

3D Printed Brain Aneurysm Model for Aneurysm Clipping Practice

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Background

Introduction

Clipping is a common surgical treatment for brain aneurysms. First, the head is imaged to analyze and assess the location of the aneurysm, Once a prediction of the best possible approach is made, the surgeon will perform a craniotomy to place a small metallic clip on the neck of the aneurysm. This prevents blood from entering into the aneurysm sac so that it can no longer pose a risk for bleeding. The clip remains in place for life, and the aneurysm will shrink and scar down permanently after clipping.

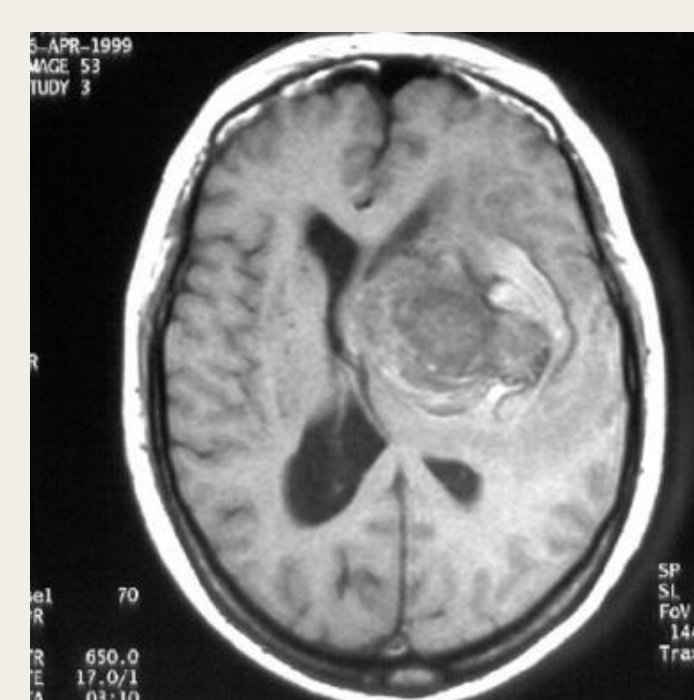


Fig 1: MRI of aneurysm

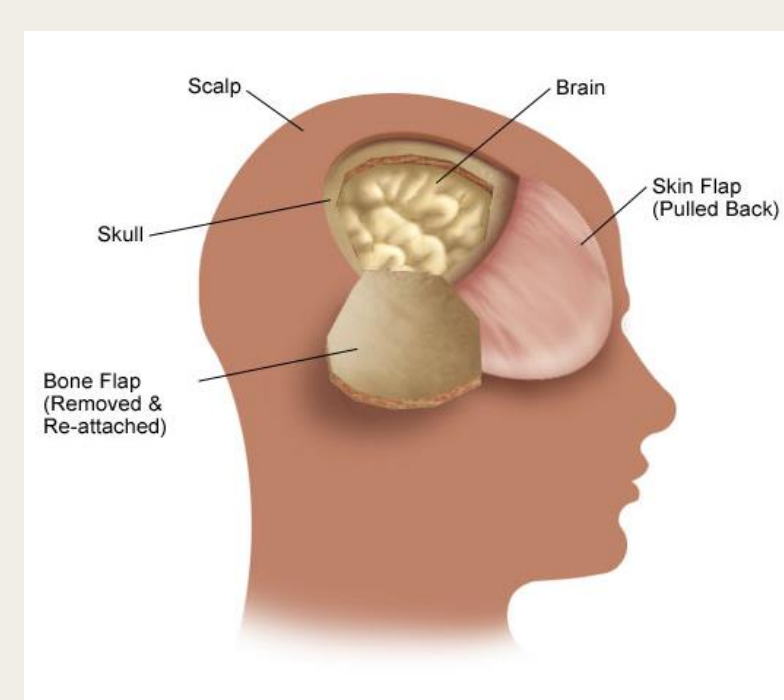


Fig 2: Sketch of craniotomy



Fig 3: Illustration of aneurysm clip

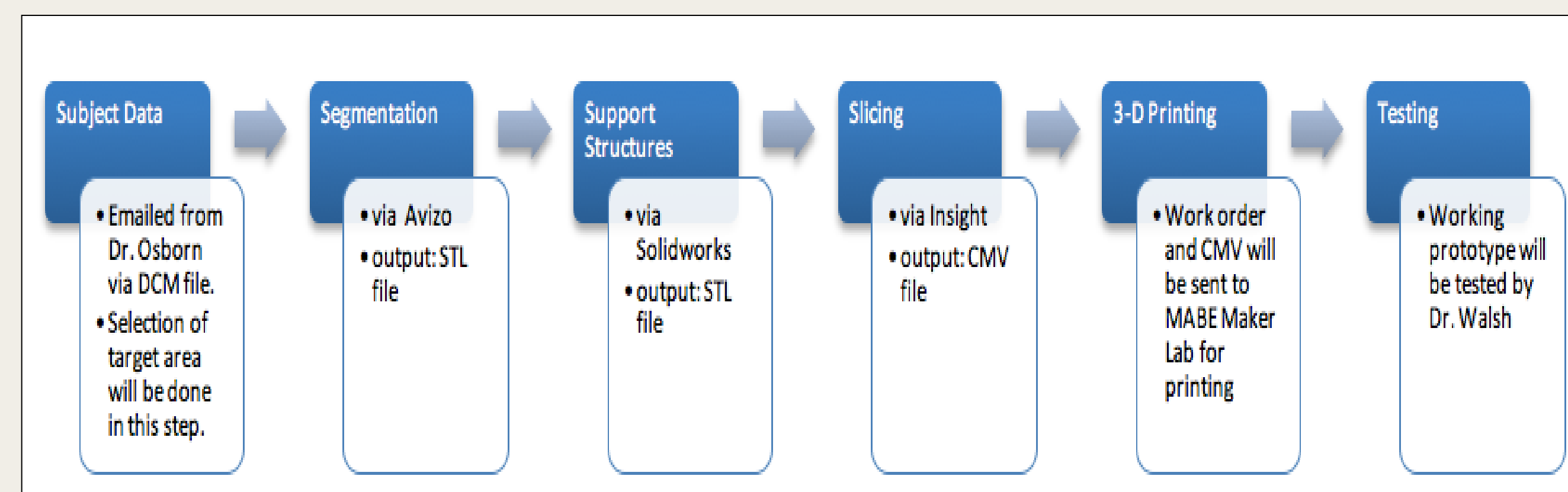
Problem

In an aneurysm clipping, doctors usually are not aware of what type of clip they will need before the surgery. Everyone's brain is different and the shape of an aneurysm is always unique as well as the placement within the brain. This creates different pathways and obstacles within the brain that must be avoided and worked around in order to perform a successful clipping.

Objective

The purpose is to create an arbitrary system using 3D printing to model the brain aneurysm that will function as a way for doctors to be able to practice/train clipping specific aneurysms on a model before clipping the aneurysms during surgery.

Design Overview



Specifications

