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Commissioning and Clinical Evaluation of Formlabs BioMed Flex 50A Resin for Patient-Specific Bolus Fabrication in Radiotherapy

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ABSTRACT

Purpose: Flexible biocompatible 3D-printing materials offer new opportunities for customized bolus fabrication in radiotherapy. This study evaluates the Formlabs 4BL printer with BioMed Flex 50A resin through geometric, density, water-equivalency, and dosimetric commissioning for clinical bolus applications.
Methods: A commissioning workflow was developed to assess geometric accuracy, material density, relative electron density (HU), and dosimetric equivalence. Twelve bolus samples with varying thicknesses and geometries were fabricated and analyzed using caliper measurements, CT-based comparisons, and MeshLab point-cloud analysis. A MATLAB-based workflow quantified bulk density, HU uniformity, and internal density variations. Thickness equivalency and effective path length (EPL) were evaluated for 5-, 10-, and 20-mm boluses using TPS calculations and PDD measurements for photon (6–15 MV) and electron (6–20 MeV) beams. Clinical feasibility was assessed using a head phantom with a 1-cm printed bolus by comparing plans with and without bolus using PDDs, isodose distributions, DVHs, and OSLD surface-dose measurements.
Results: Printed boluses demonstrated high geometric accuracy, with a mean dimensional deviation of 0.06 mm and all Hausdorff metrics below 1 mm. CT analysis showed consistent HU values (18–32 HU) and strong internal uniformity. Measured thicknesses closely matched TPS-derived effective path lengths, confirming water-equivalent behavior across photon and electron energies. In phantom studies, use of the bolus increased mean PTV dose from 93.9% to 101.3% and increased surface dose from 2.4–4.5% to 102–106%. OSLD measurements agreed with TPS calculations within 4.3%.
Conclusion: The Formlabs 4BL printer with BioMed Flex 50A resin produced geometrically accurate, water-equivalent, and dosimetrically reliable patient-specific boluses. Clinical validation demonstrated improved target coverage and accurate surface-dose delivery, supporting routine clinical implementation.

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INTRODUCTION

Bolus is a soft and resilient material used in radiotherapy to increase skin dose or to compensate for irregular patient contours. The most important property of bolus materials is their water-equivalent electron density, which ensures accurate dose delivery at the skin and superficial tissues. **Biomed Flex 50A**, a flexible resin developed by **Formlabs**, has been designed for biomedical applications and is biocompatible and nontoxic for use on the human body. The aim of this study was to evaluate the feasibility of using Biomed Flex 50A resin as a bolus material in radiotherapy by assessing key parameters such as geometric accuracy of the boluses, mass density, relative electron density, transmission factors compared to solid water and equivalency to water by PDD curves.

METHODS AND MATERIALS

The study systematically investigated geometric accuracy, material properties, and dosimetric performance of 3D-printed bolus materials.

1. **Geometric Accuracy**

Test boluses were designed and fabricated using the clinical 3D-printing workflow. Dimensional accuracy was assessed using caliper measurements and comparison with nominal dimensions. CT-derived surface meshes of printed boluses were registered to the reference STL files in MeshLab, and geometric agreement was quantified using average alignment error, mean Hausdorff distance, and RMS Hausdorff distance.

2. **Bolus Density Evaluation**

A custom MATLAB script was developed to evaluate bulk density, internal uniformity, and defect regions in printed boluses. DICOM CT datasets were imported and converted to Hounsfield Units (HU) using Rescale Slope and Intercept values from the DICOM headers.

3. **Thickness Equivalency and Effective Path Length (EPL)**

Boluses with nominal thicknesses of 5, 10, and 20 mm were fabricated. EPL and PDD shifts were evaluated for photon (6 MV, 6FFF, 10 MV, 10FFF, 15 MV) and electron (6–20 MeV) beams. Measured physical thicknesses were compared with TPS-calculated EPL values, and mean differences and standard deviations were calculated.

4**. Phantom Validation and Surface Dose Measurement**

A patient-specific 1-cm bolus was generated on a head phantom and fabricated using BioMed Flex 50A resin.
Geometric agreement between the printed bolus and reference STL was evaluated using MeshLab. Treatment plans with and without bolus were compared using PTV coverage, PDD profiles, isodose distributions, and OSLD-measured surface dose.

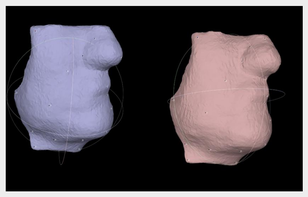

Figure 1. MeshLab Point to Point Match.

Figure 2. Formlabs 4BL 3D Printer.

