Clinical Integration of Multi Jet Fusion 3D Printing-Based Bolus for VMAT Chestwall Patients

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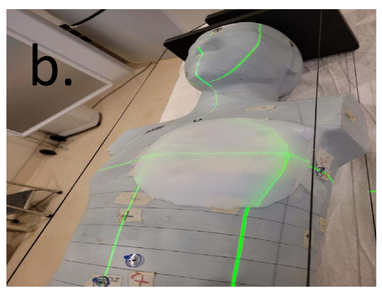
Introduction

This work aims to evaluate highly flexible Adaptiiv On Demand (AOD) MultiJet Fusion (MJF) 3D printing-based Moulded Silicone Bolus (3DM-SIL) for use within a clinical workflow for VMAT chest wall (CHWL) and compare it with semi-rigid AOD MJF 3D printed thermoplastic polyurethane bolus (3D-TPU). Indications for use, properties and tolerances for planning, QA and on-treatment set-up considerations are investigated and described.

Materials and Methods

- VMAT (6MV) chestwall patients at Nova Scotia Health receive chestwall bolus every other day unless there is clinical indication for daily bolus.
- The routine bolus in use is Superflab. 3D printed bolus (3D-TPU) from Adaptiiv is used at the discretion of radiation therapists and planners based on anatomical indications of the chestwall, i.e. if excessive air gaps between bolus and skin are anticipated. Another indication for use of 3D-TPU bolus is DIBH due to its simplified on-treatment setup compared to Superflab.
- Patients are scanned at CT without bolus and then, in Eclipse, a virtual water equivalent 5mm bolus is added to half the fractions.
- Daily CBCT is used to verify the positioning of patient and bolus.
- The dosimetric aim of this work was to investigate if 3D-TPU and 3DM-SIL bolus from Adaptiiv can be used interchangeably in our clinic for chestwall patients.
- The use of 3DM-SIL bolus may be preferable for some patients due to its less rigid form compared to 3D-TPU.



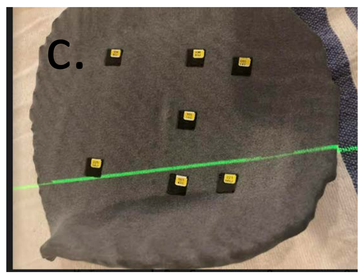


Fig 1: Adaptiiv 3DM-SIL bolus sitting on its mould (centre). Another mould for placement of OSLDs is also shown (a) 3DM-SIL bolus placed on an anthropomorphic phantom (b) Adaptiiv 3D-TPU bolus with inserts for OSLDs for the same anthropomorphic phantom (c)

Nomenclature	Criteria
PTV_Eval_High_05	$V_{95\%}$>95% D_{10cc}<4280cGy $D_{0.03cc}$<4400cGy
Body	D_{10cc}<4280cGy $D_{0.03cc}$<4400cGy
Lung_Ipsi	V_{500}<60% V_{1000}<45% V_{2000}<25% Mean< 1000cGy
Lung_Contra	Mean<300 cGy V_{500}<10%
Lungs	V_{500}<50% V_{750}<25% V_{2000}<10% Mean<600cGy
Heart	Mean<200cGy
Breast_Contra	V_{1000}<15% Mean<400cGy

Table 1: Dosimetric Criteria for VMAT Chestwall with nodal irradiation (4000Gy/15)

- A VMAT chestwall plan was generated in Eclipse. (Fig 2)
- Dose was calculated assuming water equivalent bolus, per current departmental guidelines for Superflab and 3D-TPU.
- Plan verification measurements were performed with OSLDs for 3D-TPU bolus and for 3DM-SIL bolus, on the phantom. (Fig 1)

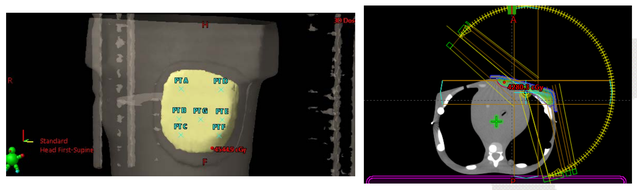


Fig 2: OSLD placement (a) and VMAT plan (b) in Eclipse.

Results

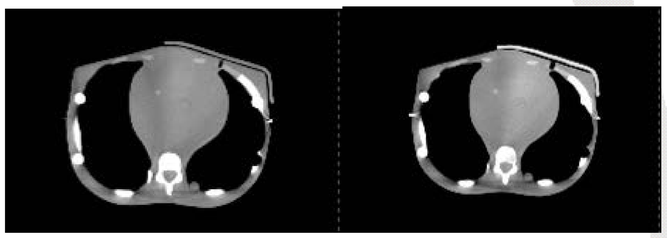


Fig 3: CBCT images of 3D-TPU (a) and 3DM-SIL (b) bolus.

- CT imaging of the 3DM-SIL bolus showed the following properties in Eclipse (AXB 15606):

- HU: 150-190
- Density: ~1.12 g/cc
- Material: ~97% cartilage, 3% bone

- CT imaging of the 3D-TPU bolus showed the following properties in Eclipse (AXB 15606):

- HU: ~20
- Density: ~1.02 g/cc
- Material: Muscle Skeletal

OSLD Readings:

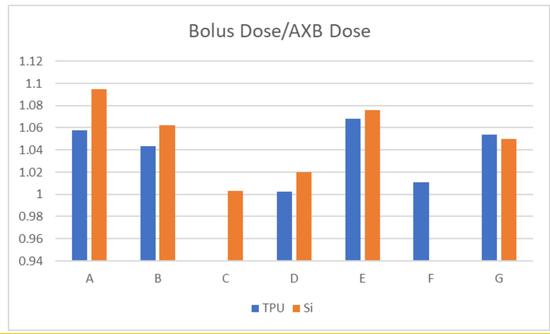


Fig 4. OSLD doses under 3DM-SIL and 3D-TPU bolus compared to Eclipse predictions (assuming water equivalent bolus). Locations A-G are shown in Fig. 2.

More Results

Effect of bolus material assignment:

Using water equivalent bolus assumption:

- OSLD readings under 3DM-SIL bolus were on average 1% (range -0.4 to 3.5%) higher than readings under the 3D-TPU bolus.
- 3D-TPU bolus on average recorded higher readings within 4% (range 0.2% to 5.7%) compared with AXB reported doses. This range is consistent with our institutional experience with Superflab.

- Upon further investigation, assignment of material = water (HU changed incrementally from 0 to 200), changed the predicted values of dose only by 0.5%.
- Plan calculation on a CT scan of the phantom with the 3DM-SIL bolus in place, increased the predicted doses on average by 1.2% (range -0.2% to 2%) resulting in a closer match with the measured values.
- Upon further investigation with a solid water phantom (slabs) and a parallel plate chamber (Advanced Markus), 3DM-SIL bolus showed similar attenuation to solid water (within 0.1%) but increased backscatter (3% increase in exit dose compared to solid water for a 4cm^2 field.)

Conclusion

- Our OSLD measurements show that readings under a 5mm 3DM-SIL bolus are slightly higher than 3D-TPU bolus in a chestwall plan. This is most likely due to the increase in backscatter, due to 3DM-SIL's higher Z material.
- Scanning with the 3DM-SIL bolus does not guarantee perfect agreement between measurements and Eclipse's AXB predictions due to inherent uncertainty in measurements, commissioning data at shallow depths, and the fact that 3DM-SIL is not an available material in the AXB library.
- Our measurements support the fact that scanning with 3DM-SIL bolus results in measurement doses within 4% (range -1 to 7%) compared to AXB predictions.

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