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The Development of a Multi-Material 3D Printed Brachytherapy Training Phantom for Enhanced Resident Training

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INTRODUCTION

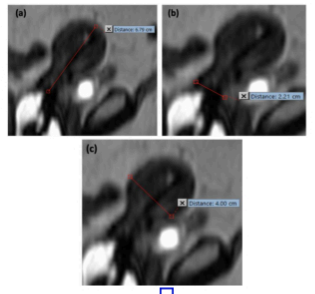
The utilization of brachytherapy practice in clinics has been declining over the years. The decline has been linked to a variety of factors including a lack of training opportunities[1,2]. To improve the quality of intracavitary and interstitial HDR brachytherapy education, a multi-material modular 3D printed pelvic phantom kit prototype simulating normal and cervix pathological conditions has been developed. This comprehensive training phantom is intended to serve as a novel aid in the "300 in 10 Strategy" put forward by the American Brachytherapy Society which calls to train 30 competent brachytherapists per year over the next 10 years[3].

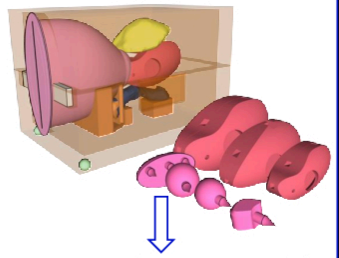
AIM

To improve the quality of intracavitary and interstitial HDR brachytherapy education, we aim to develop a modular 3D printed pelvic phantom kit simulating normal and cervix pathological conditions. The implementation of this phantom in physician resident education will allow for a more thorough and comprehensive training, resulting in improved resident confidence when performing such procedures in the clinic.

METHODS

- Phantom anatomy was derived from pelvic CT and MRI scans from 50 representative patients diagnosed with localized cervical cancer.
- The following were retrospectively measured and analyzed: uterine body dimensions, uterine canal dimensions, uterine canal angle, and HRCTV volumes.
- Statistics on the above measurements were used to construct four different uteri in 3D CAD software, Shapr3D.
- Shore durometer values were determined using an equation relating Young's modulus of elasticity(Pa) values to shore A values.
- Soft-tissue anatomy was 3D printed on a Stratasys J750 PolyJet printer using Agilus blends (shore 30 and 70), while rigid modular components were printed using Vero (shore 85).





$$S_H = 100\, erf\left(3.186 * 10^{-4}\sqrt{E}\right)$$

RESULTS

Design and Printing Specifications:

Four uteri were constructed using the dimensions listed in Table 1.
CAD designs were assigned the shore A durometer values listed in Table 2 and printed in the corresponding materials.

Training Phantom Kit Inventory:

The final design of the training phantom (Figure 1) includes the following STL files:

- 1x Outer Case
- 3x Anteverted Uteruses (* 2 embedded GTVs in the small and large uterus)
- 1x Retroverted Uterus
- 4x External GTVs
- 1x Vaginal Canal
- 1x Rectum
- 1x Bladder

Cost Analysis:

This cost is based on a series of quotes which shows an average price for the part materials (Agilus and Vero) purchased from the manufacturer to be about $178 per kg, and the average price for the support material (FullCure 705) to be about $62.50 per kg:

Primary Materials: 2,869 g x $178/kg = $510.00

Support Materials: 1,935 g x $62.50/kg = $120.94

Total cost of materials: ***$630.94***

Table 1: Uterus Design Dimensions

	U1	U2	U3	U4 *
Body Length	5.81 cm	7.87 cm	9.93	7.87 cm
Body Width (top of cervix)	2.02 cm	2.74 cm	3.45 cm	2.74 cm
Body Width (midpoint)	3.15 cm	4.45 cm	5.74 cm	4.45 cm
Canal Length	5.81 cm	6.23 cm	7.63 cm	6.23 cm
Canal Width	0.34	0.42	0.50	0.42
Canal Angle	19.1°	27.6°	36.1°	27.6°

*Retroverted

Table 2: Material Properties Assigned to Prints

	Photopolymer	Shore A Value
Uterus	Agilus	30
Vagina	Agilus	30
Rectum	Agilus/Vero	70
Bladder	Agilus	30
HR-CTV	Agilus	30
Outer Box	Vero Clear	85
Box Grips	Agilus/Vero	40
Inner Box Supports	Agilus/Vero	50
Modular Connections	Vero Clear	85

