3D-printed surface mould applicator for high-dose-rate brachytherapy

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Introduction

- In high-dose-rate (HDR) brachytherapy treatment of superficial tumors, catheters are placed in a wax mould, which lays on top of thermoplastic mesh mask (Figure 1). The mask restricts motion of the patient during treatment.
- Manual fabrication of the wax mould is tedious, fine adjustments is not feasible, and therefore optimal dose distribution cannot be guaranteed
- We've developed a method and software to generate a 3D-printed rigid mould to replace the conventional wax mould in this treatment.

Figure 1. Current practice for HDR consists of the wax mould (red) placed on top of the thermoplastic mesh mask (white). Our project aims to replace the construction of the wax mould with a 3D-printed model.

Methods

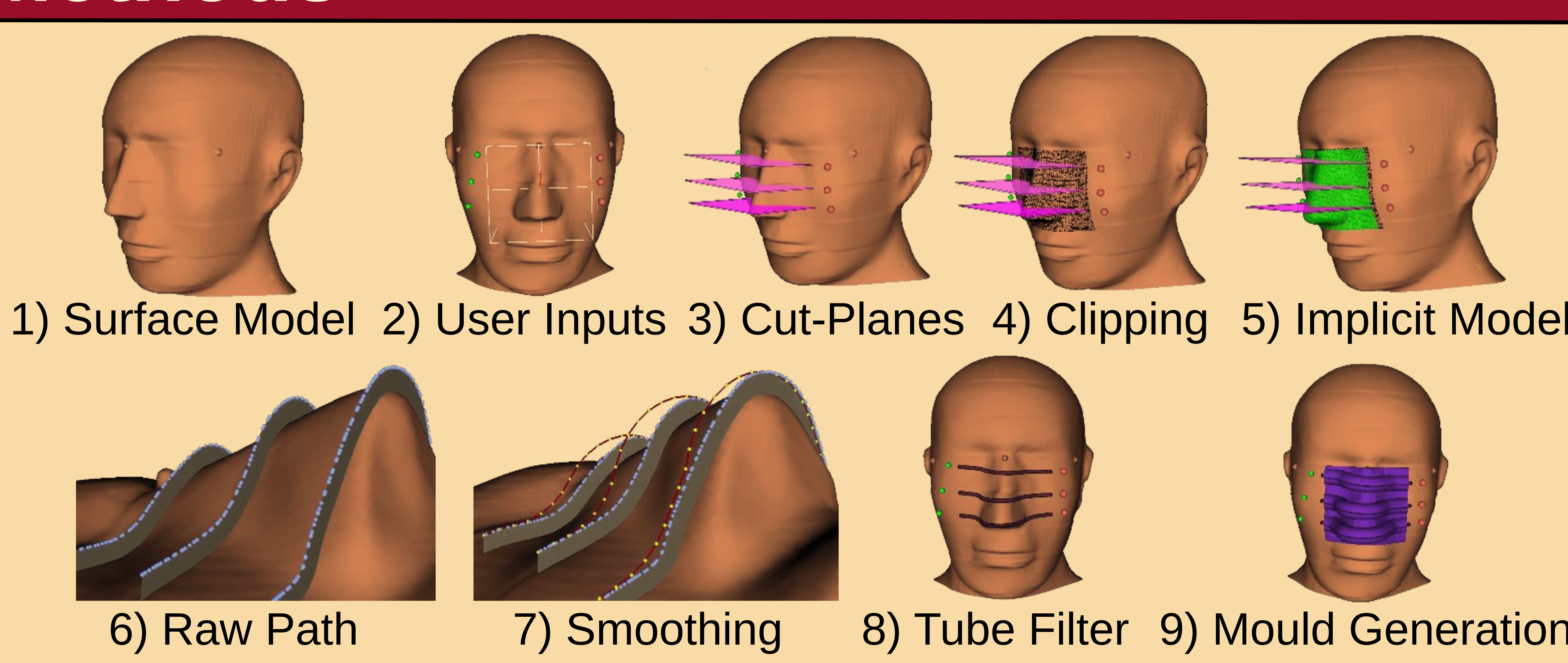

Figure 2: A flow diagram representing the process of generating the 3D model from a closed surface model of the patient.

- An algorithm was developed as an extension to 3D Slicer (www.slicer.org) that takes a CT scan, user-defined catheter endpoint positions, mould region, and catheter diameter and allowed curvature parameters as inputs.
- The printed model has hollowed out channels that the catheter can be pushed through holding them in place for dose delivery.
- Initial prints of the 3D-generated model had issues with support material remaining in the channels. A slit was introduced running along the front-side of the mask to help with quick dissolving of the support material.

