The Use of 3D Printing in the Fabrication of Cadmium-Free Electron Cutout Blocks

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INTRODUCTION

Electron blocks composed of a low melting point alloy (LMPA) are commonly used for defining the field shape of clinical electron beams. Current implementations of the block fabrication process involve numerous steps which are subjective and prone to user error. Furthermore, significant bowing of the electron block frame is sometimes observed, resulting in premature frame decommissioning. Recent works have investigated the feasibility of utilizing 3D printing technology to replace the conventional electron block fabrication workflow[1,2]; however, these approaches involved long print times, were not compatible with commonly used cadmium-free LMPAs, and did not address the problem of frame bowing. In this work, we present a new 3D printing approach that remedies these issues.

METHODS

Patient plans containing electron block apertures were generated, and the corresponding DICOM RT files were exported from Eclipse v13.6. A custom Python GUI (**Fig. 1a)** was developed and used for importing files and generating 3D printable models of the planned aperture. Jigs for insert frames ranging from 6x6cm^2 to 25x25cm^2 (**Fig. 1b**) were designed to facilitate positioning of the negative while simultaneously reducing frame bowing.

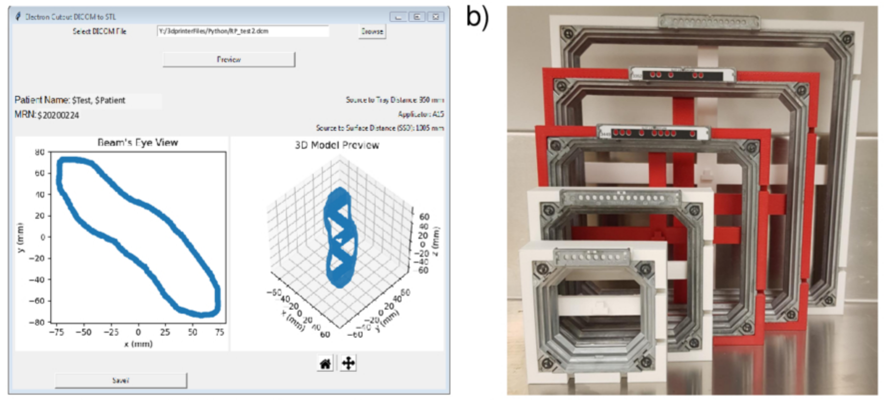

Fig 1. a) A screenshot of the GUI developed for creating the 3D printed electron beam aperture negatives. b) An image of the 3D printed jigs and electron block frames.

All 3D models were sliced using Simplify3D and printed with a Raise3D N2 3D printer. Acrylonitrile Butadiene Styrene (ABS) printer filament, which has a melting point of 107°C, was used for the 3D printed parts to prevent warping at the high temperatures of the molten cadmium-free LMPA (95°C).

3D PRINTED ELECTRON APERTURES

BLOCK FABRICATION AND VALIDATION

A photograph of a conventional Styrofoam aperture negative and a 3D printed aperture negative for the same patient is shown in **Fig. 2a**. The 3D printed negative includes an alignment lock for accurate and reproducible positioning in the center of the frame (as shown in **Fig. 2b**), and the supports prevent elastic deformation of the negative due to the force of the molten LMPA. No warping of the 3D printed parts was observed due to the high melting point of the ABS. Gafchromic film measurements (**Fig. 2c**) demonstrated that field sizes produced by blocks generated with the 3D printing technique had less than 1% difference in field FWHM when compared to the corresponding Eclipse plans.

Fig 2. a) A comparison of a conventional Styrofoam aperture negative and the 3D printed aperture negative. The support structures and the lock that mates with the 3D printed jig are indicated with arrows. b) A photograph of the assembled 3D printed aperture negative, alignment jig, and block frame. c) Profiles for a block with a 13cm diameter circular aperture. The profile predicted in Eclipse is shown in blue, and the profile extracted from the Gafchromic film measurement is shown in orange.

3D PRINTED JIG DESIGN

The 3D printed jigs were created using Autodesk Inventor. A photograph of the 20x20cm^2 jig is shown in **Fig. 3a**. The frame has two features of note:

1. A T-shaped key in the center of the frame supports, which mates with the lock on the aperture negative to ensure proper aperture positioning.
2. Contoured interior edges that are matched to the external contours on the Varian III electron block insert frame. A close up of the contours is shown in **Fig. 3b**.

