

Using 3D printer technology to advance and optimize the use of bolus in the Radiotherapy workflow



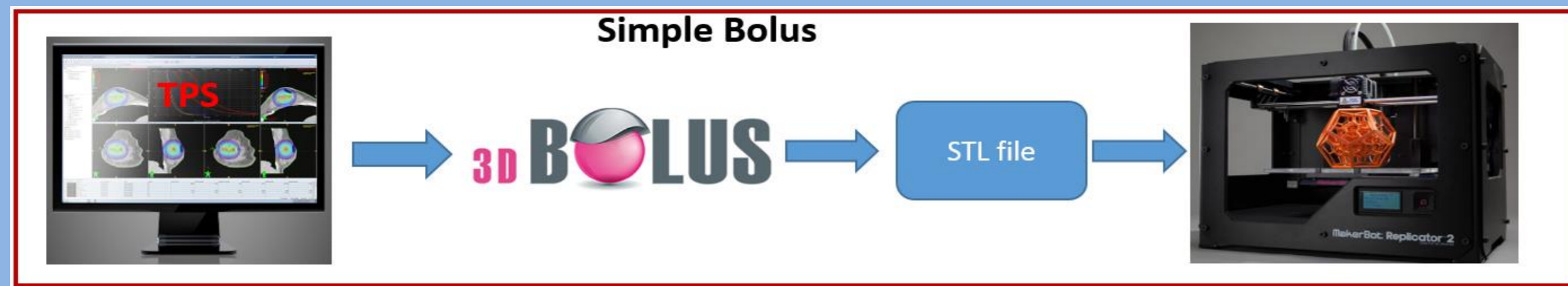
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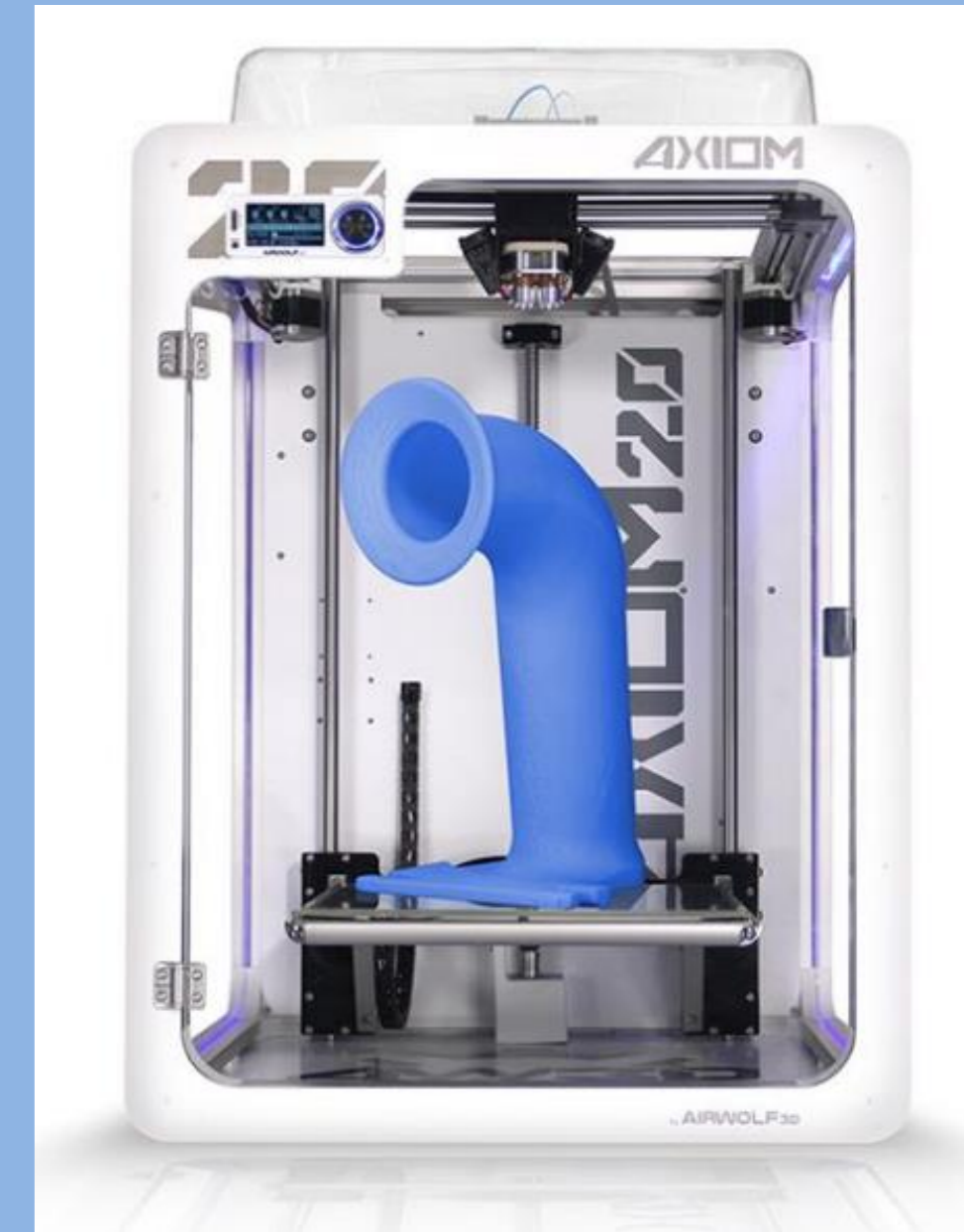
INTRODUCTION

