79th stle Atlanta
Annual Meeting & Exhibition | May 18-22, 2025

HARVEY MUDD COLLEGE

Modification of Abrasiveness of SLA Additive Manufacturing Produced Components through Metal and Ceramic Additives

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Clarification of Today's Talk

Exploration of **Wear Resistance and Abrasiveness** in DLP Additive Manufacturing Produced Components with **Porcelain Ceramic Additives**

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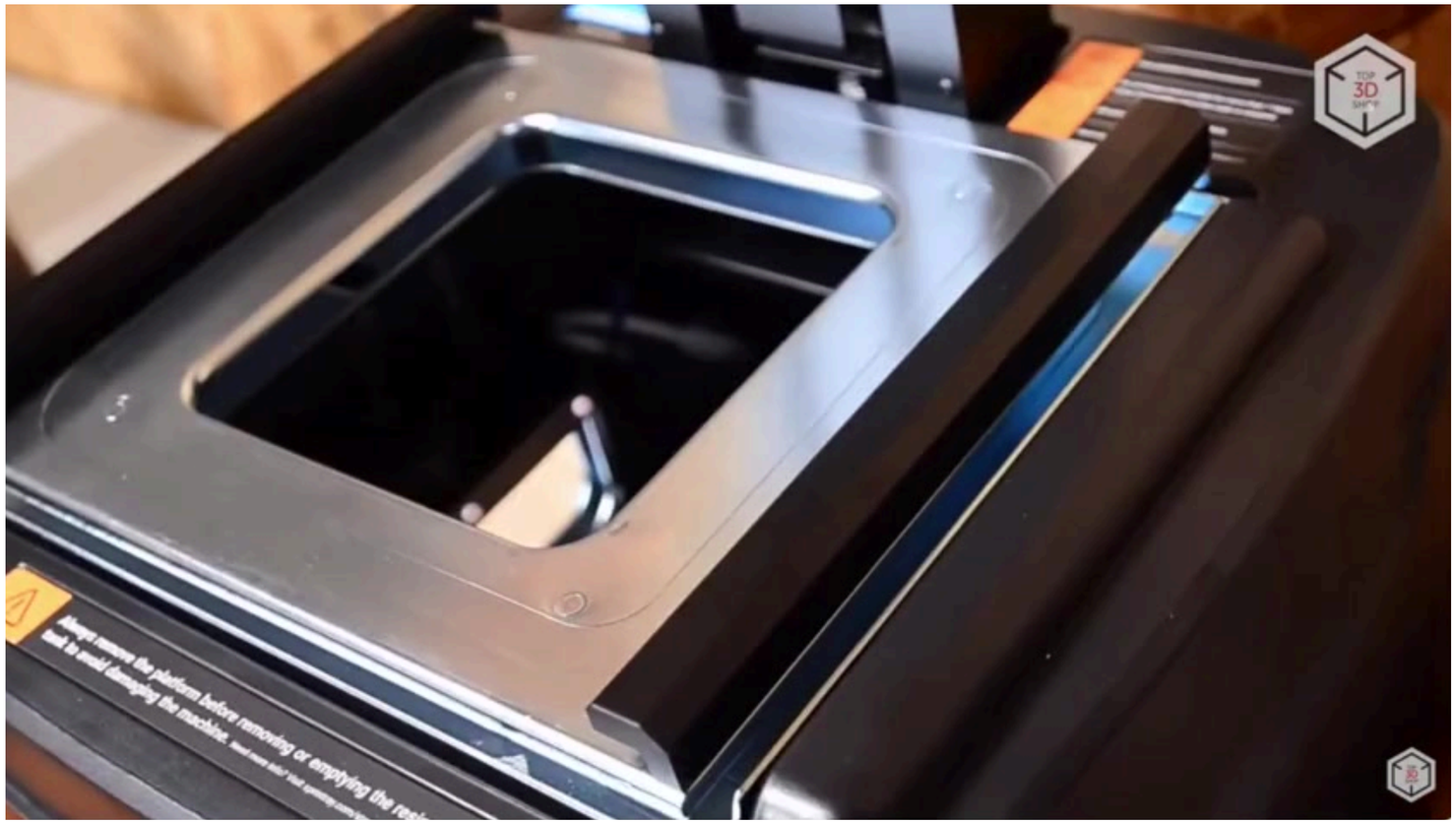
Agenda



1. About DLP Resin Printing
2. Modifying Surfaces with Additives
3. Why Denture Resin?
4. Methods
5. Testing
6. Results
7. Challenges
8. Conclusion, Next Steps

