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Annual Meeting & Exhibition | May 18-22, 2025

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Influence of SLA Additive Manufacturing Patterning Techniques on the Wear of Metal Countersurfaces for 3D Printed Ceramics

LEILANI ELKASLASY*, MIRANDA BRANDT, KANOA PARKER, GORDON G. KRAUSS
DEPARTMENT OF ENGINEERING, HARVEY MUDD COLLEGE, CLAREMONT, CALIFORNIA USA
*CORRESPONDING AUTHOR: LELKASLASY@HMC.EDU



Research Scope

Investigate Effect of Additive Manufacturing Patterned Ceramic on Abrasive Wear of Metal Countersurfaces.

Patterning an AM-printed surface was expected to reduce wear through trapping of debris.

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Agenda

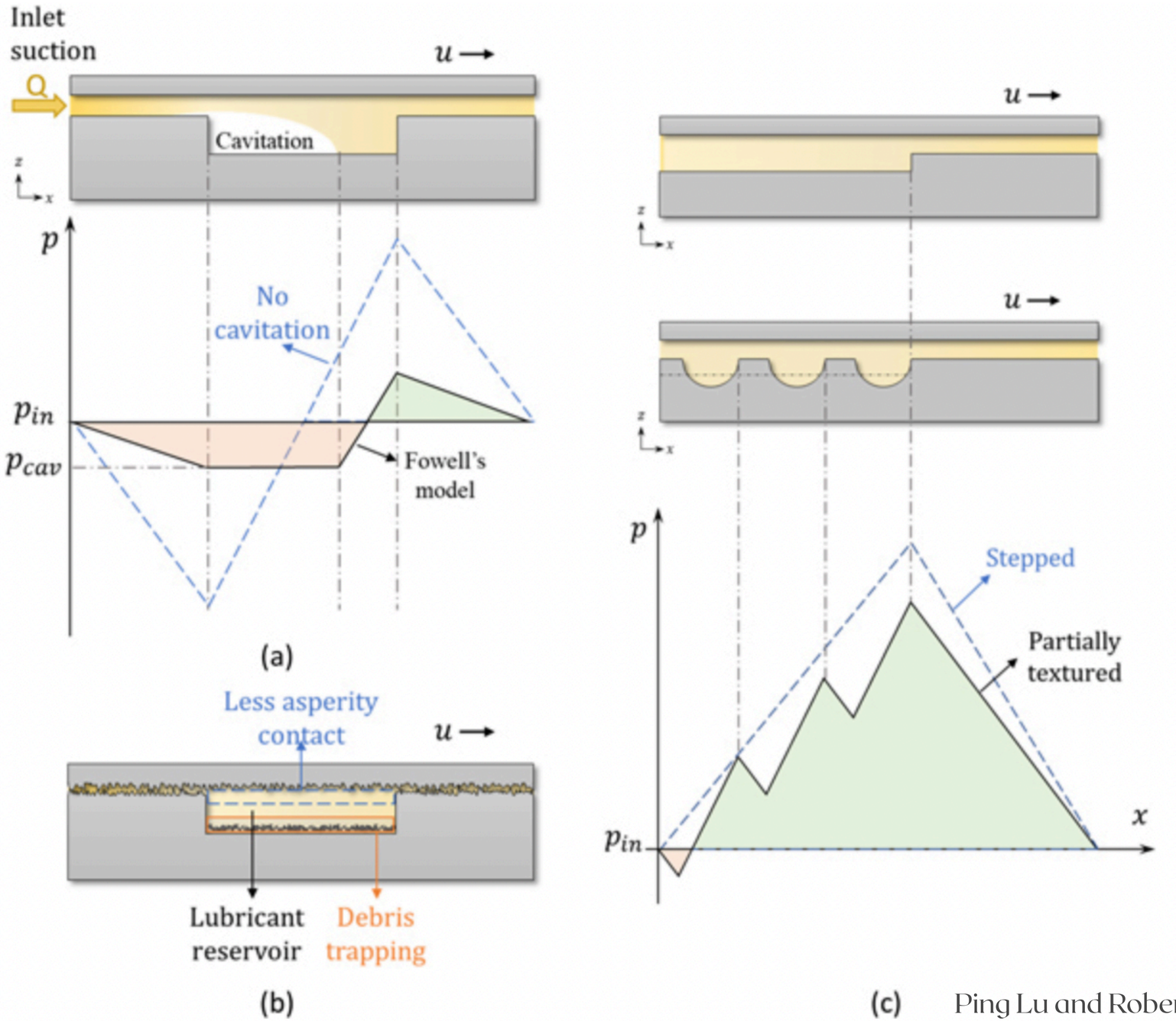
1. Project Scope
2. Background
3. Fabrication and Testing
4. Results
5. Conclusions
6. Next Steps

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Patterning Theory



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Ping Lu and Robert J K Wood 2020 Surf. Topogr.: Metrol. Prop. 8 043001

Access to Patterning Instruments:

Current Instruments Used:

- Micro-electric discharge machining (Micro EDM)
- Focused ion beam
- Abrasive jet machining (ABJ)
- Femto Second Lazers

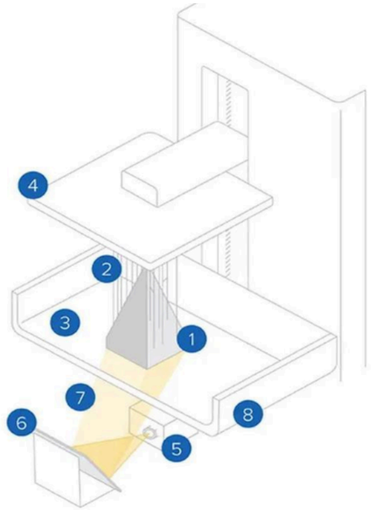
While highly precise- these tools can be expensive and not widely accessible



Ping Lu and Robert J K Wood 2020 Surf. Topogr.: Metrol. Prop. 8 043001

Fabrication and Testing

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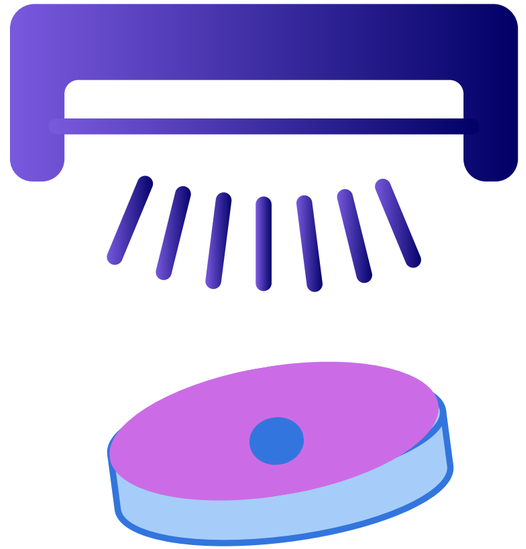


DLP SLA
Resin Printing

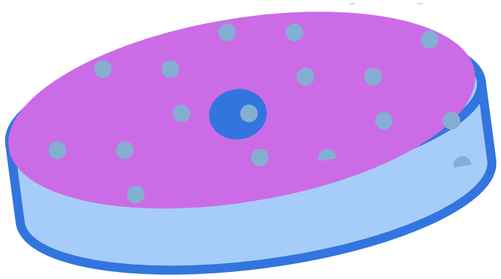
Dental Resin + Ceramic Particles



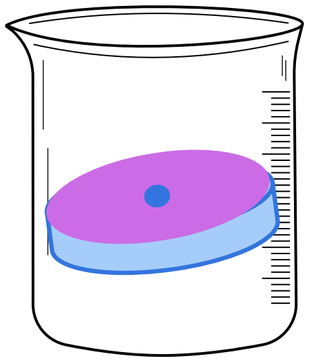
Surface Doping



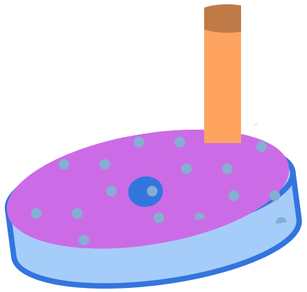
UV Curing



Surface
Patterning



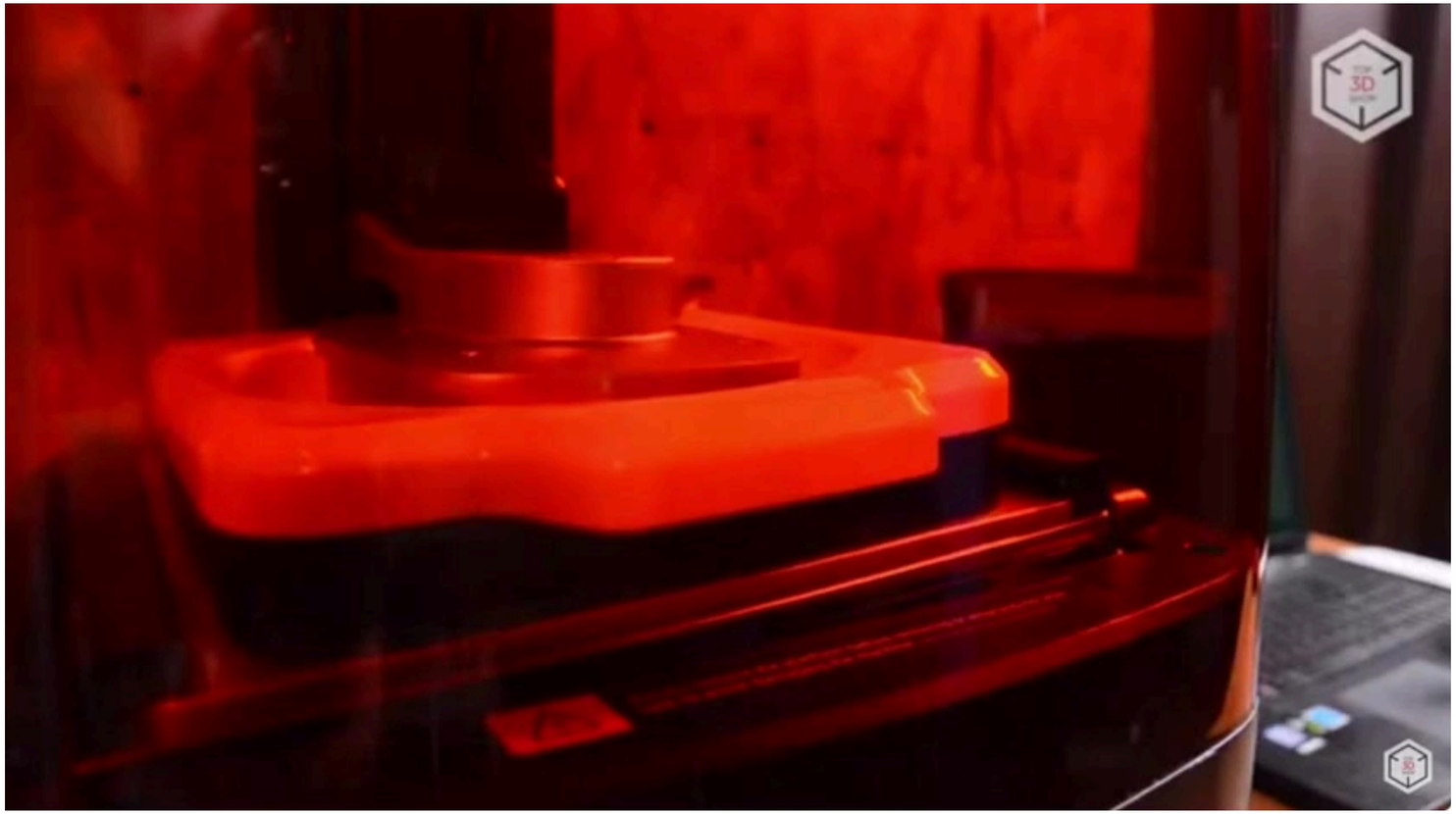
Glycerine
Curing



Testing!