Optimal channel diameter, minimum curvature, and slit diameter has to be determined for each catheter and printing material combination. Software was developed that generates a calibration object (Figure 3) to test several parameter combinations by printing a single object.

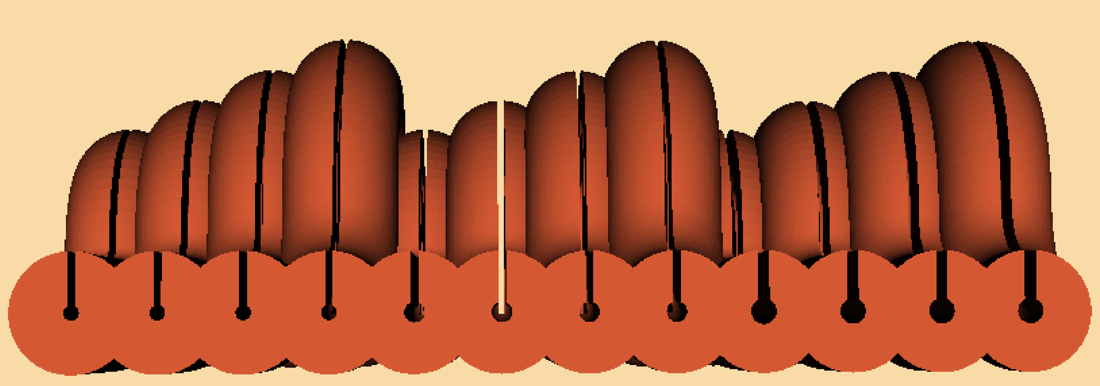

Figure 3: 3D model of the calibration object, used to test 12 different channel parameter combinations (diameter, slit width, curvature) to ensure that the HDR catheter fits within the final mould print.

Results

The methods were tested on three anonymized patient CT data sets and thermoplastic meshes received from Kingston General hospital (Figure 4). We generated 3D mould objects for each patient (Figure 5), inserted catheters, and placed the mould to the thermoplastic mesh (Figure 6, left).

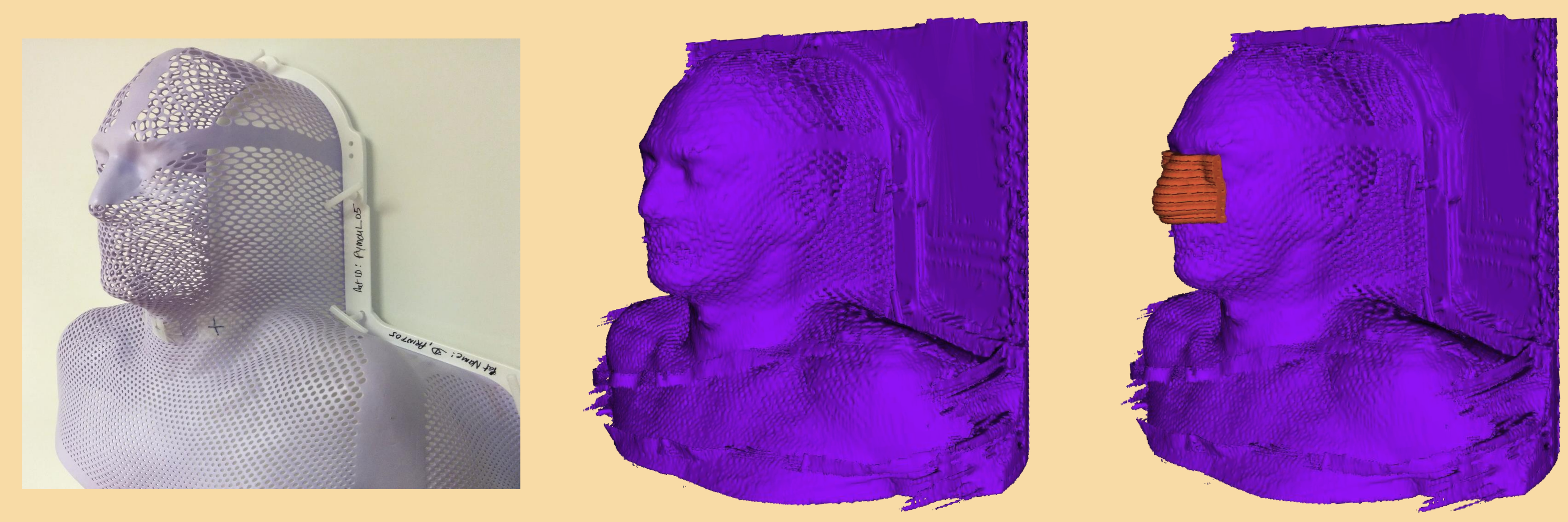

Figure 4. A thermoplastic mesh received from KGH (left) was modeled from CT scans (middle). Our algorithm generated a mould (orange right) through which catheters can be inserted for dose delivery.