3D printing is a relatively new and exciting area with a wide range of applications. Seeing the potential of 3D printing in the radiotherapy setting, we made the decision to acquire the 3DBolus package with funds kindly donated by the Friends of St Luke's. 3D Bolus is a system designed with a radiotherapy mind-set and therefore integrates well with our existing treatment planning software and clinical workflow. It enables us to create cost-effective, customised bolus for complex cases where conventional solutions would typically come up short. 3DBolus uses the bolus structure generated in our treatment planning system (Varian Eclipse) and converts it into a file ready to print on a 3D printer. The final bolus printed is based on the patient's CT body contour customised precisely to the patient's surface. This study compares 3D printed bolus with standard bolus over a number of cases using two flexible materials called Ninjaflex and Wolfbend.



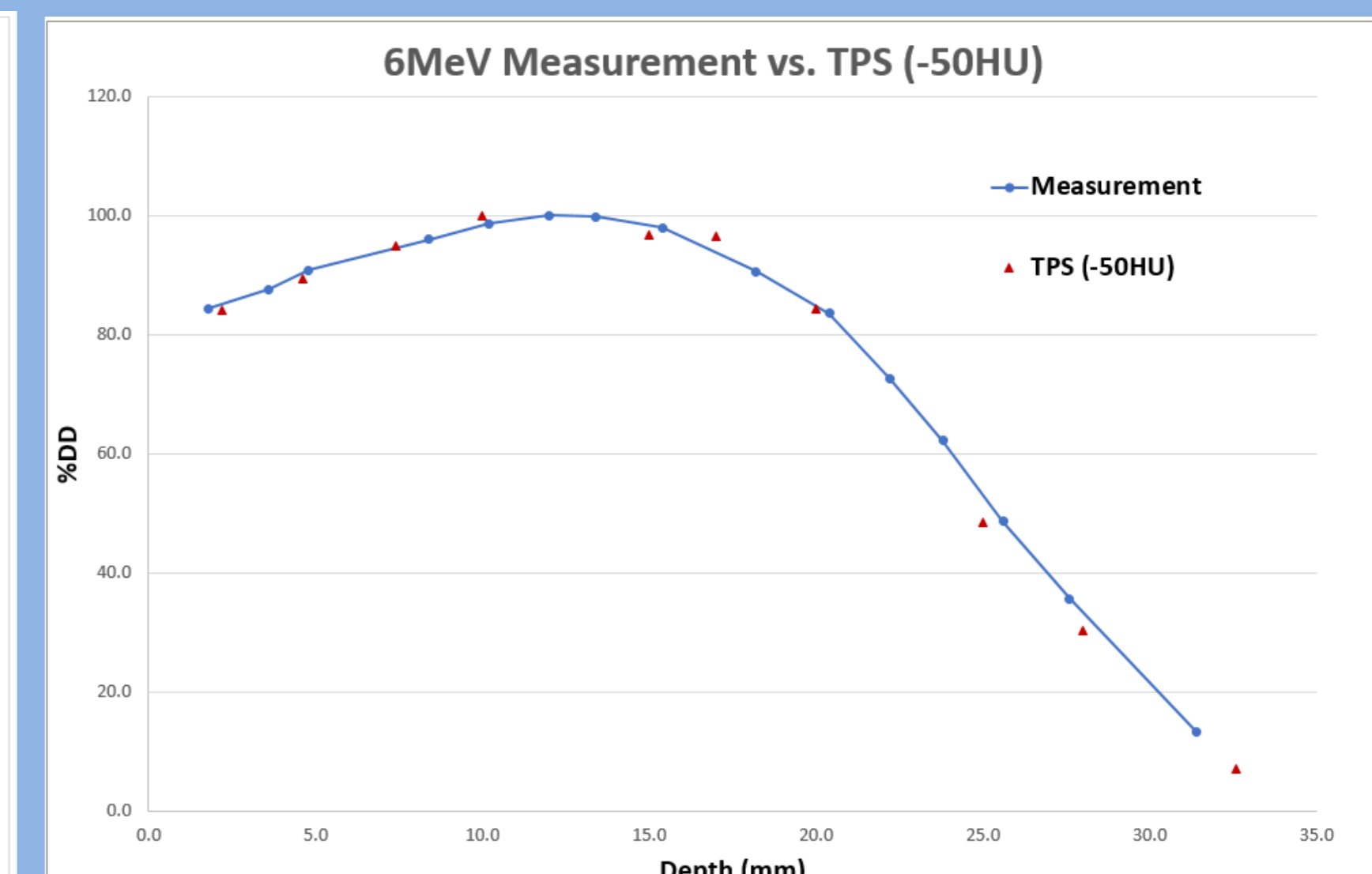
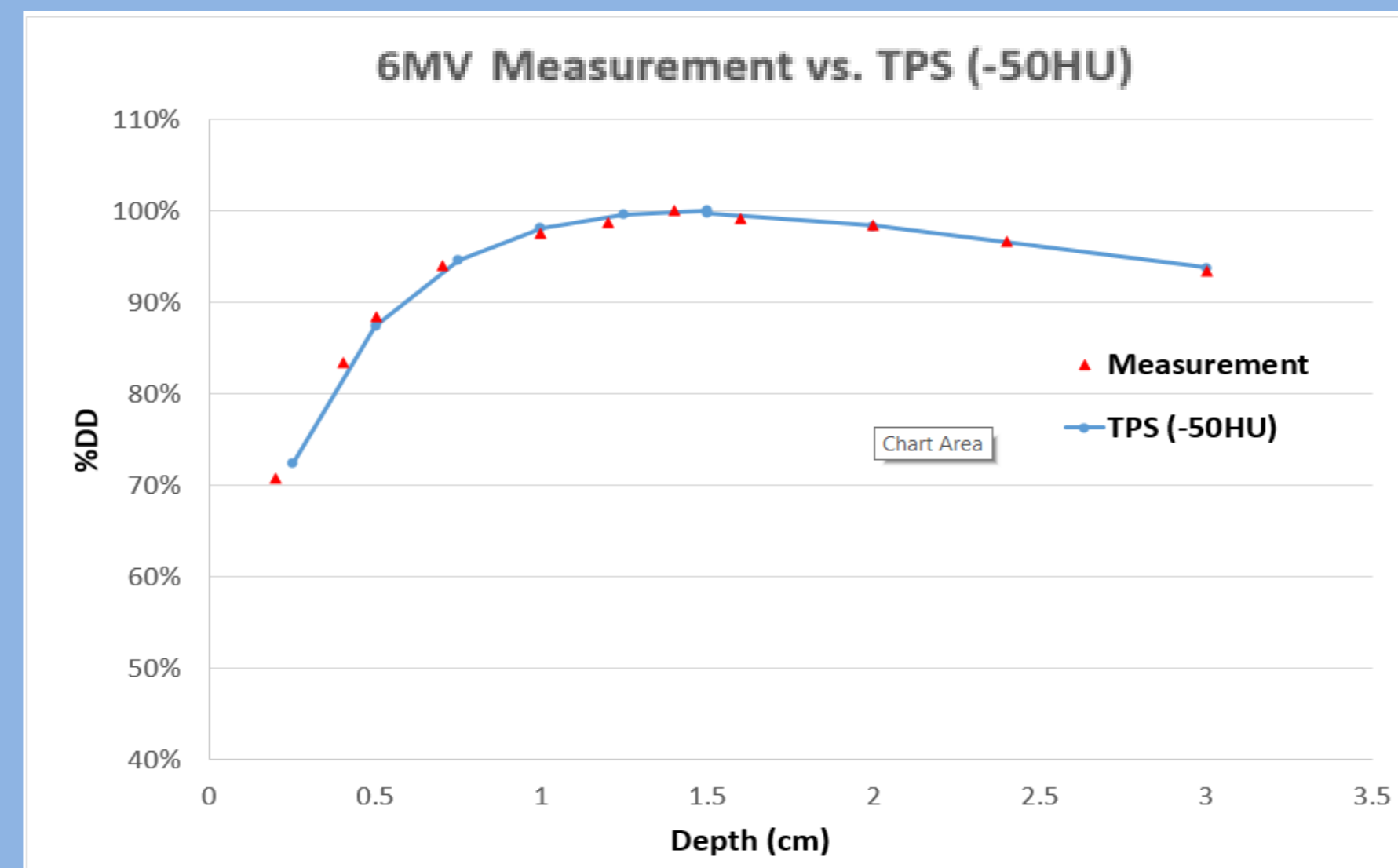
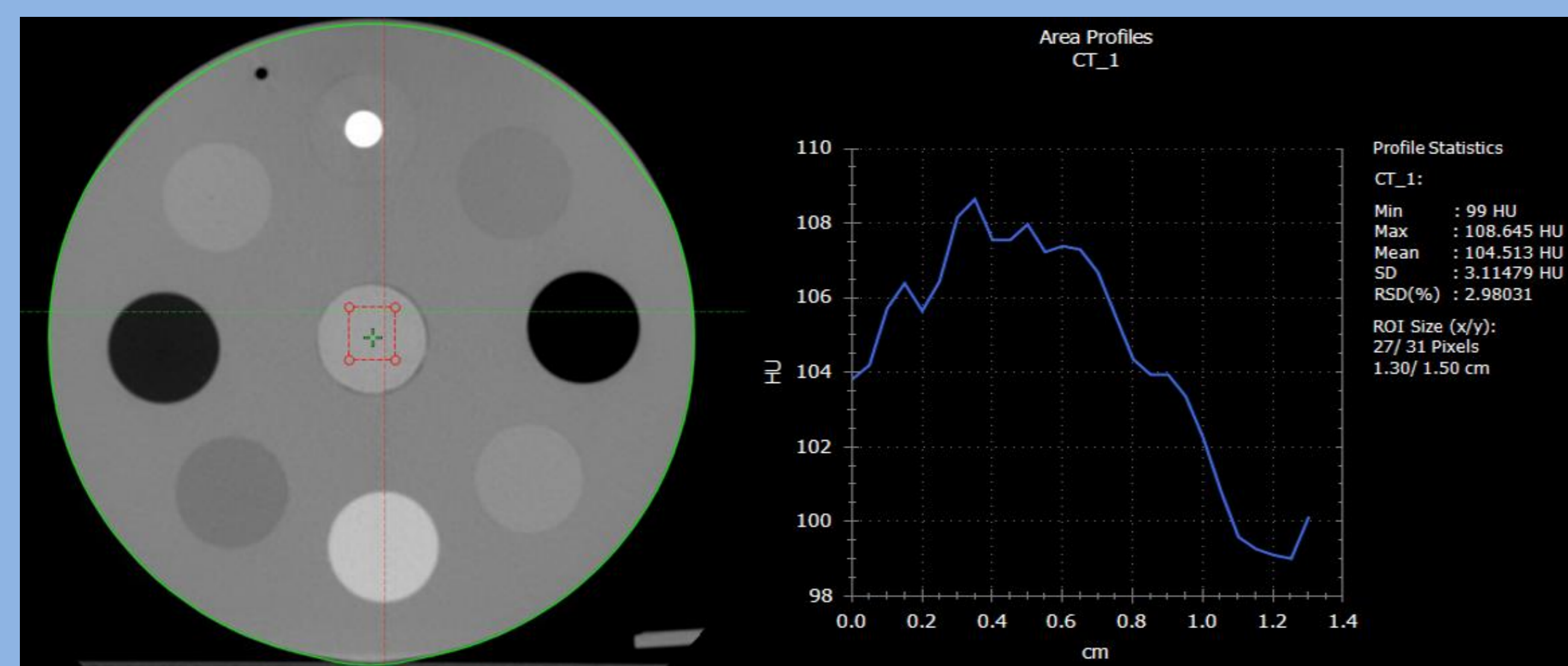
3D PRINTER

