Dosimetry simulation for 3D-printed eye plaques with dose modulation

Y. MA[1], T. LESCOT[1], L. BEAULIEU[1,2] and M.A. FORTIN[1,2]
1 Laval University, Quebec, Canada
2 Cancer Research Centre (CRCEO), CHU de Quebec, Quebec, Canada

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INTRODUCTION

- Eye plaque brachytherapy is one of the most common and effective treatments for ocular melanoma.
- COMS (collaborative ocular melanoma study) eye plaques are state-of-the-art eye plaques of clinical use[1].
- The concept of a three dimensional(3D) printed plaque were developed. It utilizes the same gold-alloy backing as COMS plaques, but the radioactive isotope-containing and/or silastic insert materials are printed within the backing.
- Conceptually, 3D-printed plaques have quite a lot design and implementation flexibilities, which potentially improve dosimetry distribution.

AIM

- To prove the concept of 3D-printed eye plaques and explore its dosimetric benefits over COMS.

METHOD

- The development of 3D eye models are based on a selection of clinical cases. One is a typical “dome-shaped”, medium-sized tumor. The second one is a “mushroom-shaped” tumor, i.e. a tumor extending deep in the vitreous body. A third pseudo test case was proposed to have an asymmetric shape in the transverse direction.
- For dosimetry simulation, ALGEBRA (a Monte Carlo simulation code focusing on Brachytherapy based on Geant4 toolkit) was utilized[2].
- An 18 mm diameter COMS gold-alloy backing was selected based on the size of the tumors, according to the selection criteria described in AAPM task group 129 report[3]. Pd-103 containing and silastic materials were 3D-printed within the pit of the backing.
- The COMS eye plaque of the same size with 21 seeds was selected for comparison purpose. The benchmark seeds are TheraSeed Model 200.
- The resultant dose distributions of 3D-printed were compared with the COMS eye plaque full loading. The dose was explored using dose ratio maps, isodose lines, dose profiles and dose-volume histograms (DVHs).

RESULTS

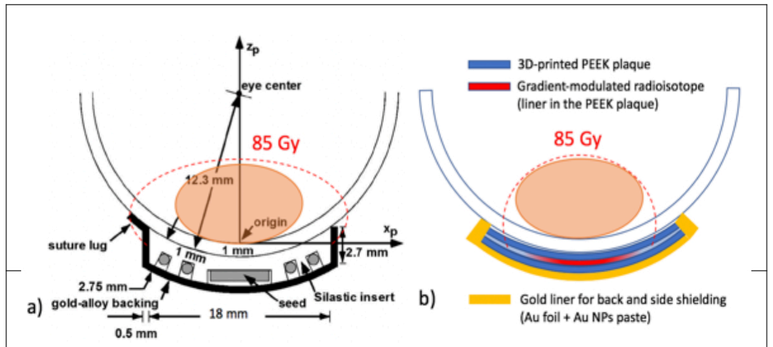


Fig. 1 Concept of 3D-printed eye plaque. Left: COMS eye plaque. Right: 3D printed eye plaque.

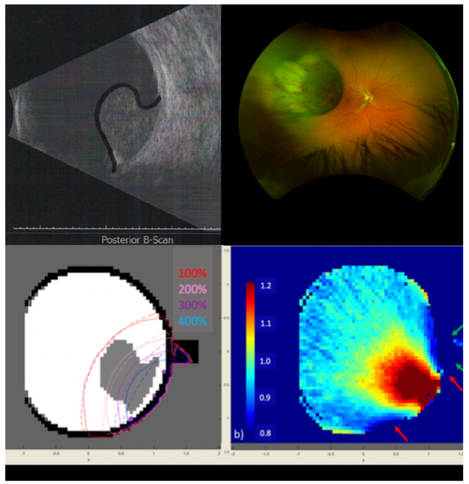
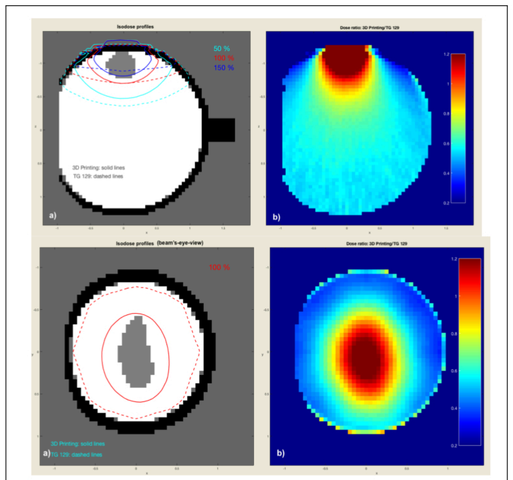


Fig. 2. Mushroom-shape ocular melanoma/ case.

- *Upper panels: ultra-sound image and optical image of the tumor site.*
- *Lower panels: geometry and isodose lines (left) and dose ratio maps. Solid lines: 3d printed, dashed lines: COMS plaque.*
- *As indicated by the arrows, the specific positions in the eye anatomy where optical nerves are located are receiving lower absorbed dose then the COMS full loaded eye plaque.*
- *This deep-pointing ocular melanoma case is challenging for the conventional COMS eye plaque technique. Usually, higher dose goes to the eye in order to cover the whole clinical target volume (CTV).*



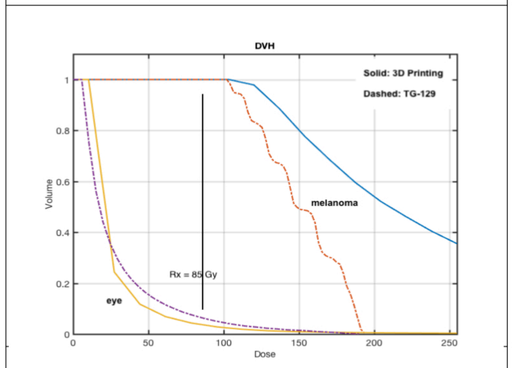


Fig. 3 The asymmetric case. Upper: geometry and dose ratio maps on the sagittal and transverse directions respectively. Lower: Dose-volume histograms for the CTV (melanoma) and organ-at-risk (eye).
Solid lines: 3d printed, dashed lines: COMS plaque.

CONCLUSIONS

- A potential technique by using three-dimensional (3D) printing technology was proposed to reduce the radiation toxicity of the key optic structures.
- The radioactive isotopes (such as ^{103}Pd) can be 3D printed onto the inner surface of the eye plaque backing and as such the distribution of radiative material manifest a shape following the shape of tumor projected onto the plaque along the plaque central axis.
- Beyond, 3D printing can implement non-uniform distribution of the radioactive material on the inner surface of plaque.
- The tech opens another degree of freedom to further improve dose distribution. This way, dose escalation (or spearing for the same target dose) is feasible and it enables personalised plaque brachytherapy of ocular malignancy.

ACKNOWLEDGEMENTS

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CONTACT INFORMATION

E-mail: yunzhi7@yahoo.com