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DLP Projection Components

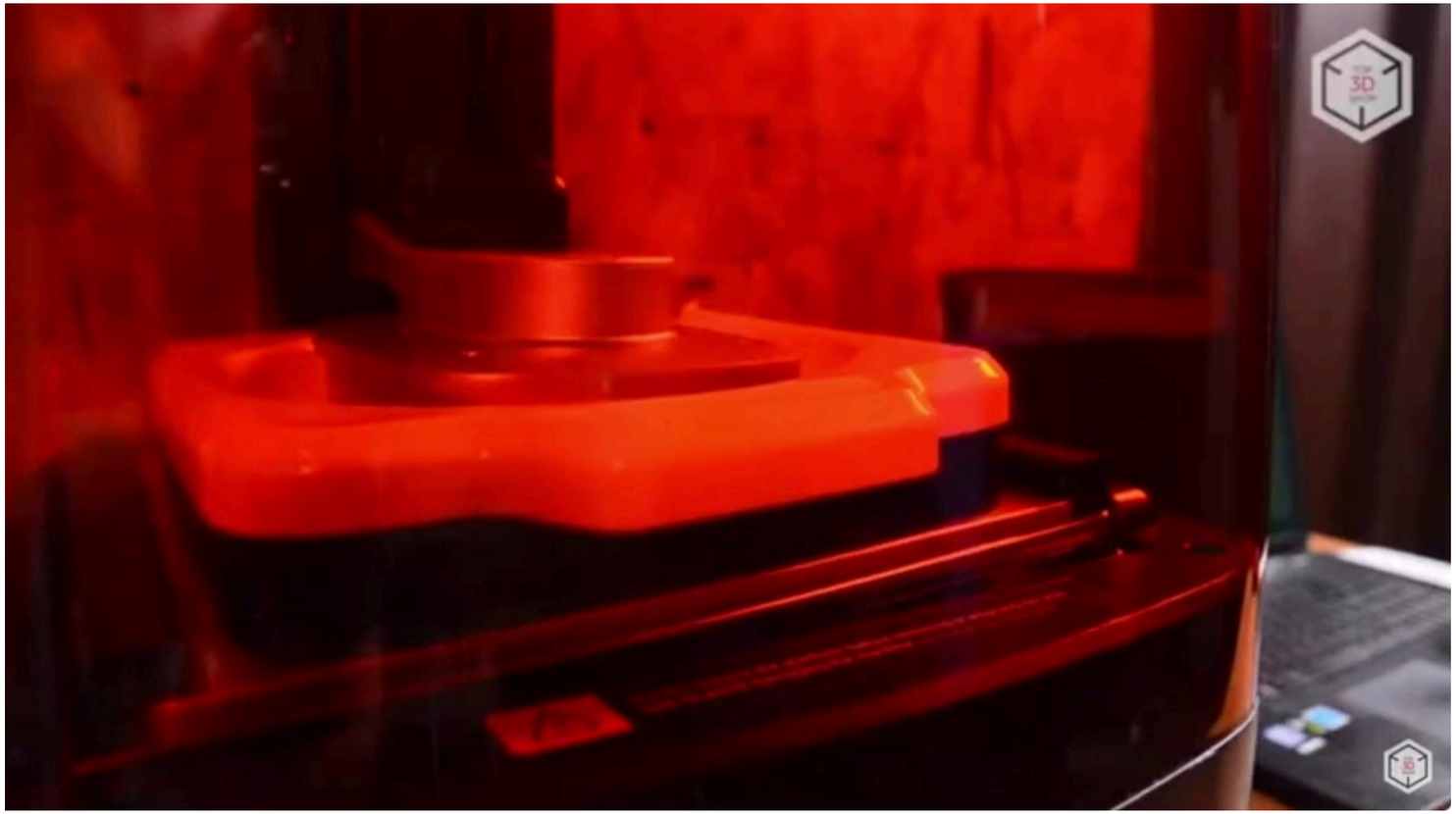


Stereolithography: 3D printing process that uses a UV laser to cure liquid resin.

Digital Light Processing: Uses a light projector rather than a laser to cure liquid resin one layer at a time

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

Video Demonstration of Printing



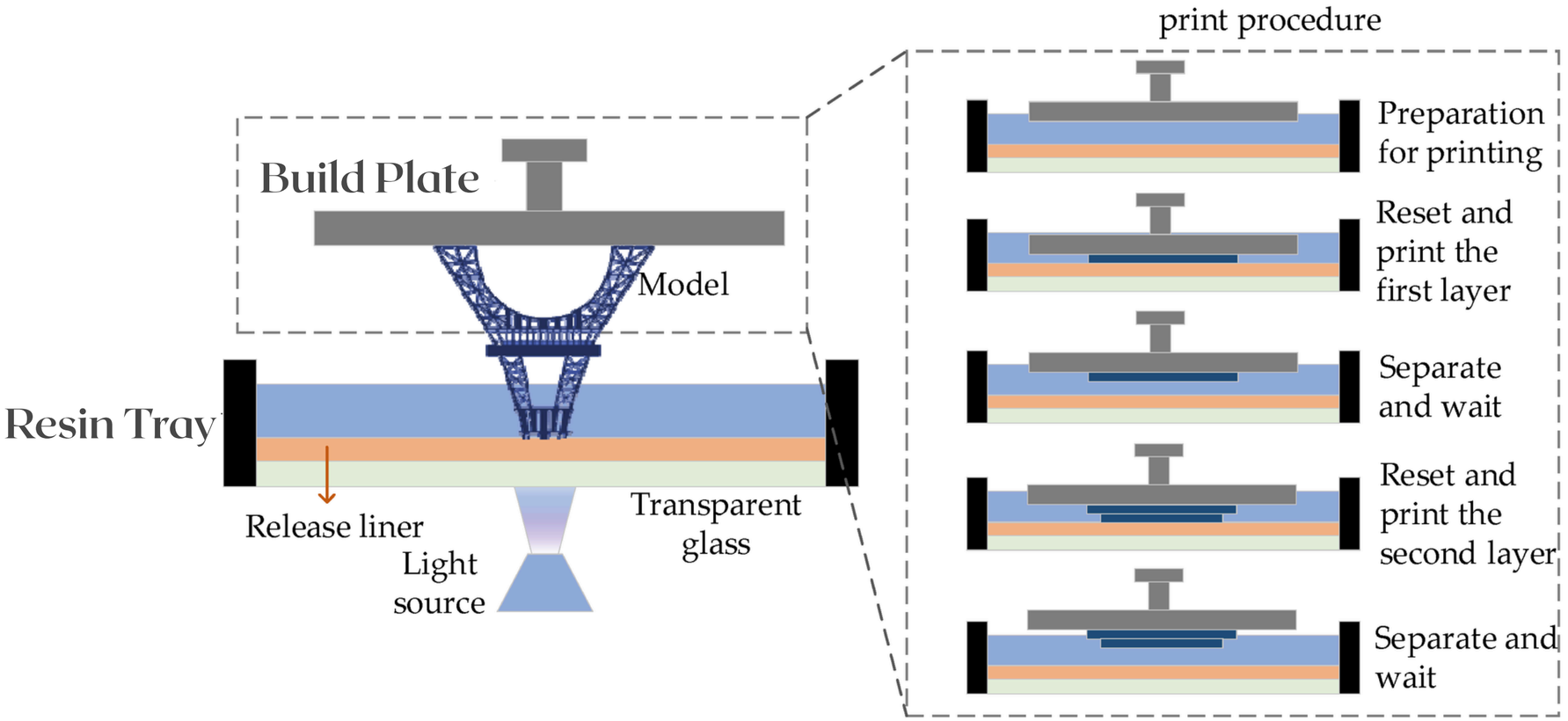
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https://top3dshop.com/product/sprintray-moonray

