3D BOLUS

Advancing the fight against Cancer


Greenland
Alaska
Yukon
Northwest Territories
Nunavut
Canada
British Columbia
Saskatchewan
Québec
Ontario
Washington
North Dakota
New Brunswick
Oregon
Michigan
Halifax
Wyoming
Iowa
Utah
Indiana
Maryland
California
Kansas
North Carolina
Texas

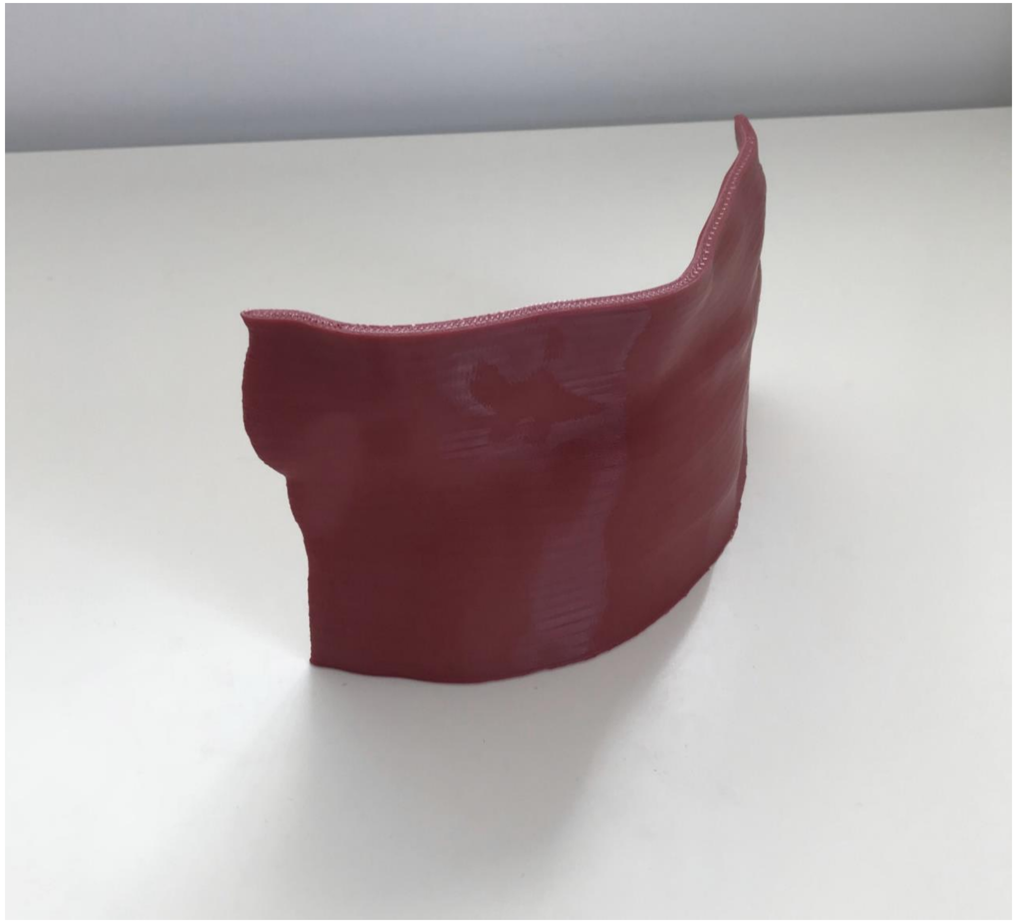

Photo: © Parks Canada, Ron Garnett, 2007

CONTENTS

Additive Manufacturing: Creating a physical object from a computer generated file.

History of Additive Manufacturing

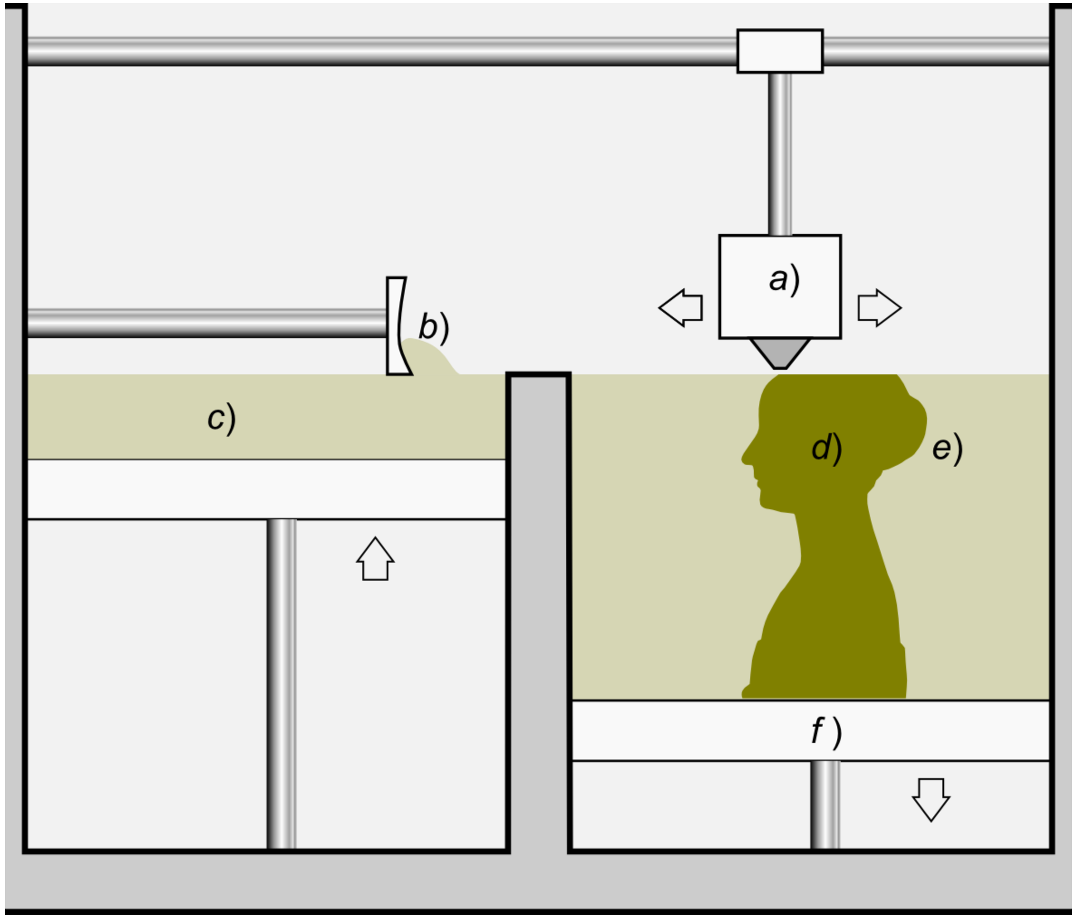
- Process of creating an object by adding pieces of material to one another.
- Technology has been around for roughly 35 years.
- Designed for rapid prototyping of complex objects.
- Differs from CNC milling in that it creates an object from nothing opposed to removing material from a block.



Powder Bed Printing

Powder bed machines use fine dust and a curing laser to solidify and create a three dimensional object.

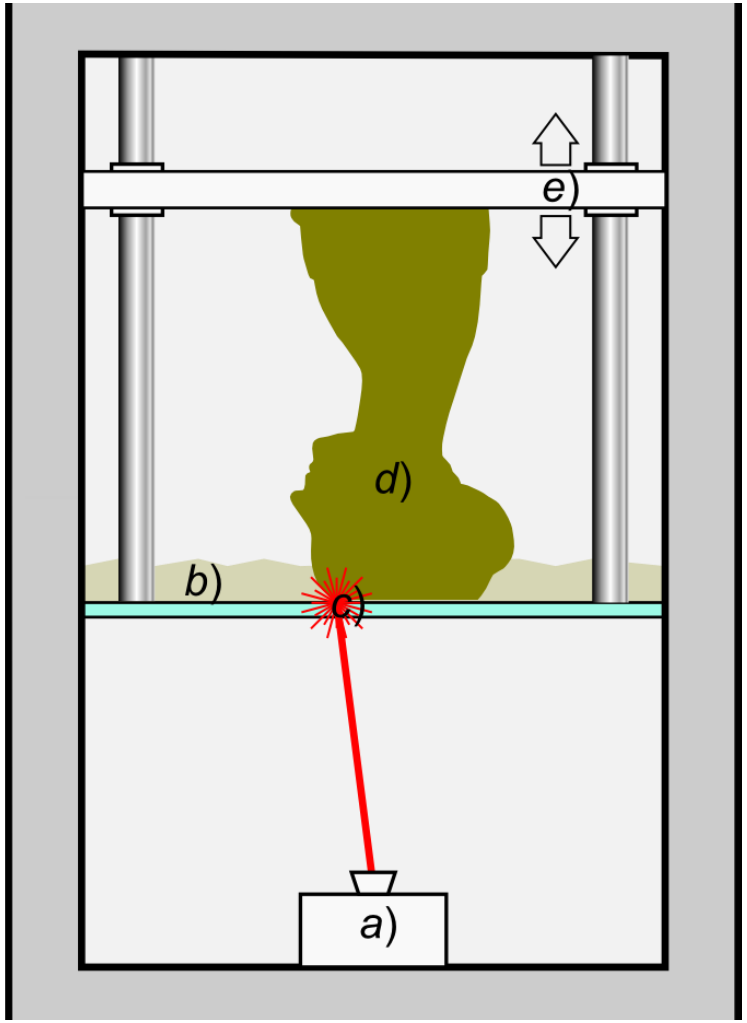
- Moving piston adds a layer of dust.
- Laser scintillating hardens the dust is the desired position based on computer model.
- Print bed lowers, allowing a new layer of dust to be placed on previous layer.
- Can print very complex parts.



Stereolithography Apparatus (SLA)

SLA machines use resin and an ultraviolet laser as a curing agent to print an entire cross section at a time.

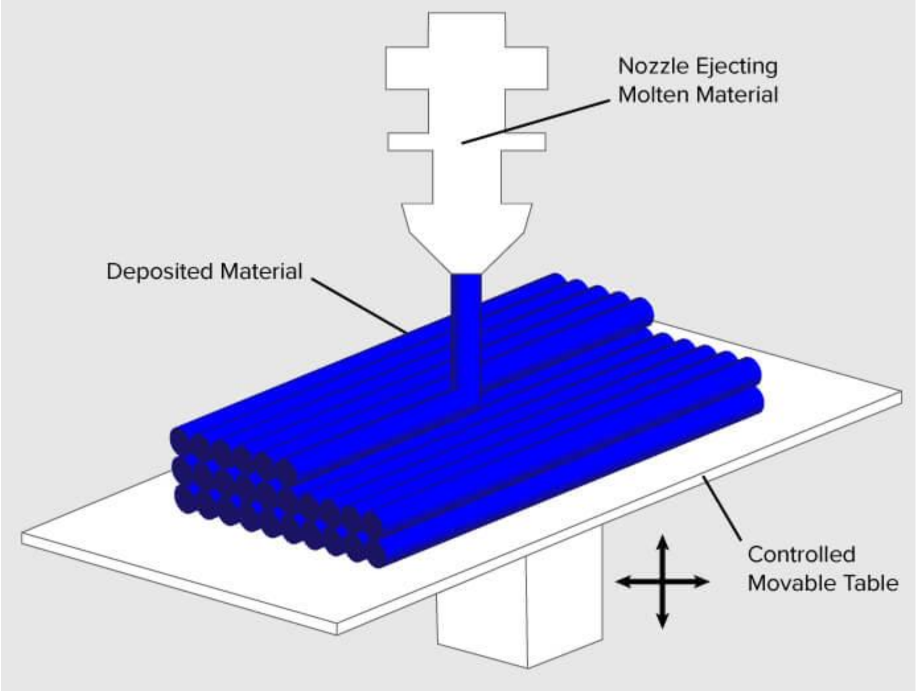
- Part prints upside down
- Cross section of the part is projected by UV light onto the resin bath.
- Print bed lowers, allowing a new cross section to be projected.
- Can print complex parts quickly.



