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# A Custom 3D Printed Film Jig for Robust Autoradiography of the GYN Ring Applicator

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## ABSTRACT

A custom 3D-printed film jig was developed to improve the robustness and efficiency of autoradiographic verification of HDR source dwell positions in Varian GYN ring applicators. The jig, fabricated using a Bambu X1C 3D printer, secures the applicator and radiochromic film in a fixed geometry, eliminating uncertainties associated with manual stem marking and removing the need for external reference irradiation.

Repeated measurements demonstrated high reproducibility, with positional uncertainty of 0.51 mm for 8 of 9 dwell positions, while one dwell showed a larger 1.45 mm deviation likely related to machine-inherent factors. Film-to-film variability (0.62 mm) exceeded observer variability (0.36 mm, n=3).

This low-cost and practical approach simplifies workflow, reduces setup complexity, and provides reliable verification suitable for both commissioning and routine HDR GYN applicator QA.

## INTRODUCTION

- Accurate verification of source dwell positions is essential for safe and effective HDR brachytherapy, particularly for GYN ring applicators where source wire slack and mechanical tolerances can introduce clinically relevant positional uncertainty.
- Vendor-recommended autoradiographic verification methods are limited by setup variability, including manual stem marking, inconsistent setup, and dependence on external reference irradiation such as kV or electron beam imaging.
- These additional steps increase workflow complexity and reduce reproducibility in routine clinical QA.
- To address these limitations, we developed a custom 3D-printed film jig designed to provide fixed applicator positioning, reproducible film alignment, and simplified autoradiographic verification for Varian HDR GYN ring applicators.

## RESULTS

- The 3D-printed jig substantially simplified the autoradiographic workflow by eliminating manual stem marking and external geometric reference procedures. The fixed-geometry design enabled rapid and reproducible applicator setup with consistent film positioning across repeated measurements.
- Five independent trials demonstrated strong reproducibility for most dwell positions, with 8 of 9 dwell locations showing positional uncertainty within 0.5 mm RMS. Dwell position #2 demonstrated a larger deviation (~1.45 mm RMS), likely reflecting inherent afterloader or source wire mechanical uncertainty rather than jig-related error.
- Overall film-to-film variability averaged 0.62 mm, and the inter-observer variability averaged 0.36 mm across three independent reviewers, indicating that setup-related variation exceeded observer-dependent analysis uncertainty. The jig enabled reliable visualization and verification of dwell position geometry without additional reference irradiation.

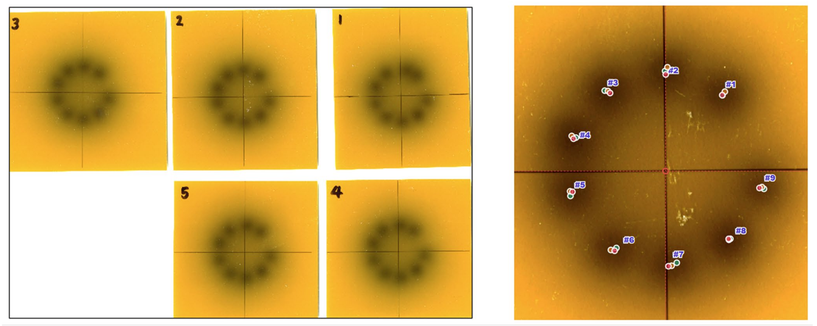


*Figure 2. (Left) Five independent trials demonstrate jig reproducibility; variability in dwells #1 and #2 reflects inherent afterloader uncertainty. (Right) Film#2 showing inter-observer variability (n=3) in dwell center-point identification.*

