Comparison of Film Scanner and Single-Point Transmission Densitometer: EBT4 Radiochromic Film Dose Calibration

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INTRODUCTION

Film is typically read using a flatbed scanner, but these scanners are susceptible to systematic (Type B) uncertainties, including those associated with scanner warm-up, film orientation, and film placement.

An alternative method is the use of a transmission densitometer, an optical instrument that measures the optical density of semitransparent materials such as radiochromic film. For point-dose measurements, a transmission densitometer may provide a simpler workflow while eliminating several scanner-related Type B uncertainties.

AIM

To compare dose calibration of Gafchromic EBT4 radiochromic film irradiated with 6 MV photons using a flatbed scanner and a single-point transmission densitometer for point-dose measurements in in-vivo dosimetry.

METHOD

16 mm discs were cut from sheets of EBT4 film for potential use as in-vivo dosimeters because they conform more readily to patient anatomy and eliminate sharp corners. Film discs were calibrated in solid water using incremental doses up to 10 Gy delivered with a 6 MV photon beam. Dose calibration curves were generated using (a) 8-bit and 16-bit digitization with an EPSON 12000XL flatbed scanner employing a one-scan technique to minimize Type B uncertainties, and (b) point measurements obtained with an X-Rite Model 331 transmission densitometer using a 3D-printed centering jig to ensure reproducible aperture placement. Calibration data were fit using rational least-squares functions. Finally, percent depth dose (PDD) spot checks and an end-to-end HDR brachytherapy test using a Freiberg Flap applicator were performed. Film doses were determined using all three calibration curves.

Figure 1. Using an arbor press and arch punch, 16-mm discs were cut from sheets of EBT4 film and calibrated in solid water using 6 MV photons.

Figure 2. An EPSON 12000XL flatbed scanner was used to create calibration curves. *A 3D-printed holder was used to ensure reproducible film positioning.*

Figure 3. An X-rite Model 331 transmission densitometer was used to create a calibration curve. *The X-Rite Model 331 transmission densitometer was calibrated using the manufacturer's calibration strip.*

RESULTS

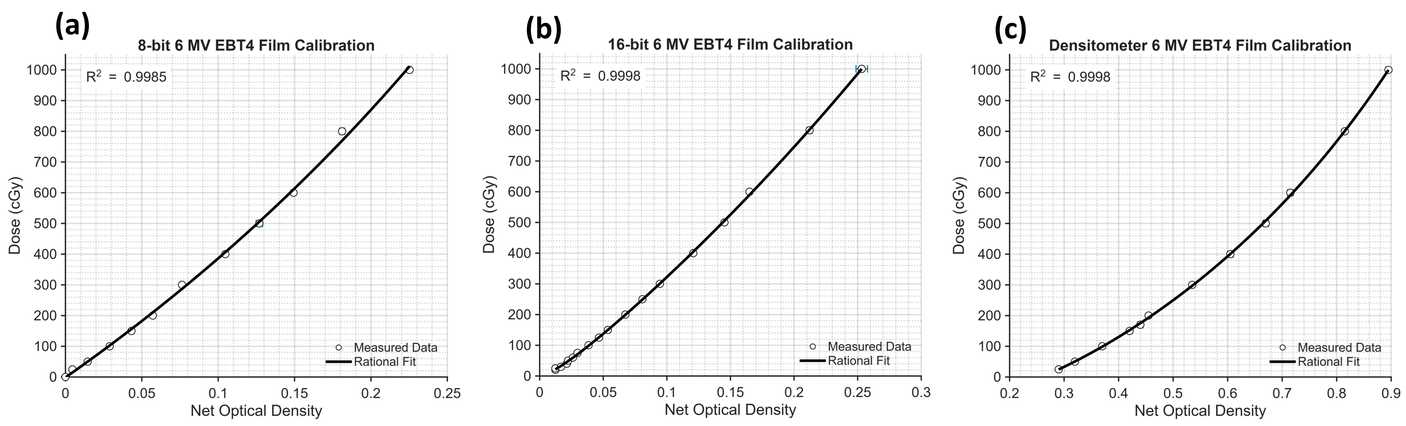
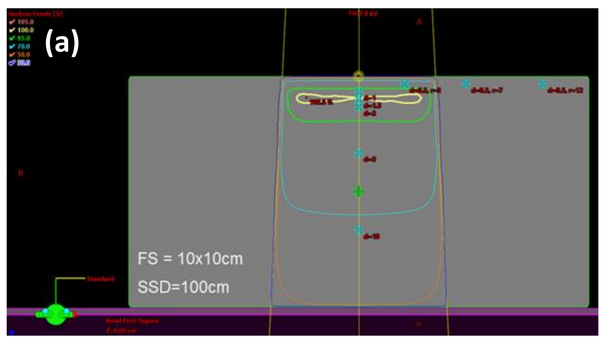