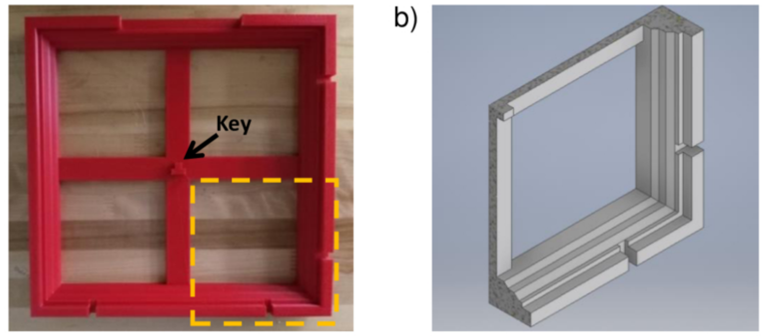

Fig 3. a) A photograph of the 3D printed 20x20cm^2 jig. b) A quarter sectional view of the region outlined by the yellow-dashed box in a).

MULTI-APERTURE BLOCKS

Some techniques, such as electron grid therapy[3], require the production of multi-aperture electron blocks. Without access to a machine shop, this would involve tedious manual placement of numerous Styrofoam negatives which could lead to imprecision in the final grid layout. As a proof-of-concept for generating such multi-aperture blocks, we used our 3D printing technique to create blocks depicting the COMP and AAPM logos (**Fig. 4**). Precise positioning of several apertures of various shapes and size was possible, and fine details in the logos were preserved. Going forward, we plan to assess the feasibility of using our technique to simplify the electron grid block fabrication process.

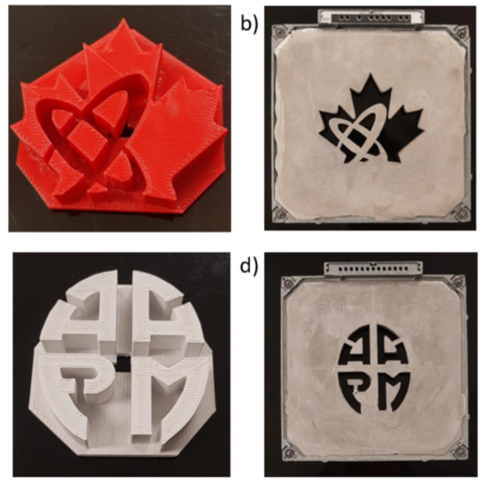

Fig 4. Examples of multi-aperture field shapes that can be created using the 3D printing technique. The 3D printed negatives shown in a) and c) were used to generate the blocks shown in b) and d), respectively.

FRAME BOWING ANALYSIS

An extreme example of frame bowing is shown in **Fig. 5a**. The bowing is caused by the outward force of the molten LMPA on the frame, and results in the frame no longer fitting in the electron applicator. As shown in **Fig. 5b**, use of the 3D printed jigs was found to reduce the magnitude of frame bowing by a factor of approximately 2 in both the lateral and sup-inf directions.

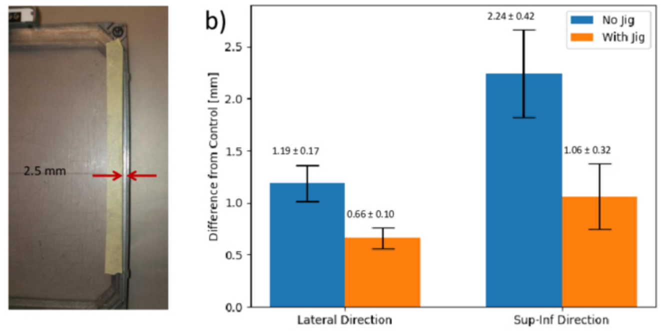

Fig 5. a) A photograph of a 25x25cm^2 electron frame exhibiting extreme bowing. b) Average frame bowing in the lateral and sup-inf directions for electron frames supported with/without the 3D printed jig during the block fabrication process.

CONCLUSIONS

Our technique produces electron blocks with fields having high geometrical accuracy, reduces insert frame bowing, and can produce complex electron blocks without the need for specialized machine shop equipment. The printed negatives require 1–2 hours of printing time and cost approximately $2 per patient, while the jigs cost approximately $10 and can be used to produce multiple blocks before replacement.

REFERENCES

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