Evaluation of SLA 3D Printing Resins for Preclinical MRI Research

FAMU-FSU College of Engineering

NATIONAL HIGH MAGNETIC FIELD LABORATORY

Huyen Bui and Malathy Elumalai

Background

The RF (Radio Frequency) program at the National High Field Magnetic Laboratory (NHFML) develops MRI probes for the 900 MHz MRI (Magnetic Resonance Imaging) magnet to aid in the preclinical studies of small rodents. In order to support the varying body sizes and anatomy of the rodents, different stereotaxic animal cradles need to be machined for each conducted study. However, machining multiple cradle variations with non-magnetic materials can quickly escalate production costs. Stereolithography (SLA) 3D printing is a cost-effective alternative to machining that would allow researchers to rapidly create prototype parts.

This study evaluates the material properties of resins printed using the Form 3 (Formlabs, Inc.) SLA printer when exposed to various external influences. All High Temp and Black QA (Quality Assurance) prints were printed with 25 µm resolution, all Tough QA prints were printed with 50 µm resolution, and all Draft QA prints were printed with 100 µm resolution to test the highest possible resolution for each resin. The results of this project will lead to a better understanding of 3D printing with SLA printers for MRI studies.

Figure 1: Formlabs Form 3 SLA 3D Printer [1]

Figure 2: Stereotaxic rodent cradle used in preclinical MRI studies [2]

Methods

A QA print was designed using Autodesk Inventor to evaluate resin performance under each category. Appropriate PPE was used throughout all experiments. Changes in dimensions as well as qualitative data was recorded for each QA print. The Mitutoyo 8-inch digital caliper (MFG #500-197-30) was used to collect measurement data.

1. **Temperature:** The QA print consisted of an outer cylinder with dimensions of: OD = 25 mm, height = 25 mm; and an inner cylinder with dimensions of: OD = 20 mm, height = 10 mm. Each QA print was left in the Form Cure (an automated post-curing machine used to improve material properties) for 120 minutes at 65 °C to replicate the time it takes to cure an MRI coil pattern onto a G-10 former. Changes in dimensions were measured after each print was exposed to heat.

2. **Solvent Resistance**: The QA print consisted of three identical hollow cylinders on a raised platform. To prepare the Tergazyme (Alconox #1301 enzyme-active powered detergent), 0.5 g of Tergazyme was mixed with 50 mL of water in a graduated cylinder. 7.5 mL of IPA (isopropyl alcohol) and Tergazyme, and one Peroxigard wipe were placed in each cylinder, respectively. Each solvent was left in the QA print for 24 hours. All liquid solvents were transferred using disposable pipettes. Changes in dimensions and surface quality of the print were noted after the solvents were removed.

3. **Resolution:** The QA print consisted of several through-holes, holes, cylinders, walls, gaps, and other physical features commonly found in animal cradles. Each feature's dimensions were compared with the original design to determine tolerance values for each type of resin.

4. **Machinability:** The QA print consisted of a rectangle with several holes that were drilled, tapped, and threaded. Qualitative data about each print's material properties was recorded.