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.

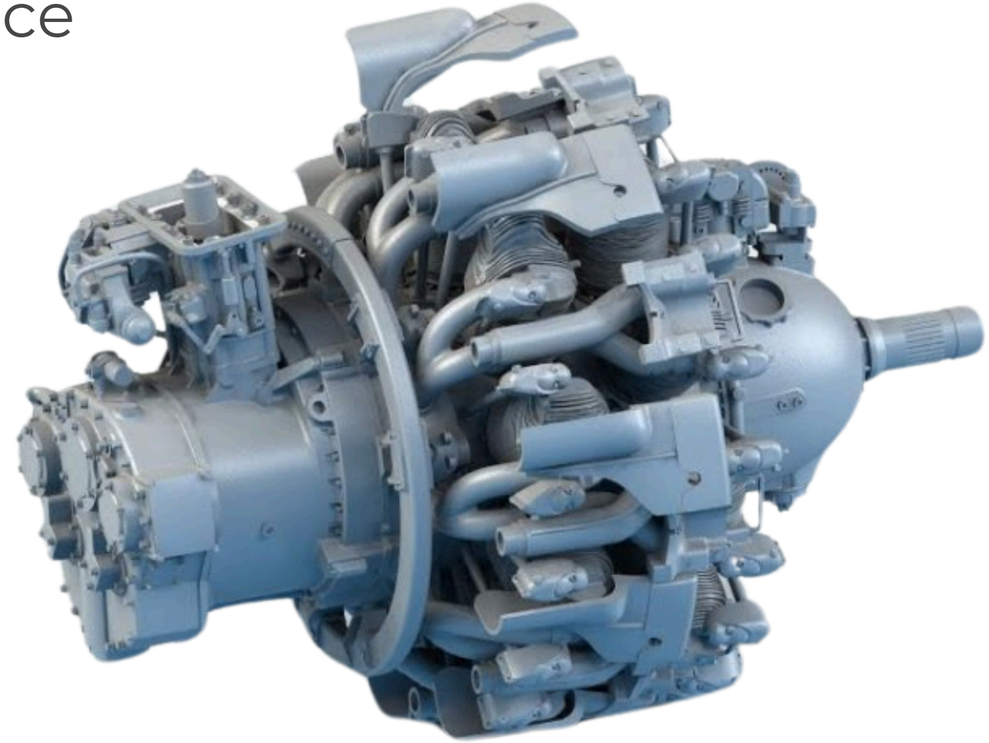
Print Applications

Dentistry



https://tecsol3d.com/es/pdf/T3D_S_Moonray.pdf

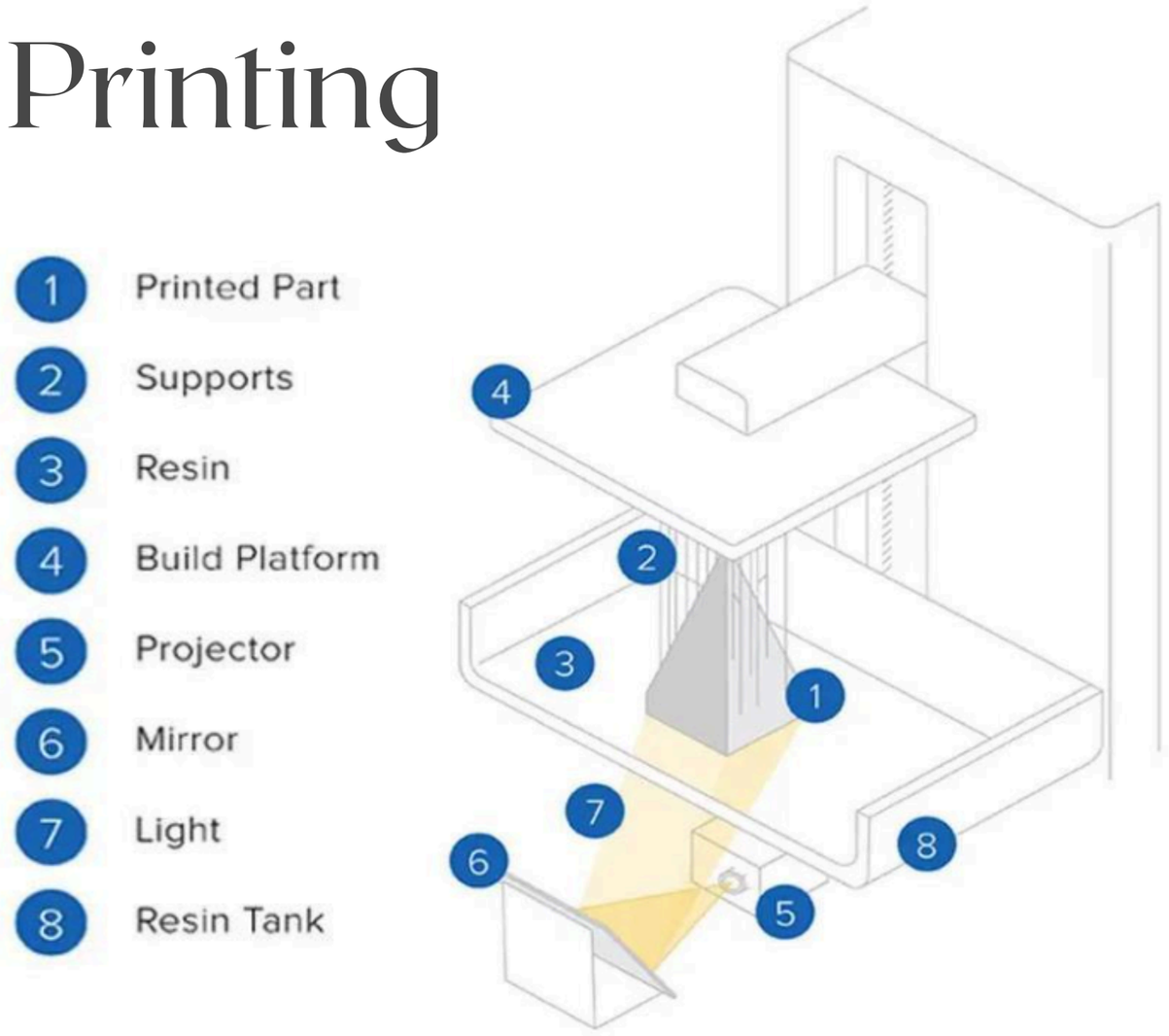
Aerospace



https://www.youtube.com/watch?v=e33SS3o4vKY&ab_channel=FlyingSModels

Advantages of DLP Printing

- Provides finished, smooth surfaces with no tooling required
- Higher Resolution ~ 20 µm layer thickness
  - Minimum Lateral Feature Size 100 µm
- Build Volume: 130 x 80 x 200 mm
- Print Speed: 100 µm/hour



https://ameralabs.com/blog/the-complete-resin-3d-printing-settings-guide-for-beginners/?srsltid=AfmBOop2Zhm_mLRUrYnp9lPNk1Iy9sNh_QYtHd5XJrhgu6AczYTF3SHP