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Video Demonstration of Printing



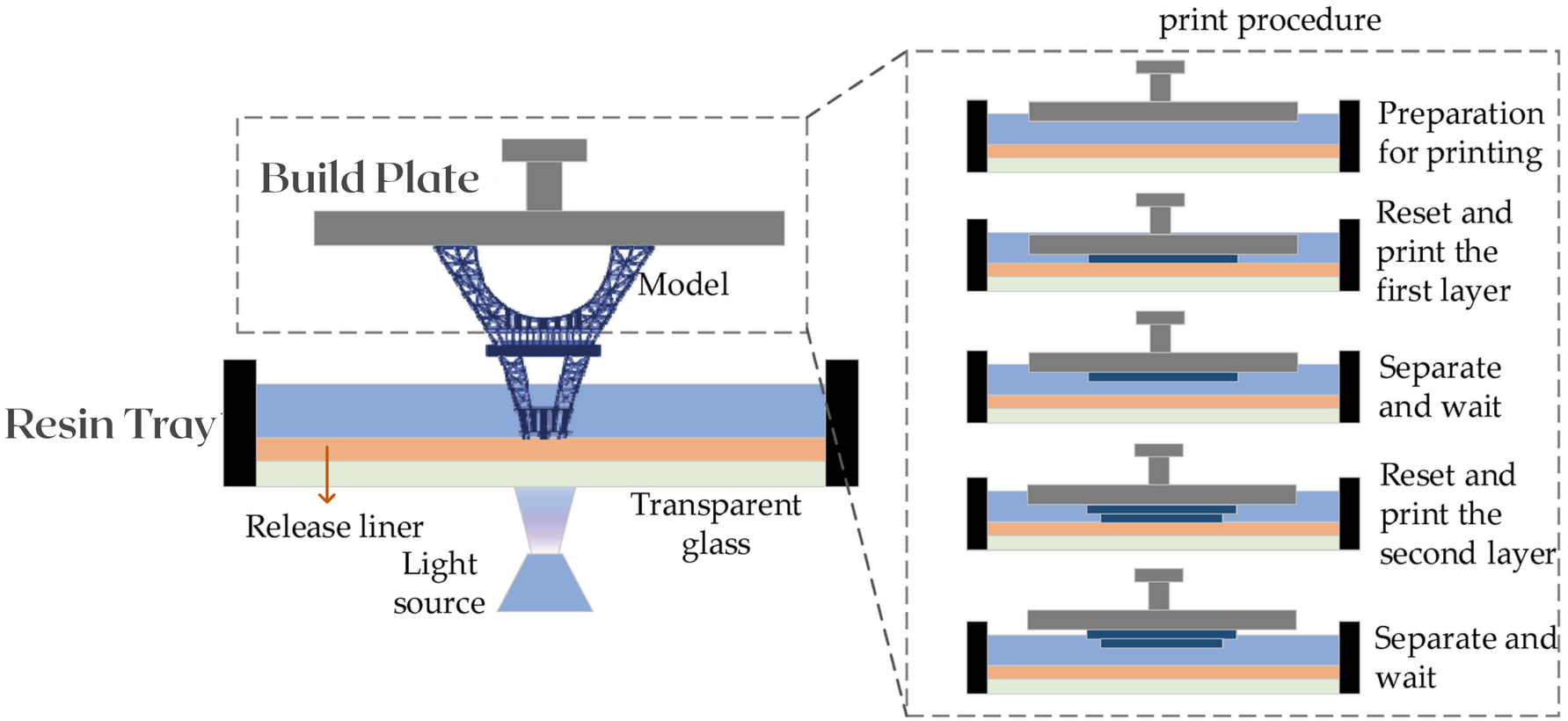
HTTPS://WWW.YOUTUBE.COM/WATCH?V=V_3VLYPJNNU&AB_CHANNEL=TOP3DSHOPINC.



https://top3dshop.com/product/sprintray-moonray

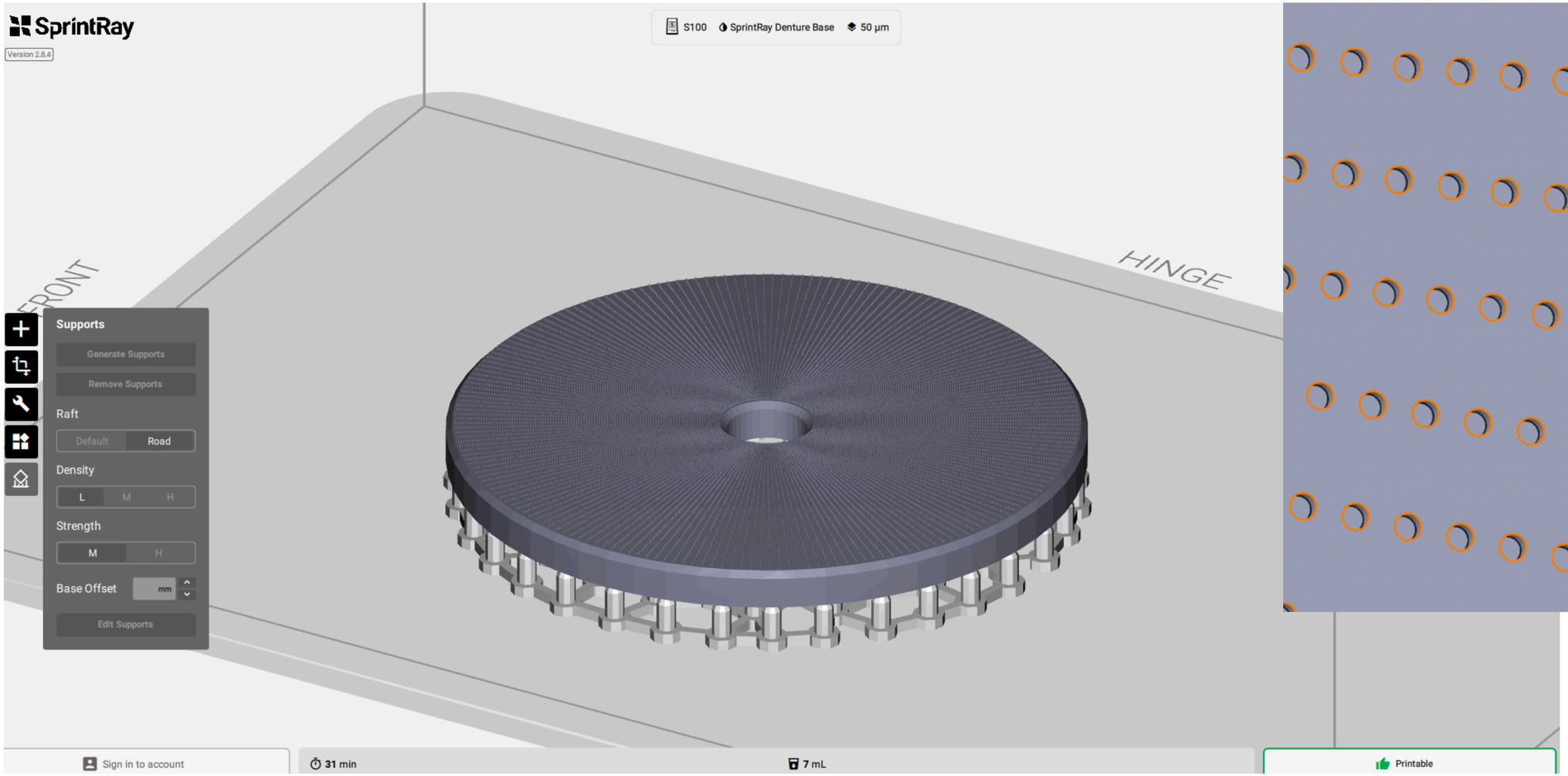
Mechanisms of DLP Printing

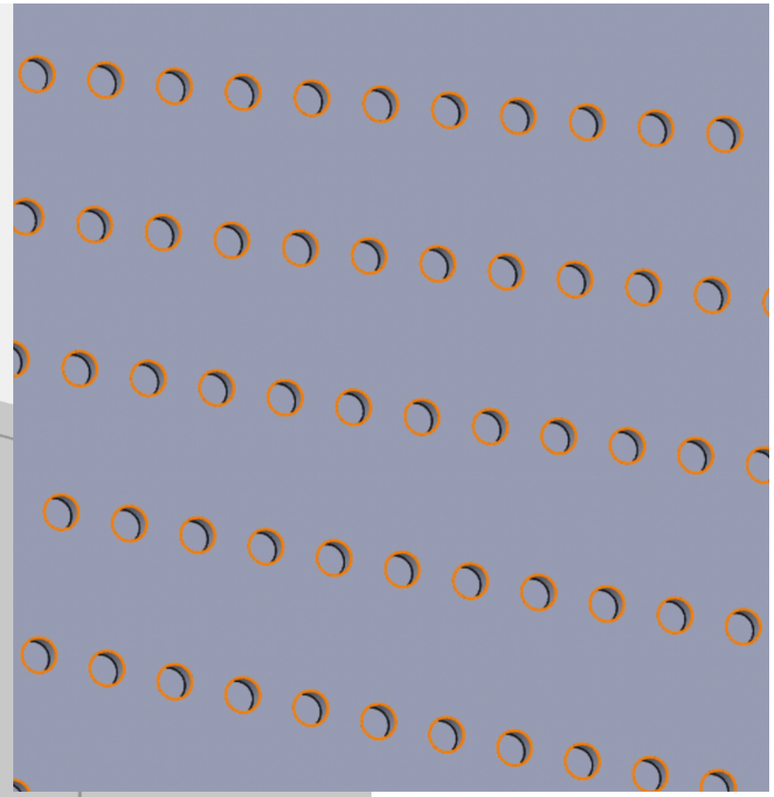




Y. Wang, M. Zhang, Y. Li, and H. Liu, “Study of Forming Performance and Characterization of DLP 3D Printed Parts,” Materials, vol. 16, no. 10, p. 3847, May 2023, doi: 10.3390/ma16103847.