The model needs to be durable enough to be able to perform mock clippings, as well as mirror a specific patient's brain.

Materials

The model is primarily constructed from an acrylonitrile butadiene styrene (ABS) polymer, which is compatible with the Fortus 400mc printer in the MABE Maker Lab.

Specifications

ABS is utilized to represent comparably hard structures within the region of interest (ROI), such as bone, blood vessels, and cranial nerves. Because ABS is a rigid plastic with tensile yield stress of around 41 MPa¹, it is similar to that of cortical bone (around 50 to 70 MPa)².

Dimensions

Cube prototype model

The current prototype cube model has outer dimensions of 51x51x51 mm, with wall thickness of 2.5 mm. The craniotomy hole, which can vary in size depending on the necessary surgical pathway is approximately 13 mm in diameter. The neck diameter of the arbitrary aneurysm structure is 2.5mm.

Final model

The final model, consisting of one quadrant of the upper skull (sliced coronally at the midline of the zygomatic bone), will have dimensions identical to those of the patient from which the skull data is derived. The length (front to back) of the model will be roughly 110 mm, the width will be 90 mm, and the height will be roughly 100 mm. The thickness will be around 6.8 mm. The diameter of the middle cerebral artery, where aneurysms can often manifest, is approximately 4 mm. Aneurysm neck (area to be clipped) diameter can range approximately from 1.5 to 9 mm depending on the size and type of the aneurysm. The aneurysm itself may have a maximum diameter of anywhere from 4 to 20 mm⁵.