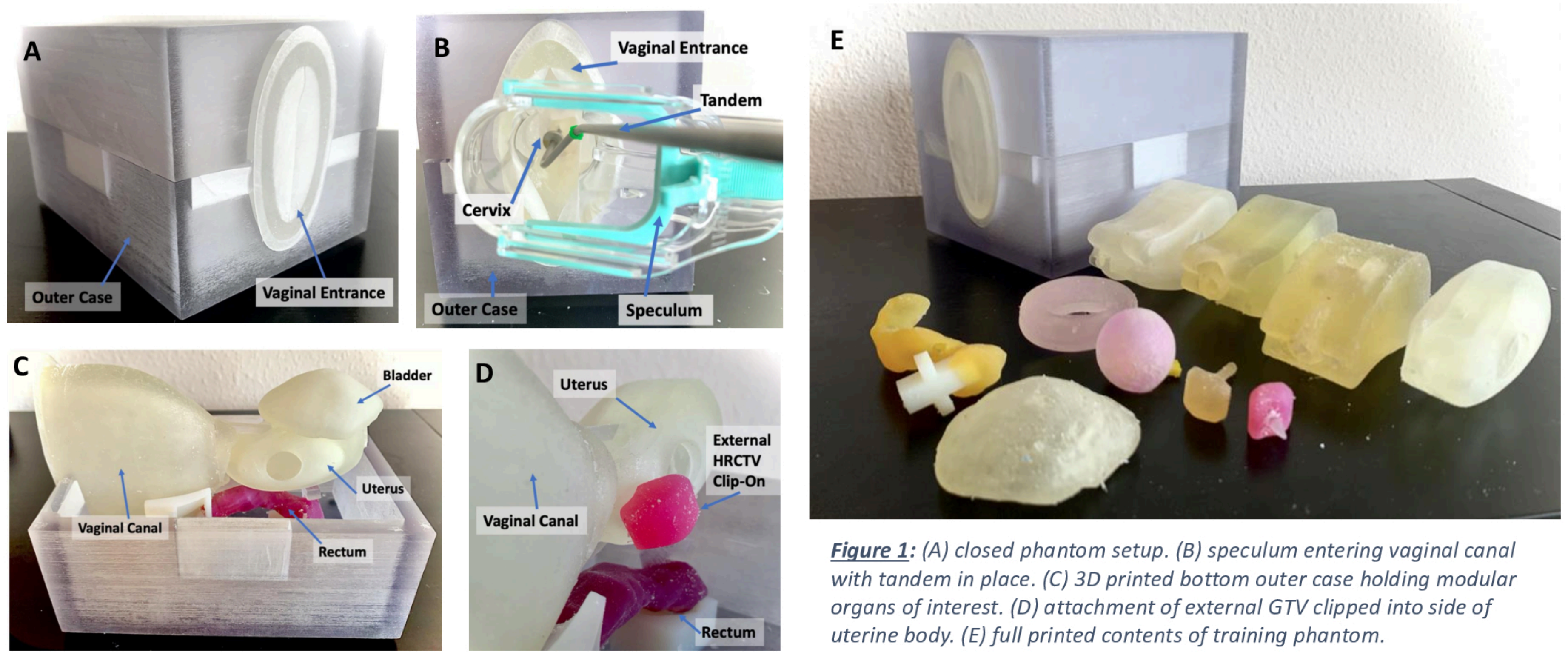


***Figure 1**: (A) closed phantom setup. (B) speculum entering vaginal canal with tandem in place. (C) 3D printed bottom outer case holding modular organs of interest. (D) attachment of external GTV clipped into side of uterine body. (E) full printed contents of training phantom.*

CONCLUSIONS

We have developed a modular pelvic phantom with detachable anatomical components allowing for a more thorough and comprehensive training for medical residents. This work demonstrates the feasibility of using patient CT/MRI data to design and manufacture complex 3D printed anatomical structures. Our presented 3D printed kit exhibits four major advantages over existing phantoms in that: (1) It incorporates **flexible materials** which accurately mimic human tissue properties, (2) the phantom can be **entirely and directly printed** without the use of molds and external materials (3) printing the uterus in clear materials allows for the physician to **assess resident performance** of tandem and needle insertions without needing access to a medical imaging scanner, and (4) the **cost** for manufacturing the full phantom training kit is significantly less than most existent training phantoms on the current market, making this an ideal option when selecting training tools.
We hope that by creating an accessible and low-cost training phantom we can help improve resident comfort in performing these procedures and contribute to the American Brachytherapy Society call for 30 new brachytherapists per year over the next 10 years.

REFERENCES

1. **Marcrom SR, Kahn JM, Colbert LE, et al.** Brachytherapy Training Survey of Radiation Oncology Residents. *Int J Radiat Oncol Biol Phys*. 2019;103(3):557-560. doi:10.1016/j.ijrobp.2018.10.023
2. **Compton JJ, Gaspar LE, Shrieve DC, et al.** Resident-reported brachytherapy experience in ACGME-accredited radiation oncology training programs. *Brachytherapy*. 2013. doi:10.1016/j.brachy.2013.06.004
3. **Harari PM et al.** Brachytherapy: Call to arms. Brachytherapy Take it forward. The Am Soc Radiat Oncol Mag. 2019:5. www.astro.org.

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S.C, O.C, E.S, and J.C have a patent pending on the device presented.

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