Results

TEMPERATURE

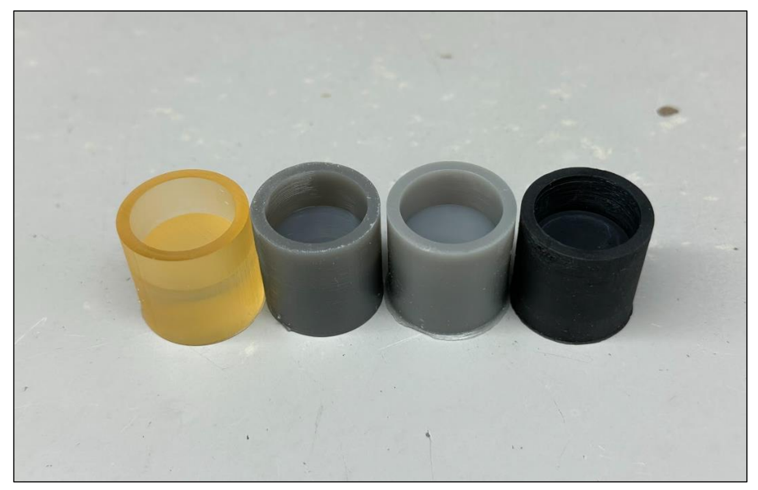

Figure 3. Temperature QA Prints

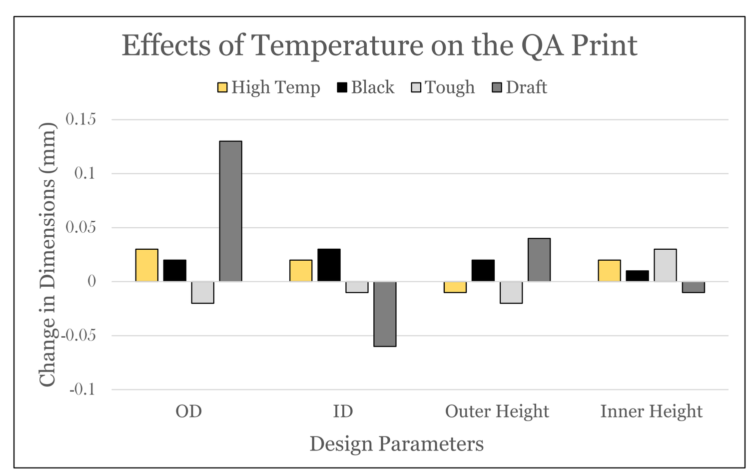

Figure 4. Effects of Temperature on QA Prints

SOLVENT RESISTANCE

Figure 5. Solvent Resistance QA Prints

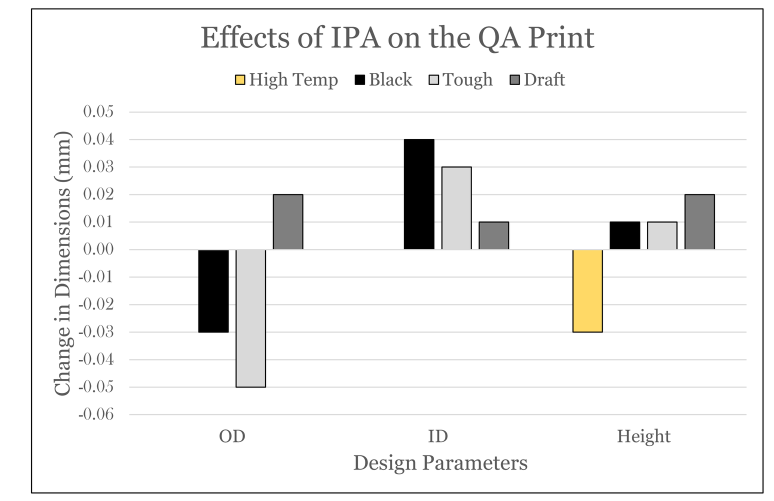

Figure 6. Effects of IPA on the QA Print