Methods

Segmentation

The region of interest (ROI) that contains the aneurysm and other supporting vessels can be defined using Inveon software at the UT Medical Center or using Avizo, accessible in SERF. Once the ROI is selected, the data is segmented using Avizo. A tolerance in Avizo is used to highlight the specific tissue density and then it is possible to go layer-by-layer through the CT and selected the area we are looking for. The skull is further segmented into the quarter section where the ROI is located, shown in Fig 4.

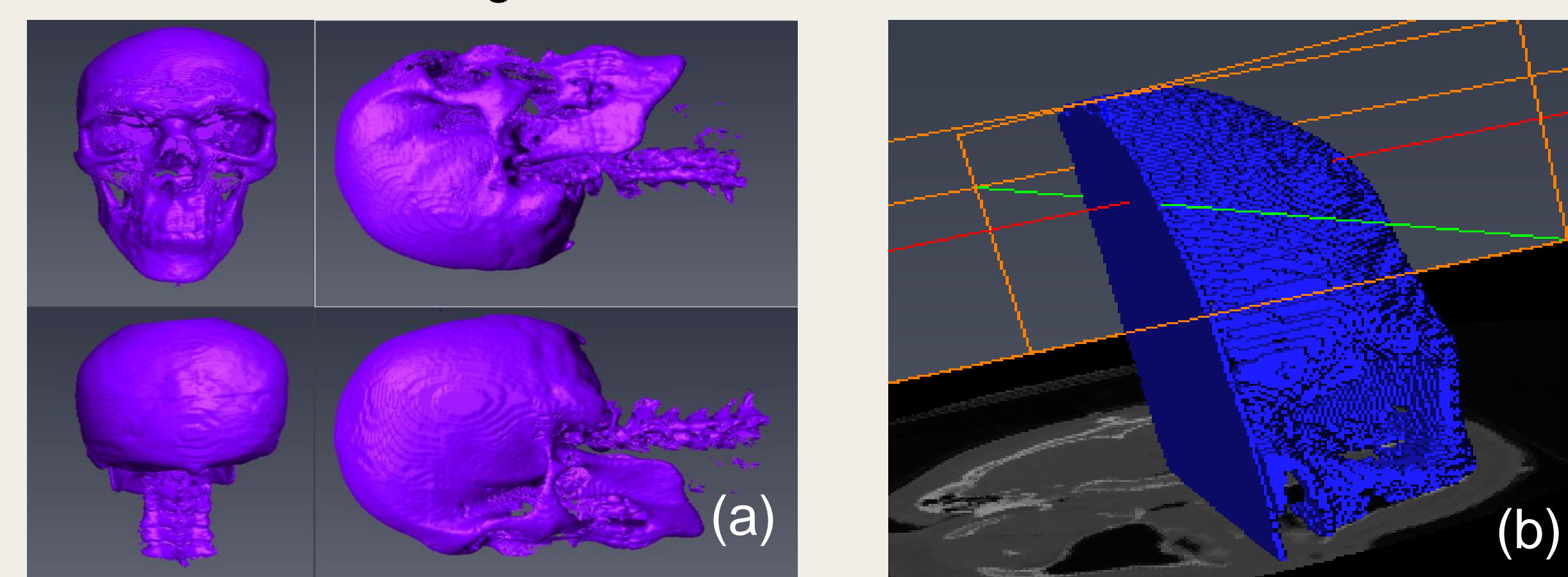


Fig 4: (a) Segmentation of full skull in Avizo and (2) quarter skull with additional solid surfaces

A wall was added to the inside and bottom of the quarter skull to provide support to the model.

Methods (cont'd)

Slits were cut into the skull and support wall to insert the arbitrary aneurysm and other structures in the correct orientation. A pathway to the aneurysm can also be created in Avizo. This model will be exported as an STL to prepare for 3-D printing.

