Validation of the Montreal split-ring applicator in a gynecological phantom simulating clinical implants conditions in intracavitary/interstitial brachytherapy

Marie-Ève Roy[1,2], Maroie Barkati[2], Marie-Claude Beauchemin[2], Yuji Kamio[2,3] and Stéphane Bedwani[1,2,3]

[1]Université de Montréal, Montreal, QC, [2]Centre Hospitalier de l'Université de Montréal (CHUM), Montreal, QC, [3]Centre de Recherche du CHUM (CRCHUM), Montreal, QC

Figure 1. 3D-printed (a) M1 cap; (b) M2 cap assembled on the right SR of the CT/MR split-ring applicator and compared to the 5x5 build-up cap shown on the left SR.

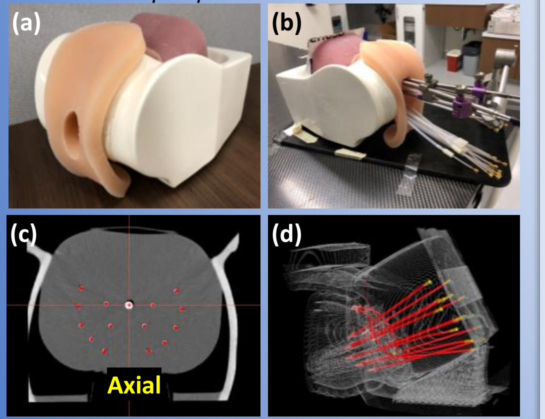

Figure 2. Silicone GYN phantom (a) fully assembled; (b) ready for CT-scanning; (c) axial CT image of IS needles in the fantom; (d) 3D reconstructed trajectories

PURPOSE

This work improves the Montreal split-ring (MSR) applicator's design for patient-specific combined intracavitary/interstitial (IC/IS) brachytherapy (BT) of cervical cancer, making it compatible with smaller patient anatomies. An evaluation of needle trajectories errors in implantable structures simulating clinical conditions was carried out using an in-house designed gynecological (GYN) silicone phantom.

METHODS

Adaptiiv caps were redesigned using Fusion 360™ to create two new cap models, shown in Figure 1. Both caps have two additional IS needle positions inside the split-rings (SRs). The guiding tube slots were moved under the SR in the M2 caps. These novel caps reduce the outer radius of up to 8.4 mm. Caps were 3D-printed by stereolithography (SLA) using BioMed Clear resin on a Form 3B (Formlabs) printer. Silicone recipes (Smooth-On) were optimised using feedback from radiation oncologists to simulate clinical implants. Figure 2 shows a GYN fantom made using a female condom model (3B Scientific) as outer shell. The vaginal cavity was made of Dragon Skin 10NV 1:2 Slacker™ mass ratio, and the implantable structures were made of both Ecoflex 00-30 4:1 Slacker™ and Ecoflex 00-20 FAST 4:1 Slacker™ mass ratios to mimic cervical and hard tumor tissues. The MSR applicator was inserted in the phantom and CT-scanned. Applicator and needle trajectories were reconstructed in Oncentra Brachy (Elekta) TPS and registered with CAD models for error analysis.

RESULTS AND DISCUSSION

A statistical analysis of the needle trajectory deviations was carried out using the novel caps in air and silicone implantable structures simulating clinical situations (cervical tissue and hard & heterogeneous tumors). The mean distance-to-agreement (DTA) and variations in pitch, yaw and roll angle of 42 needle trajectories at 14 different angles from 0° to 45° were calculated in each experiment and compared to the Venezia™ applicator's performances in the same conditions. Figure 3 presents the measured means of each parameters for all applicators in silicone simulating cervical tissues. M2 caps were shown to minimize errors compared to the M1 caps, this difference being attributed to the longer needle tunnels of the M2 caps. The performance of the MSR applicator was not influenced by the implant medium. No clinical differences were noted between the M2 caps and the Venezia™ applicator, making the M2 caps more suitable for clinical use than the M1 caps.

CONCLUSION

Four new needle positions were added to the MSR applicator, and its size was reduced. A silicone GYN phantom simulating clinical implant conditions was successfully made. Negligible differences were observed between the performance of the MSR applicator with the M2 caps and the Venezia applicator, but M2 caps have shown some improvement over the M1 caps.

CONTACT INFORMATION

marie-eve.roy.14@umontreal.ca

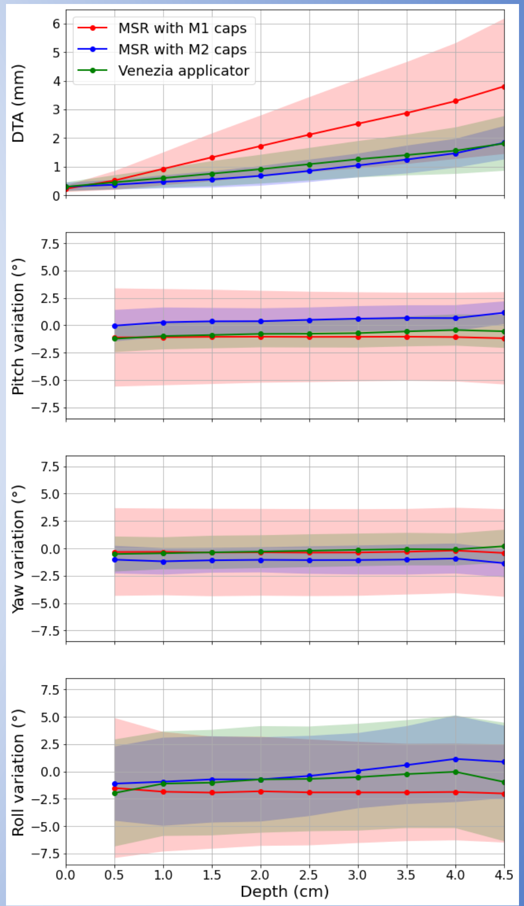

Figure 3. Comparison of applicators in cervical tissue-like silicone implantable structure using round IS needles.