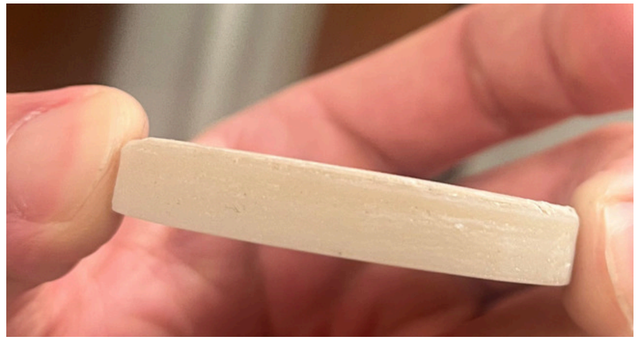
"SLA vs. DLP vs. MSLA vs. LCD: Guide to Resin 3D Printers," Formlabs. Accessed: Sep. 15, 2024. [Online]. Available: https://formlabs.com/blog/resin-3d-printer-comparison-sla-vs-dlp/

Research Scope

Characterize the wear resistance and abrasiveness of components produced using DLP printing with commercially available denture resin with ceramic additives.

Denture Resin

- Simple curing process involving food-grade glycerin
- Durable and more sturdy compared to other resins
- Contains acrylic oligomers and monomers
- Approximately as dense as water
- Biocompatible