The AirWolf Axiom 20 3D printer was used to print each bolus using both Ninjaflex and Wolfbend filaments. Each bolus was printed using a 0.5mm nozzle with 100% fill selected. Ninjaflex used a 0.35mm layer height, print temperature of 255°C and bed temperature of 40°C. Wolfbend used a layer height of 0.3mm, print temperature of 240°C and a bed temperature of 100°C. Due to the flexible nature of each filament, the print speed was reduced to 40mm/s for Ninjaflex and 60mm/sec for Wolfbend with retraction tuned to ensure pressure build-up at the printer nozzle did not result in the filament jamming. Print settings were saved in a print material "profile" to enable users to quickly prepare the printer for the filament and bolus required.



COMMISSIONING THE 3D PRINTER

Before using 3D bolus clinically, a number of questions needed to be answered. Several dosimetric slabs of varying thickness were printed to investigate the dosimetric properties of each printer material. A high resolution CT scan (0.625mm slices) and Vernier calipers were used to verify the geometrical accuracy, uniformity and reproducibility of each printed slab. Measurements were undertaken using the PTW Roos and Advanced Marcus ionisation chambers under both TMR and PDD setups for photons and electrons. These measurements were compared against calculations undertaken in Varian Eclipse using varying bolus thicknesses to replicate measurement conditions (based on Burleson et al, 2014). A CT density insert for the CIRS electron density phantom was also printed to compare the relative electron density (RED) assessed by the CT scanner against the relative electron density found via measurement. CT scans suggested the uniformity of Ninjaflex and Wolfbend was +/-15HU and +/-5HU respectively. Film measurements verified that there were no differences in uniformity within each print (< 1%). Each print width/length was within 0.9mm and depth within 0.3mm of that which was planned. Dosimetric measurements demonstrated that Wolfbend represented a material corresponding to 100HU (RED 1.067, mass density 1.091g/cm³) and Ninjaflex -50HU (RED 0.961, Mass density 0.973g/cm³). 6MeV was most sensitive to changes in HU and was used to fine tune both materials in the TPS. HU values were only valid using the print settings outlined.



Left: CT electron density phantom with a Wolfbend printed insert. CT estimated HU shown. Right: Measurement of Ninjaflex slabs vs. TPS showing a HU of -50 represents the materials density.

CLINICAL EVALUATION

Implementing 3Dbolus clinically was done in three stages. First, a number of test boluses were generated for the RANDO phantom, including a breast case and a nose case. These were imaged at CT to compare the fit of 3D printed bolus vs. conventional bolus. Second, several cases were chosen as possible 3Dbolus candidates. A 3D bolus was generated based on the planned bolus and was imaged on the patient using CBCT to compare against the standard bolus used clinically. Finally, a suitable patient was selected and 3Dbolus was generated to be used clinically with Physics, Planning and RT present for the first fraction.

