APPENDIX A

A.1 Printing Parameters

Replicas were printed in both PLA (rigid walls) and Makerbot Flexible Filament (flexible walls) using a MakerBot Replicator 2 desktop 3D printer. (For printing parameters, please see Table A.1.) The printer incorporates fused deposition modeling (FDM). That is, the printing is achieved by extruding a thin filament of molten plastic that is deposited layer by layer. An advantage of FDM is its accessibility as multiple printer models are currently offered that cost less than $3,000 USD. Furthermore, the consumables are inexpensive with a 1 kg roll of bulk PLA costing about $50 USD (each aneurysm replica constitutes on the order of 3-4 g of material).

A critical step in creating a 3D printable model is to convert from an image-based file format, such as DICOM, to a surface-based file format, such as STL. Some DICOM viewers contain functionality to do this (e.g., OsiriX, OsiriX Foundation, Geneva, Switzerland). Here, surface mesh representations of the segmented aneurysm replicas were created using the contour filter command in Paraview and saved as STL files.

The STL files were opened in MakerBot Industries 3D printing software MakerWare. An infill of 0% was used to obtain hollow interiors. Following printing, the rafts, supports, and capped vessel ends were removed from the models. Each aneurysm model requires roughly 1 hr to print in PLA and 2.5 hr to print in Makerbot Flexible Filament.

Table A.1. Printing parameters for both PLA and Makerbot Flexible Filament (MFF).

Material	**Raft**	**Supports**	**Infill (%)**	**Number of Shells**	**Layer Height (mm)**	**Extruder Temp. (°C)**	**Tip Speed (Extruding, mm/s)**	**Tip Speed (Traveling, mm/s)**
PLA	Yes	Yes	0	1	0.10	230	90	150
MFF	Yes	Yes	0	1	0.10	105	10	150

A.2 MRI Imaging Parameters

T1-weighted images were acquired as “anatomical” images of the replicas. QFlow images were acquired to encode flow in the aneurysm replicas. For acquisition parameters, please see Table A.2.

Table A.2. MRI imaging parameters for T1-weighted and 3D QFlow images.

Pulse Sequence	Weighting	TR (ms)	TE (ms)	Averages	Field of View (mm)	Voxel Resolution (mm)
Spin Echo	T1-weighted	2020	9.3	1	64 × 64 × 64	0.5 × 0.5 × 0.5
Phase Contrast Gradient Echo	3D QFlow	8.8	4.5	4	64 × 64 × 64	1 × 1 × 1

A.3 3D Printing Calibration and 3D Printing Scaffolding

Good reproducibility was found between the shell thicknesses of each of the four sides of the cubes with the standard deviation in thickness ranging from 0.02 mm to 0.05 mm for a single cube. (Figure A.1). Linear regression results were as follows: $T = 0.44S + 0.02$ and $T = 0.36S + 0.04$, for PLA and MakerBot Flexible filament respectively. For aneurysms to print correctly, a scaffolding and base are needed so that overhanging structures are supported as the print proceeds. The base and scaffolding are manually removed after printing. The scaffolding and base can be seen with a representative aneurysm replica (Figure A.1).

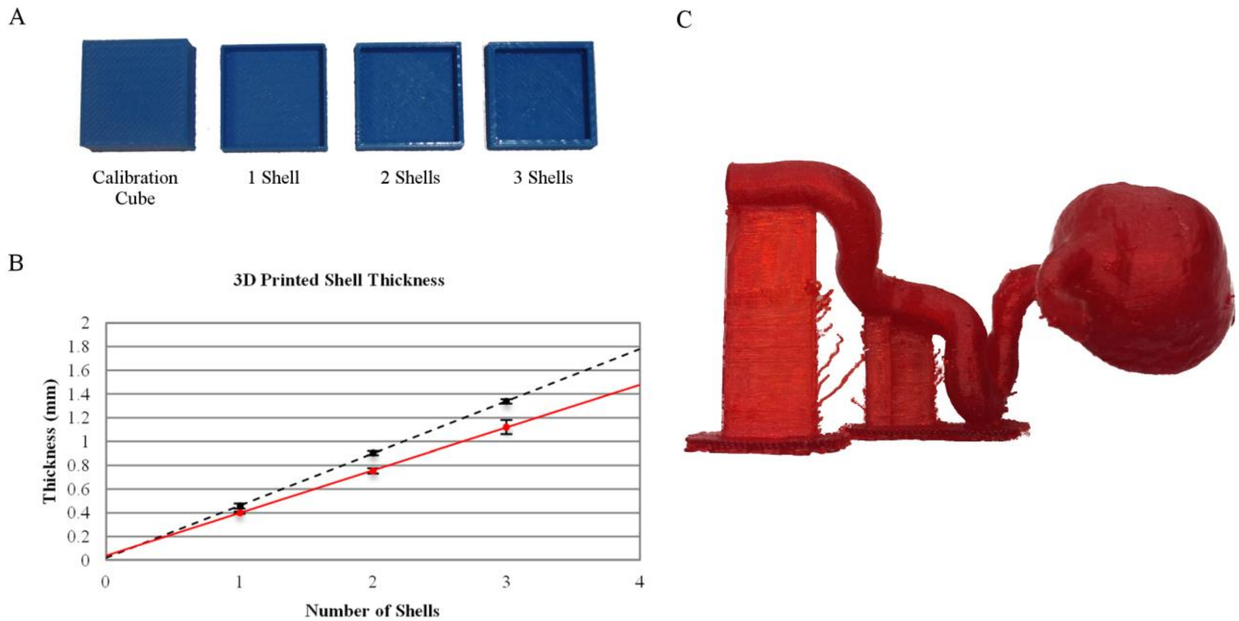

Figure A.1. A: PLA calibration cubes. B: Shell thicknesses for calibration cubes for PLA (dashed, black line) and MakerBot Flexible Filament (solid, red line); error bars represent plus or minus the standard deviation. C: Representative aneurysm replica with the base and scaffolding, both needed for correct printing, partially removed.