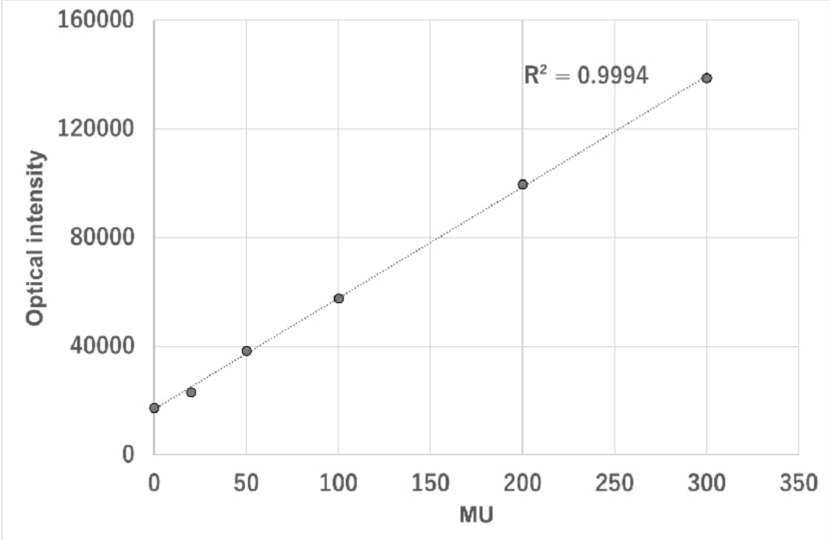

Fig. 2 The dose leneariy of the 3D-printed scintillation detector.

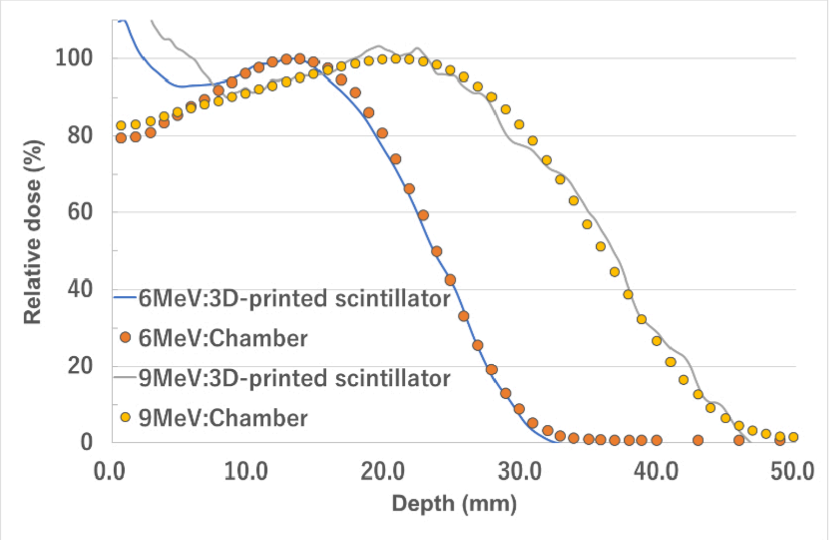

Fig. 3 PDD cureves obtained by the 3D-printed scintillation detector and ionization chamber.

CONCLUSIONS

In this study, we succeeded in 3D modeling using scintillation materials. The feasibility of a 3D-printed scintillation detector has been confirmed in obtaining the dose distribution of electron beams, and future development is expected. There is an effect of reflection which may be caused by some coloring, and investigation on materials with high transparency is continuing. In the next step of this research, we are creating a detector with the same shape as the human body using CT images. Dosimetry experiments using X-rays and protons are ongoing.

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