Custom Bolus Fabrication Improvement

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INTRODUCTION

Bolus types currently used clinically include materials such as Superflab, wax (paraffin or Bee's wax), thermoplastics, wet towels, or discarding boluses entirely and treating the patient's surface with an electron boost. When using Superflab boluses, air gaps can form between the patient and the bolus, leading to planned and delivered dose distributions discrepancies. The major downside of custom manual wax bolus fabrication is the significant amount of labor time required, which can also lead to chronic injuries (tendinitis). Thermoplastic sheets can be bought pre-made from a manufacturer, but this is often prohibitively expensive (3 boluses produced weekly amount to about $17,000 yearly).

PURPOSE

I propose using computer assisted design (CAD) software to produce custom made CNC machined aluminum molds to fabricate in-house thermoplastic bolus sheets. We are also currently investigating the option of 3D printing custom boluses.

METHOD

Aluminum molds can be designed to obtain a bolus with clinically relevant dimensions with a thickness precision down to 0.1 mm by using FreeCAD, which is a freely available CAD software. The FreeCAD design files are available on demand.

Thermoplastic pellets are melted in water at 140F, and put into the bottom part of the mold, with the top part compressing the bolus down to the desired thickness.

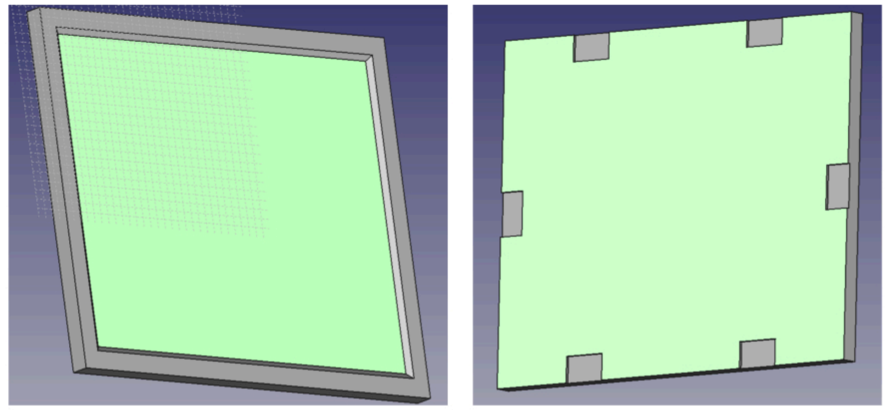

Figure 1. The left figure shows the bottom aluminum plate onto which hot wax is poured, and the right figure shows the top aluminum plate which is used to compress the wax, with six cut-outs to let excess wax exit the mold. Three bottom plates are needed to produce three different bolus thicknesses (3 mm, 5 mm, and 1 cm).

RESULTS

The custom wax bolus fabrication method used previously at UCSF requires about 5.5 hours to produce one bolus. The long time required for production mainly depends on heating and cooling down wax.

The process of shaving down the wax from 5 mm to 3 mm after it is poured and cooled down also requires about 45 minutes of manual labor (it is too difficult to attain a good thickness homogeneity of 3 mm when pouring the wax directly).

When thermoplastic instead of wax is used with the approach developed during this study, it saves about 5 hours of work for each bolus made, with a total production time of about 30 minutes. This is made possible because the heating cycle and the cooling cycle times are significantly reduced in duration.

The molds designed in this study can still be used to produce wax boluses, and this allows the fabrication process to yield a better bolus thickness precision (better precision than when shaving down the bolus from 5 mm to 3 mm thickness).

Another benefit of using thermoplastic instead of wax is that it can cut down the yearly material costs from ~$2,200 to ~$720 (thermoplastic being more affordable). The cost of CNC-machining molds (4 parts in total, with 3 bottom plates and 1 top plate) is about $750.

There are no significant dosimetric differences between the wax bolus and the thermoplastic bolus, as shown on table 1 and figure 2.