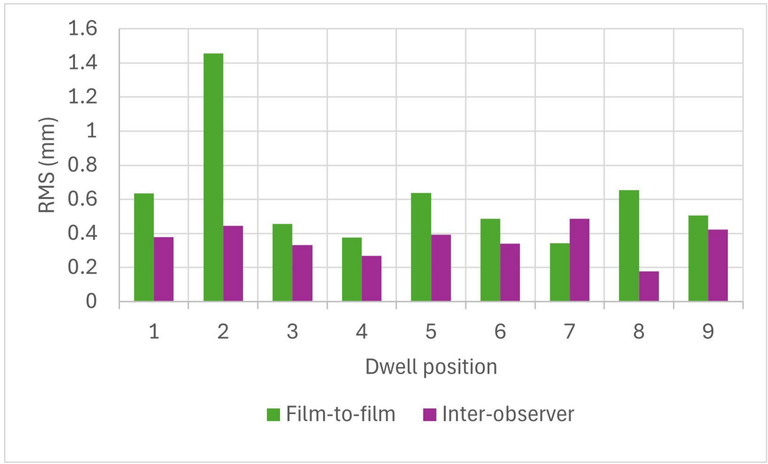


*Figure 3. Analysis of all dwell points identified on five films by three observers (total of 45 points), demonstrating significantly less film-to-film variability than inter-observer errors.*

## METHODS AND MATERIALS

- A custom QA jig was designed using CAD software (FUSION 360) and fabricated with a Bambu X1C FDM 3D printer using PLA/PETG materials.
- The jig securely immobilizes the HDR GYN ring applicator and maintains orthogonal contact between the applicator surface and radiochromic film in a fixed geometry.
- A dedicated locking segment constrains rotational orientation and minimizes setup variability between measurements.
- Autoradiographic measurements were performed using multiple independent film setups to evaluate reproducibility and sensitivity to setup variation.
- Films were analyzed to determine source center positions relative to the applicator geometry.
- No external kV imaging, electron beam exposure, or manual stem marking was required.
- A GYN plan using Varian ring applicator was developed with nine dwell positions. The plan was delivered for time times with independent phantom set up. Each film was analyzed independently by three observers.
- Positional reproducibility was assessed using RMS variation across repeated trials, while observer-dependent variability was evaluated through independent analysis.

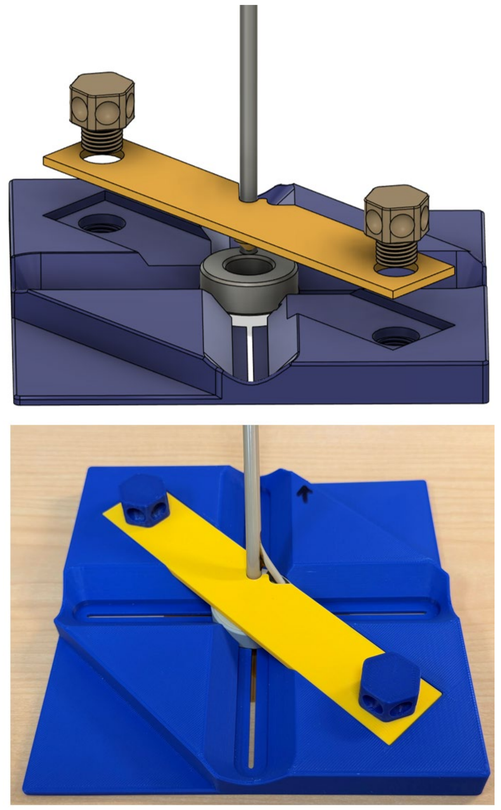

*Figure 1 3D CAD rendering (left) and final FDM-printed assembly (right) of the HDR ring applicator QA jig. The design utilizes a specialized locking segment to maintain a fixed, reproducible orientation of the applicator relative to the orthogonal film cross-hairs, eliminating the need for external imaging or manual stem marking.*

## CONCLUSION

- This work demonstrates that a low-cost 3D-printed jig can significantly improve the robustness, reproducibility, and efficiency of HDR GYN ring applicator autoradiography.
- The observed reproducibility for most dwell positions was within clinically acceptable tolerances for HDR QA, supporting the utility of the device for both commissioning and periodic quality assurance.
- The larger uncertainty observed in one dwell position is consistent with known mechanical limitations associated with ring applicator source wire transport and highlights the importance of routine verification.
- This 3D printed jig provides a practical and scalable solution for improving geometric verification and treatment safety in HDR brachytherapy QA.

## CONTACT

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