Disk Fabrication Methods :

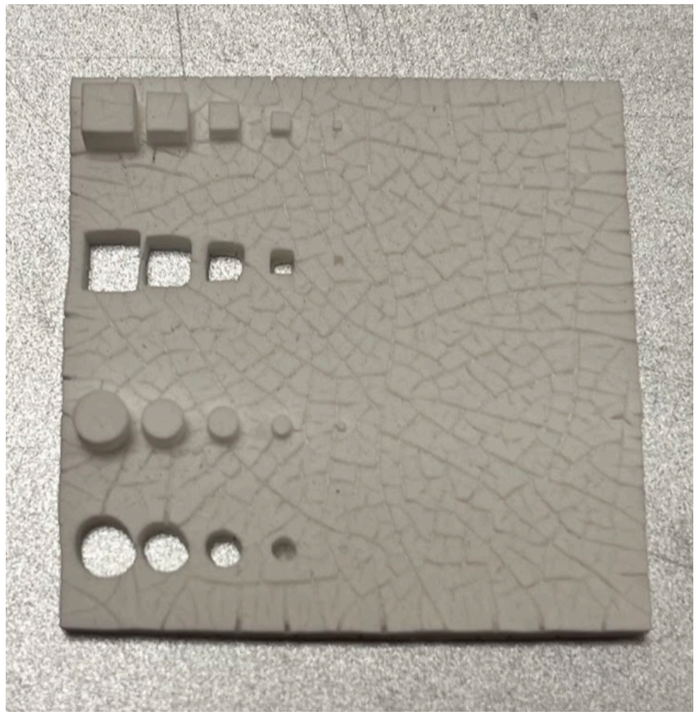


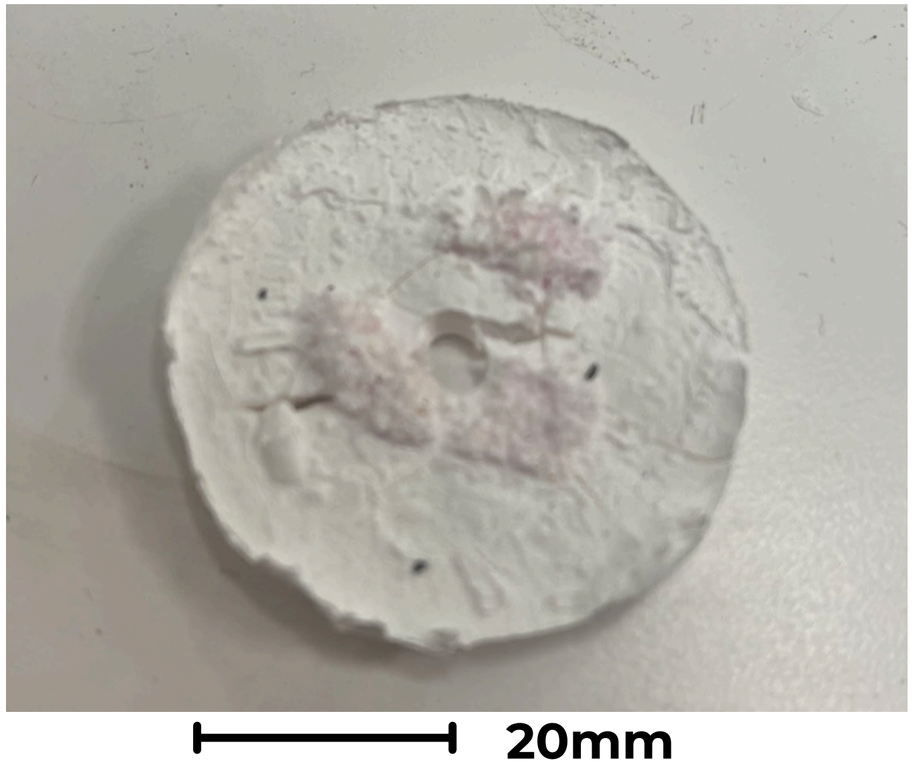


200 µm

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Disk Fabrication Methods :



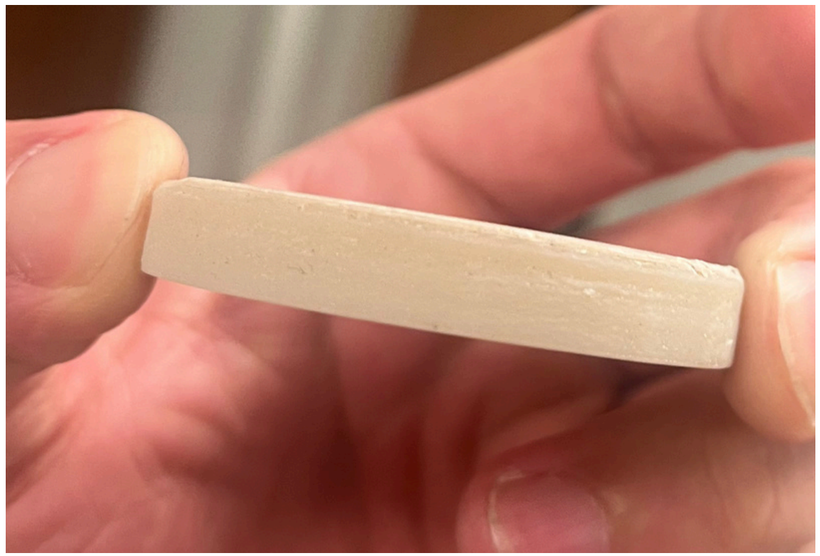


Difficulty With Fired Ceramic

Denture Resin

- Contains acrylic oligomers and monomers
- Half as dense as glass
- Durable and more sturdy compared to other resins
- Biocompatible
- Curing process involving food-grade glycerin





Before Curing

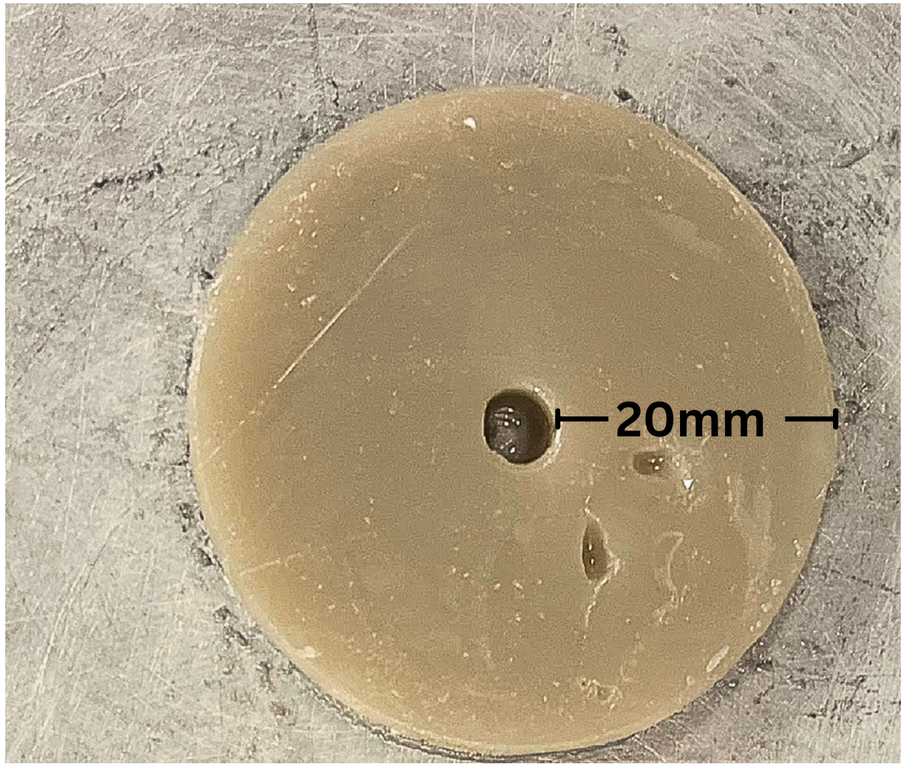
Viscosity at 25+/-0.5°C	cps	1000 < x < 2000
Density	g/cm3	1.05 < x < 1.20

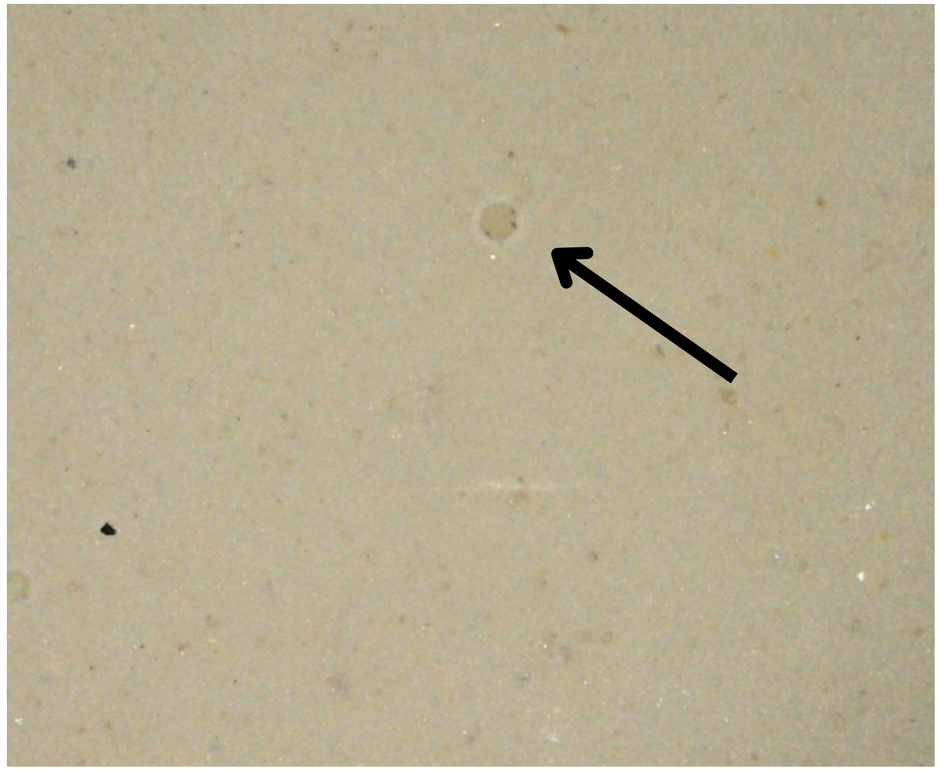
After Curing

Density	g/cm3	1.15 < x < 1.25
Flexural Strength	MPa	>50
Degree of Conversion	%	>70

TABLE FOR REFERENCE ONLY http://dentca.com/product/dentca-denture-teeth

Disk Fabrication Methods :





Difficulty With Printer Resolution

Adding Ceramic Additives to Denture Resin

Theory: Surface modification of dental resin may enhance wear resistance without compromising bulk properties.

