MAKING CUSTOMIZED BOLUS WITH A 3D PRINTER

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OUTLINE

- Advantages of 3D printed bolus
- Equipment and software
- Clinical cases
- Test case on a phantom
- Dosimetry data
- Other uses of 3d printing in radiation oncology
Greeley In the News
DISADVANTAGE OF TRADITIONAL BOLUS

- Air gaps
- Poor conformity
- In many cases, the delivery does not reflect the plan
ADVANTAGES OF 3D PRINTED BOLUS

- Conformity
- The treatment more closely matches the plan
- Reduces air gaps
- Speeds up the placement during setup
- We send a message to patients that we customize our treatments to them
PROCESS TO PRINT A 3D BOLUS

1. Decide to use 3D bolus during tx planning
2. Use TPS contouring tools to make a bolus and calculate dose
3. Export plan and structure dicom files to convert to .STL file
4. Load into Cura, and print!

Cura

Printed bolus

3.9 cm from mid nipple to bolus edge. Note lateral bolus edge.
1000 3D printers on the market!

Taz 6 – fused filament fabrication (FFF)

- Print volume: 11x11x10”
- Fast print speed (up to 200 mm/sec)
- Wide array of filament choices including flexible
- Cost of printer+ optional tool-head: $3000.00
TAZ 6 PRINTER ANATOMY

- Filament
- Print bed
- Nozzle
- Toolhead
- X-rails
- Y-rails
- Z-rails
- Filament

Close up
EQUIPMENT CHOICES - FILAMENT

- Hard filament: easiest to print with:
  - PLA, ABS, co-polyester
- Flexible filament – most difficult to work with:
  - Ninjaflex, Filaflex
- Semi Flexible – easier to work with:
  - Cheetah, Polyflex
- 1 kg spool of filament = $70.00

Pick ONE, master it!
EQUIPMENT CHOICES - SOFTWARE

**Basic:**
- Cura – slicer software, which converts an STL file to GCODE.
  - STL: contains the coordinates of the vertices of triangles that make up part.
  - GCODE: contains instruction for the printer to print each layer

**Advanced:**
- 3DCAD: Tinkercad, Fusion 360, Onshape
- 3D manipulation: Blender, Meshmixer
CASES
Case 1: Squamous cell of Right Neck

- VMAT used to cover deeper extension
- 3D bolus used to fully cover shallow areas
Case 1: Squamous cell of Right Neck

- CBCT confirmation
- US gel used for better contact
Case 2: Squamous cell right ear

- 12 MeV Electrons
- Manual thickness modulation
- Result:
  - Evenly distributed dose through ear
  - Pay attention to increase in lateral scatter
Bolus printed in 2 pieces to ensure proper fit
OTHER USES OF 3D PRINTING IN RAD ONC BRACHYTHERAPY

Custom applicators

HDR surface molds
Case 3: Breast Cancer

- 5 field breast boost
- 200cGy x 5
- 6 MV photons 3DCRT
Case 4: Breast cancer

- VMAT chest wall
Hanging filament strands due to lack of structural support
TEST PLANS
ELECTRON COMPENSATED BOLUS – 16 MEV ELECTRONS

ECT bolus created in p.d software
Covers CTV in pink color
PLAN WITH PRINTED BOLUS
PLANAR ISODOSE COMPARISON

- Curves agree well, which means bolus was printed correctly.

Magenta is virtual bolus.
OTHER USES OF 3D PRINTING IN RAD ONC PHYSICS

Chamber inter-comparison jig

A10 chamber holder
Test Plan:

- Treating entire nose with opposed beams

Hand made wax bolus
Open fields with bolus block

CTV coverage
BOLUS BOX CAN BE PRINTED AS A SHELL AND FILLED WITH WATER AND CAPPED SHUT
PLANNING TIPS

- Make the bolus “printable”
  - Avoid entering deep into ear canal
  - Complicated bolus prints better if it is thicker
  - Avoid overhangs and small footprints

- Vary the thickness in areas where more scatter would be beneficial – you can do that now!
- Add thickness to enhance scatter
Piece quality depends on:

- Nozzle temperature
- Printing speed
- Extrusion rate
- Possibly filament vendor, color

Ensuring the print starts correctly – base layer adhesion
OTHER USES OF 3D PRINTING IN RAD ONC
PATIENT EDUCATION

Prostate implant

Tandem and ovoid demonstration
COMMISSIONING:

- Literature review
- Patient safety aspects
- Material properties
- Effort
- Billing
- QA tests, documentation
- Dosimetry – PDDs, OSLs, etc
- Staff training
### Flexible Filament Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Ninjaflex</th>
<th>Cheetah</th>
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</thead>
<tbody>
<tr>
<td>Material</td>
<td>Thermoplastic poly urethane</td>
<td>Thermoplastic poly urethane</td>
</tr>
<tr>
<td>Manuf spec density (g/cc)</td>
<td>1.19</td>
<td>1.22</td>
</tr>
<tr>
<td>Measured density</td>
<td>1.12</td>
<td>1.20</td>
</tr>
<tr>
<td>CT scan HU</td>
<td>100</td>
<td>120</td>
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</table>
PATIENT SAFETY – NINJAFLEX/CHEETAH
MSDS SHEET:

If swallowed by mouth if the victim is unconscious or having convulsions. Immediate medical attention required.

SKIN: Solid material is not expected to pose a hazard in normal use, however skin contact with hot molten substance/product may cause thermal burns.
Softening temperature of NinjaFlex is 120C, which is also typical autoclave temp, so testing needs to be done.
DOSIMETRY – PHOTON PDDS

- 3D Printed 6 x 6 cm slabs of material in varying thickness
- 6 x 6 fields, 100 SSD
- Sunnuclear edge detector
6X PHOTON PDD – NINJAFLEX VS WATER

6 MV PHOTON PDD OF NINJAFLEX VS. WATER

- Ninjaflex diode
- Chamber in Water

PERCENTAGE DEPTH DOSE vs. DEPTH (MM)
PDD – ELECTRONS MEASUREMENT SETUP

IBA EFD electron diode
9 MEV ELECTRON PDD – NINJAFLEX VS. WATER

9 MeV electron PDD of Ninjaflex vs. Water

- Water - Chamber
- NinjaFlex - Diode
ABSOLUTE DOSIMETRY - OSLDS

Ninjaflex vs water

| 9 MeV Electron (dmax) | -2.2% |

3D printed mini OSLD watertank
QA OF 3D PRINTED BOLUS

We complete a checklist with the following:

- Visual inspection to detect improperly printed part
- Dimensions are measured
- CT scan of bolus to ensure uniformity within part. Average HU must be >100
- CBCT scan on 1\textsuperscript{st} day, if possible to verify fit
BILLING

- Special Physics consult ordered which covers physics time to work with dosimetrist in designing part in TPS, and for the QA that is performed
QUESTIONS

YOUR POINTY-HAIRED BOSS WANTS TO KNOW IF YOU TESTED THE NEW 3-D PRINTER YET.

WHY AREN'T YOU ANSWERING MY QUESTION?

WHAT—EVER.

SUCCESS.