Evaluating 3D printing materials for intracavitary gynaecological brachytherapy

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Introduction

Additive manufacturing (or 3D printing) allows the production of bespoke brachytherapy applicators for patients with gynaecological cancers that cannot be treated with conventional dome applicators due to scarring or irregular vaginal vaults. This study characterised the robustness and radiological properties of materials that might be used to manufacture such applicators.

Method

Six test devices were designed:

- Three 3x3 cm^2 slabs of variable height (0.5, 1 2 cm), to determine water equivalency at both kV and MV photon energies by CT and transmission measurements
- One "dog bone" for tensile strength testing
- One small brachytherapy applicator with 5 catheter channels, including blind-ended channels, to determine print quality by visual inspection, catheter insertion, and comparison of CT-derived 3D model of the printed device against the initial design
- One large brachytherapy applicator with 3 open-ended channels, to determine print quality as above.

These devices were 3D printed using four commercially available materials advertised as biocompatible (IEC 10993) and steam sterilisable: KeyGuide, Biomed Clear, MED610, and Nylon 12.

Tests were performed before and after steam sterilisation (by autoclave) of the applicator examples.

Results

Radiological properties

All materials were approximately water equivalent (within ±0.1 RED), with the largest deviation in dose beyond a 2 cm slab being 1% when compared against dose beyond a water-equivalent plastic (**Table 1**). Steam sterilisation did not alter the RED of the applicators.

Table 1: Deviation in dose, relative to water-equivalent plastic (6 MV), measured beyond 2 cm of the material slab

Material	Surface (%)	1 cm depth (%)	2 cm depth (%)
KeyGuide	0.3	1.0	1.1
Biomed Clear	0.4	0.9	1.1
Nylon 12	-1.2	0.6	0.5
MED610	0.2	1.0	1.1

Print quality

Nylon 12 (SLS) and MED610 (PolyJet) were unable to print the 2mm blind- or open-ended channels due to difficulty in removing the support material.

Blind-ended catheter channels were blocked due to poor drainage of uncured resin for both KeyGuide (DLP) and BioMed Clear (SLA) materials. Supporting material for BioMed Clear proved difficult to remove.

Following post-processing, there was good agreement between the CT-derived 3D models of the applicator devices and their initial designs, within the CT scanning resolution of 0.5mm slice width. The catheter could be comfortably inserted in all channels before steam sterilization.

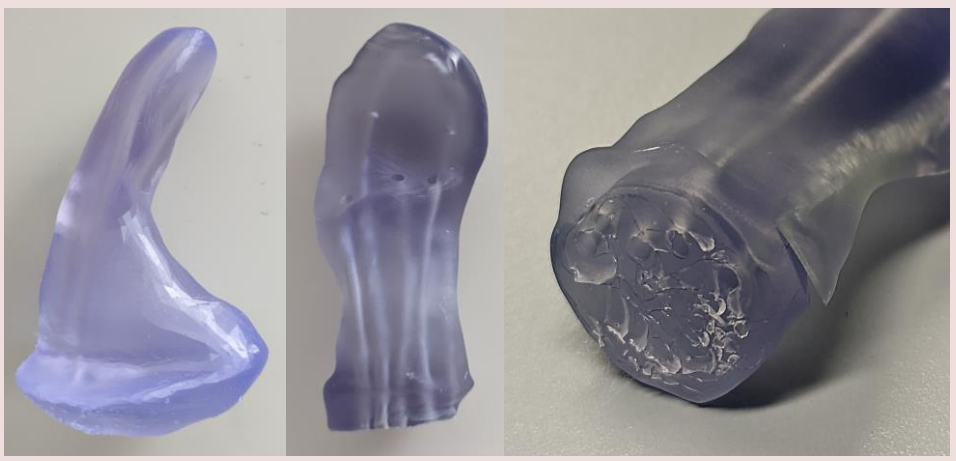

Figure 1: Large test applicator in Biomed Clear (left), small test applicator in KeyGuide (centre) and sterilisation damage to KeyGuide sample (right) showing superficial flaking and cracking through the applicator body.

Steam sterilisation

Due to poor print quality of Nyon 12 and MED610, only KeyGuide and Biomed Clear were sterilised.

The dog bone tensile pieces did not warp and maintained print quality through the sterilisation process.

The sterilisation process resulted in damage to KeyGuide applicators (**Figure 1**), particularly at channel openings or where it was suspected the resin had not adequately cured. Biomed Clear samples were unchanged.

A catheter could be comfortably inserted in all undamaged channels after steam sterilisation.

Conclusions

- All materials were approximately water equivalent, allowing use in clinical dose calculations within acceptable uncertainty.
- SLS and PolyJet technologies require expertise regarding printing and post-processing procedures, when printing long, thin channels.
- Open-ended channels provided higher quality prints and are preferred for any cleaning procedure.
- BioMed Clear was observed to be the most robust material in this investigation.
- Despite following published Instructions for Use for each material, damage to test devices still occurred.
- Any verification testing performed by the material vendor should be confirmed for the geometry of the printed device, as well as the printer (and any post processing protocols) used to manufacture the device

Disclosures

The Authors have nothing to disclose.

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