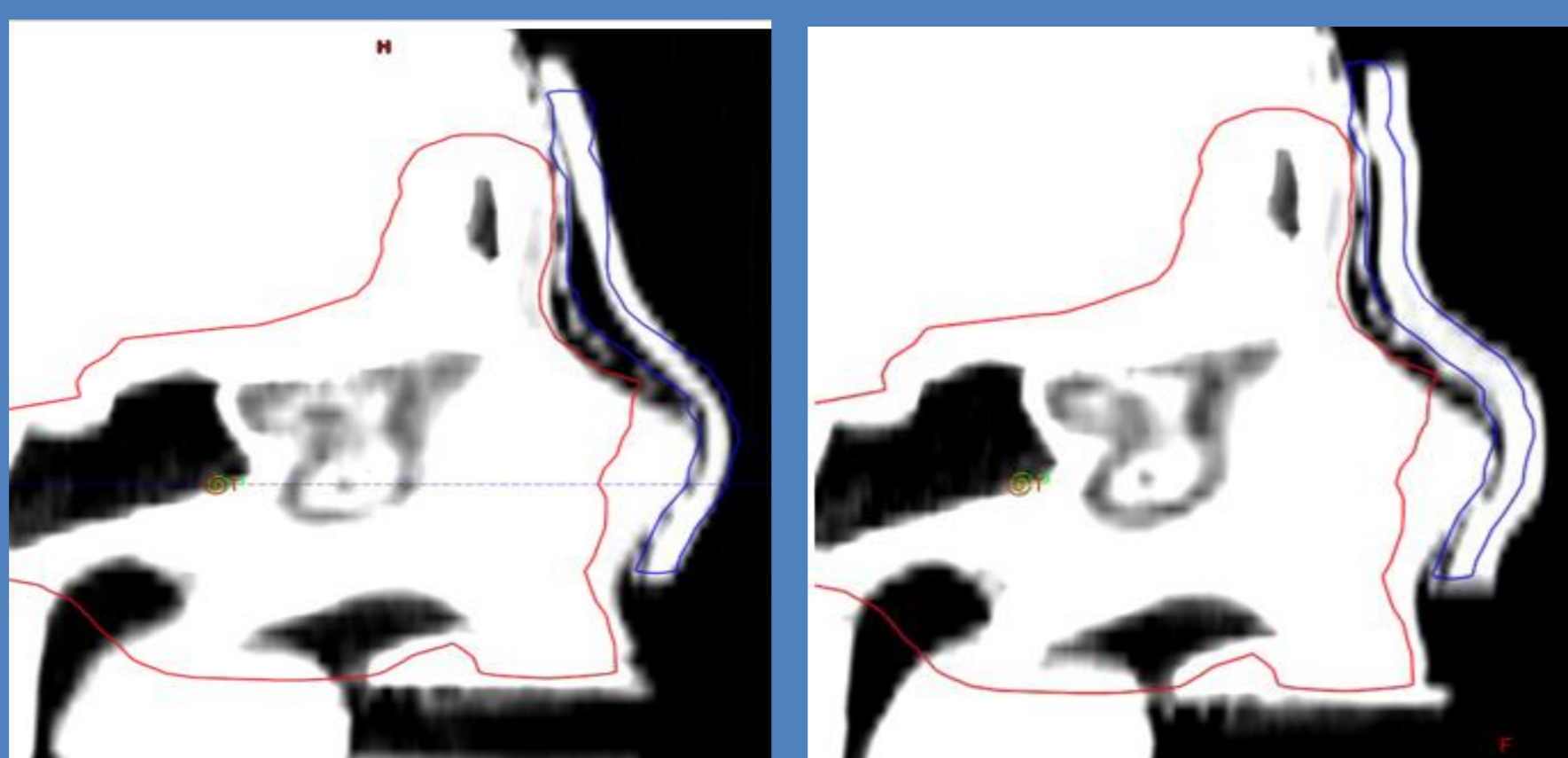


Examples of 3D printed bolus

Three cases are shown below. 1. Nasal 3D bolus fit compared to standard bolus showing an improved fit over the bridge of the nose. 2. 3D printed breast bolus generated on RANDO. The 3D printed bolus conformed to the breast contour precisely compared to the sheet of Superflab which required a large amount of time and leucoplast tape to achieve a reasonable fit. 3. Vulva SCC where wet-gauze would typically be used. The 3D printed bolus is shown to represent what was planned precisely and will remain consistent throughout treatment compared to wet-gauze.

