Prototype testing the 3D-printed Montreal split-ring applicator (GYN) using biocompatible materials

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INTRODUCTION

The addition of interstitial needles to intracavitary GYN applicators (combined IC/IS) has been shown to improve the therapeutic ratio of locally advanced cervical cancer (stages IIIB-IVA) treatments involving tumor extensions to the parametrium [1]. The multicenter EMBRACE II study protocol provides dose constraints as planning aims and dose limits for MR-delineated target structures. Commercial IC/IS brachytherapy applicators used to achieve EMBRACE II planning aims are expensive and only available in a few specialized centers, limiting the availability of this treatment option.

OBJECTIVES

The purpose of this work is to show the feasibility of upgrading a widely used IC-only applicator; the CT/MR split-ring applicator (BEBIG Medical GmbH, Berlin, Germany) as the ***Montreal split-ring applicator*** which is suited for combined IC/IS brachytherapy. Adaptiiv Medical Technologies Inc. (Halifax, Canada) recently developed ***3DBrachy***, a software that allows users to create personalized 3D-printed brachytherapy applicators without knowledge of CAD software design. 3DBrachy's Montreal split-ring software module allows users to create 3D-printable ***Adaptiiv caps*** with patient-specific needle trajectories that can be readapted between treatment fractions to improve conformity with the recommended planning aims. These caps are an improvement over a previously published non-printable generic template cap [2].

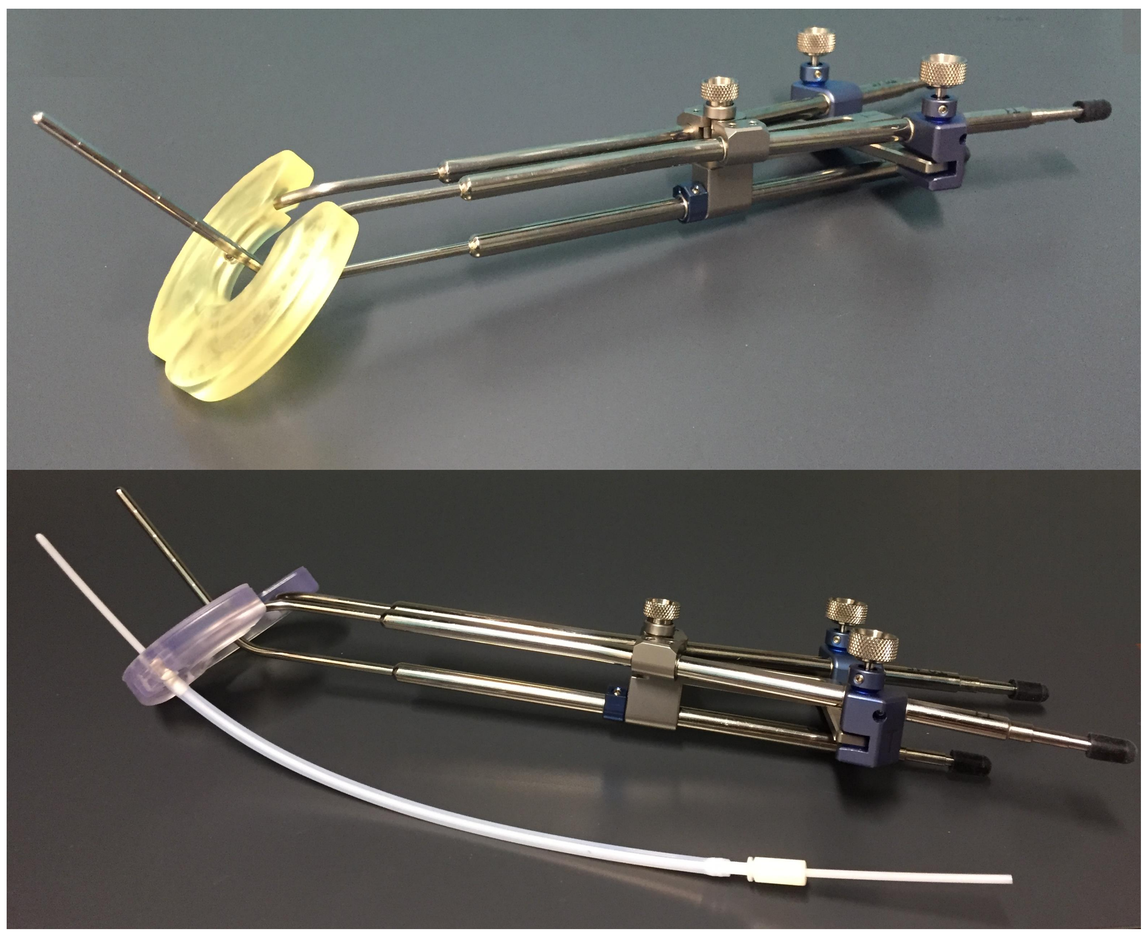

Figure 1. The Montreal split-ring applicator with IC/IS Adaptiiv caps printed using Surgical Guide (top figure) and BioMed Clear (bottom figure). The bottom figure also shows attachment of a guiding tube used by the lunar ovoids of the Venezia IC/IS applicator with Proguide interstitial needles (Elekta, Stockholm, Sweden).