Fused Deposition Modelling (FDM)

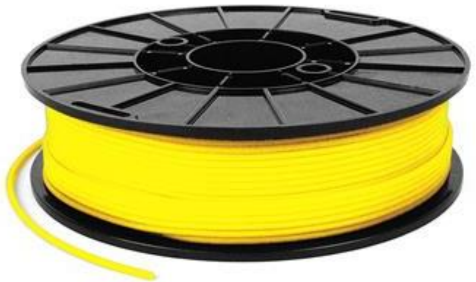
FDM printers use spools of filament as input. The different types of material is heated to its melting point before carefully being placed in the desired location by an extruder.

- Wide range of printing materials.
- More affordable machines.
- Larger build volumes.
- User friendly.



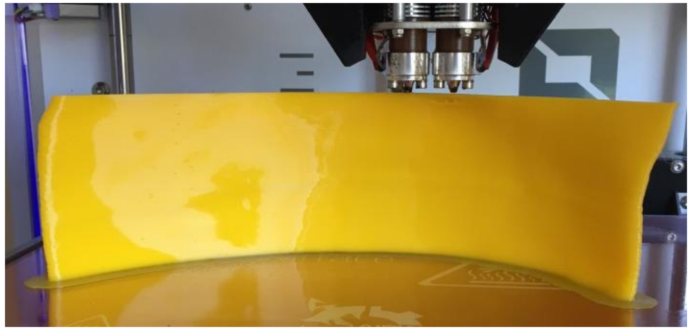
FDM printing Process

Material starts in spools of plastic where it is heated to its melting point and deposited.

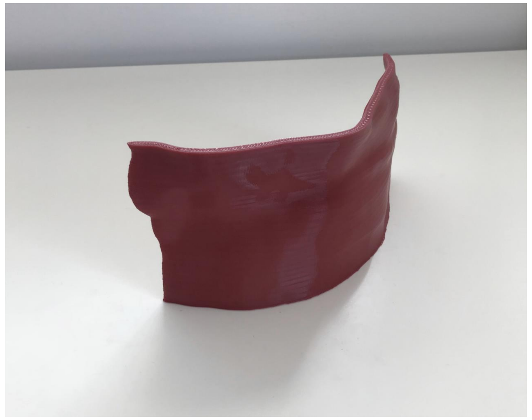


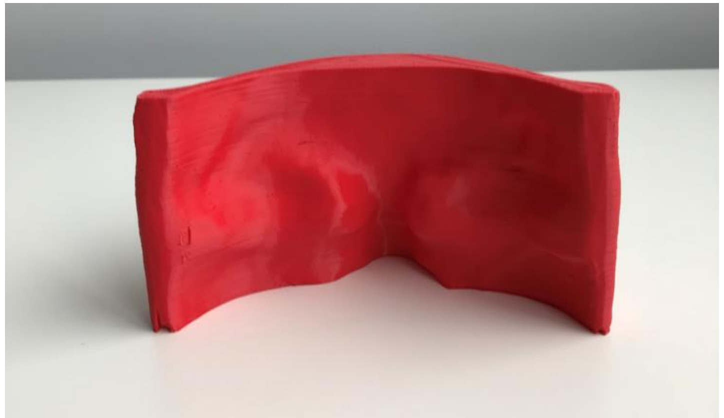
Filament Spool

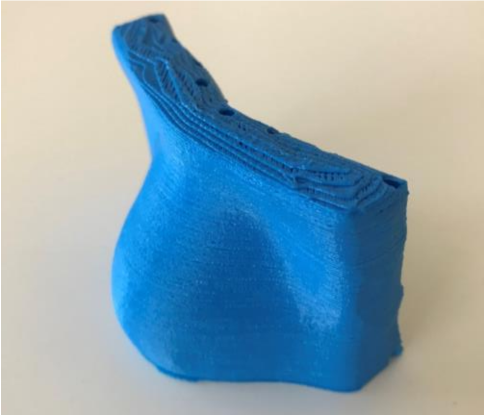
Extruder Assembly



Printing Process







3D Printed Results

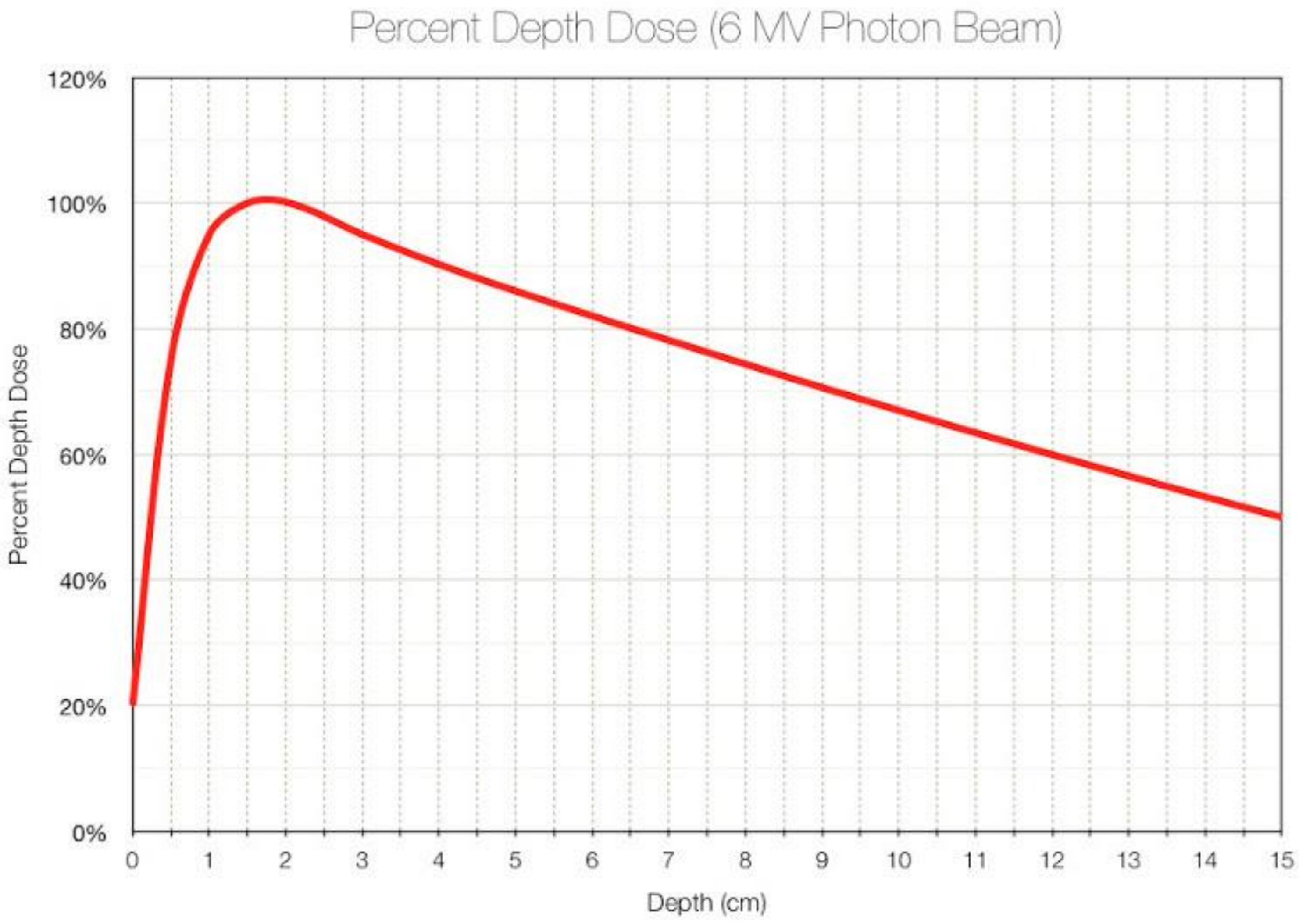
3D Printing Filament

FDM filament comes in a variety of types, colours, and properties.

Rigid		Flexible	
Pros	**Cons**	**Pros**	**Cons**
Fast printing	Requires heated bed	Durable	Slower printing
Inexpensive	hydrospopic	Excellent layer adhesion	Steep learning curve
Compatible with most 3D printers available	Potential post print modifications	Excellent platform adhesion	Decreasing flexibility as thickness increases
Less prone to movement during printing	Will snap, not bend	Similar to standard bolus material	Supports can be difficult to remove
Shallow learning curve			Tall prints tend to move during

Why Use Bolus?

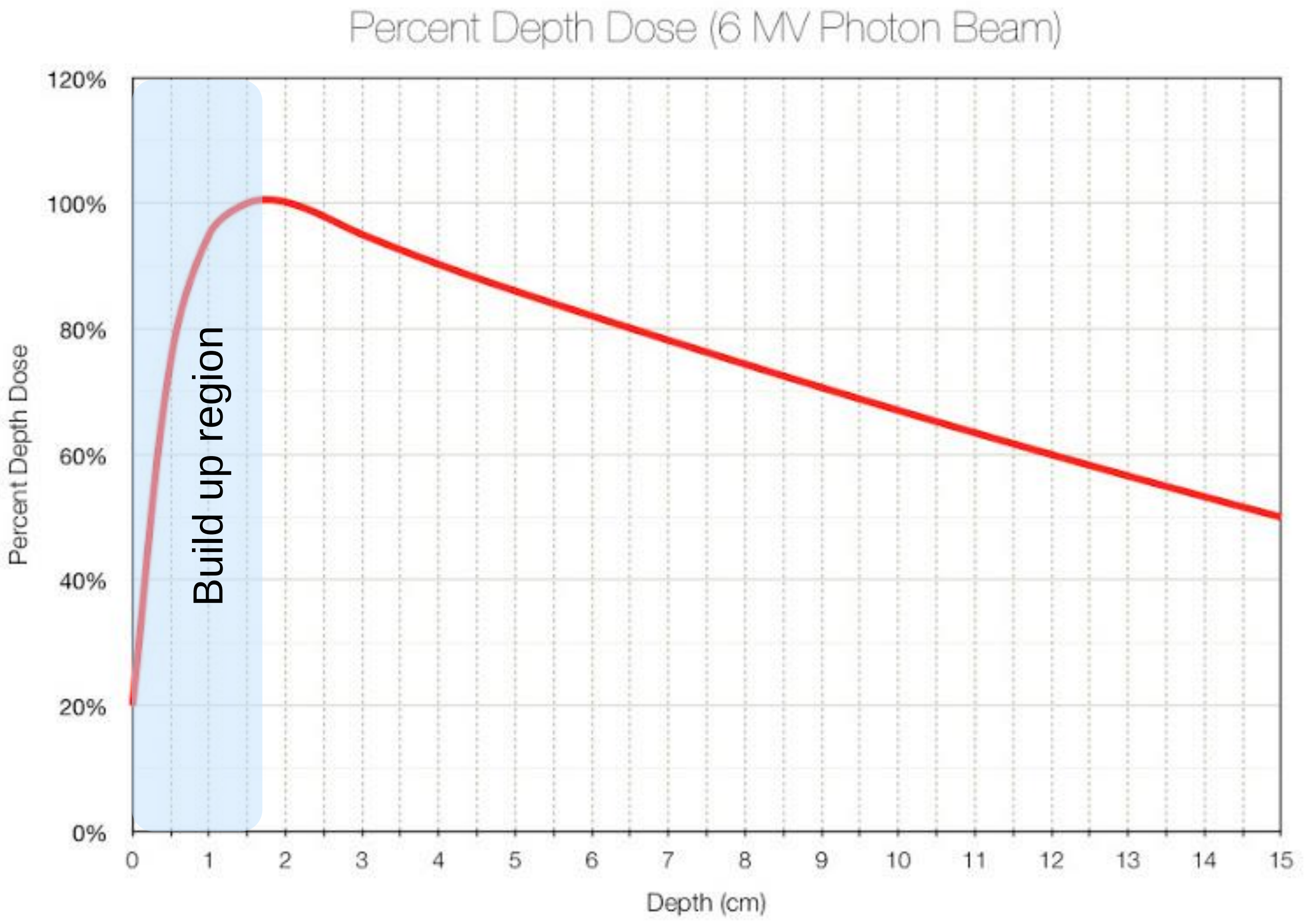
- Typical photon beam has a build up region



http://ozradonc.wikidot.com/descriptors-of-dose-distribution-photons

Why Use Bolus?