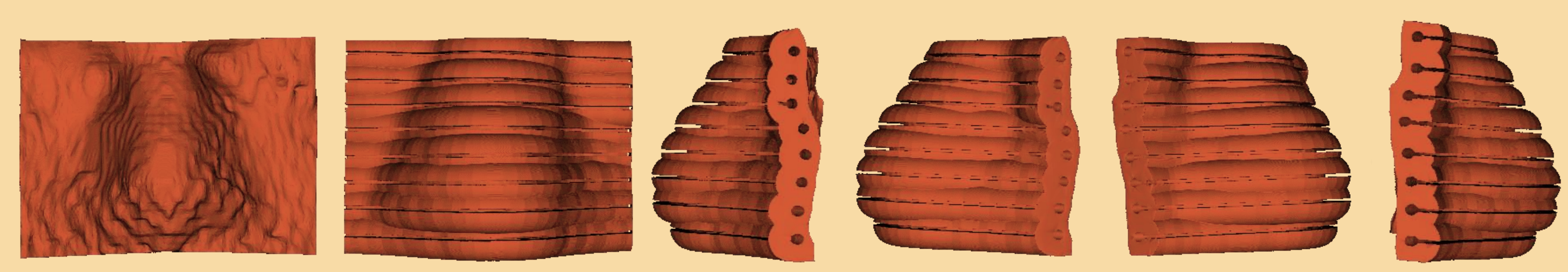

Figure 5. The 3D model if 6 different orientations : back, front, right, right-mid, left-mid, left.

After creation the model was visually verified with a CT scans (Figure 6) to fit on the thermoplastic meshes, the catheters could be successfully be threaded through the mould and could be accurately placed on the mesh.

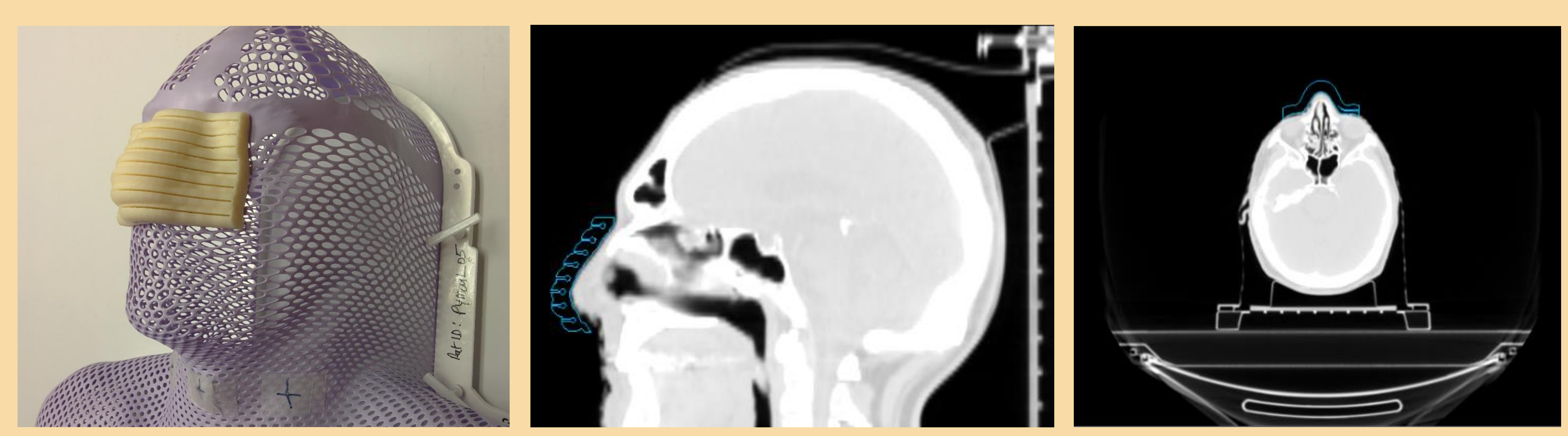

Figure 6. The printed mould resting on the thermoplastic mesh(left) and the CT scans verifying the fit of the mould (middle, right).

Conclusion

- The proposed 3D-printed patient mould is built from the patient's CT scan, and perform preliminary dosimetric analysis and adjustments are possible before printing, therefore it may outperform traditional wax moulds in term of both dosimetric accuracy and consistency.
- Additionally, the design and production of a 3D-printed mould needs only a small fraction of technologist's time, compared to fabricating wax masks.

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