Flexible film dosimeter for *in vivo* dosimetry

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Background: When tumors are located on the skin or at superficial regions near the skin, the prescribed doses cannot be delivered to the whole volume of the tumors with high-energy photon beams owing to electronic disequilibrium. Therefore, to increase doses deposited to the patient's superficial regions, layers capable of increasing the electron fluence, such as boluses, wax, or three-dimensional printed devices, should be placed on the skin. When applying boluses to patients' irregular surfaces, such as scalp, breast, perineum, and foot, there might be discrepancies in the setup of the boluses with respect to the treatment plans and the actual deliveries of the plans, which is undesirable. In such cases, in vivo dosimetry is performed to verify accurate delivery of the treatment plans to patients. For in vivo dosimetry, various dosimeters, such as a thermoluminescent dosimeter (TLD), optically stimulated luminescent dosimeter (OSLD), metal oxide semiconductor field-effect transistor (MOSFET), or GAFCHROMIC EBT3 radiochromic films (EBT3), are currently used in the clinical setting. However, these dosimeters are not flexible enough to apply to irregular surfaces. The aims of this study were to develop a flexible film dosimeter applicable to the irregular surface of a patient for in vivo dosimetry and to evaluate the device's dosimetric characteristics.

Methods: A flexible film dosimeter with active layers consisting of radiochromic-sensitive films and flexible silicone materials was constructed. The dose-response, sensitivity, scanning orientation dependence, energy dependence, and dose rate dependence of the flexible film dosimeter were tested. Irradiated dosimeters were scanned 24 h post-irradiation, and the region of interest was 5 mm 9 5 mm. Biological stability tests ensured the safety of application of the flexible film dosimeter for patients. A preliminary clinical study with the flexible film dosimeter was implemented on four patients.

Results: The red channel demonstrated the highest sensitivity among all channels, and the response sensitivity of the dosimeter decreased with the applied dose, which were the same as the characteristics of GAFCHROMIC EBT3 radiochromic films. The flexible film dosimeter showed no significant energy dependence for photon beams of 6 MV, 6 MV flattening filter-free (FFF), 10 MV, and 15 MV. The flexible film dosimeter showed no substantial dose rate dependence with 6 or 6 MV FFF. In terms of biological stability, the flexible film dosimeter demonstrated no cytotoxicity, no irritation, and no skin sensitization. In the preliminary clinical study, the dose differences between the measurements with the flexible film dosimeter and calculations with the treatment planning system ranged from –0.1% to 1.2% for all patients.

Conclusions: The dosimeter developed in this study is a flexible film capable of attachment to a curved skin surface. The biological test results indicate the stability of the flexible film dosimeter. The preliminary clinical study showed that the flexible film dosimeter can be successfully applied as an in vivo dosimeter.

Reference

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