Dosimetric Evaluation of Various 3D-Printed Materials for Patient-Specific Vaginal Brachytherapy Applicators

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2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

INTRODUCTION

- Commercially available cylindrical vaginal brachytherapy applicators often fail to maintain adequate contact with the vaginal mucosa in patients with reduced tissue compliance, resulting in air gaps and dose uncertainty. Patient-specific 3D-printed applicators have recently been proposed as a solution, yet dosimetric evaluations have been largely limited to PLA and ABS materials.
- This study evaluated the dosimetric performance of six 3D-printing filament materials (ASA, ABS, HIPS, PLA-CF, PLA, and PETG) using Monte Carlo (MC) simulations and TLD measurements to identify clinically suitable alternatives.

MATERIALS & METHODS

01 · FABRICATION

- Cylindrical applicators (35.0 mm diameter, 75.0 mm length, 17.5 mm tip, 3.6 mm source channel).
- 3D-printed from six filaments at 100 % infill density.

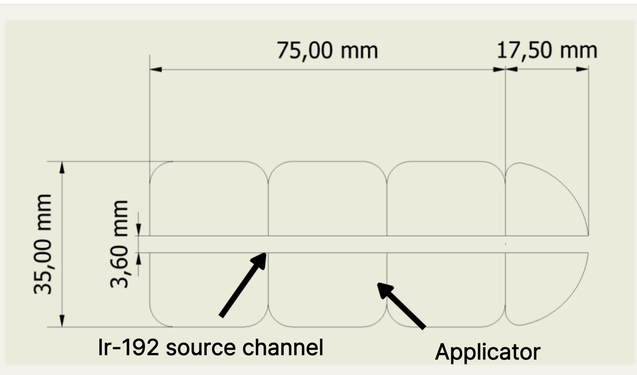

Figure 1. Applicator design (dimensions in mm)

02 · TREATMENT PLANNING

- CT images acquired with a 0.6 mm slice thickness for density analysis.
- Brachytherapy plans generated via Oncentra treatment planning system (TPS) (based on the TG-43 formalism), optimized for a uniform surface dose.

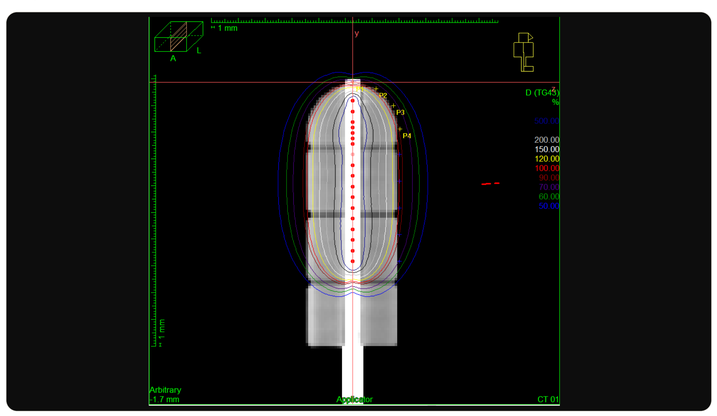

Figure 2. Isodose distribution in the Oncentra TPS

03 · SIMULATION & MEASUREMENT

- MC simulations performed using PMMA as the reference standard.
- Surface doses measured using TLD, with a tissue-equivalent bolus applied to provide adequate backscatter.

Figure 3. Experimental setup for TLD point dose measurement

RESULTS

01 · CT NUMBER ANALYSIS

- Mean Hounsfield Units (HU) varied across materials.
  - ✓ Negative HU values: ABS, HIPS, ASA.
  - ✓ Positive HU values : PLA, PLA-CF, PETG.

Table 1. CT number of six 3D-printed applicators and PMMA.

Material	Mean HU (SD)	Peak HU
PMMA	120 (8)	120
PLA	128 (20)	126
PLA-CF	58 (20)	57
ABS	-64 (19)	-61
HIPS	-93 (18)	-93
PETG	56 (28)	60
ASA	-94 (23)	-98