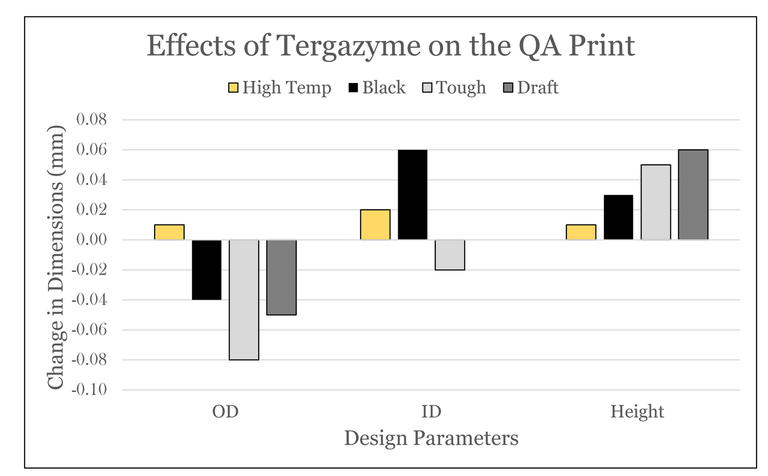

Figure 7. Effects of Tergazyme on the QA Print

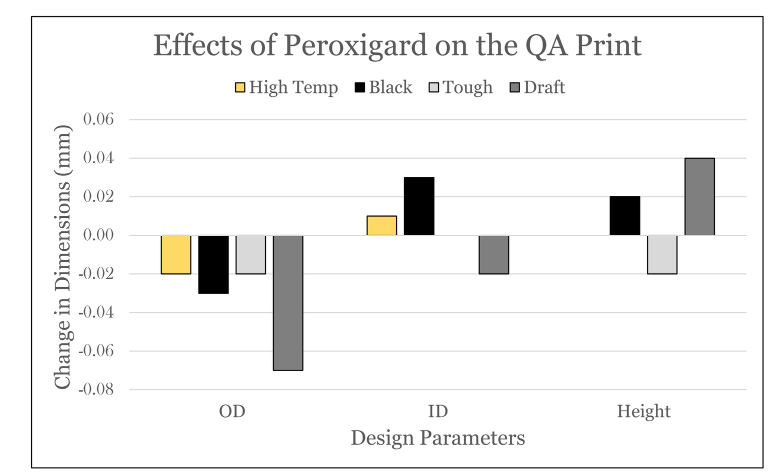

Figure 8. Effects of Peroxigard on the QA Print

RESOLUTION

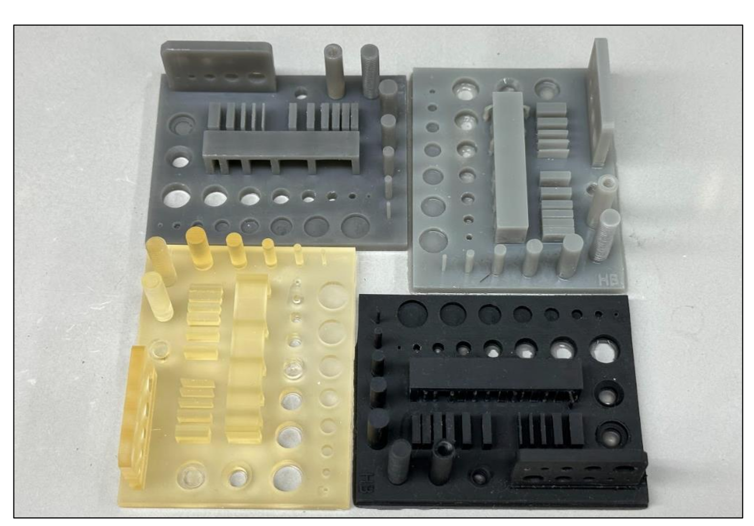

Figure 9. Resolution QA Prints

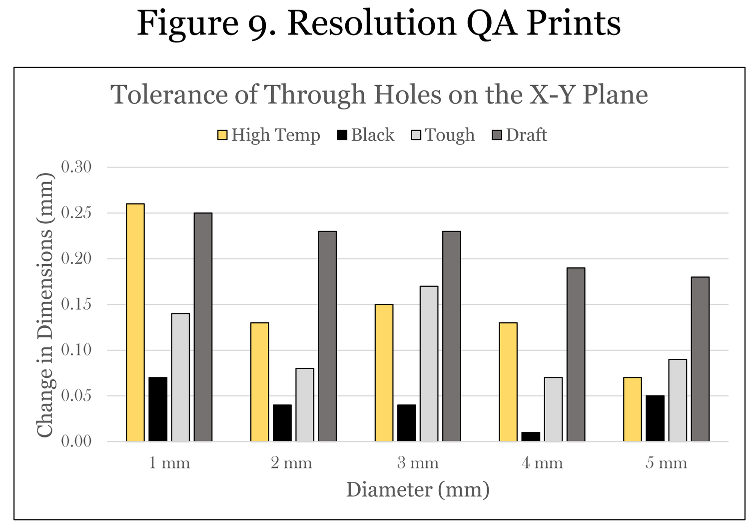