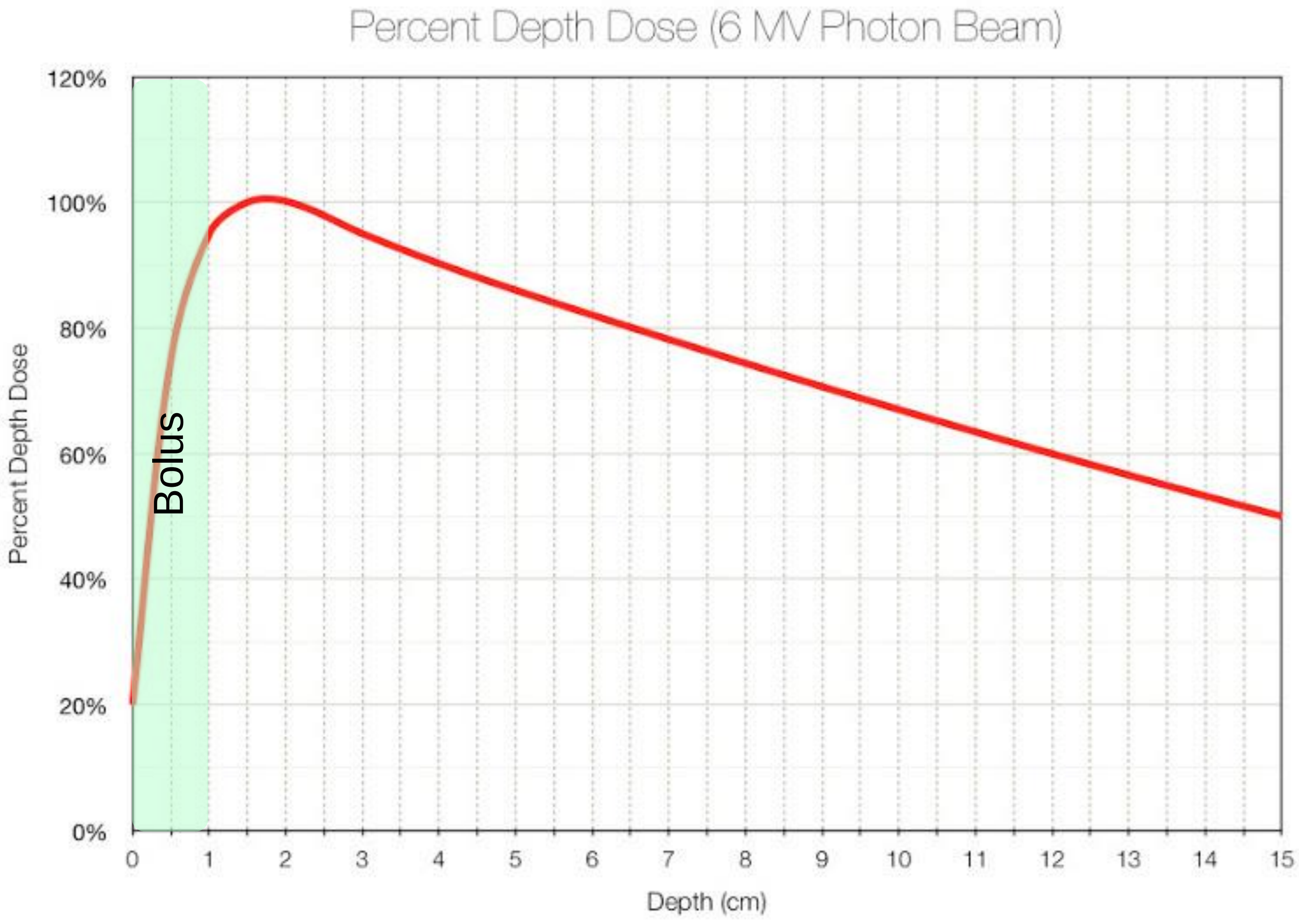
- Typical photon beam has a build up region
- Maximum dose occurs at a certain depth



http://ozradonc.wikidot.com/descriptors-of-dose-distribution-photons

Why Use Bolus?

- Typical photon beam has a build up region
- Maximum dose occurs at a certain depth
- Using a bolus causes the build up region to occur outside the patient



http://ozradonc.wikidot.com/descriptors-of-dose-distribution-photons

The Problem: Conventional bolus is a weak link.

The limitations of conventional bolus.

While each type of bolus has advantages and disadvantages, most are less than optimal when it comes to customization of fit.

Current 3D bolus techniques are very labour intensive or expensive, or do not provide a good fit.

Solution: Medical Device Software

Our software platform interfaces with treatment planning software using the DICOM RT. Our boluses can be exported using this format directly into planning software and used to accurately develop a treatment plan. Our boluses are also exported to STL files for 3D printing.

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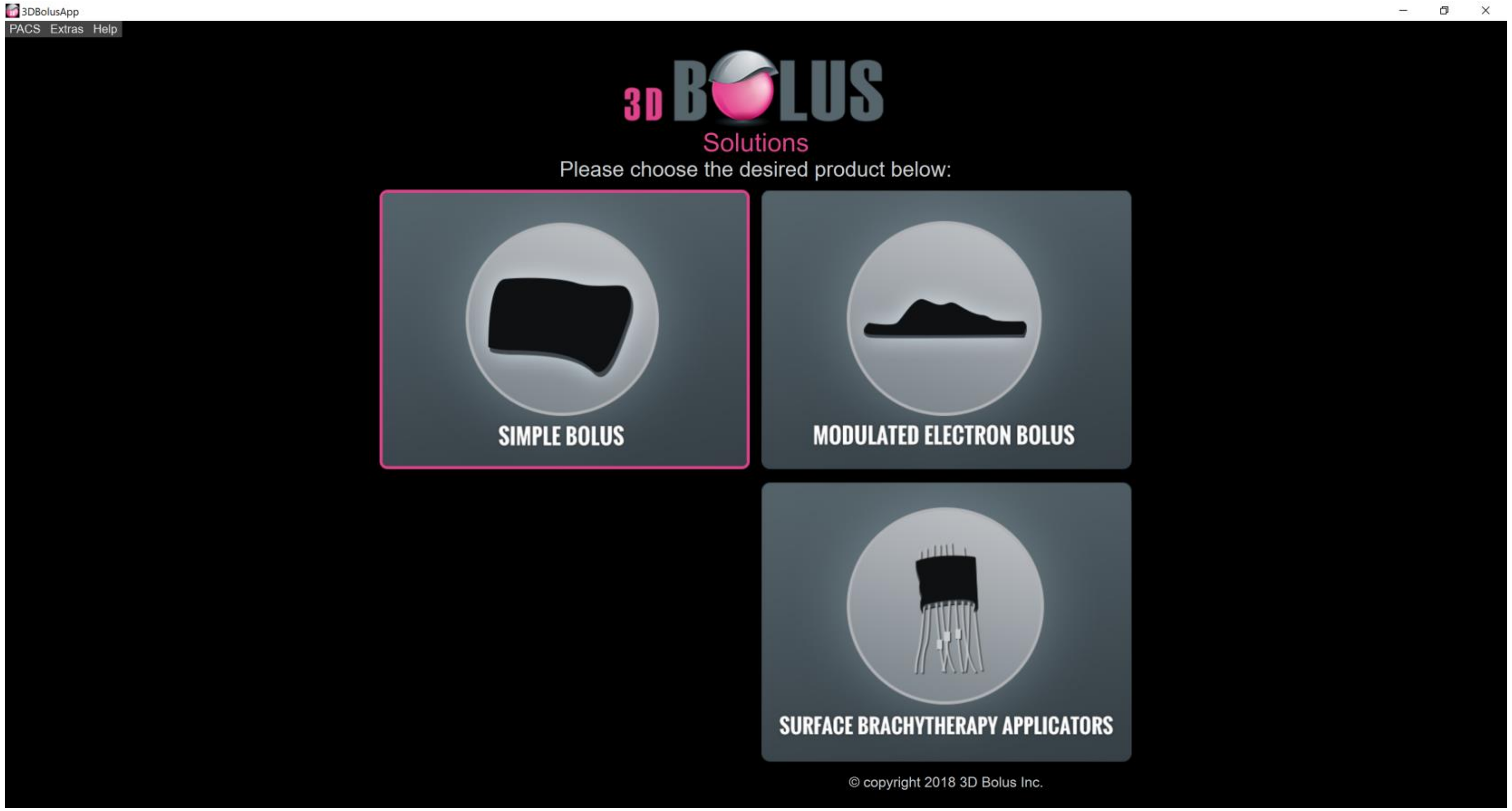


A Complete and Integrated Solution

01 Create Treatment Plan

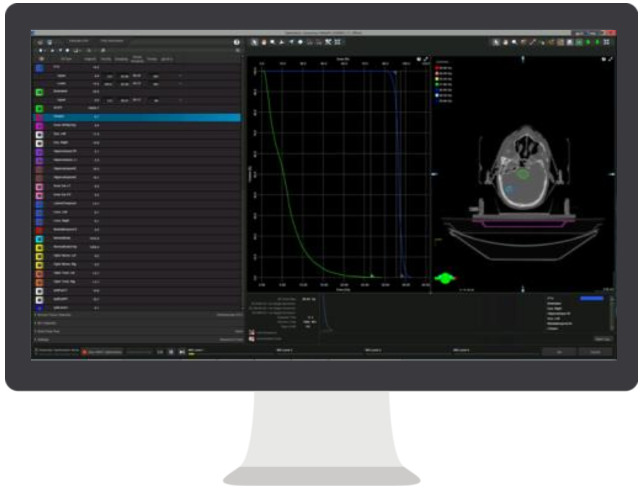
Treatment plan is created using planning software including the basic bolus.

02 Create Optimized Bolus

Select the bolus type and the system generates the printable bolus based on the client’s parameters. Review in planning software after creation.

03 Print Optimized Bolus

Select the bolus type and the system generates the printable bolus based on the client’s parameters.