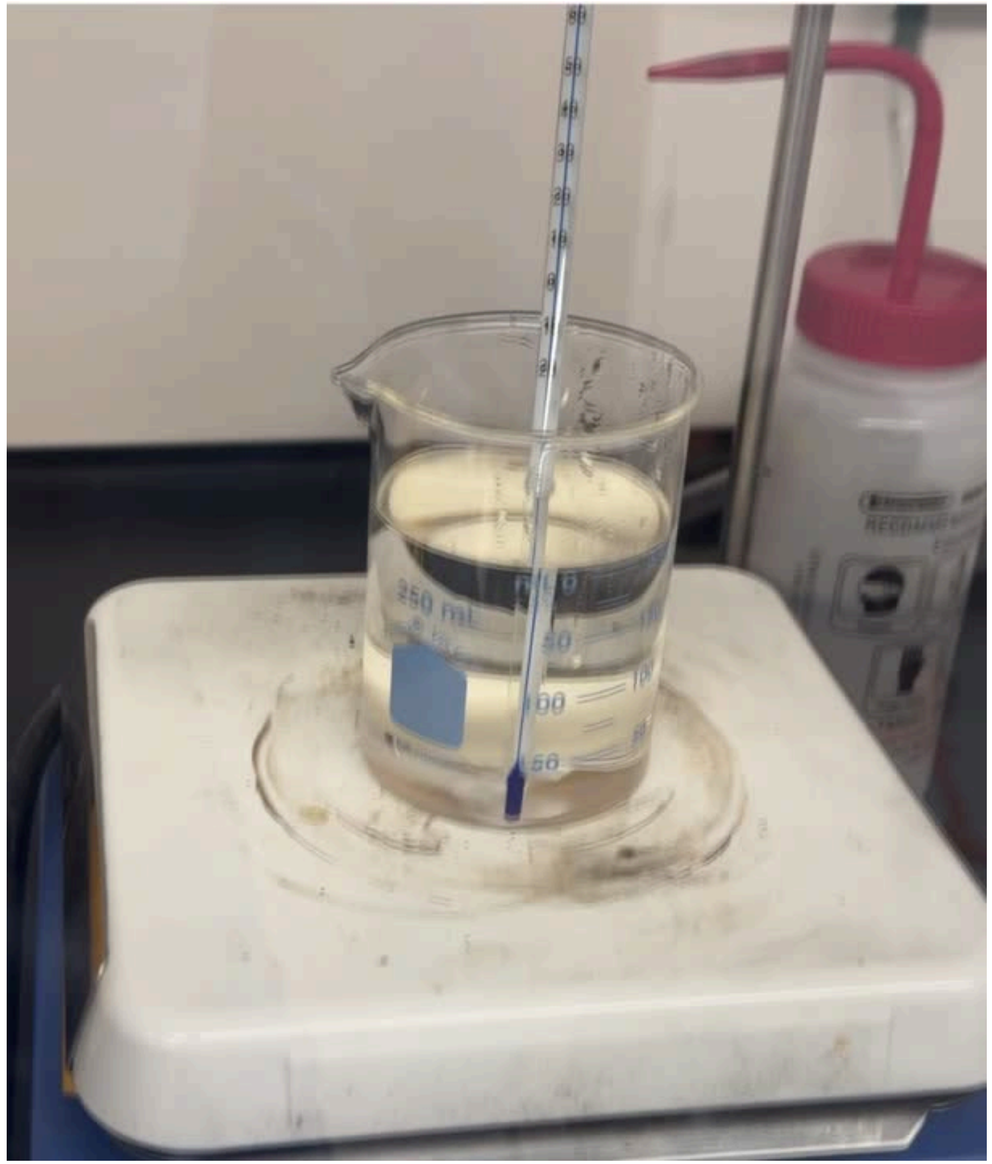


Before Curing		
Viscosity at 25+/-0.5°C	cps	1000 < x < 2000
Density	g/cm3	1.05 < x < 1.20
After Curing		
Density	g/cm3	1.15 < x < 1.25
Flexural Strength	MPa	>50
Degree of Conversion	%	>70

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

Curing Dental Resin

- Vegetable glycerine heated to a minimum of 60°F
- Samples fully submerged for 40 minutes
- Curing process solidified and hardened samples, which improved material performance



