Leipzig Applicator HDR End-to-End Testing using In-house Fabricated 16 mm EBT4 Radiochromic Film Discs

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INTRODUCTION

Commissioning of horizontal Leipzig applicators for HDR brachytherapy typically includes determination of the effective distal source position and dose output verification. We previously reported an end-to-end testing methodology using optically stimulated luminescent dosimeters (OSLDs), in which measured doses were compared with published Monte Carlo reference data. Following the discontinuation of OSLDs, we developed a refined approach using in-house fabricated EBT4 radiochromic film discs. The purpose of this work was to evaluate whether EBT4 film can provide equivalent dosimetric verification for Leipzig applicator commissioning.

MATERIAL & METHODS

EBT4 radiochromic film discs (16 mm diameter) were fabricated in-house and calibrated in solid water using a 6 MV photon beam. Custom CAD-designed, 3D-printed holders were developed for both the film discs and horizontal Leipzig applicators to ensure reproducible alignment of the film along the applicator central axis.
Expected doses to water at 3 mm depth were obtained from published Monte Carlo–based dose tables for horizontal Leipzig applicators with nominal diameters of 3 cm, 2 cm, and 1 cm.
A flatbed scanner was used to create a dose calibration curve and measured doses were then compared with Monte Carlo reference values to evaluate dosimetric agreement.

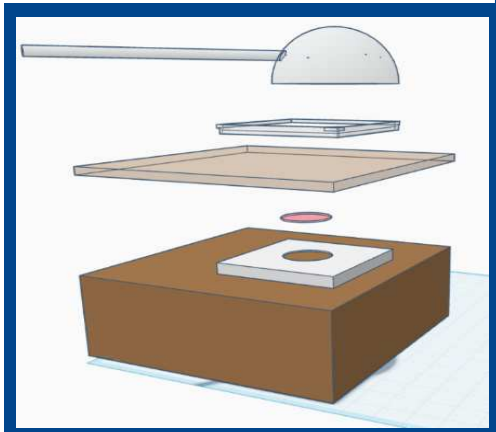

Figure 1: Deconstructed CAD design showing 3D printed film holder, 16mm EBT4 film, alignment tool and Leipzig applicator set up.

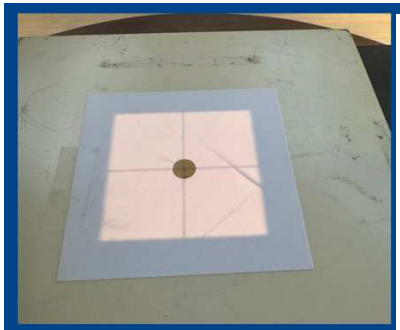

Figure 2: EBT4 film calibration setup in solid water showing the 3D-printed alignment tool used to ensure reproducible positioning of the 16 mm film discs during irradiation.

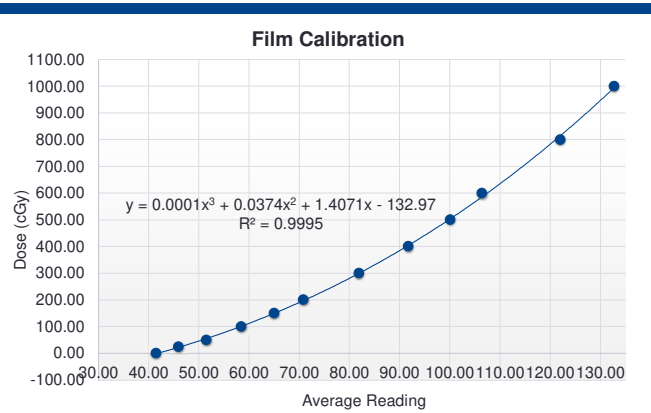

Figure 4: EBT4 film calibration generated using 6MV irradiation. Data were fit using a 3rd order polynomial function with an R^2 of 0.9995 demonstrating excellent agreement between measured and fitted values.

Figure 3: Experimental set up for dose measurement of the 1cm horizontal Leipzig applicator, consisting of solid water, a 3D-printed Leipzig alignment tool and a film holder containing the 16 mm EBT4 film positioned at a depth of 3mm. Also shown are the 2 cm and 3 cm Leipzig applicators used in subsequent measurements.

Applicator/Size	Reading	Net Optical Density	Expected dose [cGy]	Measured dose [cGy]	Percent error [%]
Leipzig-3cm	71	0.065	193.45	191.25	1.13
Leipzig- 2cm	71	0.065	194.66	191.25	1.75
Leipzig-1cm	72	0.067	197.68	199.54	0.94

Table 1: Monte Carlo expected dose vs measured dose with 16 mm EBT4 film for horizontal Leipzig applicators with nominal diameters of 3 cm, 2 cm, and 1 cm.

RESULTS

Measured doses for all Leipzig applicator sizes were within 2% of published Monte Carlo reference values at 3 mm depth. Specifically, percent differences were 1.13%, 1.75%, and 0.94% for the 3 cm, 2 cm, and 1 cm applicators, respectively. These results also demonstrate agreement to that previously achieved using OSLDs.

SUMMARY / CONCLUSION

End-to-end testing of Leipzig applicators is challenging because their high-density construction limits the use of conventional CT-based, water-equivalent verification workflows within standard treatment planning systems.
In-house fabricated 16 mm EBT4 radiochromic film discs demonstrated dosimetric agreement within 2% of published Monte Carlo reference values and provided an effective replacement for OSLDs. This methodology offers a reliable, reproducible, and clinically practical solution for end-to-end testing of Leipzig applicators in HDR brachytherapy commissioning.