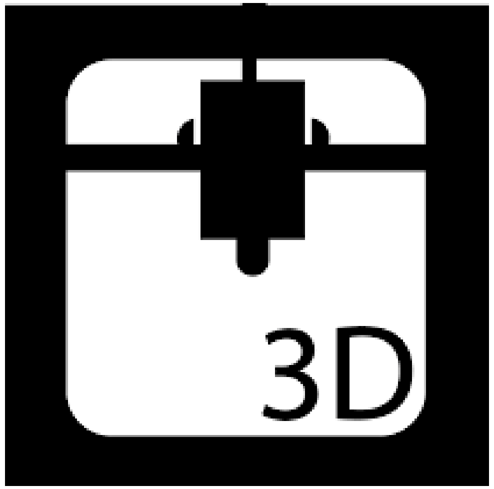


Planning Software

DICOM

3D Bolus Application

STL



3D Printer

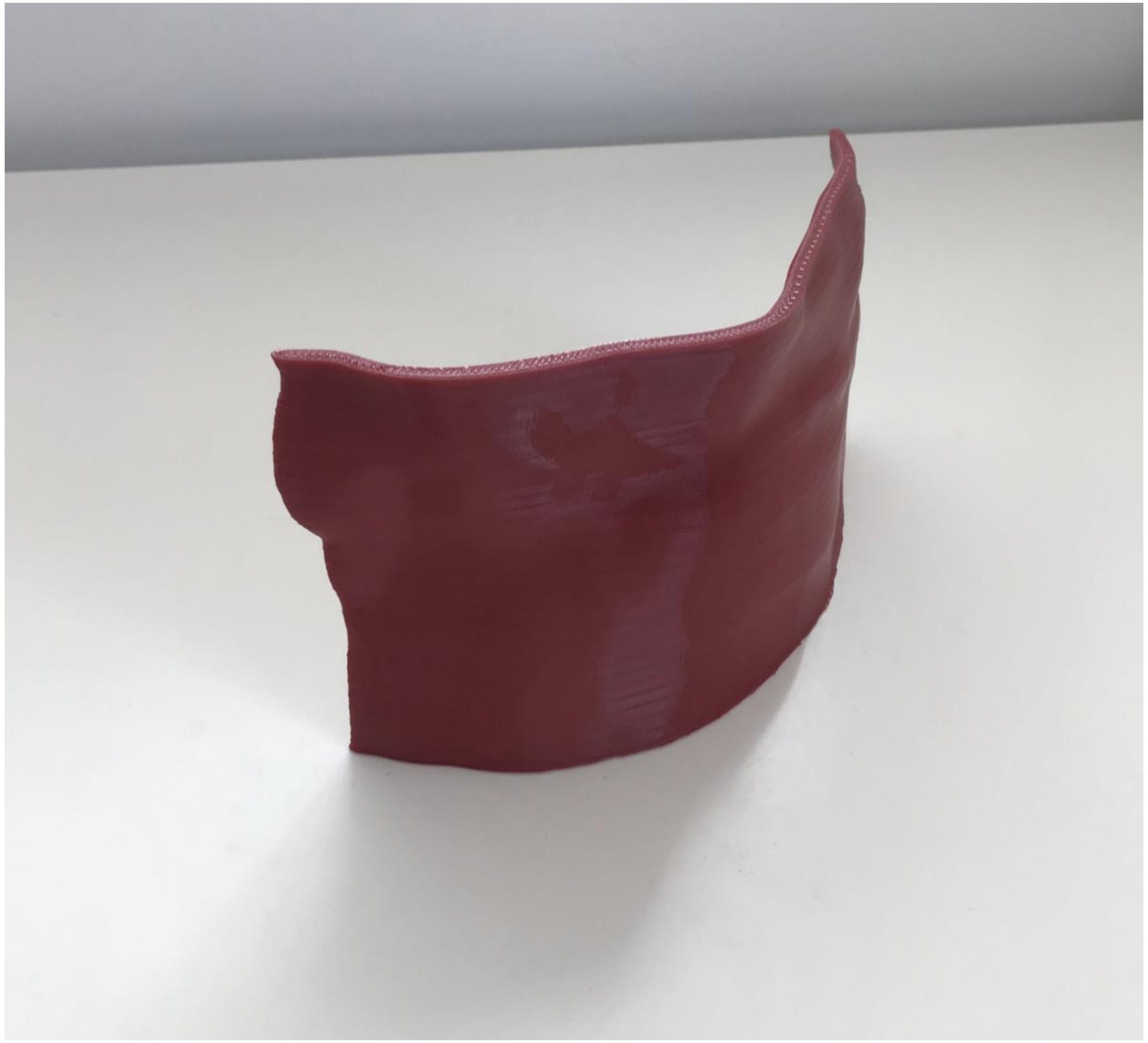
Simple Bolus:

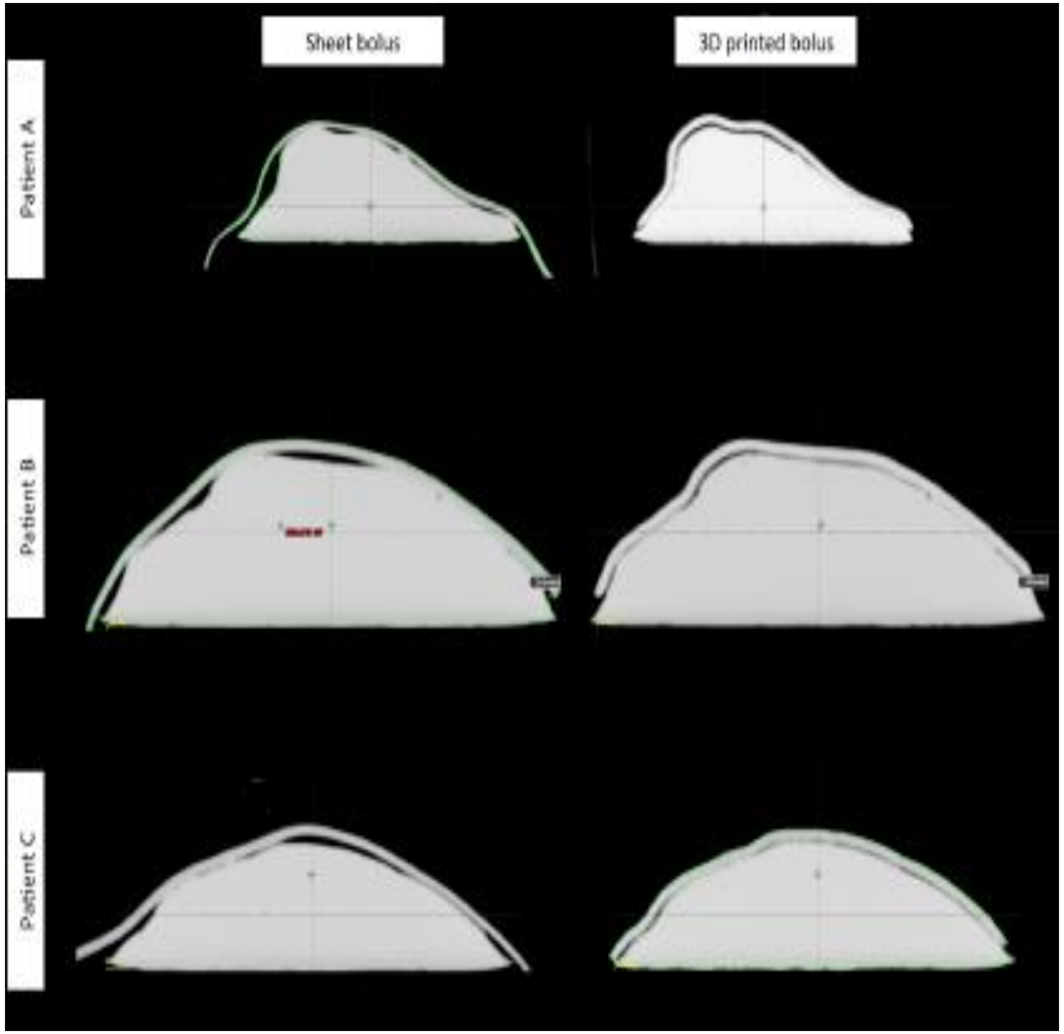
Allows users to create a customized 3D printed bolus

Simple Bolus is designed in the TPS.

It includes either a uniform thickness sheet bolus determined by a user-specified ROI, or a bolus created using a drawing tool on the CT image data.

Simple Bolus can be used for both photon and electron radiotherapy.





Conventional sheet bolus
vs
3D Simple Bolus

Comparison of sheet bolus
and 3D printed Bolus for three
gel phantoms.

"3D printed bolus reduced total air gap volume by a factor ranging from 1.4 to 16.3."

(Robar et al. 2016).

3D Bolus is more practical

3D Bolus in use for a post-mastectomy chestwall patient.

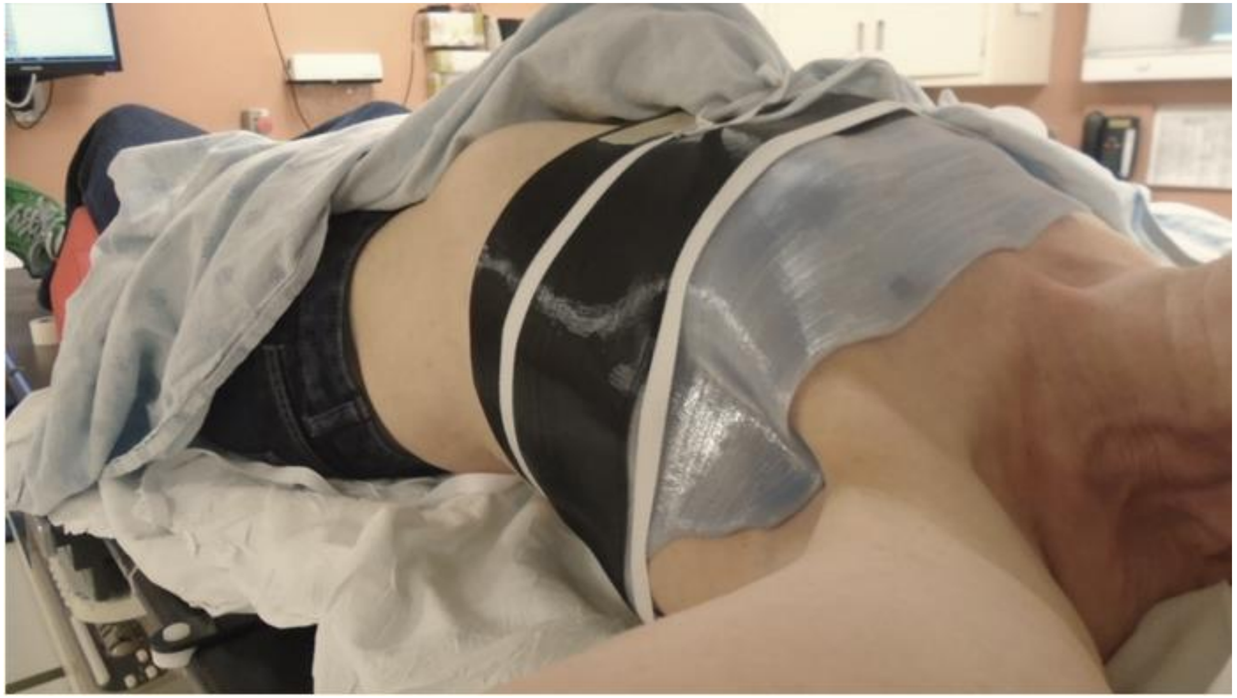
Improved fit

Minimized time spent by therapist and patient

Fully integrates with existing treatment methods.

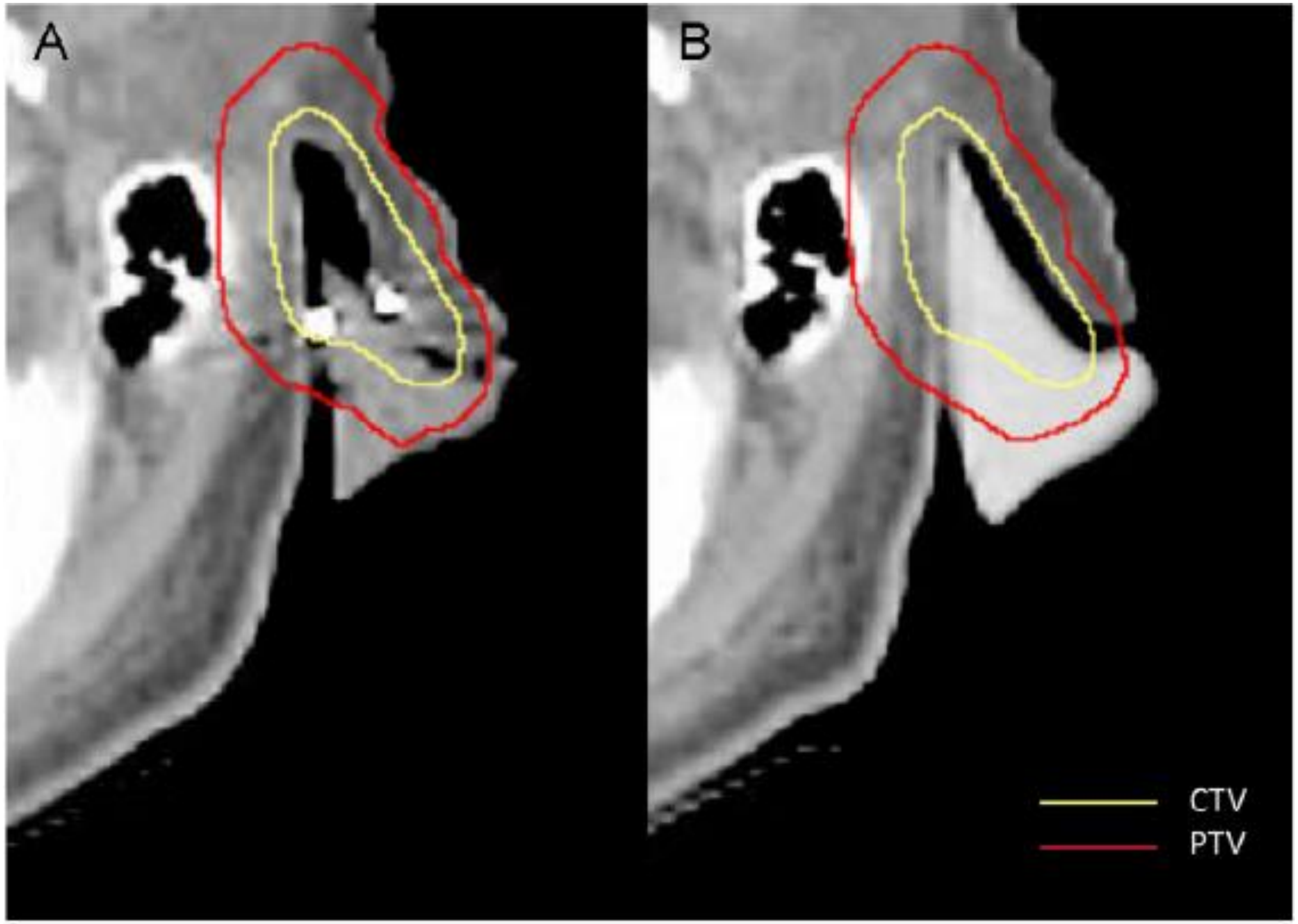
Decrease in setup time of 30%.