Additive Tested:
Dry Glacia Porcelain Powder

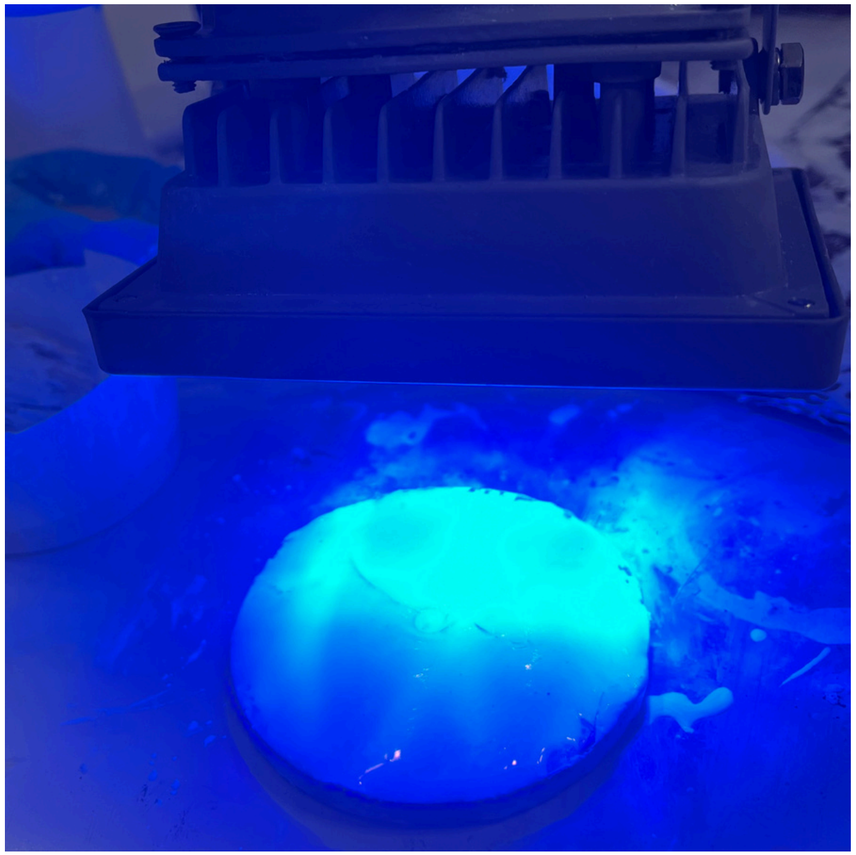


Sourced From Clay Planet

Porcelain Surface Doping:



20mm



20mm

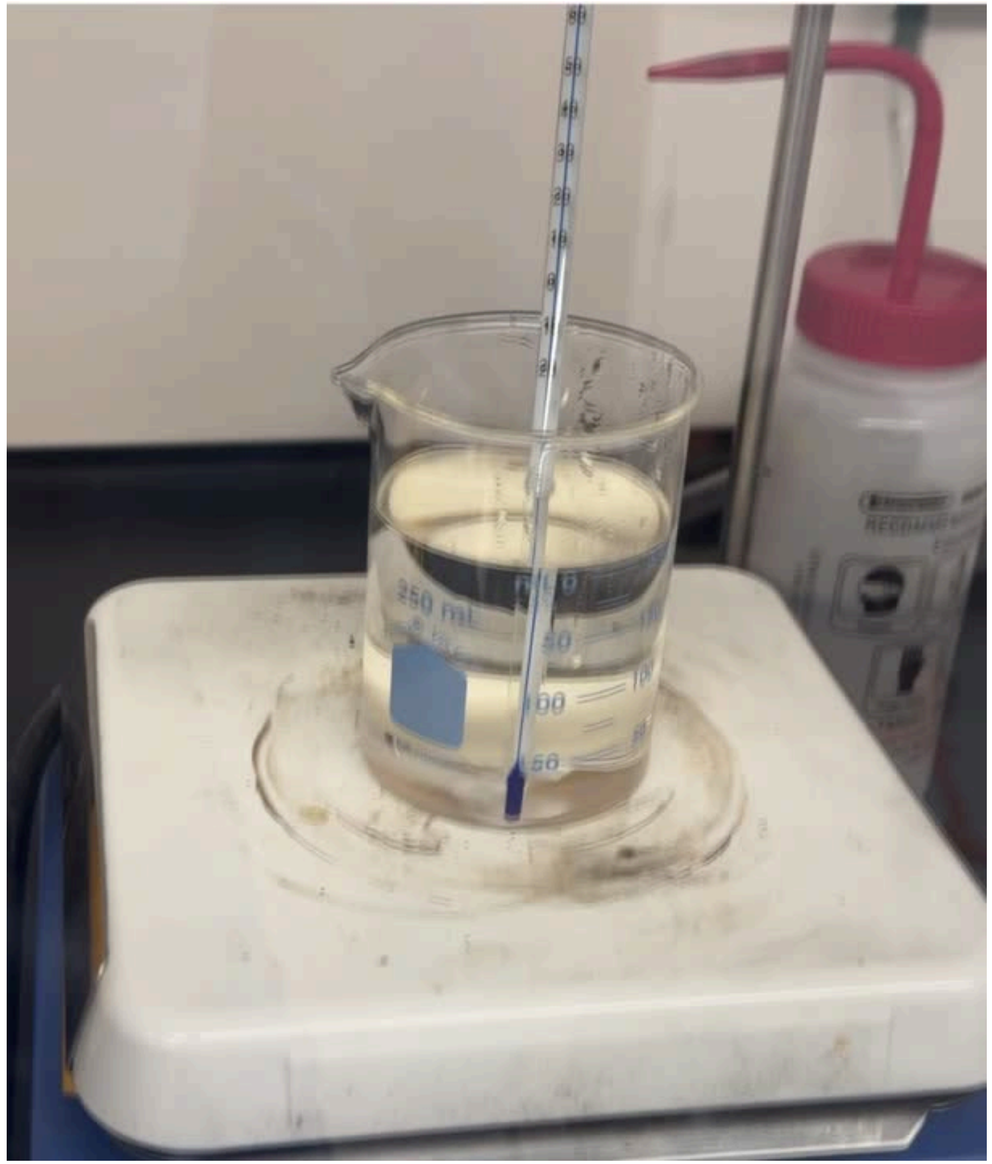
Disk Fabrication Methods :

Sand-Paper Surface Embossing Pre-Curing: 80 Grit Sandpaper

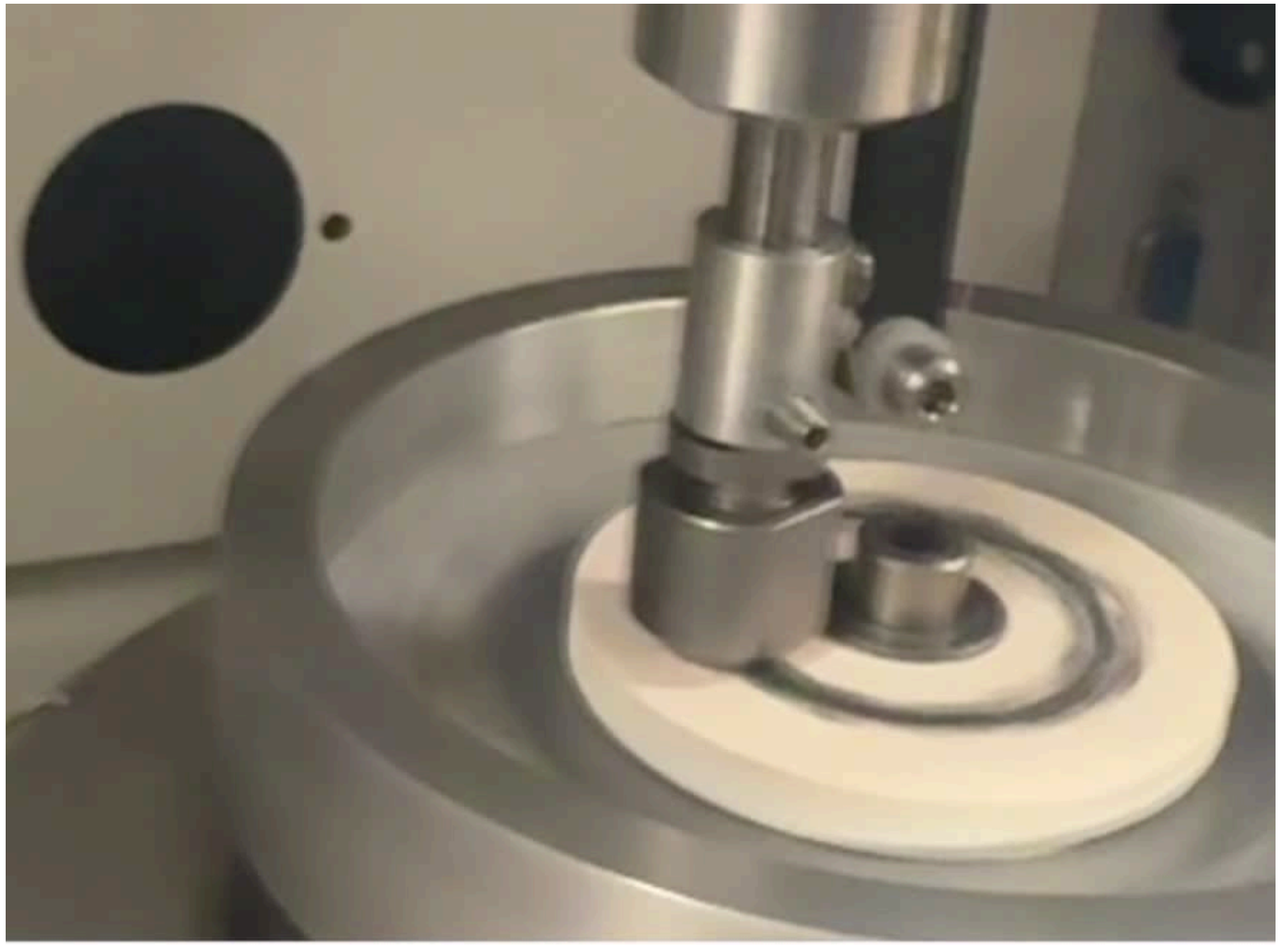


Curing Dental Resin

- Vegetable Glycerine heated to a minimum of 60°F
- Samples fully submerges for 40 minutes
- Curing process solidifies and hardens sample, which improves material performance



Metal Countersurface Testing





Bruker UMT Testing Specifications

- UMT via pin-on-disk method
- Cycles in intervals of 1, 10, 100, 1k, 10k and 50k
- Tracks characterized by location and inspected through profilometers
- 52100 Steel Ball
  - Hardness: 62 HRC
  - Size: 3.2mm
  - Force: 1N
  - Speed 75 mm/s
  - Dry Sliding
  - 30-40% humidity
  - 70° F



Wear Volume Theory:

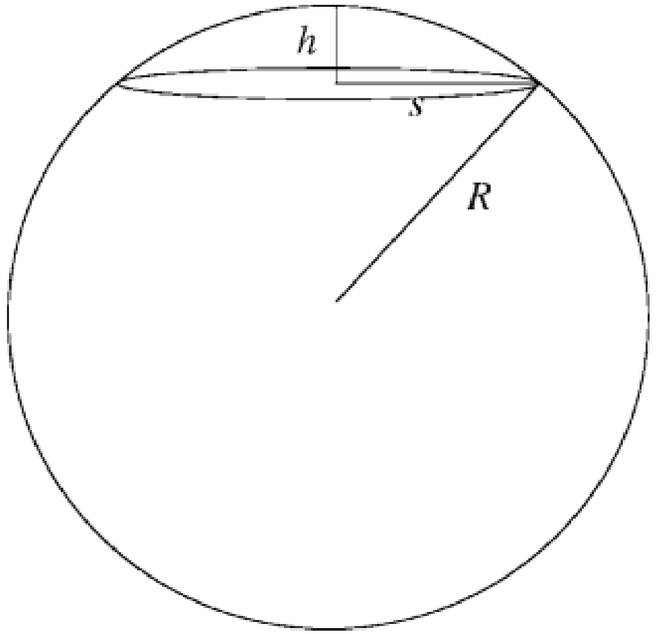
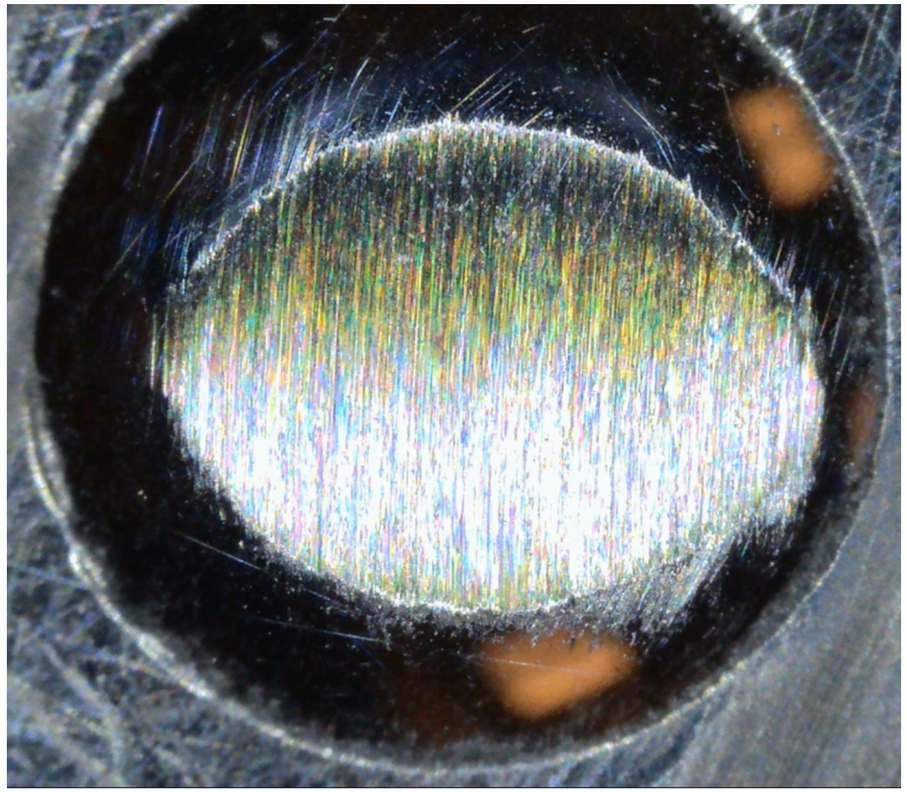


Figure 1. Schematic drawing of a ball with a missing “cap”, corresponding to a wear scar.



[2] S. J. Harris and G. G. Krauss, “Improved technique for measuring the ball volume removed in a ball-on-disk test,” Tribology Letters, vol. 10, no. 3, pp. 187–188, Apr. 2001, doi: 10.1023/A:1009014524815.

Wear Volume Equations:

$$V = \pi * \left[h * R^2 - \frac{R^3}{3} + \frac{(R-h)^3}{3} \right]$$

[1]

$$h = R - \sqrt{R^2 - s^2}$$

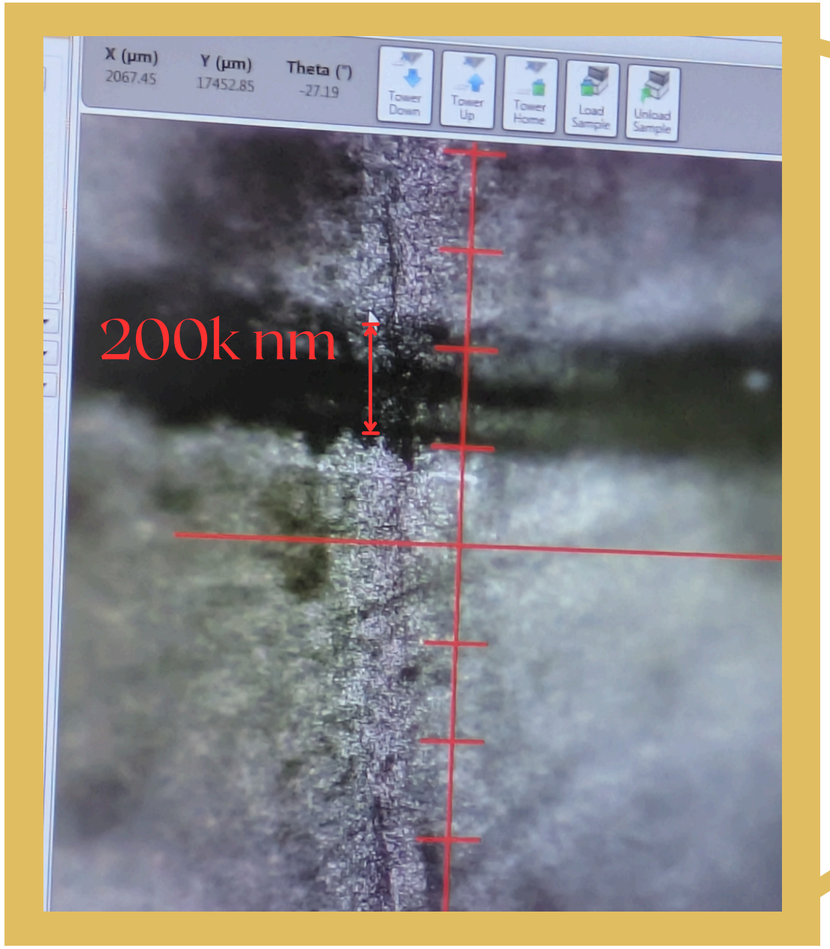
[2]

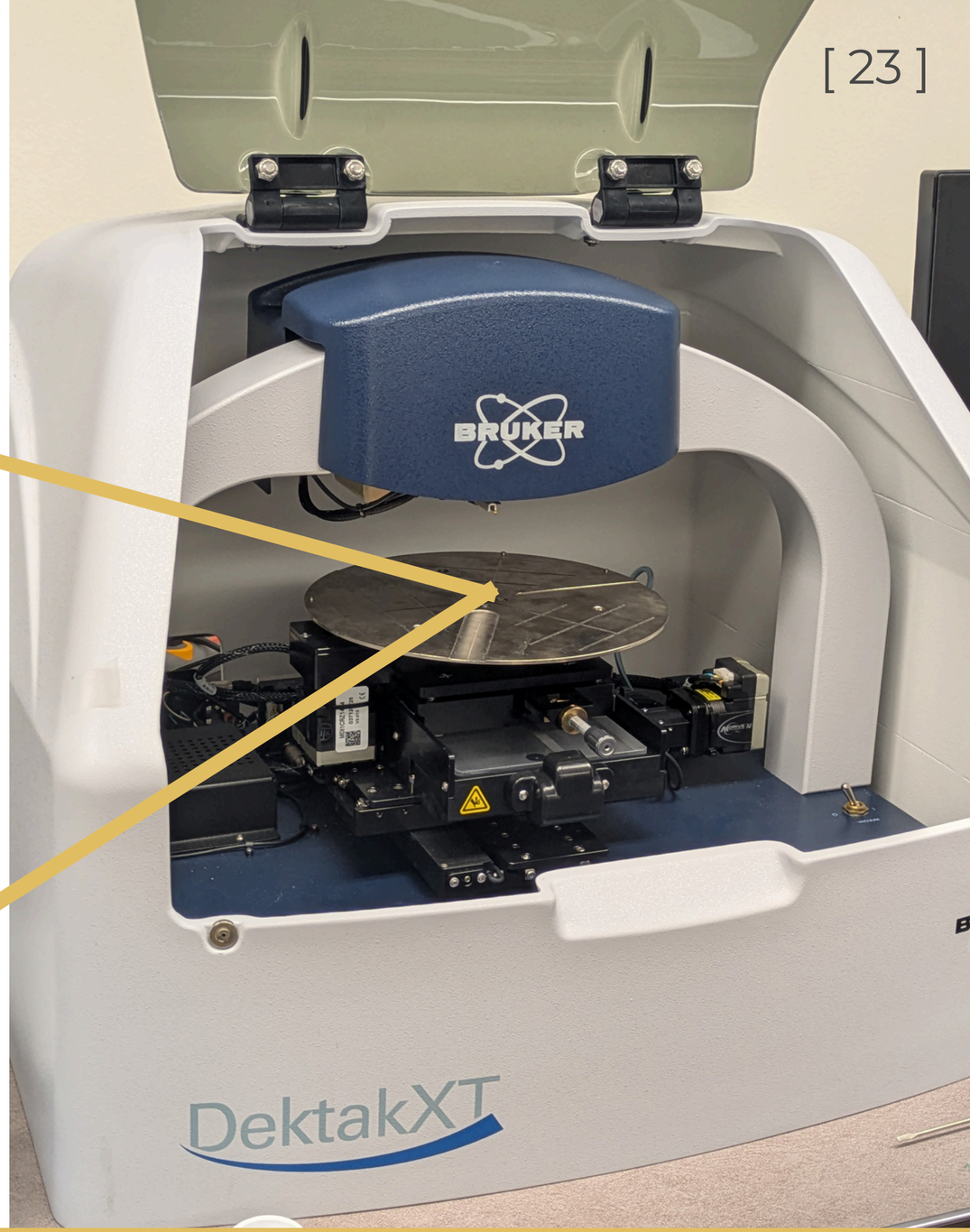
R: Steel Ball Radius

h: Scar height given by pythagorean theorem

s: Scar Radius

Dektak

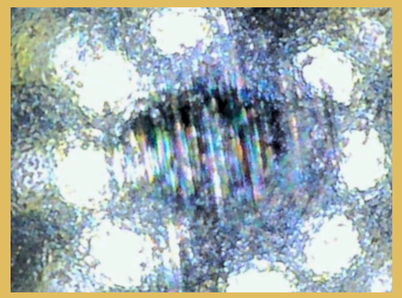
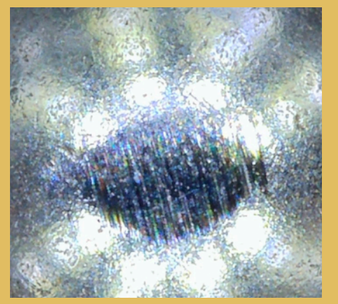

X (µm)
2067.45
Y (µm)
17452.85
Theta (°)
-27.19
Tower Down
Tower Up
Tower Home
Load Sample
Unload Sample
200k nm


BRUKER
DektakXT

Results

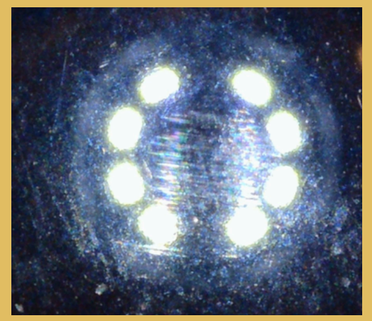
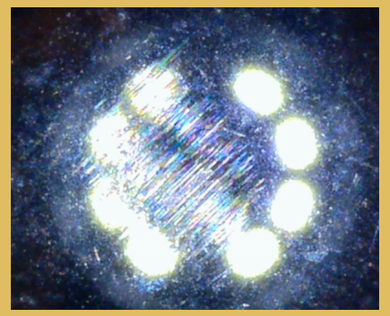
Unpatterned