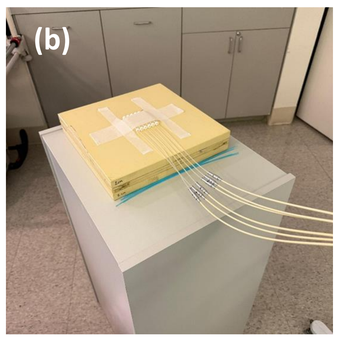
Figure 4. Rational least-squares fits accurately described all calibration curves ($R^2 \geq 0.998$). *Although the densitometer and scanner measurements are reported on different scales, each calibration exhibited excellent agreement with the fitted model.*

Calibration data from the flatbed scanner and transmission densitometer were well fit by rational functions ($R^2 \geq 0.998$). Based on the calibration curve, the transmission densitometer provided an effective dose resolution of approximately 6 cGy at 50 cGy and 17 cGy at 500 cGy, corresponding to the smallest measurable optical density increments.

Spot-check PDD measurements were within 5% of the TPS dose using calibration curves generated with both the flatbed scanner and the transmission densitometer. For the HDR end-to-end test using the Freiberg Flap applicator, the 16-bit scanner calibration measured dose within 5%, while the 8-bit scanner and transmission densitometer calibrations measured dose within 10%.

(a)	TPS Dose Eclipse AAA [cGy]	8-bit scan measured dose [cGy] (% error)	16-bit scan measured dose [cGy] (% error)	Densitometer measured dose [cGy] (% error)
PDD measurements				
d=1 cm	343.7	332.4 (-3.3%)	347.2 (+1.0%)	337.2 (-1.9%)
d=2 cm	345.1	328.1 (-4.9%)	341.0 (-1.2%)	332.4 (-3.7%)
d=5 cm	300.7	286.2 (-4.8%)	292.5 (-2.7%)	290.2 (-3.5%)
d=10 cm	232.1	224.8 (-3.1%)	235.0 (+1.3%)	229.2 (-1.2%)





(b)	TPS Dose Oncentra [cGy]	8-bit scan measured dose [cGy] (% error)	16-bit scan measured dose [cGy] (% error)	Densitometer measured dose [cGy] (% error)
End-To-End measurements				
Freiberg Flap	500.0	552.7 (+9.5%)	515.7 (+3.1%)	474.5 (-5.1%)

Table 1(a) and Figure 5(a) show the setup and results of the PDD spot checks. Table 1(b) and Figure 5(b) show the setup and results of the End-to-End test using a Freiberg Flap applicator for HDR Brachytherapy. *EBT4 film calibrated with 6 MV photons can be used for HDR dose measurements because it exhibits minimal energy dependence over the photon energy range investigated.[1]*

CONCLUSIONS

For point-dose measurements in in-vivo dosimetry, a single-point transmission densitometer demonstrated acceptable dosimetric accuracy while providing a streamlined workflow. Although 16-bit scanner calibration offers greater grayscale precision, transmission densitometers eliminate several scanner-related Type B uncertainties while reducing equipment cost, workspace requirements, and dependence on a dedicated computer workstation.

CONTACT INFORMATION

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REFERENCES

1 In-vivo dosimetry using in-house fabricated 16-mm EBT4 radiochromic film discs and ImageJ software. Snap oral presentation presented at: 2026 Joint AAPM | COMP Annual Meeting; July 22, 2026; Vancouver, BC, Canada.