Improved patient experience.



Case #1
Simple Bolus

- 74-year-old man with a BCC in the mid aspect of the left posterior pinna.
- Bolus designed in TPS (Eclipse).
- Bolus filling the retroauricular space was required to achieve sufficient surface dose.
- Photon Arc Rx = 60Gy/30#.

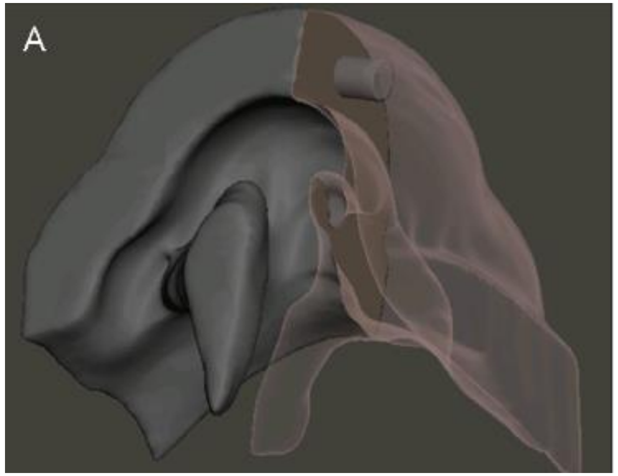


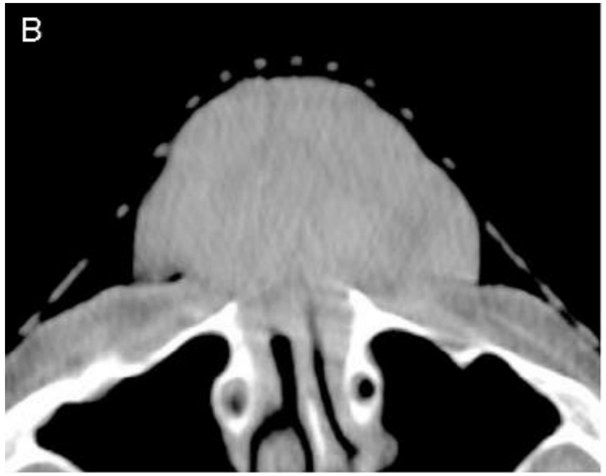
Comparison between the photon boluses for treatment of a BCC of the pinna. Axial slices of the planning CT showing the fit of (A) the manually manufactured thermoplastic Aquaplast bolus and (B) the 3D-printed PLA bolus. (Color version of figure is available online.)

Zhao et al.

Case #2
Simple Bolus

- 68-year-old man with recurrent SCC to nasal septum.
- Bolus designed in TPS from post-op CT.
- Uniform 1cm over exterior nose and fill air cavities to 25mm from nares.
- Bolus bisected along sagittal plane for easy insertion.
- VMAT Rx = 60Gy/30#.

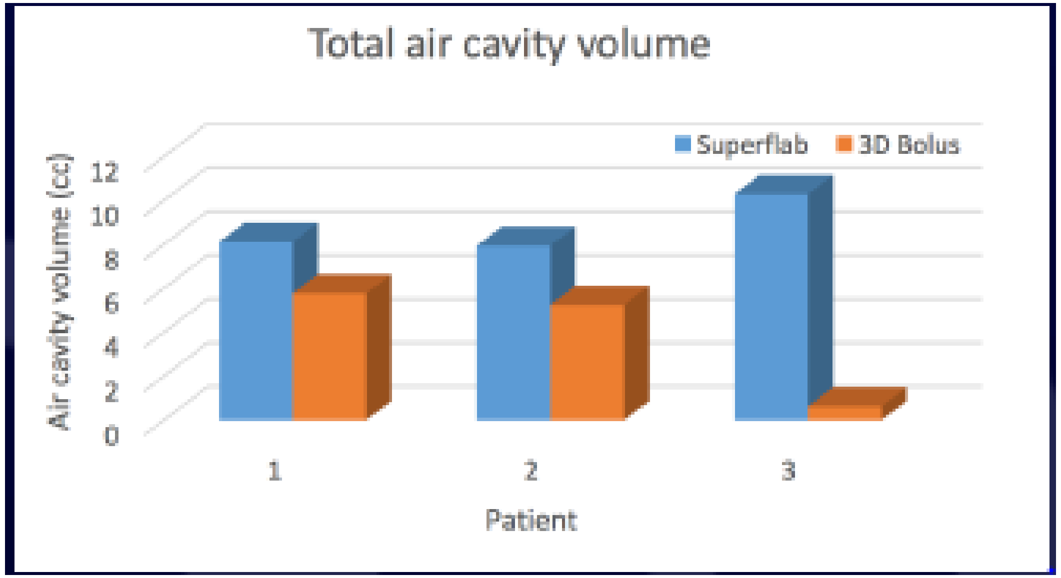


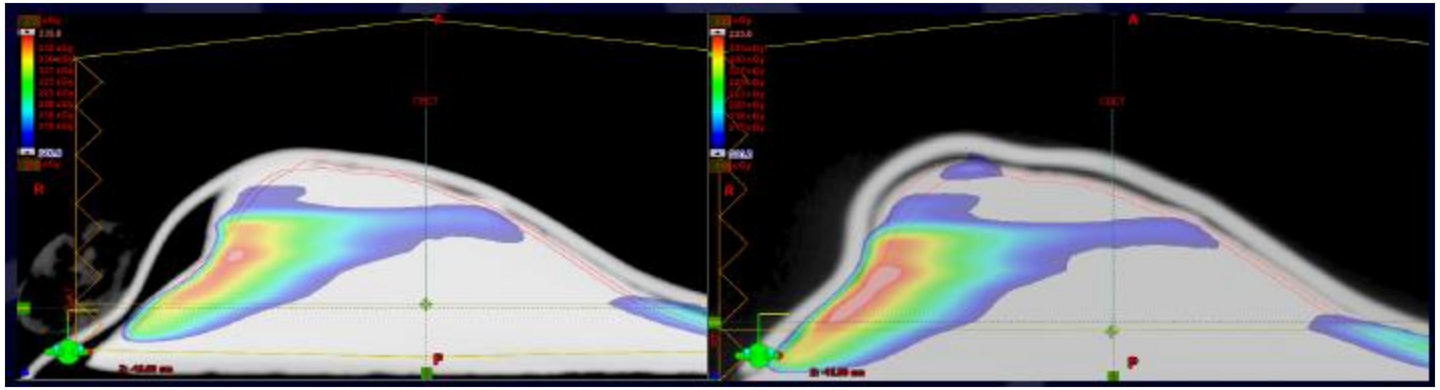


Zhao et al.

Findings:

- Total air cavity was reduced by 3D printed bolus by a factor ranging from 1.4 to 16.3.
- Systematic differences in dose distribution were observed between sheet bolus (left) and 3D printed bolus (right) when the same treatment plan was applied.





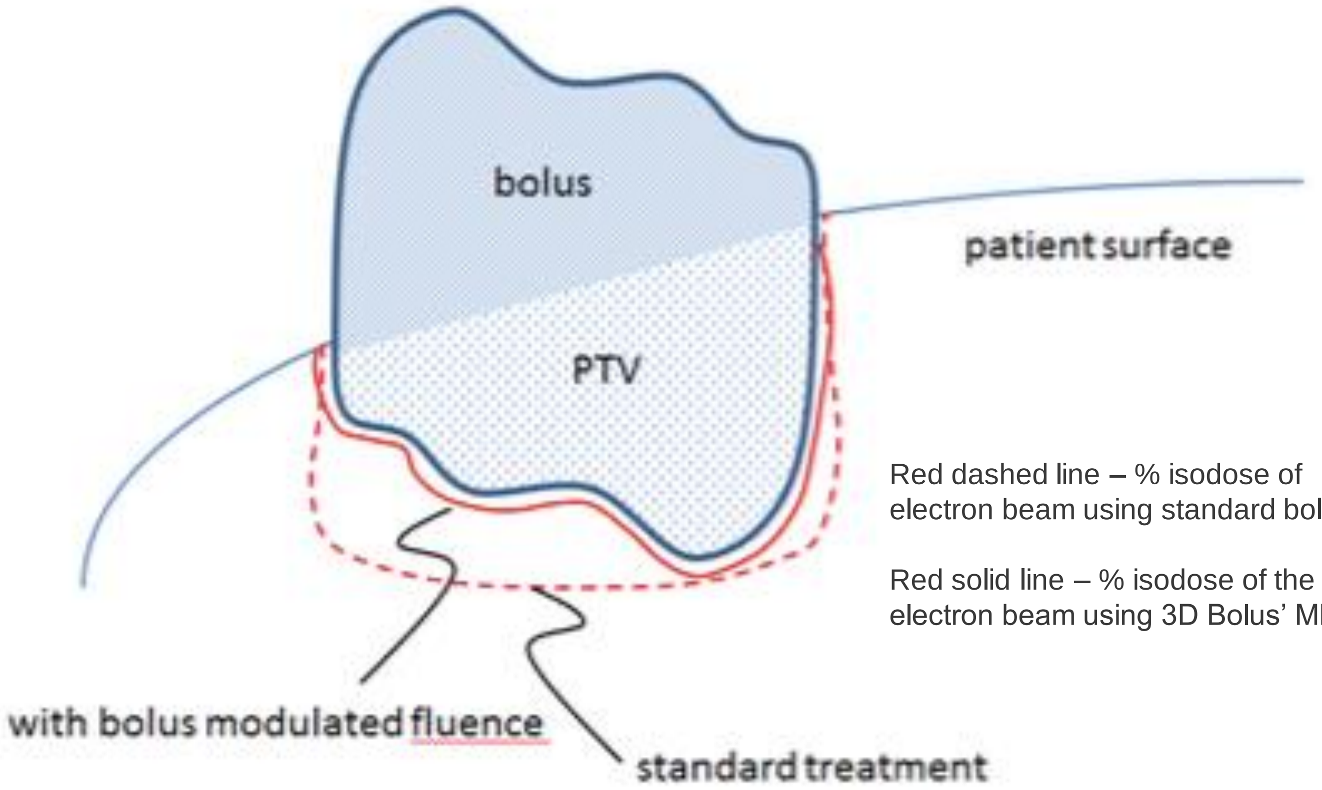
Robar et al.

3D Modulated Electron Bolus (MEB)

Shape of the 3D Bolus modulates the electron beam to achieve conformity of the radiation dose distribution to the tumor volume below.

Standard bolus gives a covering but a non-conformal isodose surface is produced (red dashed curve).

3D Bolus is customized, changing the surface shape to allow for tailoring of dose distribution (red solid curve).