Ceramic Additives for 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

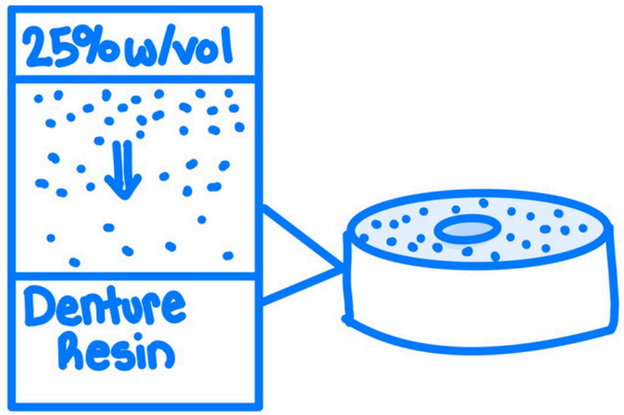
Hypothesis

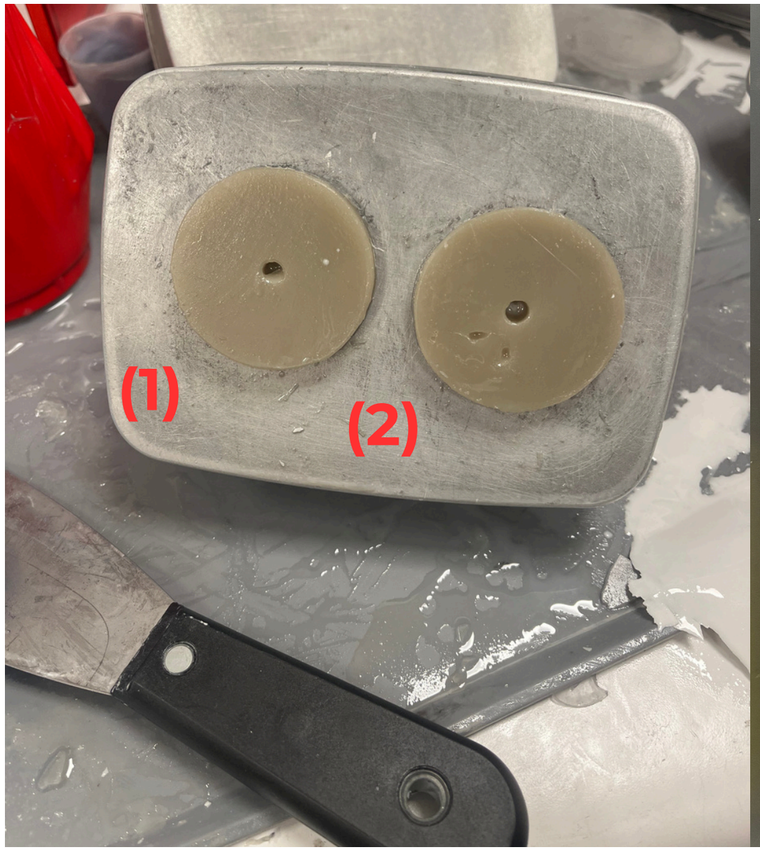
By adding a top layer of porcelain we will be able to alter dental resin surface abrasiveness and wear resistance.

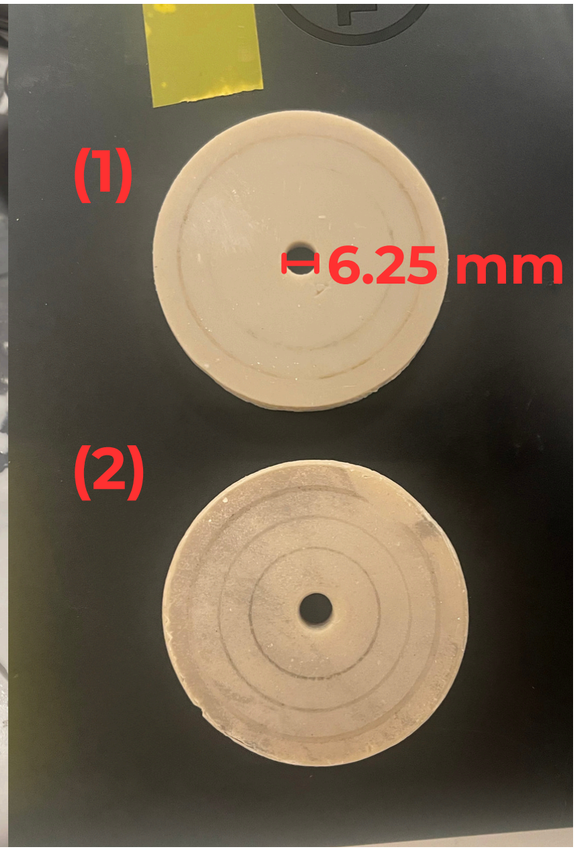
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Mixture of Denture Resin and Porcelain Powder

- Sample 1: Fully-doped porcelain
  - 25% weight by volume
- Sample 2: Gradient of porcelain







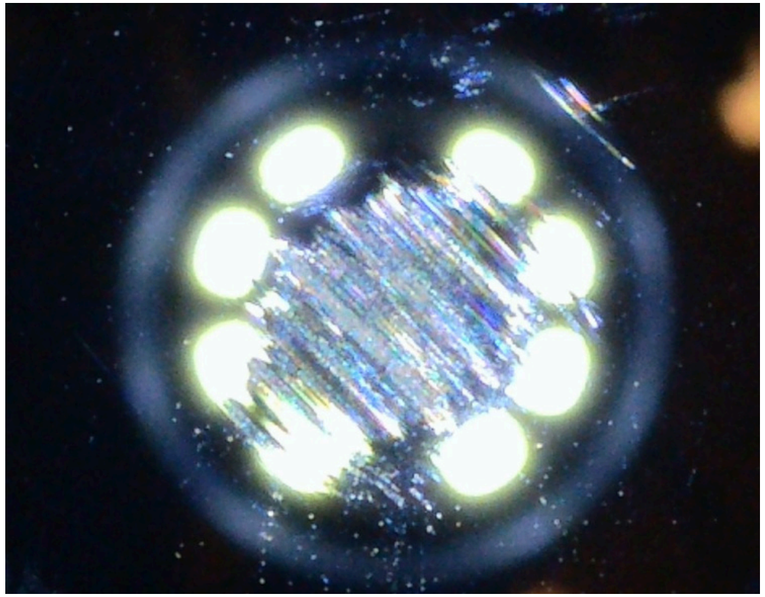
Testing of Denture + Porcelain Disks

- 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 Balls
  - Hardness: 62 HRC
  - Size: 3.2 mm
  - Force: 1N
  - Speed 75 mm/s
  - Dry Sliding
  - 30-40% relative humidity
  - 21-22 °C

