Performance of a novel, water-equivalent commercial scintillation dosimeter for small fields and high dose rate external beam dose measurements.

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The purpose of this study is to evaluate the performance of a novel, commercially available plastic scintillation dosimeter (PSD), the Exradin W1 (Standard Imaging, WI – Fig. 1), for small fields and high dose rate external beam delivery (~2400 cGy/min) and compare its performance to commonly available ion chambers and diodes.

The W1 PSD, CC-series ion chambers and SFD stereotactic diode (IBA), A12 ion chamber (Standard Imaging) were used for standard measurements (PDDs and beam profiles) and small fields/high dose rate (HDR) measurements from a Varian HD MLC under regular and SRS modes. Output factors (OF) and TMRs for field sizes down to 0.5x0.5 cm\textsuperscript{2} and dose rates from 400 to 2700 MU/min were explored. Under standard field conditions, the W1 PSD was found to be accurate (0.17%) and reproducible (0.14%). Beam profiles and PDDs were in-line with ion chamber measurements (<0.5%). Example of PPDs and in-line beam profile are shown in Fig 2.

For CyberKnife OF, we showed that the PSD does not required any correction factors even for the smallest three cone diameters, while the uncorrected measurements from the diodes differed by as much as 5% for the 5 mm cone. For the Varian HD MLC, the output factors of all the dosimeters are within 1% for field sizes down to 1.75x1.75 cm\textsuperscript{2}. Output factors are shown in Fig. 3 for the 6 MV beam in SRS mode. Differences relative to the W1 increase quickly for smaller fields, to -7.3% (CC01), -21.1% (CC04) and +5.1% (SFD) for 0.5x0.5 cm\textsuperscript{2}.

Dose rate effects on Pion and diode's correction factor were extracted for the A12, CC13 and SFD dosimeters corresponding, at a dose rate of 2700MU/min, to about 1.2% for the ion chambers and 5.7% for the SFD. Fig. 4 provides an overview of the dose rate effect for uncorrected measurements from the A12, CC13 and SFD relative to the W1 measurements. The SFD dose rate dependence changes by 9% from 400MU/min to 2700MU/min, while Pion corrections were as high as 6.3% for electron beams. All corrected values agree with uncorrected W1 measurements within 0.5%.

The water-equivalent W1 PSD dosimeter allows for accurate and precise dose measurements of small fields and high dose rate SRS delivery, without any correction factor needed, enabling enhanced QA/QC and in vivo applications.
Figure 1: The Exradin W1 plastic scintillation detector is composed of a 1 mm diameter and 3 mm scintillating fiber as active sensor coupled to a 3 meter long clear collecting plastic fiber and photodetector capable of measurement in multiple wavelengths to perform the chromatic removal.

Figure 2: Depth dose measurements for 1 electron and 2 photon beams (left) and in-line beam profile comparing the W1 to the CC04 ion chamber.

Figure 3: Output factor as function of Micro MLC field size as measured with various dosimeters. SFD measurements resulted in higher output factor by 5% in agreement with previous measurements and correction factors available in the literature. Ion chambers were plague by volume averaging.

Figure 4. Uncorrected dosimeter responses as a function of dose rate for photon (Varian SRS mode) and electron beams. Fully corrected measurements, using the standard two-voltage method to extract Pion, yield values <0.5% relative to the W1.