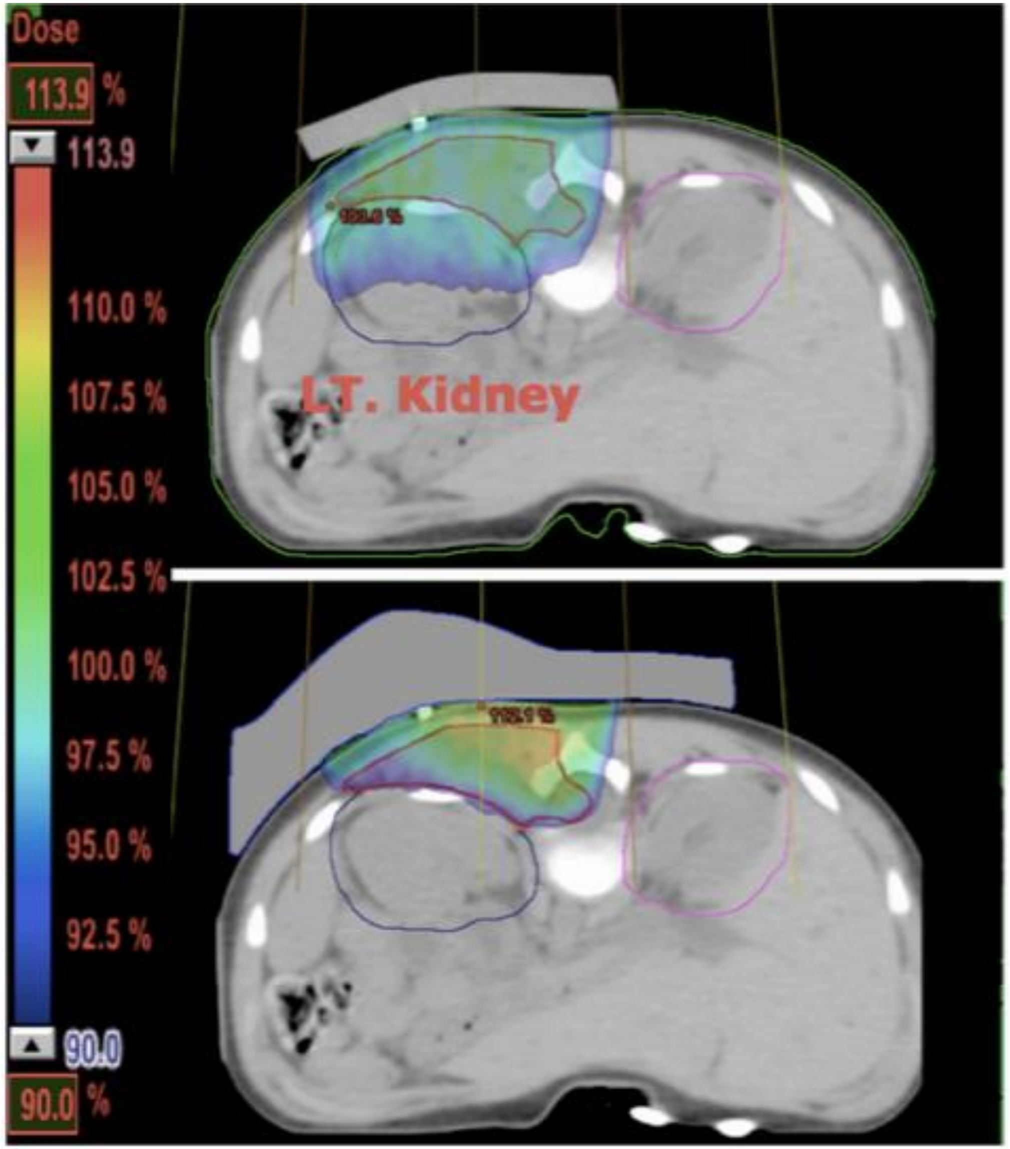


Red dashed line – % isodose of electron beam using standard bolus.

Red solid line – % isodose of the same electron beam using 3D Bolus' MEB.

Finding:

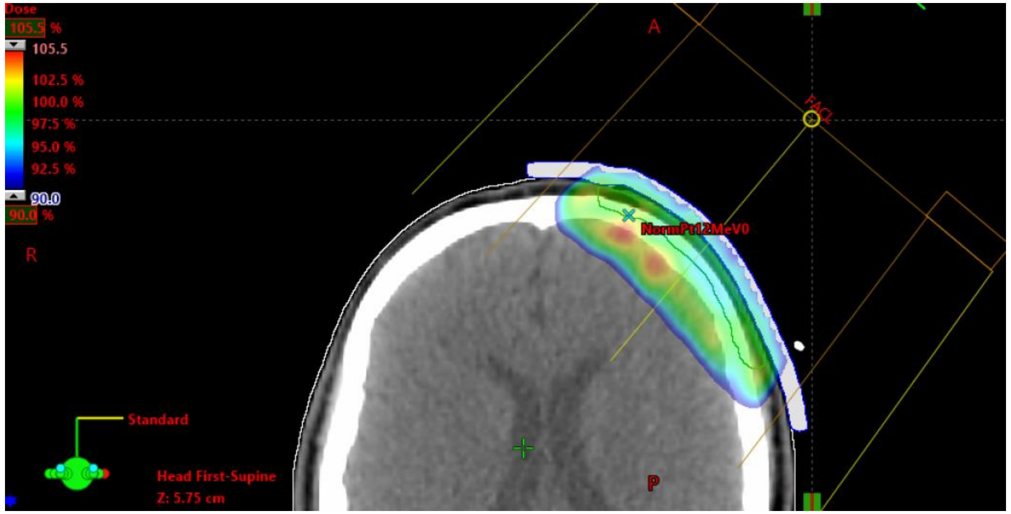
- 7 year old rhabdomyosarcoma patient
- MERT plan yields a reduction of mean dose by 38.2% in left kidney relative to uniform bolus.

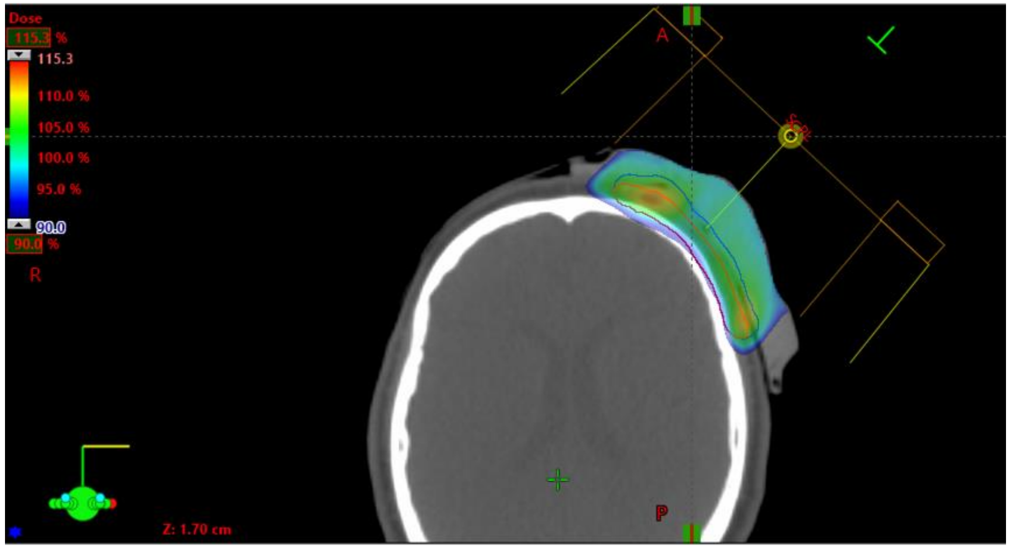


MODULATED ELECTRON BOLUS CASE STUDY #1

Adult patient with mycosis fungoides of the scalp

- Decreasing air gaps while achieving suprior dosimetry.
- Tailoring of the 90% isodose to follow the distal contours of the PTV, while improving the sparing critical OARs

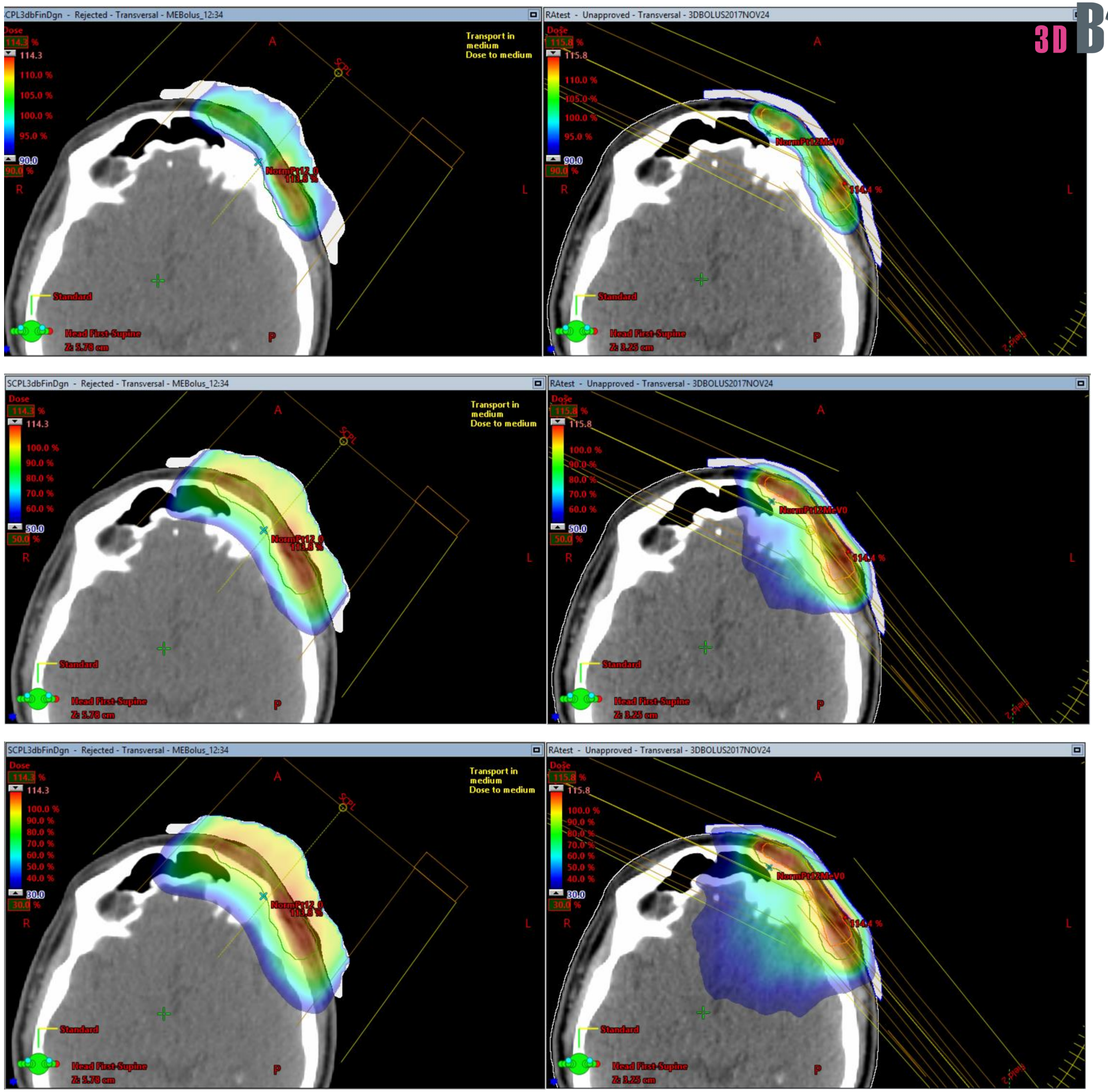




MODULATED ELECTRON BOLUS CASE STUDY #1

The modulated electron bolus plan is superior to the IMRT plan

Comparisons of the MEB plan to a IMRT plan illustrate the significant skin sparing effect at various prescription isodose lines.