RESULTS

Geometric accuracy was high across all samples, with mean dimensional deviation of 0.06 mm and all Hausdorff metrics <1 mm. Mesh-to-mesh analysis for the phantom bolus showed an alignment error of 0.007 and RMS Hausdorff distance of 0.138 mm.
Material density evaluation showed consistent bulk HU values across boluses (mean HU ~18–32), with 0% low-density regions and low fractions of high-density regions for most prints, indicating strong internal uniformity.
Measured thickness values closely matched TPS EPL values for all bolus sizes, with mean differences of +0.20 mm (5 mm), +0.18 mm (10 mm), and –0.06 mm (20 mm).
PDD curves with bolus showed excellent agreement with water-equivalent expectations for all energies.
Phantom validation demonstrated clinically meaningful dosimetric improvements: mean PTV dose increased from 93.9% (no bolus) to 101.3% (with bolus), with a ~1.3 cm shift in buildup depth. Surface dose increased from 2.4–4.5% to 102–106%. OSLD measurements agreed with TPS within 2.6–4.3%.

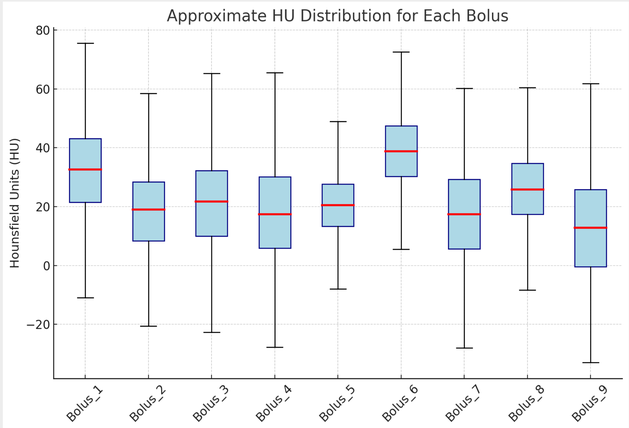

Chart 1. Plot showing HU distribution for each 3D-printed bolus, indicating internal density variability.

Surface Dose				
	Without Bolus (cGy)	Without Bolus (%)	With Bolus (cGy)	With Bolus (%)
Point A	4.3	2.4	186.8	103
Point B	8.1	4.5	181.4	106
Point C	6.1	3.4	184.9	102
Point D	6.9	3.8	188.8	104

Table 1. OSLD measurements and TPS-calculated doses

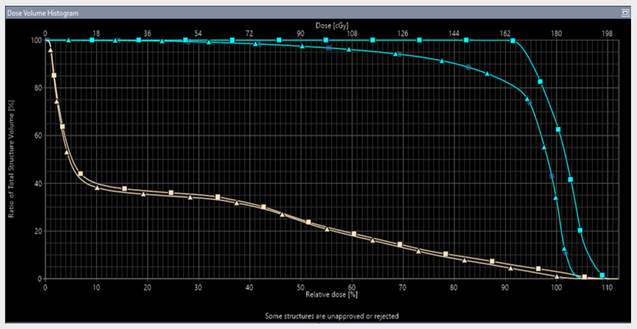

Figure 3. Comparison of dose–volume histogram, the mean dose to the planning target volume, with and without bolus.

DISCUSSION

The evaluated boluses demonstrated strong geometric agreement between the designed and printed models, indicating high accuracy and reproducibility of the fabrication workflow. Minor variations were mainly attributed to surface complexity rather than manufacturing limitations. A MATLAB-based CT analysis workflow enabled quantitative assessment of bolus density and homogeneity using HU-based metrics, confirming acceptable material uniformity with variations largely related to surface effects and CT-related artifacts. PDD analysis for photon and electron beams showed good agreement with TPS predictions, with expected dmax shifts and electron buildup behavior within uncertainty. Treatment planning results demonstrated improved PTV coverage and increased surface dose with bolus application, consistent with the intended dosimetric effect. Overall, results support the clinical accuracy and effectiveness of the fabricated bolus.

Figure 4. isodose distribution with and without Bolus

CONCLUSIONS

The Formlabs 4BL printer with BioMed Flex 50A resin produces geometrically accurate, dosimetrically stable, and water-equivalent patient-specific boluses suitable for clinical radiotherapy use. The material shows excellent HU uniformity, minimal internal defects, and consistent thickness equivalency across energies. Clinical validation confirms improved target coverage and accurate surface dose delivery. These findings support full clinical adoption and workflow integration of this 3D-printed flexible bolus solution.

REFERENCES

1. Kairn T, et al. Phys Eng Sci Med. 2021 — 3D printed bolus QA and tolerances
2. Malone C, et al. J Appl Clin Med Phys. 2022 — evaluation of 3D printed bolus fit and dosimetry
3. Liu Q, et al. Med Phys. 2016 — effect of density variation on photon dose calculation (IMRT/SBRT)

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