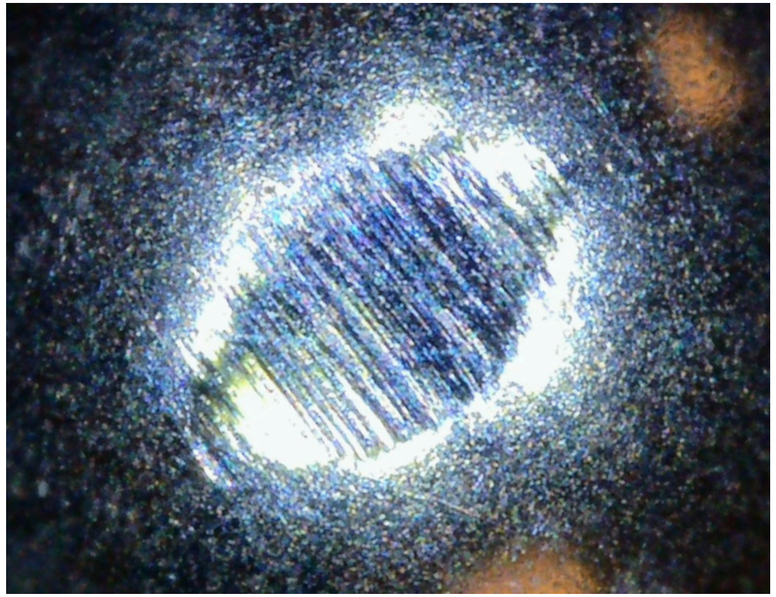


Scars of Denture + Porcelain Disks

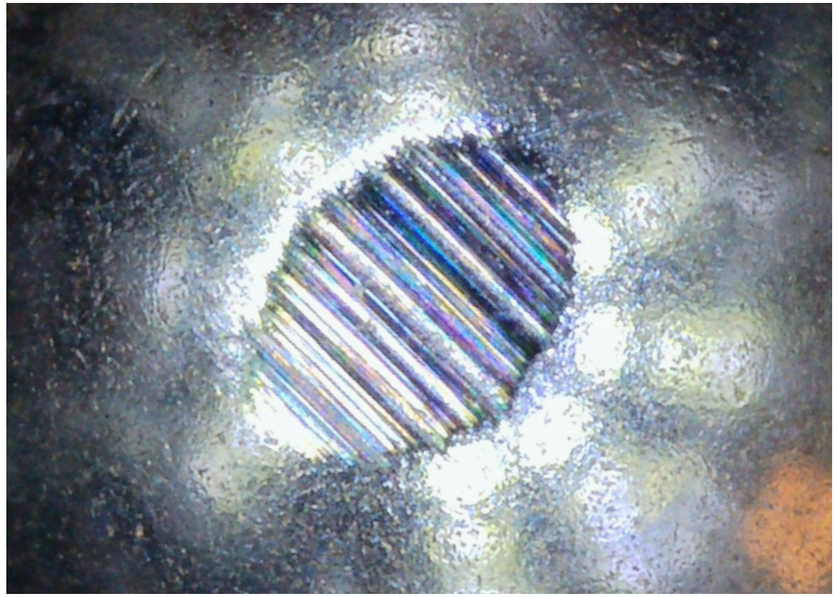
10k Cycle Tests



Undoped



Gradient



Fully Doped

Wear Volume Calculations

Where R is the radius of the ball:

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

h is the height of the scar given by the Pythagorean Theorem:

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

s is the radius of the scar.