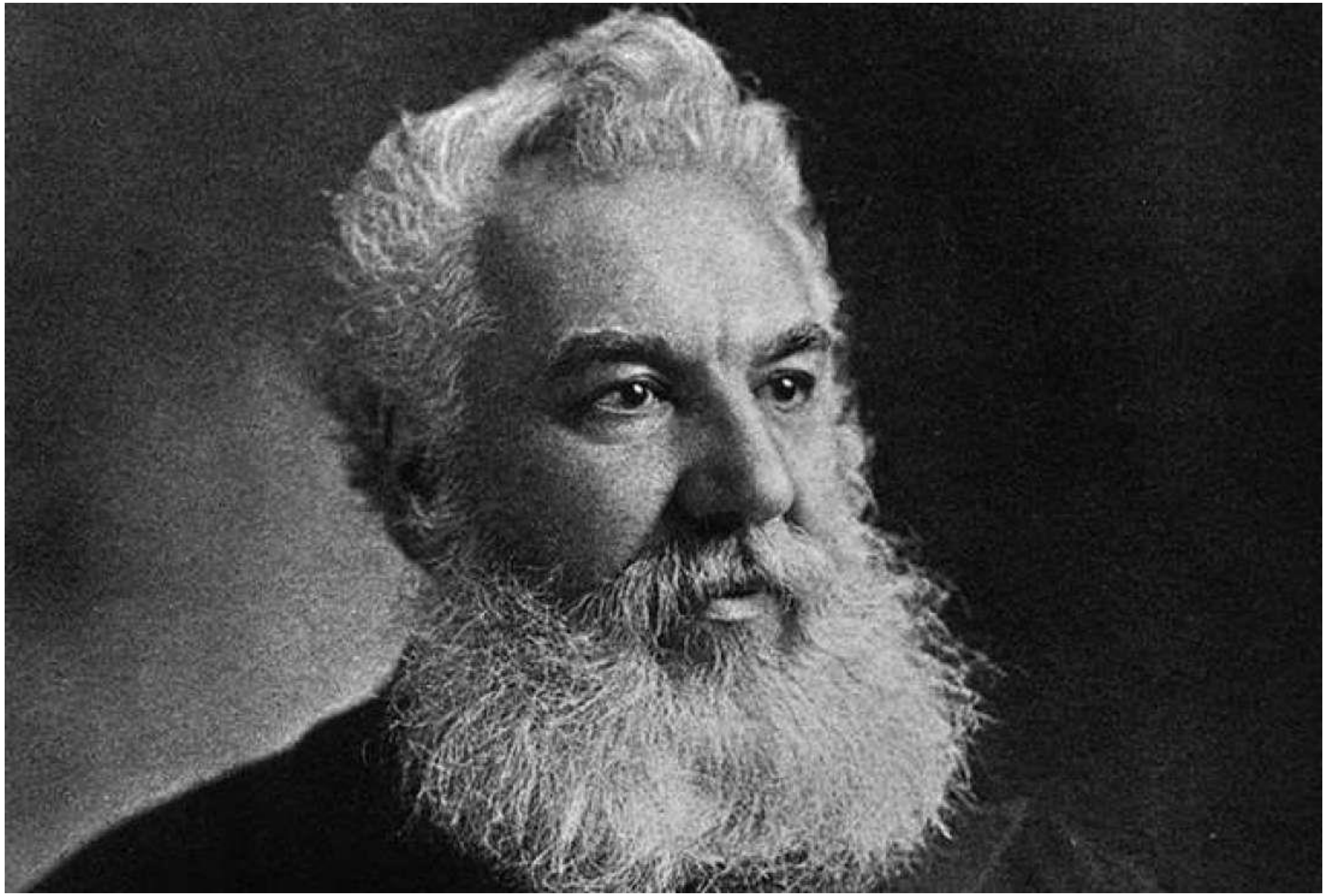
90%

50%

30%

…there is no reason why a tiny fragment of radium sealed in a fine glass tube should not be directly inserted into the very heart of the cancer, thus acting directly upon the diseased material…

~ Alexander Graham Bell



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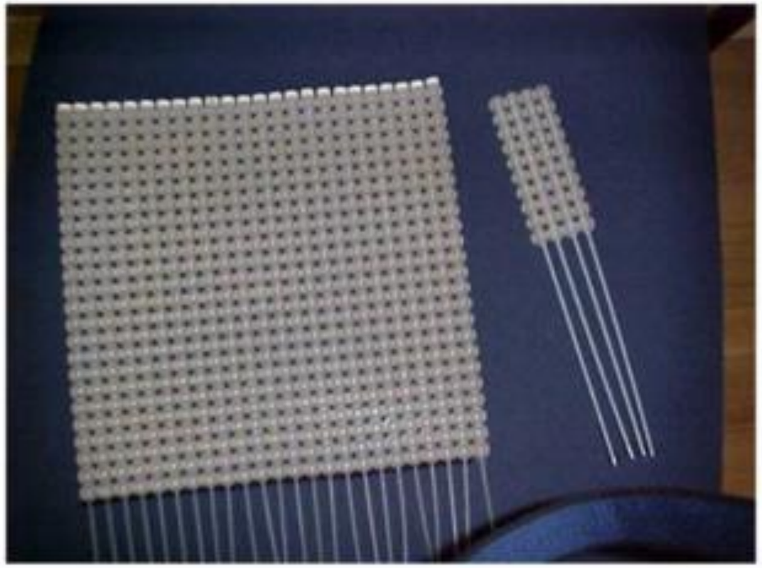
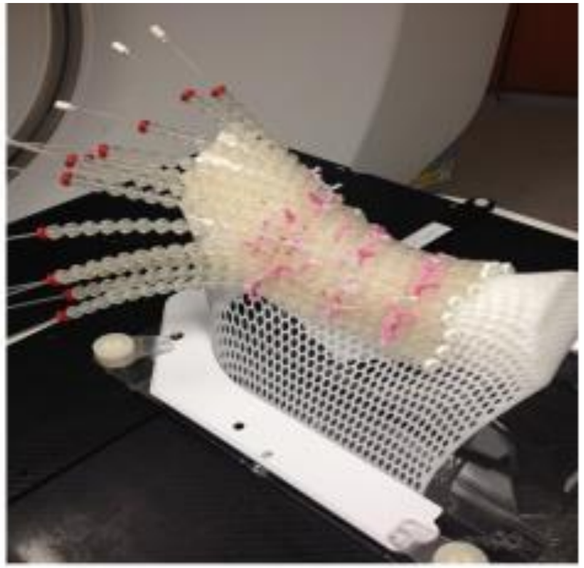
Common Surface Brachytherapy Techniques

The clinical application of current surface brachytherapy techniques has its challenges

Example of wax applicator
Source: Jones *et al*. Introduction of novel 3D-printed superficial applicators for high-dose-rate skin brachytherapy. *Brachytherapy*. 2017;16;409-414.



Example of a sheet of Freiburg Flap fitted with catheters



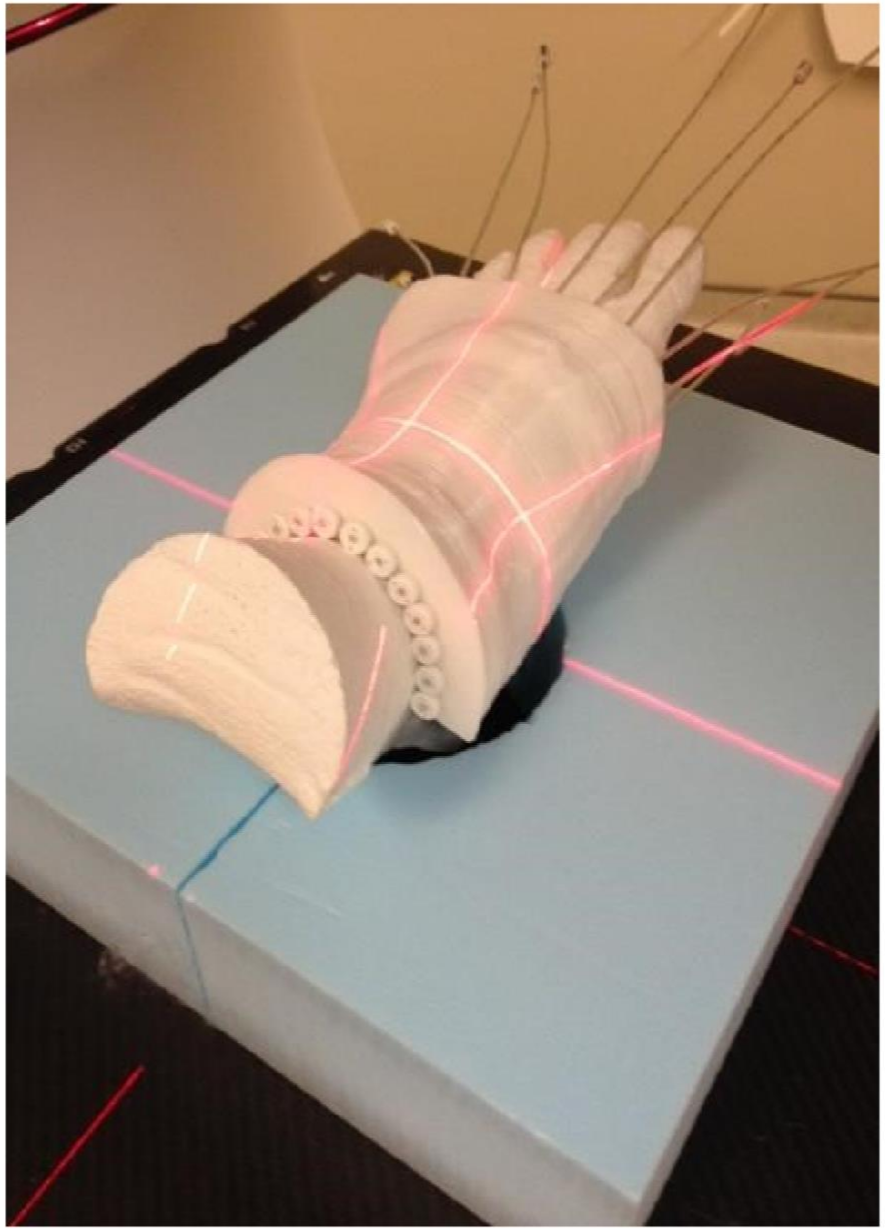
Freiburg Flap sewn into thermoplastic mesh for a foot phantom
Source: Clarke. 3D Printed Surface Applicators for Treatment of Skin Cancer using High Dose Rate Brachytherapy. *Masters Thesis.* 2016

3D Printed Applicators

Patient specific devices designed from CT information.

Improvements:

- Improved patient conformity
- Reproducibility
- Tighter margins, minimizing air gaps
- Machine fabrication
- User customization
- Improved dose distribution

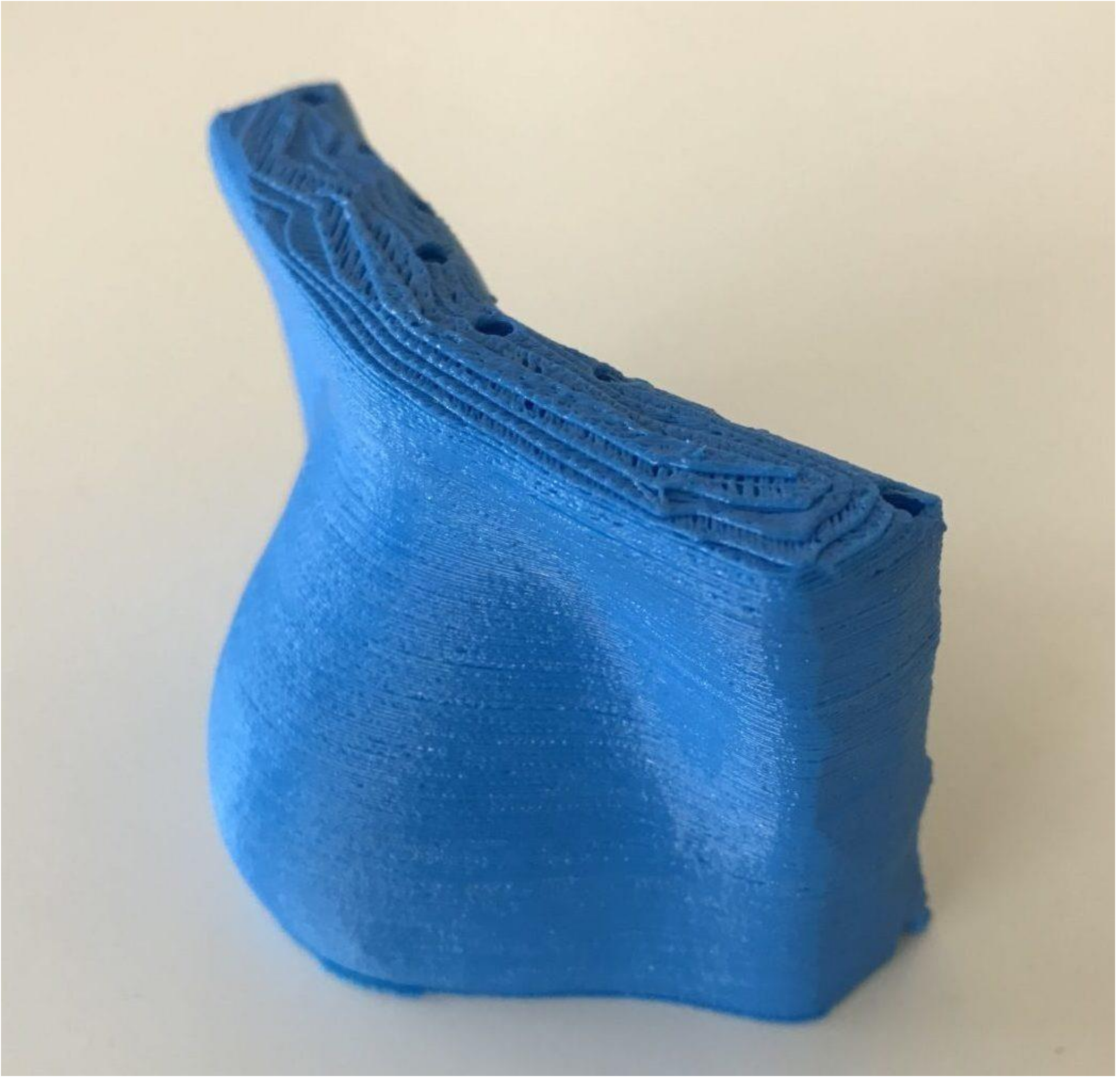


HDR Surface Brachytherapy:

Surface brachytherapy is a method to treat superficial lesions with high dose rate radiation.