Figure 10. Tolerance of Through Holes

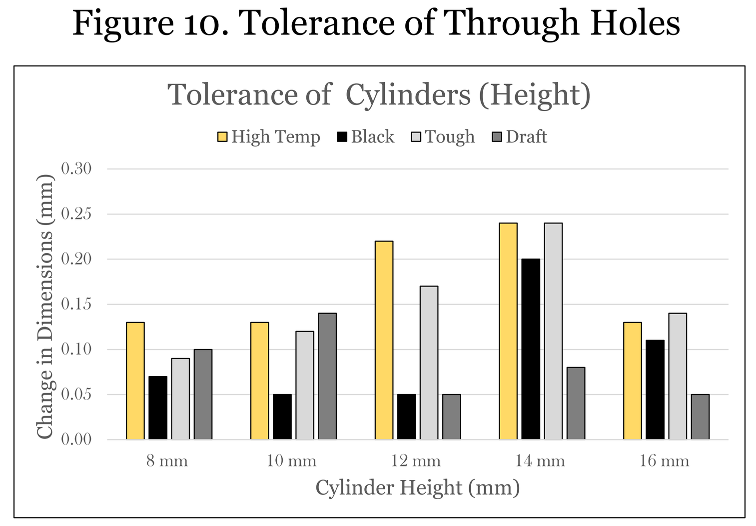

Figure 11. Tolerance of Cylinders (Height)

MACHINABILITY

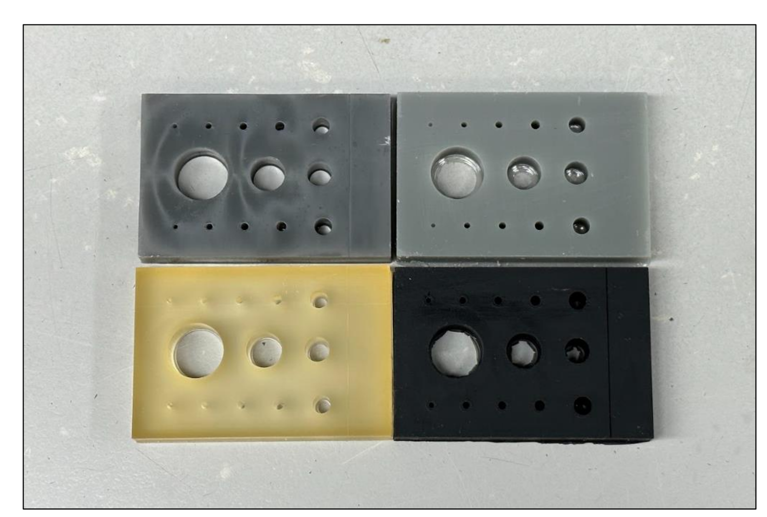

Figure 13. Before Machining QA Prints

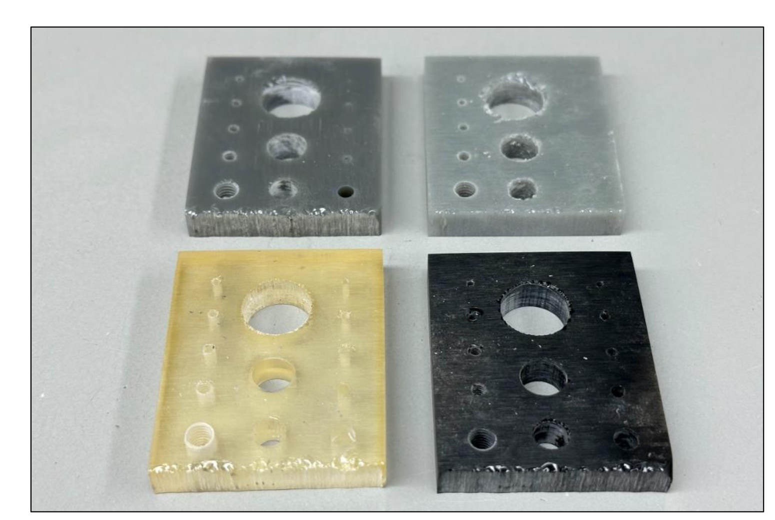

Figure 14. After Machining QA Prints [3]