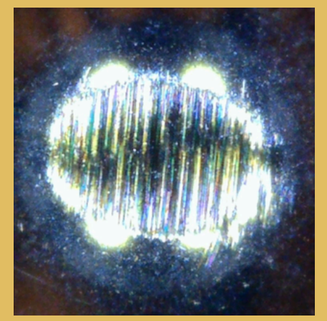



1 10 100 1k 10k

Patterned

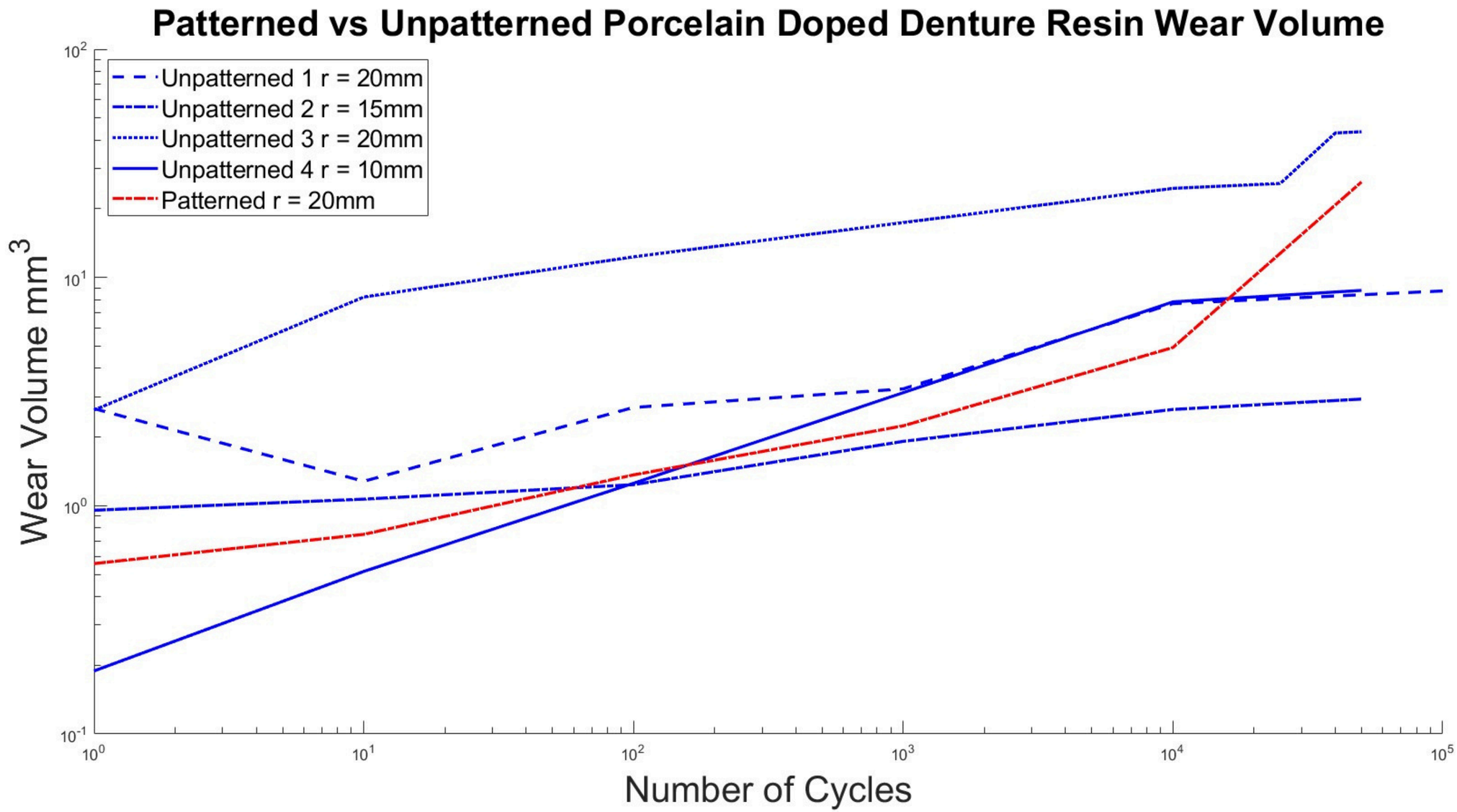



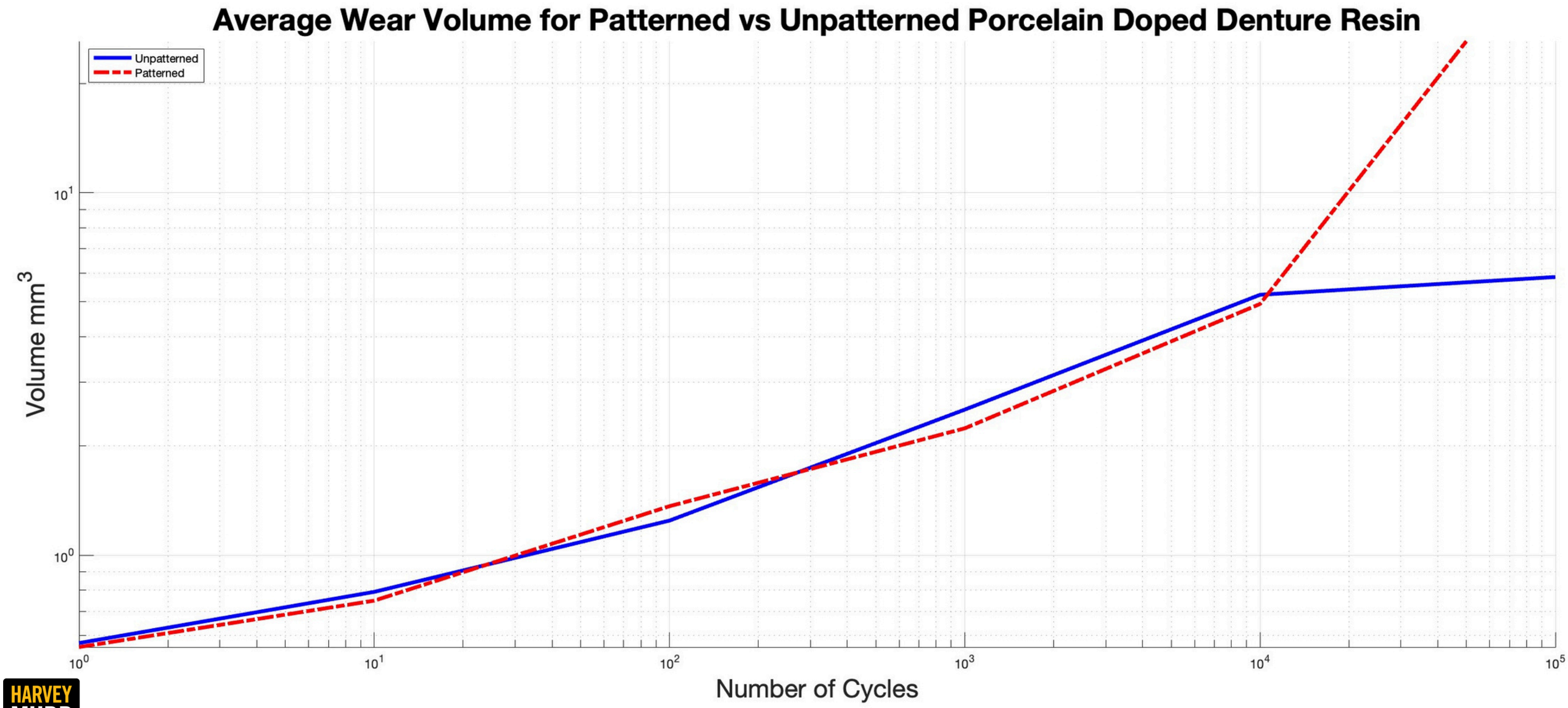
Wear Scars

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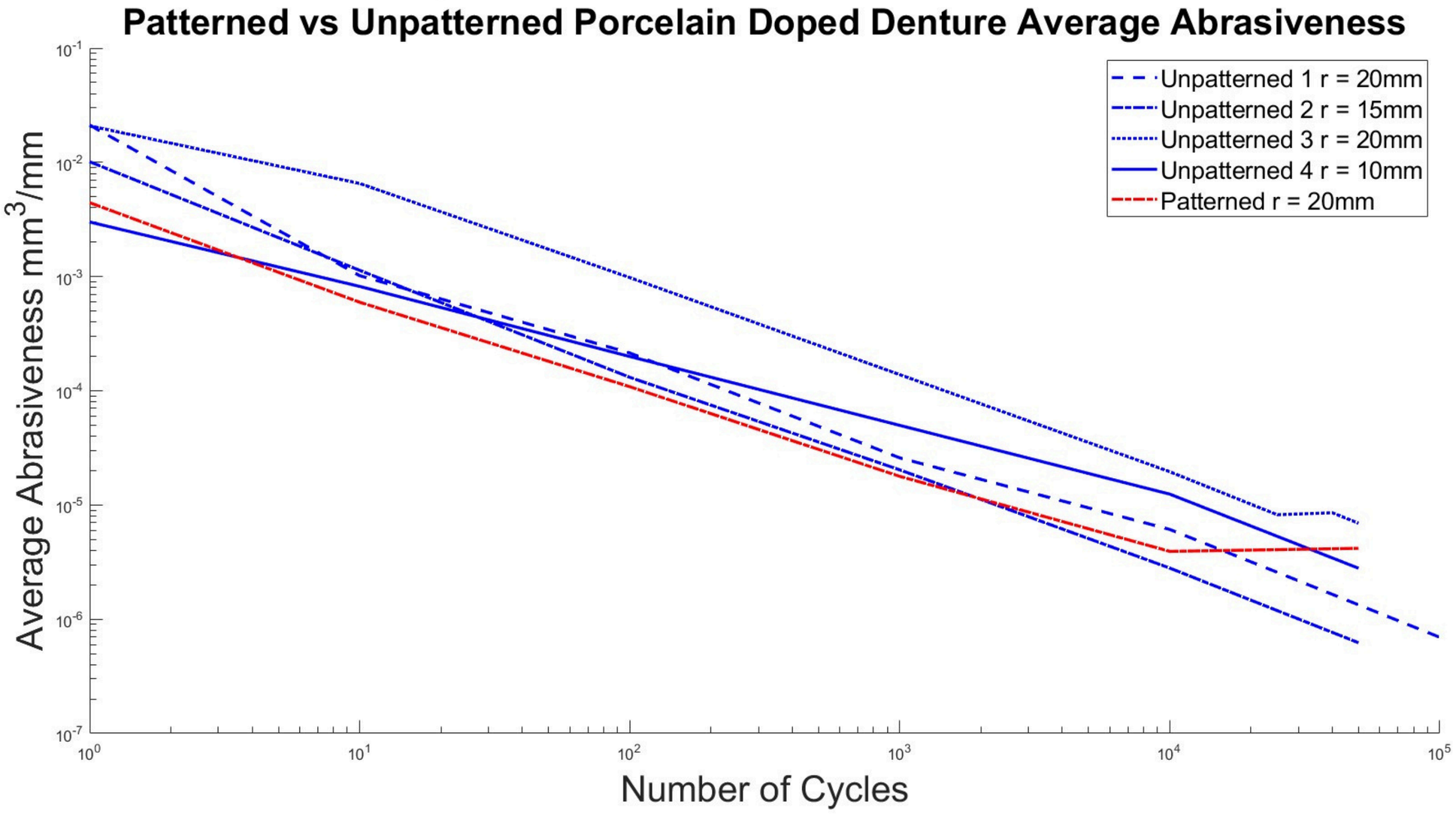
Results: Countersurface Wear Volume