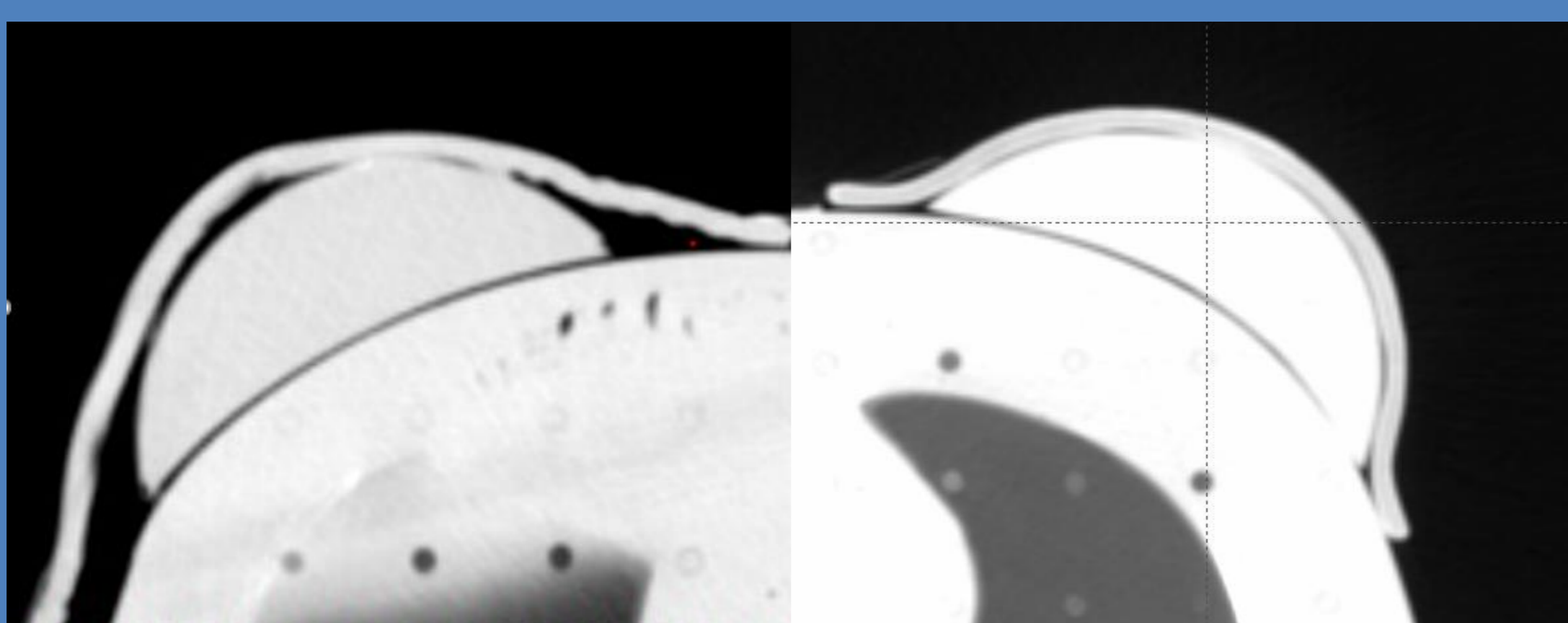
1. Nasal case

Standard bolus (Left) vs. 3D printed bolus (Right)