Material	Ideal Thickness	Dose (%)	Measured Thickness	Dose (%)	Relative error (%)
Wax	2.0	70.6	2.2	69.0	2.4
Wax	3.0	77.3	3.0	77.1	0.2
Wax	4.0	83.7	4.1	83.2	0.6
Wax	5.0	89.2	5.2	88.1	1.2
Wax	6.0	92.3	6.2	91.8	0.6
Wax	7.0	95.4	7.5	94.4	1.1
Wax	8.0	96.8	8.3	96.4	0.4
Wax	9.0	97.7	9.1	97.6	0.1
Wax	10.0	99.0	10.6	98.6	0.4
Thermo	3.0	83.9	4.1	77.1	8.8
Thermo	5.0	92.2	6.2	88.1	4.6
Thermo	8.0	98.5	9.9	96.4	2.1
Thermo	10.0	99.5	11.3	98.6	1.0
Vendor Thermo	5.0	88.2	5.0	88.1	0.2

Table 1. Percent depth dose for different bolus types and different bolus thicknesses measured with a caliper.

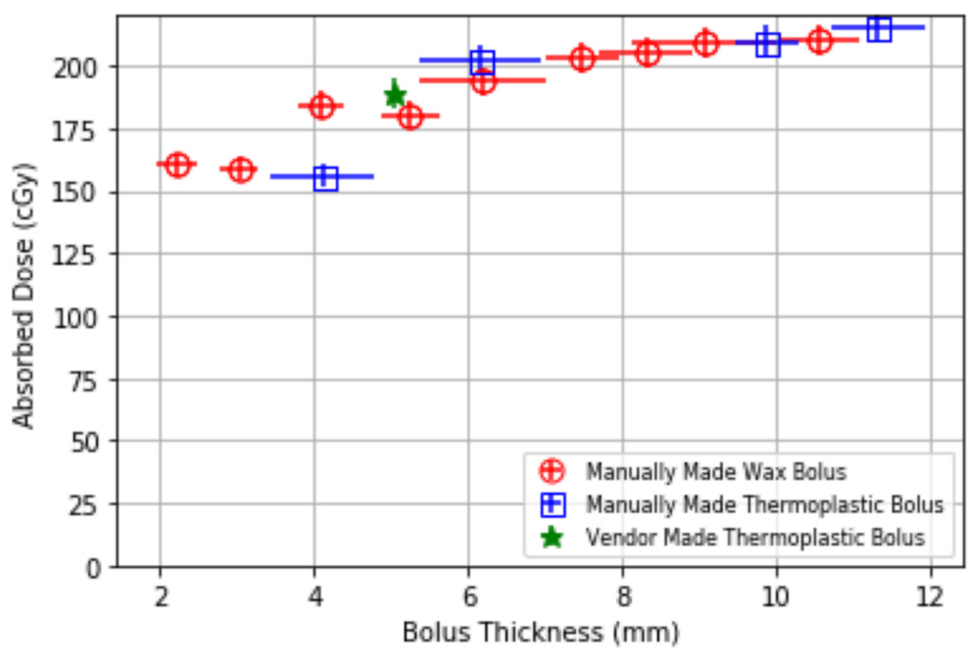

Figure 2. Absorbed dose measured with OSLDs for 14 different bolus thicknesses.

DISCUSSION

The CNC machined molds can help reduce the thickness uncertainty in the custom bolus fabrication process. The transition from wax to thermoplastic also reduces the fabrication time from 5.5 hours down to half an hour. We are still working on this project, and are currently investigating the possibility of using 3D printing to produce custom boluses. The main limitation of using 3D printers to produce boluses for breast treatment is the maximal printed piece size and the maximal printing speed. To be clinically achievable, we estimate that a 3D printer needs to be able to print objects of 25 cm x 25 cm (and x 3 mm, 5 mm, or 1 cm for the thickness) in less than 12 hours. This is challenging since most printers have a maximal printable object size smaller than 20 cm x 20 cm (in the X and Y directions), and have a maximal stable printing speed of ~75 mm/s. Transitioning to 3D printing would allow further cost savings since wax costs about $160/kg and thermoplastic about $36/kg; however, polylactic acid (PLA) used for 3D printing costs only $20/kg.

CONCLUSION

Using molds would decrease bolus thickness uncertainty associated with the manual bolus fabrication process. With the time, effort and cost saving potential, we recommend transitioning to a thermoplastic bolus fabrication process. Depending on the outcome of our 3D printing study, we might decide to use 3D printing instead of molds, if the fabrication process is achievable in a reasonable timeframe.

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CONTACT INFORMATION

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