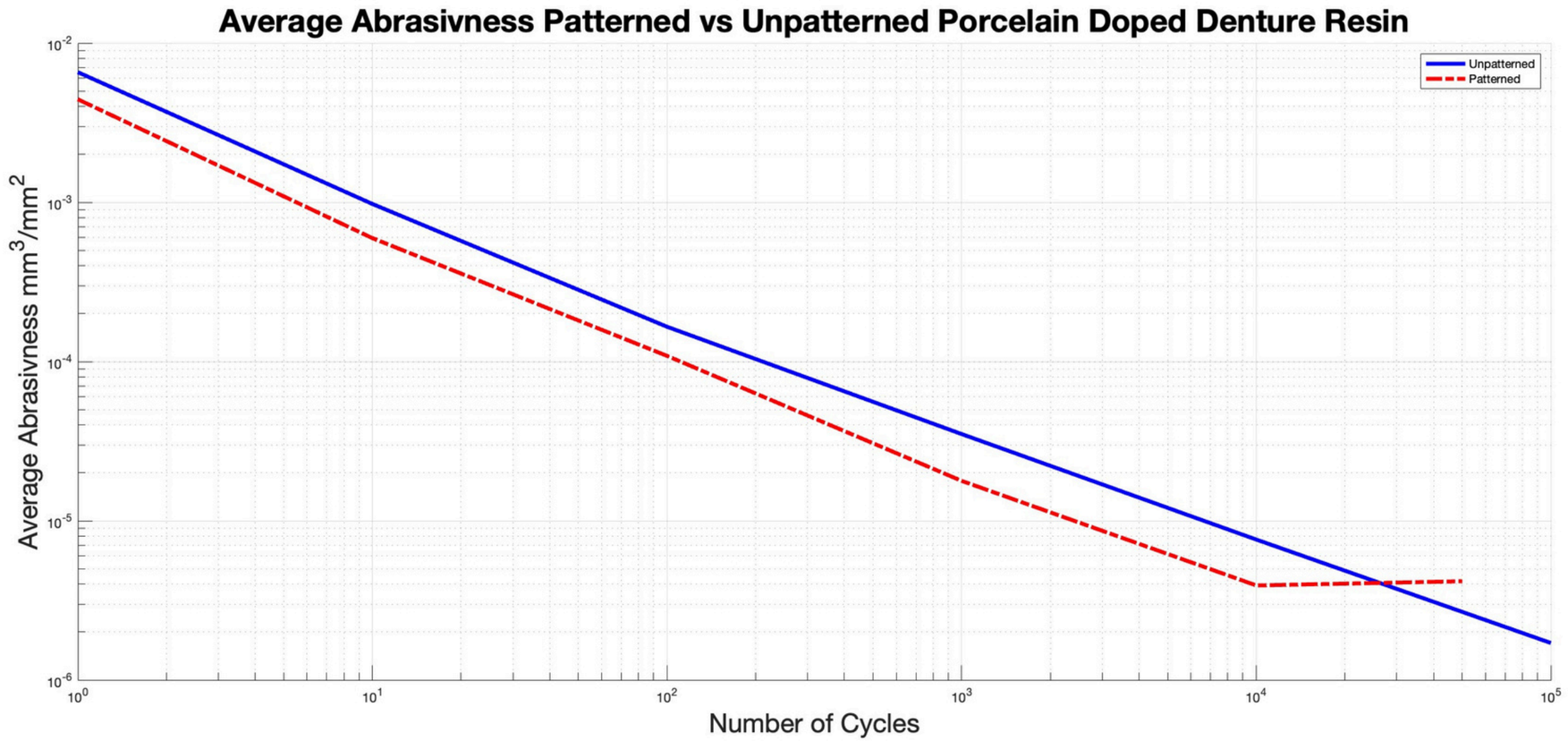
Results: Countersurface Wear Volume



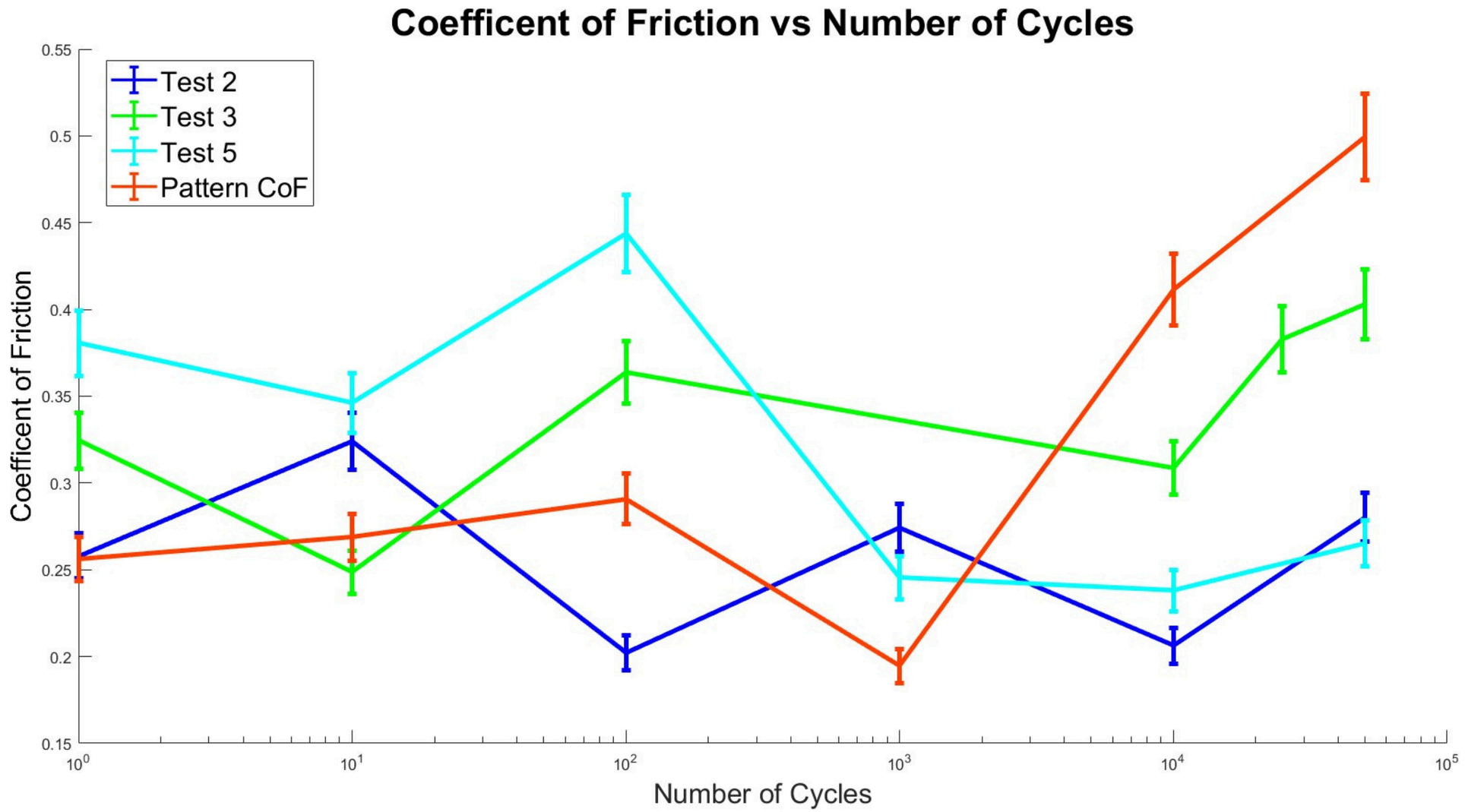
Results: Average Abrasiveness



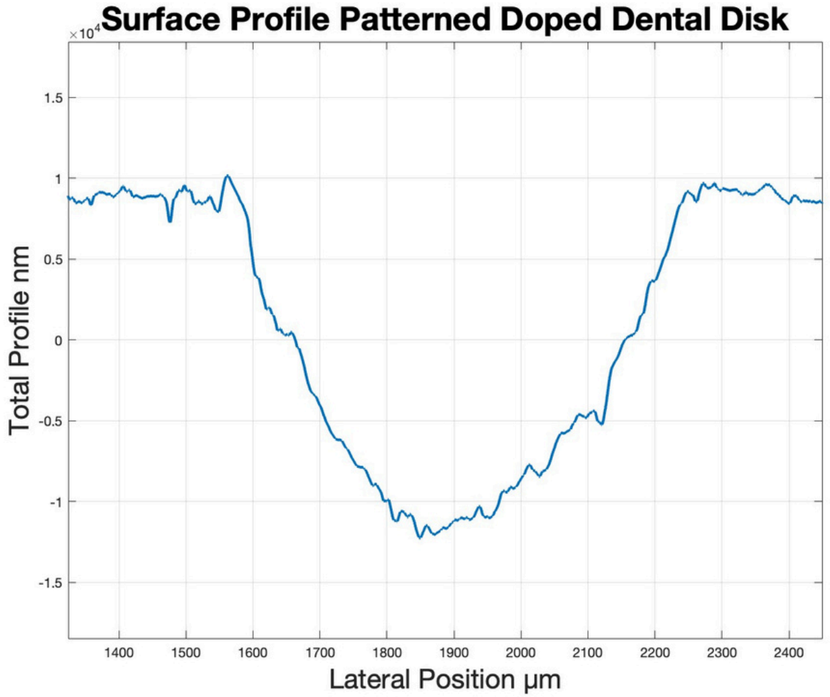
Results: Average Abrasiveness



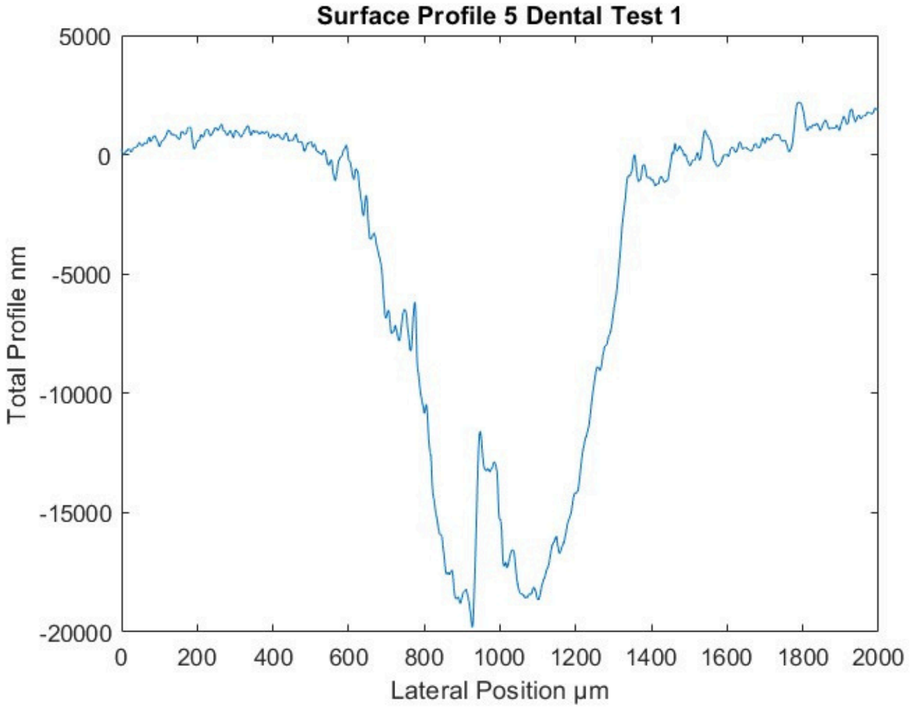
Results: Coefficient of Friction



Disk Wear Track Profile :