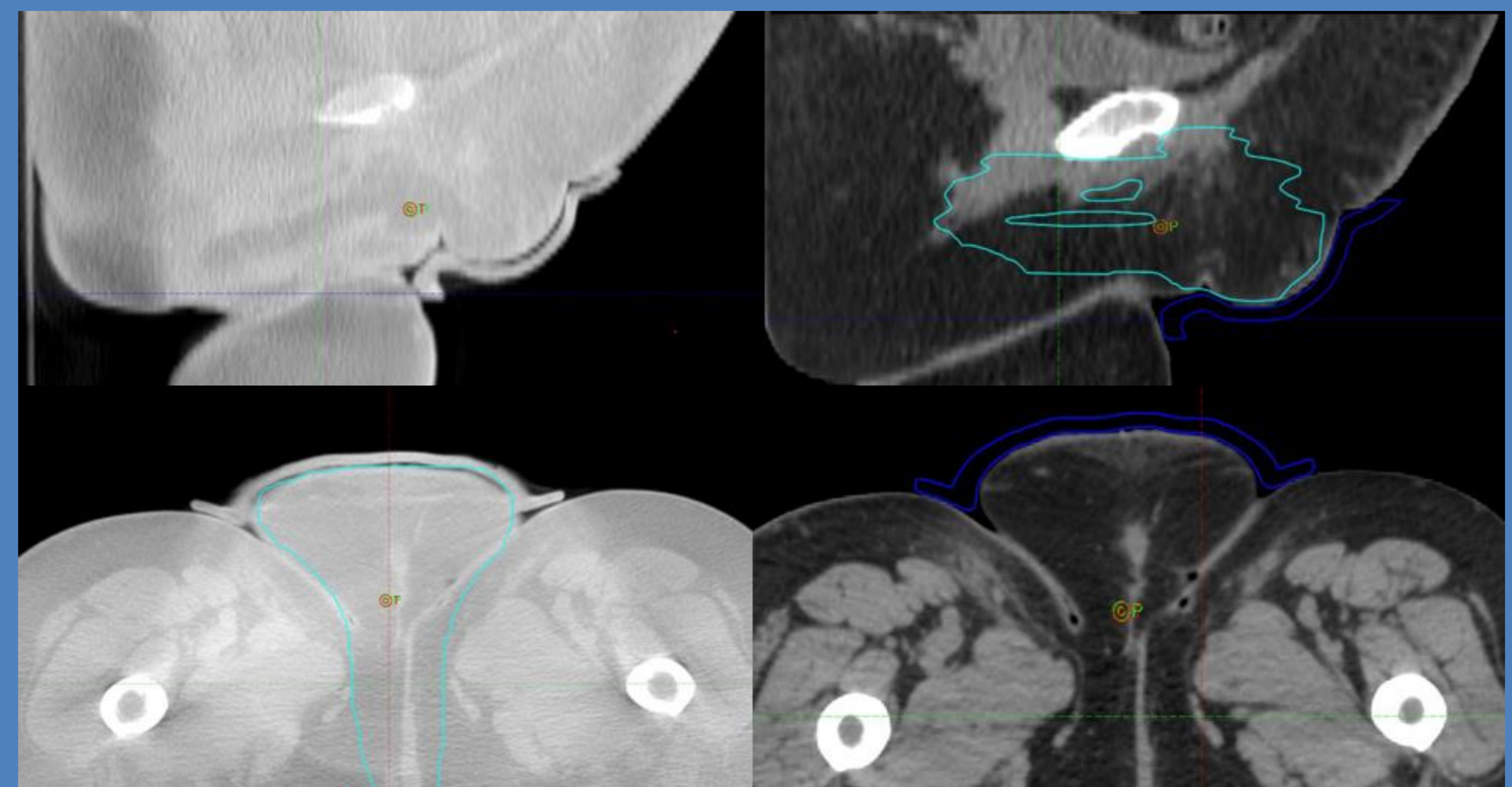


2. RANDO breast case

Standard bolus (Left) vs. 3D printed bolus (Right)



3. Vulva case – 3Dprinted bolus (left) vs. planned bolus (right)



DISCUSSION AND CONCLUSION

3D printed bolus was found to have a similar density to standard bolus and conform well to patient anatomy for a variety of treatment sites when compared to existing bolus methods used in our clinic. Each 3D printed bolus corresponded precisely what was reviewed by the Radiation Oncologist on the patient's treatment plan, which may not be the case when trying to reproduce the planned bolus using traditional methods. For sites of tumour response or change in anatomy, a new bolus structure could be created using the patients CBCT imaging and printed for the next patient fraction. Finally, efficiency gains in treatment preparation times were noted using a 3D printed solution, especially in comparison to wet-gauze.

REFERENCES:

- Shiqin Su, Kathryn Moran, James L.Robar, "Design and production of 3D printed bolus for electron radiation therapy", JACMP Vol:15, No.4 2014
- J.L. Robar et al, "3D printed bolus for chestwall radiation therapy", Poster presentation ESTRO 35, 2016.
- Burleson et al. Use of 3D Printers to create patient-specific 3D bolus for external beam therapy. Journal of Applied Clinical Medical Physics. 16(3):166-178 2015