- **High Temp –** smooth, matte finish; required a higher drill pressure to break through material; produced fine, abrasive chips; exhibited more breakout of material
- **Black**: smooth, matte finish; waxy and pliable; chips ranged from dusty powder to short, soft curls; exhibited minor breakout of material
- **Tough**: glossy, tacky finish; was easy to drill into; exhibited no breakout
- **Draft**: smooth finish; less powdery; not abrasive; produced short chips

Tolerance Values for Various Features on QA Print (± mm)

Design Feature	Resin Type			
	High Temp	Black	Tough	Draft
Through-Holes (X-Z)	0.0562	0.0625	0.1250	0.1125
Through-Holes (X-Y)	0.1480	0.0420	0.1100	0.2160
Holes (X-Z)	0.0725	0.0725	0.1400	0.1475
Holes (X-Y)	0.1480	0.0420	0.1100	0.2160
Cylinder Diameter	0.0220	0.0380	0.0240	0.0400
Cylinder Height	0.1700	0.0960	0.1520	0.0840
Thin Walls	0.0260	0.0100	0.0600	0.0700
Thin Gaps	0.0360	0.0560	0.0280	0.0320

Figure 12. Tolerance Values for Various Features

Discussion

All positive values on the graphs indicate a decrease in dimensions (shrinking), and all negative values indicate an increase in dimensions (expansion).

- Black, High Temp, and Tough resins exhibited the least average amount of change in dimensions (±0.02 mm) after being exposed to high temperatures. Draft resin had the most change in dimensions (±0.06 mm). However, the effects of temperature on all resins is so minimal that it can be considered negligible (Figure 4).
- The solvents used were IPA, Tergazyme, and Peroxigard, which are typically used to clean parts. For all three solvents, the OD increased, the ID decreased, and the height increased (Figures 6, 7 and 8). High Temp resin performed the best with an average change of ± 0.0122 mm, followed by Tough (±0.0311 mm), Black (±0.0322 mm), and Draft (±0.0322 mm). No change was observed in the surface quality of all QA prints. Since the largest change in dimension overall was -0.08 mm, the effects of solvents on all resins can be considered negligible in this context.
- Overall, Black resin had the lowest average tolerance value (±0.0482 mm). High Temp resin had the second lowest average tolerance value (±0.0848 mm), followed by Tough resin (±0.0936 mm) and Draft resin (±0.1148 mm).
- Through-holes oriented on the X-Y plane and cylinder height both exhibited the largest range of tolerance on all QA prints (Figures 10 and 11). This may be due to Z-axis compression that occurs while printing.
- Most physical features that were designed in the QA print showed up in the final print, demonstrating that resolution does not limit the types of features one can design in a print.
- After evaluating the qualitative data, it was determined that Black resin is the best resin for machinability due to it's pliable and non-abrasive nature. However, both Tough and Draft resins could serve as substitutes depending on the functionality of the part.

Conclusion

Based on these results, one can conclude that the resin printed with the highest resolution will have the least number of dimensional changes when exposed to a range of external factors. Any new parts to be designed for 3D printing will need to factor in the tolerance values determined from this study, and existing parts will need to have their dimensions altered accordingly. However, since each resin type is designed with a specific function in mind, one must consider each resin's advantages and disadvantages when selecting one to use.

High Temp resin will be used for components that will be exposed to high temperatures such as coil formers and animal cradles that will be in contact with hot water or air. Draft resin will be used for prototype parts. Tough resin will be used when material strength is needed, such as for parts in a mechanical assembly.

Moving forward, the MRI lab will begin using Black resin due to it performing well in all four categories (temperature, solvent resistance, machinability and resolution).

Future Work

Due to limited time and the high cost of the Formlabs resin used for the 3D printing, only one trial was conducted for each category tested.

A topic that can be investigated in the future is the feasibility of using a cheaper SLA printer to complement the workload of the Form 3. A potential candidate is the Anycubic Photon Mono X (Anycubic). The same QA tests would need to be run using Anycubic resins.

References

[1] Image from https://formlabs.com/3d-printers/form-3/
[2] Rodent cradle designed by the RF Program at the NHFML
[3] QA prints machined by Joe Collins from the NHFML