Patterned
Wear Volume -1.257 mm^3



Unpatterned
Wear Volume: -4.4198 mm^3

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Conclusions:

→ Surface Modification of indentations seems to reduced abrasiveness of Additive Manufactured Porcelain Coating on DLP-SLA printed Dental Resin Disk.

→ Countersuface wear was minimally impacted by patterning until 50k revolutions.

→ Disk wear track seems to be smoother for patterned disk and track wear volume was significantly less

Future Works:

1) **Further Testing**
→ Observed differences due to surface patterning were slight, and further testing would be neccescary to draw definitive conclusions

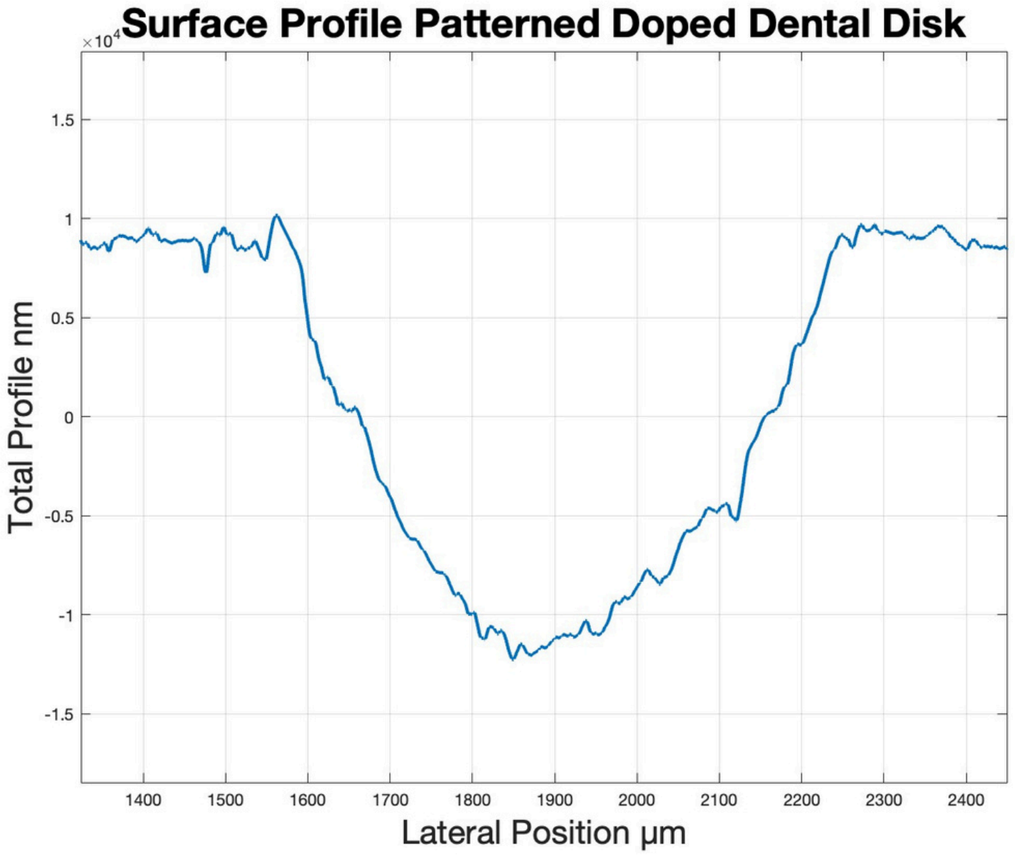
2) **Printer Modification**
→Increasing Printer resolution would help produce better characterized patterns in dental resin and pure ceramic.

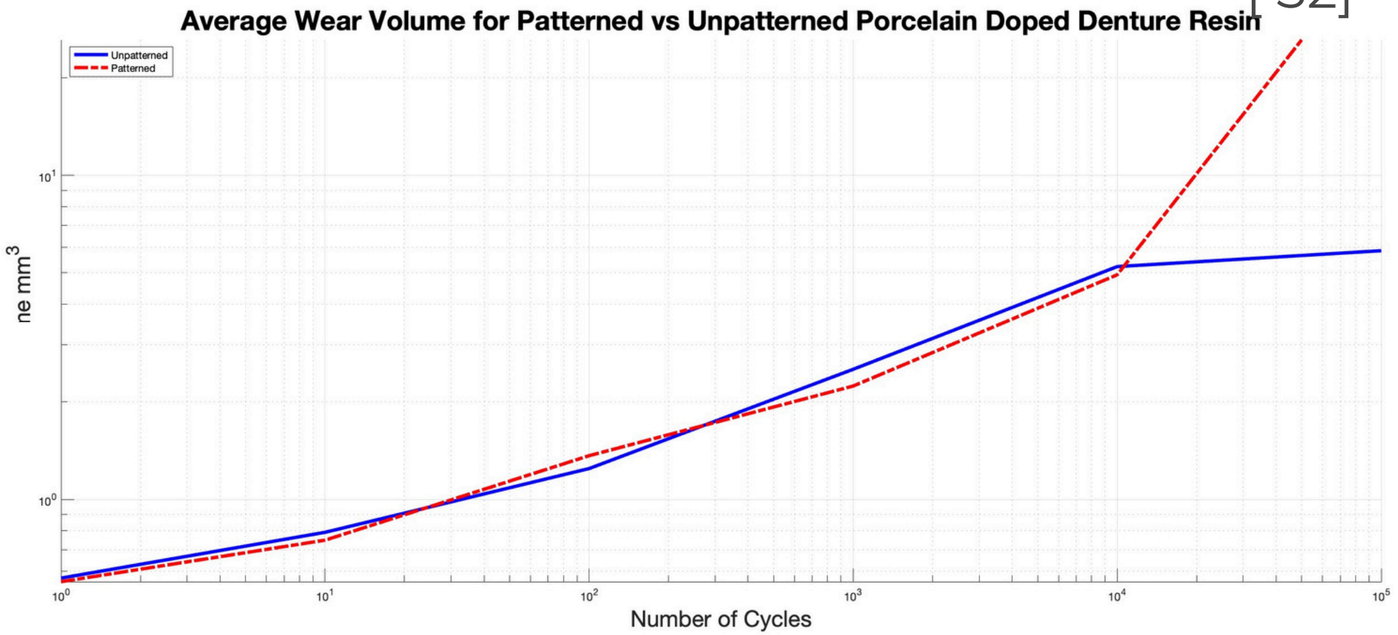
3) **Wet Sliding**
→ Adding lubricant to pin on disk testing would allow the full effects of patternign to be examined

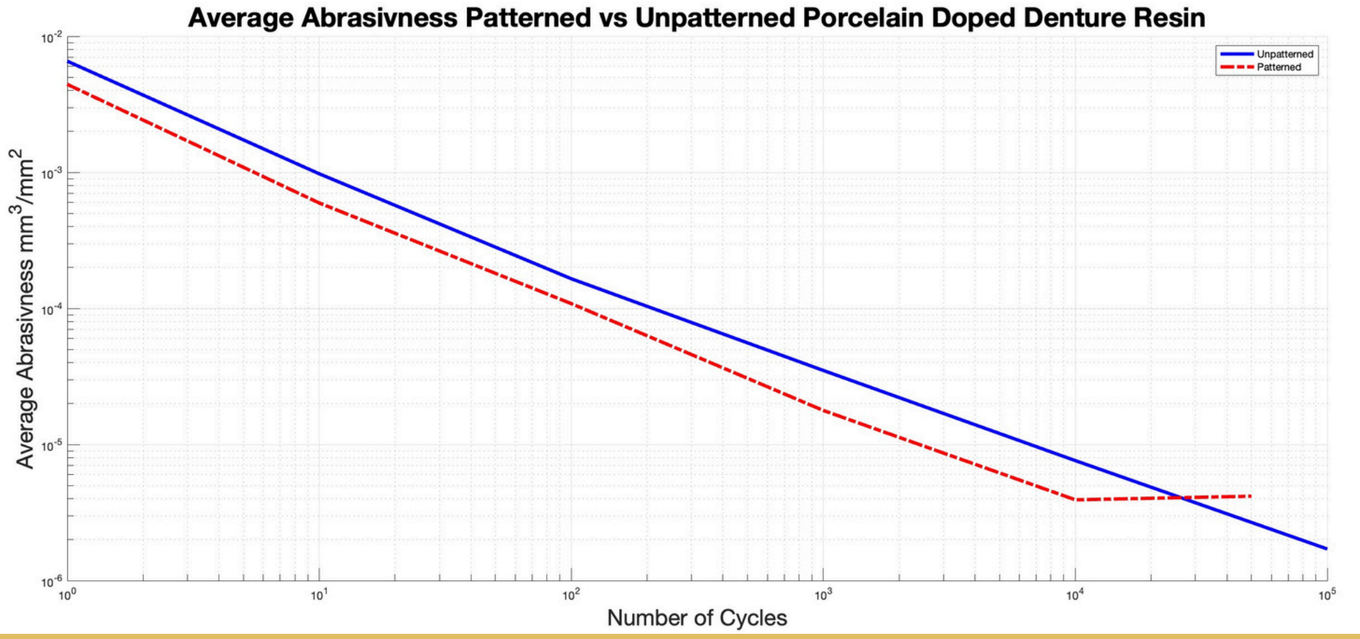
4) **Resin Formulation**
→ Improving ceramic formulation for full ceramic disk

Summary

Thank you! Questions?







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Acknowledgements

- Our Advisor, Professor Gordon Krauss
- New Lab Members: Jack Van Der Reis, Rai Wandeler, Ellen Yu, & Julia Kolt.
- Alumni Hunter Whaples and Sophie Yu for donations of resin materials to the lab
- Professor Breznay from the Physics Department for the use of the Dektak
- Our Engineering Department Support Staff: Jacob Stampei and Xavier Walters