Development and Evaluation of a 3D-Printed Anthropomorphic Head and Neck Phantom for End-to-End Radiotherapy Quality Assurance

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Background:
Quality assurance in radiotherapy is critical for ensuring the accurate delivery of treatment. Recent advancements in 3D printing technology allow for the creation of cost-effective, patient-specific phantoms, potentially revolutionizing QA workflows.

Objective:
The aim of this study was to evaluate the feasibility and performance of an in-house 3D-printed anthropomorphic head and neck water phantom for conducting End-to-End QA tests in radiotherapy.

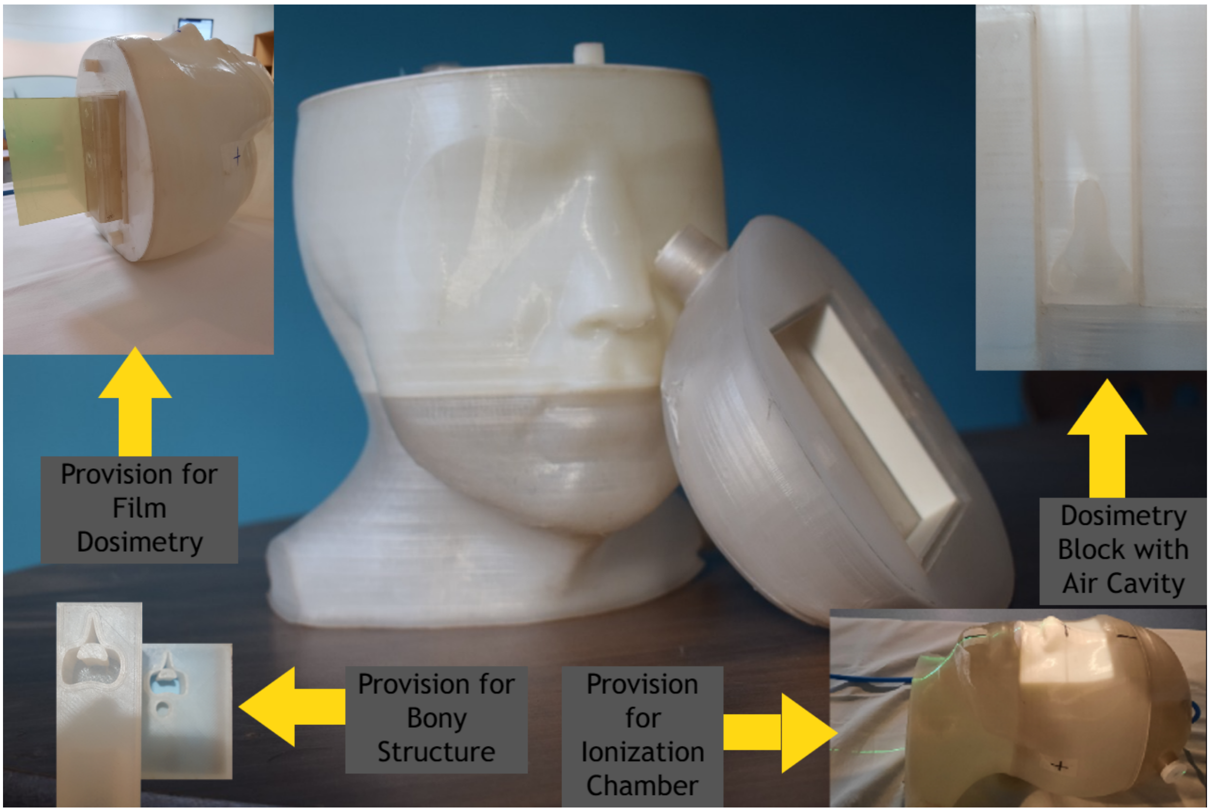
Material and Methods:
A head and neck water phantom was 3D-printed using Poly-Lactic Acid (PLA), a nearly tissue-equivalent material with a physical density of 1.2 g/cc. The phantom was designed to be water-fillable with 5 mm wall thickness and equipped with provisions for housing Ionization Chambers and radiochromic films.
The phantom was imaged using a CT scanner with a slice thickness of 2 mm. Five patient-specific QA plans were created using the Accuray Precision Treatment Planning System.
These plans were delivered to the phantom using the Accuray Tomotherapy Radixact X-9 system. Point dose measurements were taken with a Standard Imaging Exradin A1SL Ion Chamber, Slimline Miniature Shonka (0.053 cc). Planar dose measurements were conducted using Gafchromic films.
Calculated and measured point doses were compared as a percentage dose difference at a specified location. Planar dose analysis was conducted based on film placement in transverse and sagittal planes. AAPM guidelines were followed for Gamma Index analysis using criteria of 2%/3mm, 2%/2mm, and 3%/2mm.

Results:
Point Dose Agreement: The deviation between calculated and measured point doses was within ±0.5%.
Planar Dose Agreement: Film-based planar dose QA passed the Gamma Index criteria for all five patient-specific plans, with passing rates between 95% and 99%.

Conclusion:
This study demonstrates that a customized, low-cost 3D-printed anthropomorphic phantom is a feasible solution for conducting End-to-End QA tests in radiotherapy. The phantom's performance highlights its potential as a viable alternative to commercially available solutions.

Future work could focus on expanding the range of clinical cases tested and benchmarking against commercial phantoms.

Keywords:
3D-Printed Phantom, Radiotherapy, End-to-End QA, Quality Assurance



In-house 3D-printed anthropomorphic head and neck phantom with provisions for Ionization chamber and Films

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