Solidworks

The arbitrary aneurysms are created in Solidworks.

Insight

The STL files from Avizo and Solidworks are brought into Insight to slice the models and create support structures to prepare for 3D printing. In this step, we review our fundamental engineering knowledge to optimize the orientation to print with minimal support material. Further, this optimization will minimize the cost of printing. Once orientation and slicing are finalized, the file is saved as a CMB and sent to the MABE Maker Lab for printing.

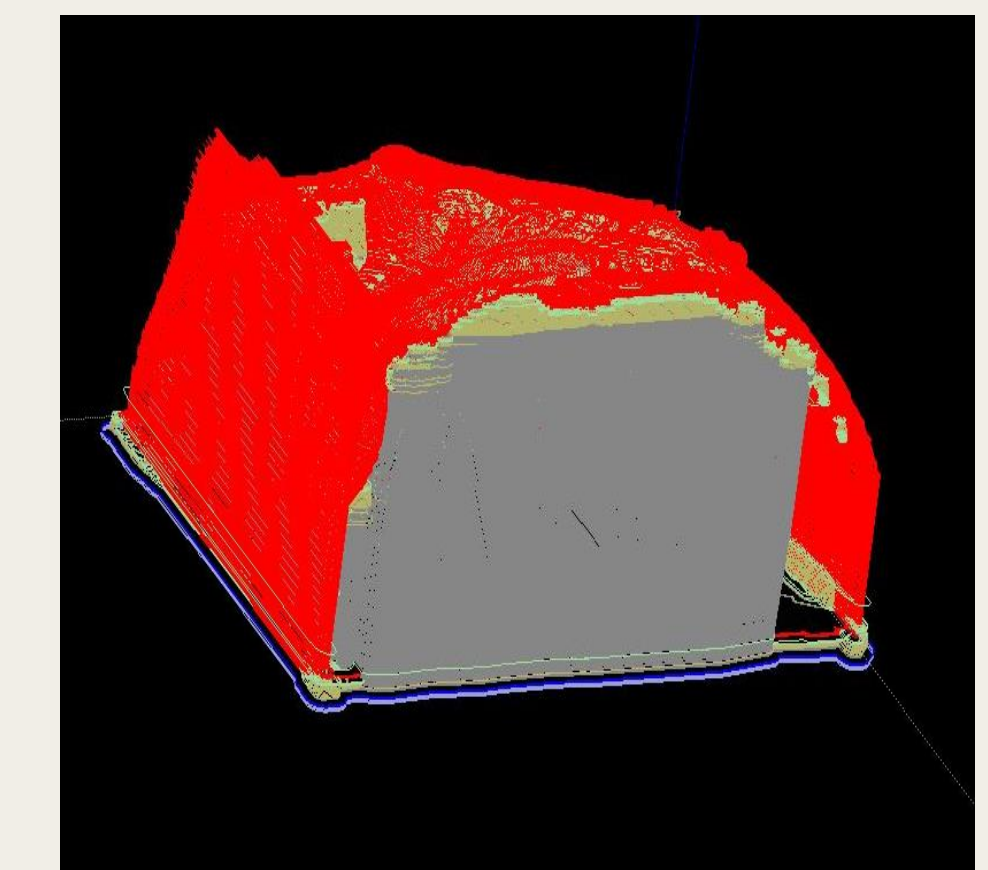


Fig 5: Insight rendering of slices and supports

MABE Maker Lab

The Fortus 400 printer uses ABS and a dissolvable support material that is water soluble to print the model. Once the model is printed, it sits in a bath until the support structures have dissolved.

Finally, a craniotomy hole can be drilled in the model. This model can be tested by the neurosurgeon we are collaborating with, Dr. Walsh. Following the test, modifications can be made to the model to make it more realistic and helpful to surgeons, who will be using it to practice.

Results

Current Prototype

We have created a full working prototype and are working on our final design. For the prototype, there was success with clipping the vessel, as seen in Figure 6.



Fig 6: (a) Initial working prototype and (2) the prototype being tested by going through the clipping process

Final Prototype

The first step of the final prototype has been completed, the section of the skull. The steps we have left are to create the aneurysm and the slits to attach it to the skull.