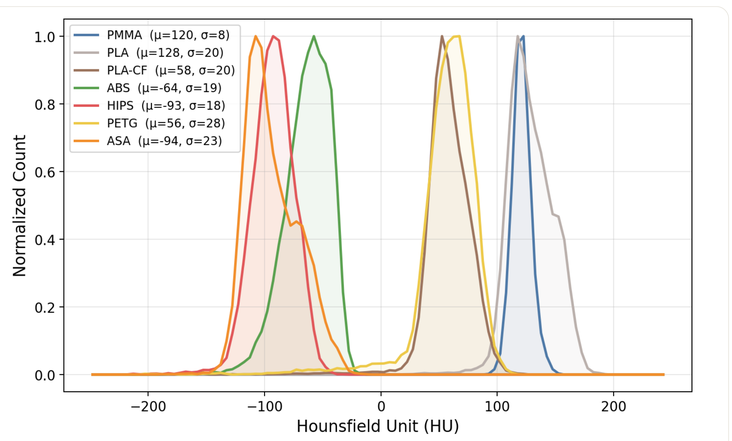

Figure 4. CT number distributions of six 3D-printing materials and PMMA

02 · MC DOSIMETRIC EVALUATION

- All materials matched the PMMA reference within < 2%, with PETG (+0.46%) and PLA (+0.67%) showing highest dosimetric agreement.

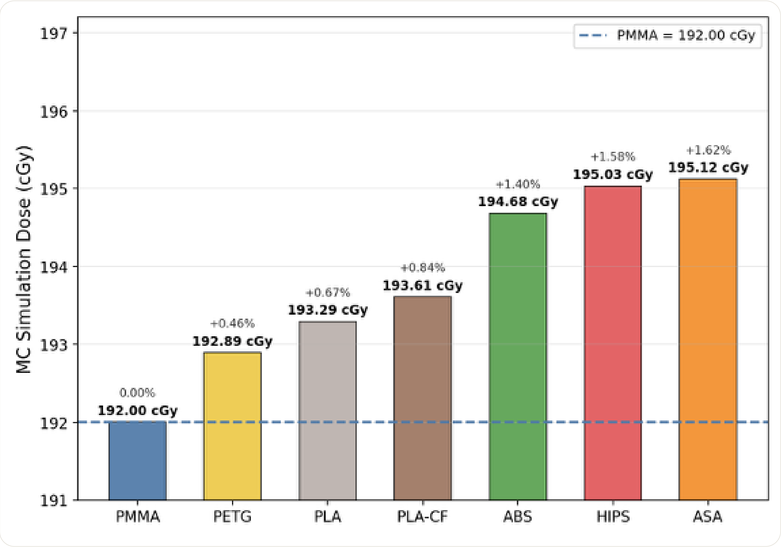

Figure 5. MC simulated doses of 3D-printed applicators relative to PMMA

03 · TLD DOSIMETRIC EVALUATION

- ASA, ABS, HIPS remained within 0.1 to 1.1%.
- PLA, PLA-CF, PETG deviated -7.1 to -3.7% (most within ~5% TLD uncertainty).

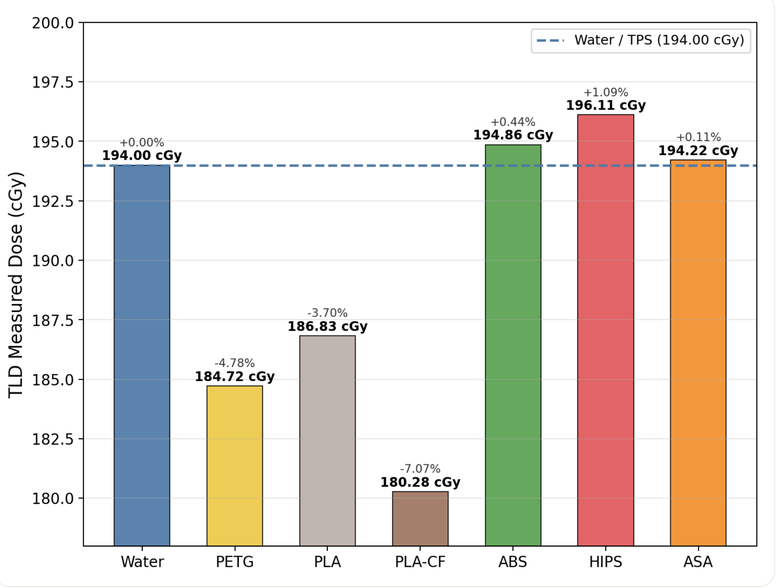

Figure 6. TLD measured doses of 3D-printed applicators relative to Water/TPS (TG-43 formalism)

CONCLUSIONS

- While CT and MC evaluations indicated PLA and PETG offer optimal radiological tissue equivalence (within 2% of PMMA), TLD measurements suggested ASA and HIPS yield more reliable physical dosimetry.
- Therefore, applicator material selection should be tailored to specific clinical priorities.

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