METHODS

CAD models of standard CT/MR split-ring 5 mm buildup caps were reproduced using Fusion 360™. These caps were then made widder and integrated to 3DBrachy along with models of interstitial guiding tube notches. OncentraBrachy TPS (Elekta, Stockholm, Sweden) was used to produce a cap design preplans containing needle trajectories as reconstructed source paths that were exported as dicom RT-plan. In 3Dbrachy, the generic widened cap was co-registered and guiding tube notches were subtracted following the preplan needle trajectories to generate printable .STL files. Adaptiiv caps were then printed using a Form3 SLA printer (Formlabs Inc., Massachusetts, USA) using two resins; Surgical Guide (ISO 10993 biocompatibility & 50 µm resolution) and BioMed Clear (USP Class VI biocompatibility & 100 µm resolution) as shown in figure (1).

RESULTS AND DISCUSSION

As shown in figure (2), Adaptiiv caps prototypes were printed and tested for the following properties both pre- and post-sterilization:

1. Smooth gliding of the titanium split-ring into the printed canal.
2. Secure attachment of interstitial guiding tube notches.
3. Proper fixation using the original CT/MR attachment screw.

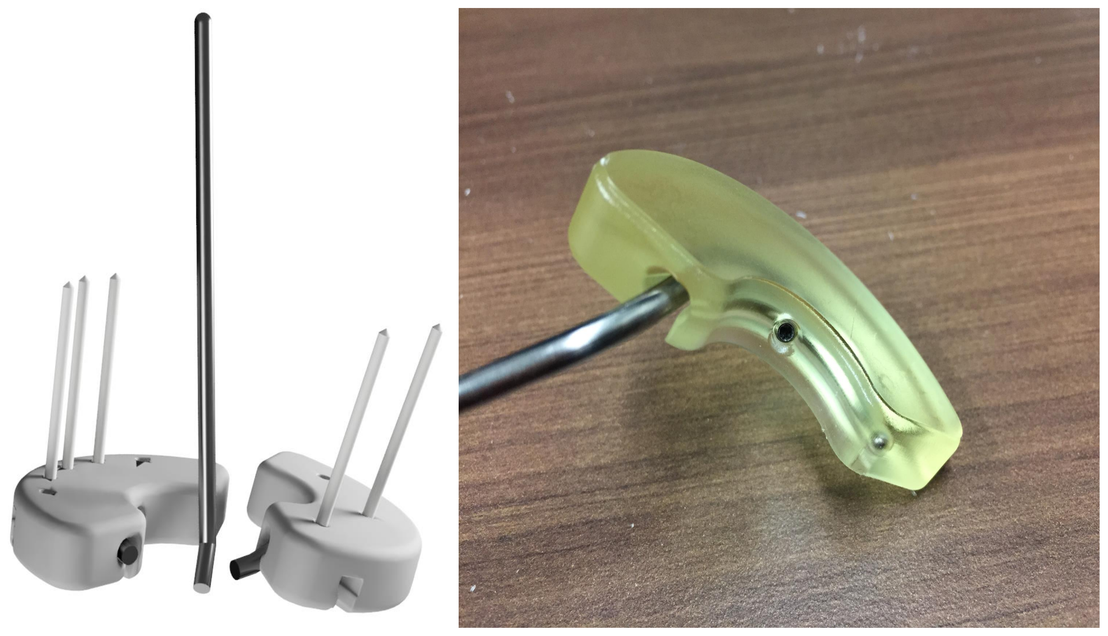

Figure 2. The left figure shows a CAD example of an Adaptiiv cap pair with interstitial needles that can be produced using 3DBrachy's workflow. The right figure shows post-sterilization fixation of the attachment screw with a cap printed using Surgical Guide resin for prototype testing.

The printed prototypes were verified to be functional following the successful testing of the properties stated above. In particular, secure attachment of guiding tube notches for interstitial needle obliquity angles of 15°, 30° and 45° was verified. Fixation screw thread was found to be the most sensitive feature of the printed caps. A minimum resolution of 0.1 mm in 3DBrachy was found to be necessary for proper screw fixation using BioMed Clear printed with a layer height of 100 µm. Using these settings, the number of times the screw could be re-used before stripping the threads was found to exceed 10 times which is satisfactory considering the disposable nature of these caps. The sterilization protocol involved steam sterilization at 132 °C in an autoclave for 4 minutes followed by a 25 minutes dry phase which was not found to negatively impact the results for prototype testing.

CONCLUSION

Stereolithography-based 3D-printing technology was successfully used to produce prototypes of the Montreal split-ring applicator suited for combined IC/IS brachytherapy. A dedicated module in Adaptiiv's 3DBrachy software allows users to design Adaptiiv caps with patient-specific needle trajectories. Prototypes printed with Surgical Guide and BioMed Clear resins were verified to be functional both pre- and post-sterilization for interstitial needle obliquity angles ≤ 45°. Future studies will aim to characterize dosimetric advantages of using Adaptiiv caps with patient-specific needle trajectories over generic needle trajectories used by commercial IC/IS applicators.

REFERENCES

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