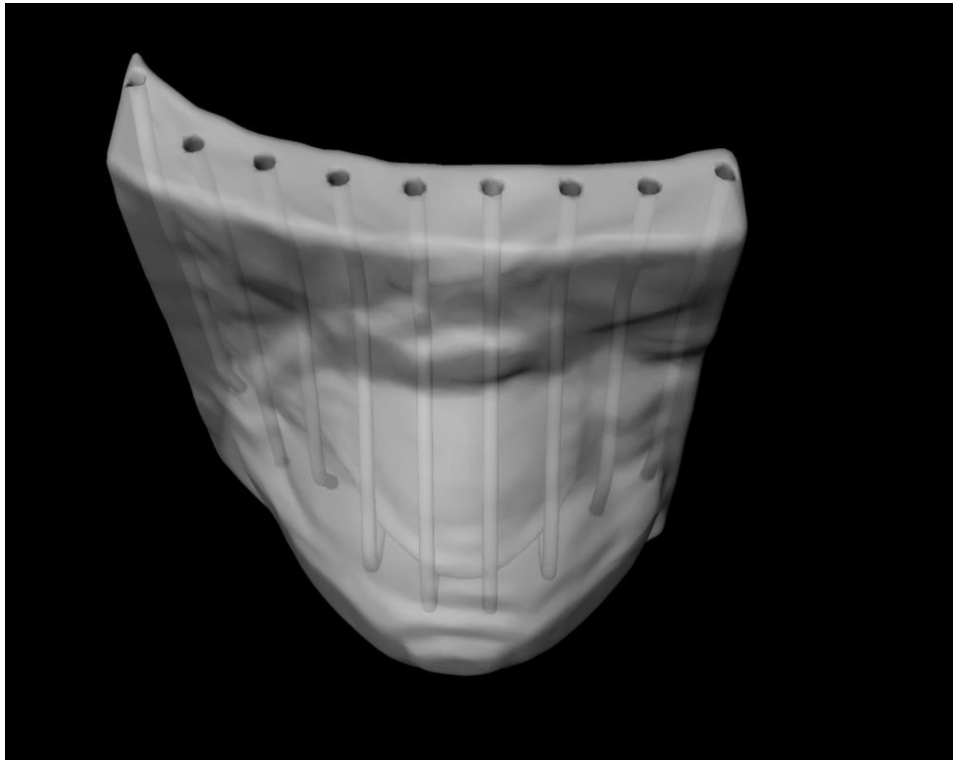
The 3D Bolus module allows users to create patient specific applicators that have hollow catheter trajectories printed directly into the structure.

This highly customizable method of surface applicator will provide superior dose distributions compared to other common techniques.



3D Bolus: Brachytherapy

High Dose Rate (HDR) surface brachytherapy is a technique used to treat various types of skin lesions including basal and squamous cell carcinoma.



Custom algorithm generates potential catheter positions within the structure itself.

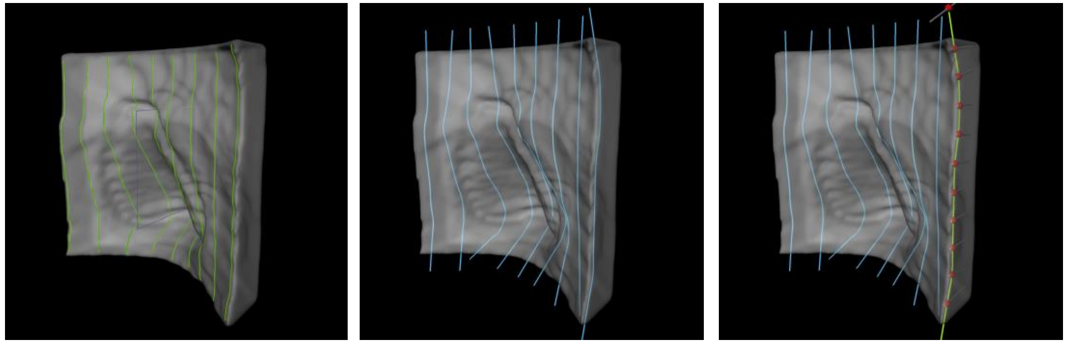
A subtraction operator creates hollow trajectories to allow the free movement of the radioactive source through the applicator.

Custom fit with minimal air gaps.

Optimized catheter trajectory.

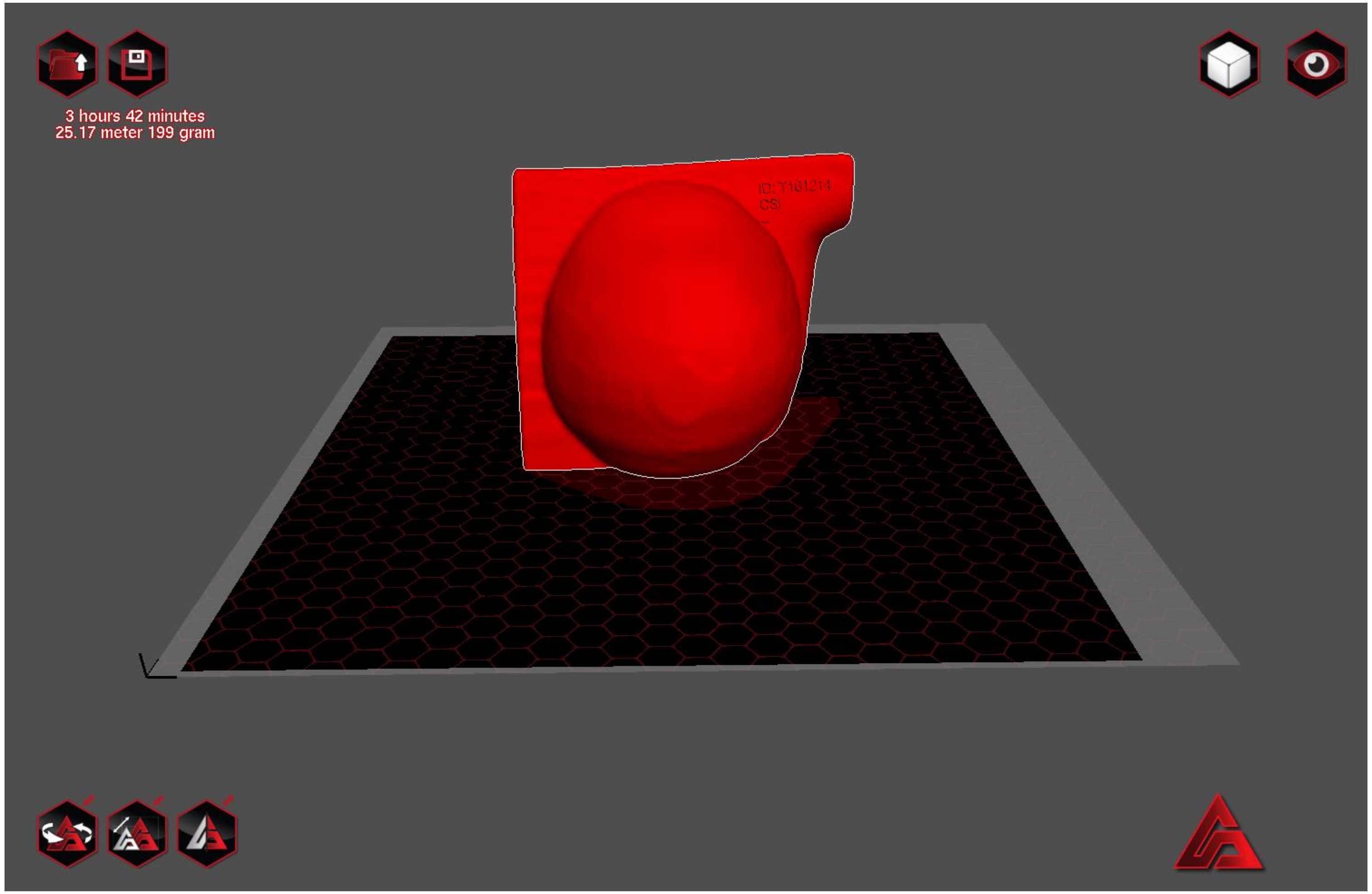
Consistent distance from source to patient surface.

Allows manual manipulation of catheter trajectories



Creating a Printed Device

- Load patient specific file to be printed
- Enter printer settings (Filament melting temperature, print speed, etc)
- Export object as gcode (language interpreted by 3D printer)

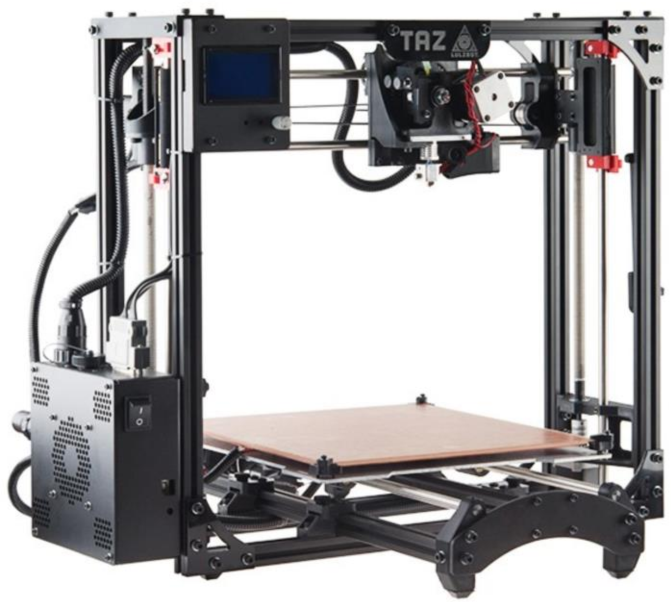


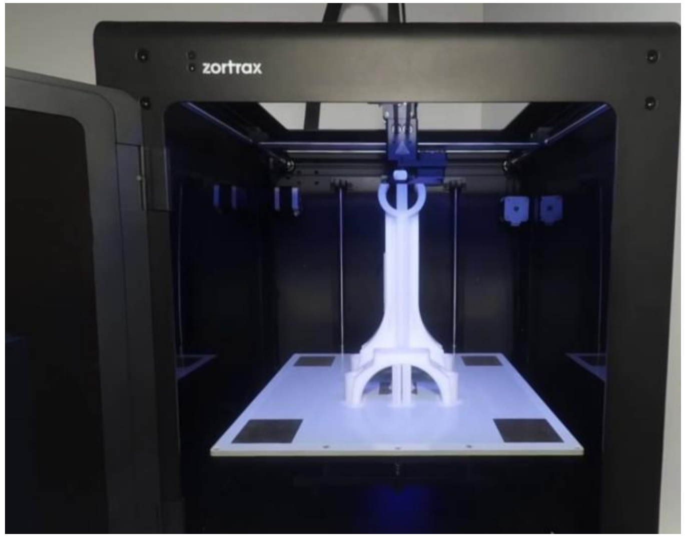
3D Printing

A variety of 3D printers can be used to create patient specific medical devices

Items to consider:

- Print bed
- Compatibility with printing materials
- Ease of use for the customer
- Adjustable settings
- Accuracy





A Platform to Commercialize Our Innovation Pipeline

Our platform has been designed to allow for rapid prototyping of new modules. This will allow our team to listen to you, customers, develop new ideas to solve clinical needs and then design, develop and deploy further product offerings to the market.

3D BOLUS

Questions/Comments