Wear Volume Calculations

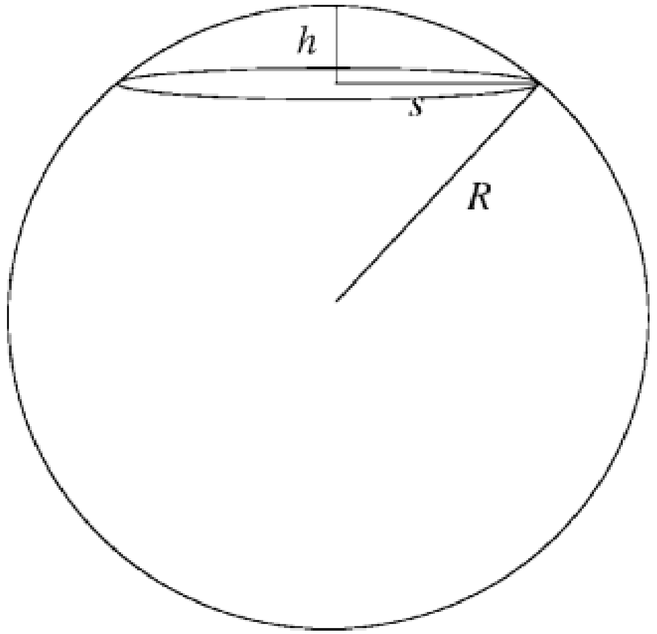
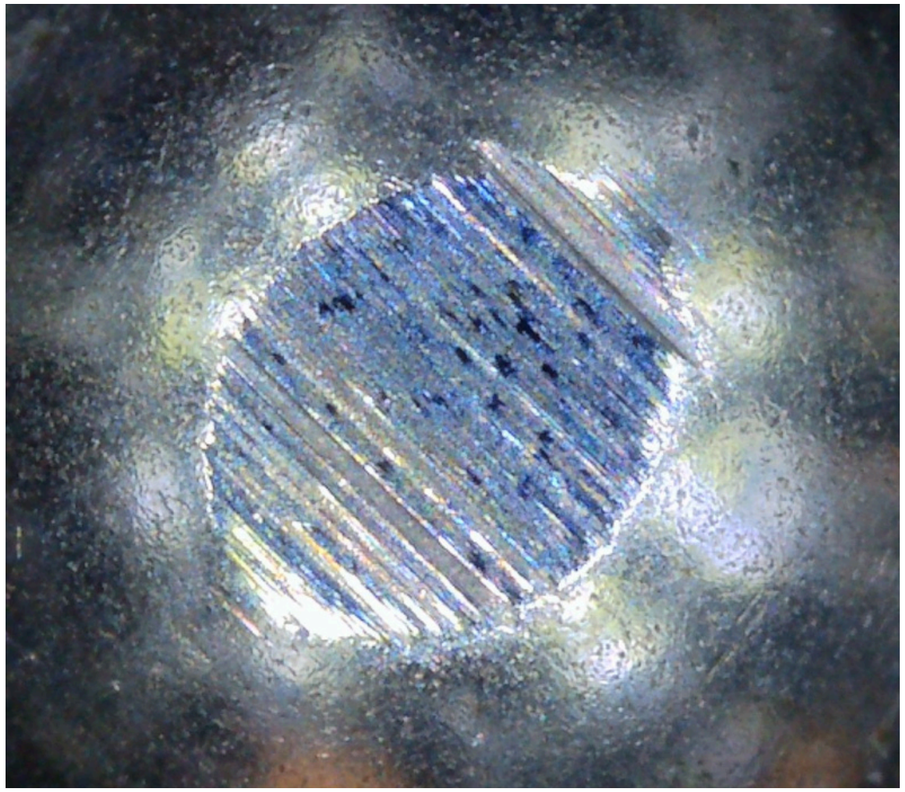
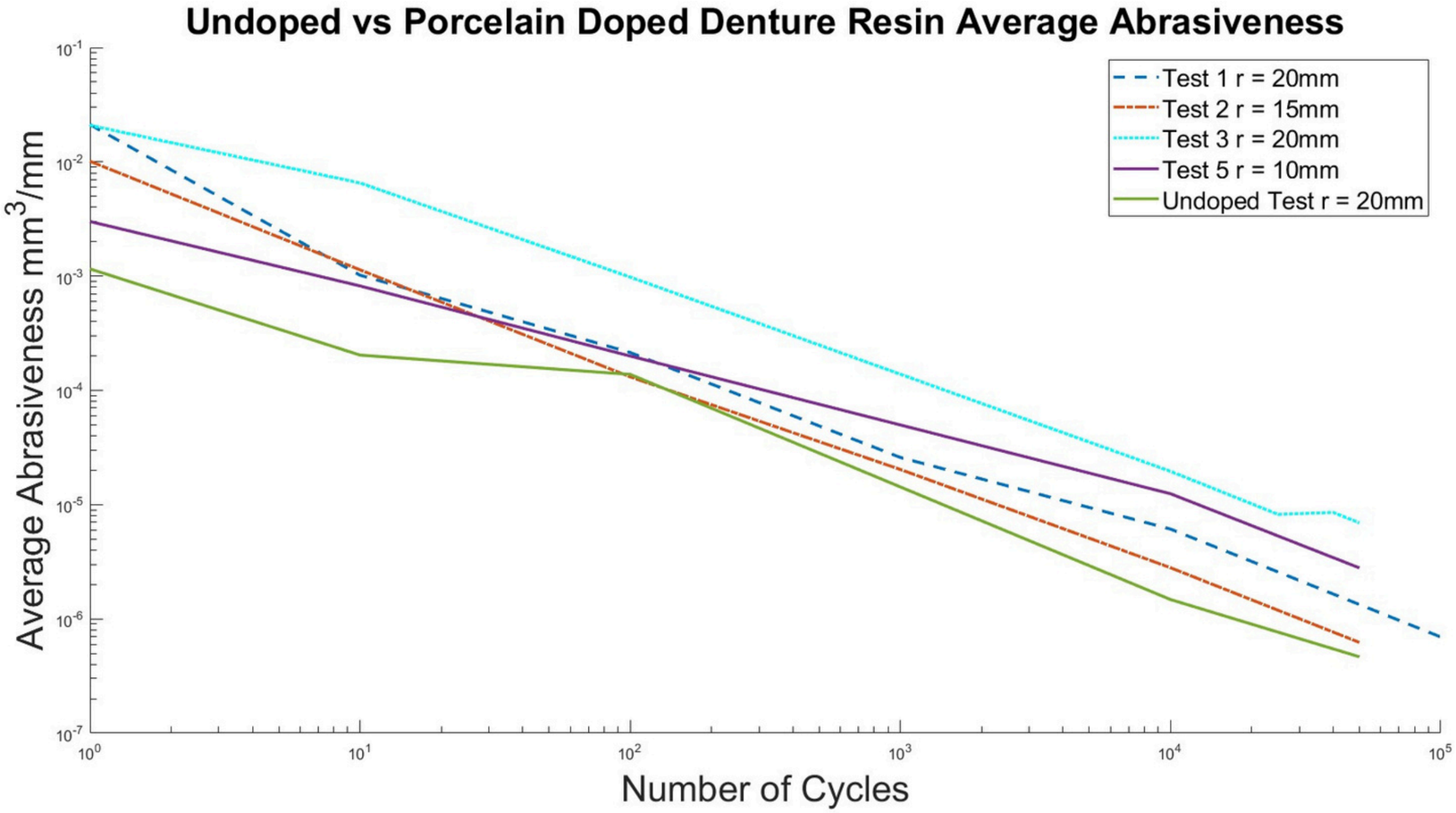


Figure 1. Schematic drawing of a ball with a missing "cap", corresponding to a wear scar.

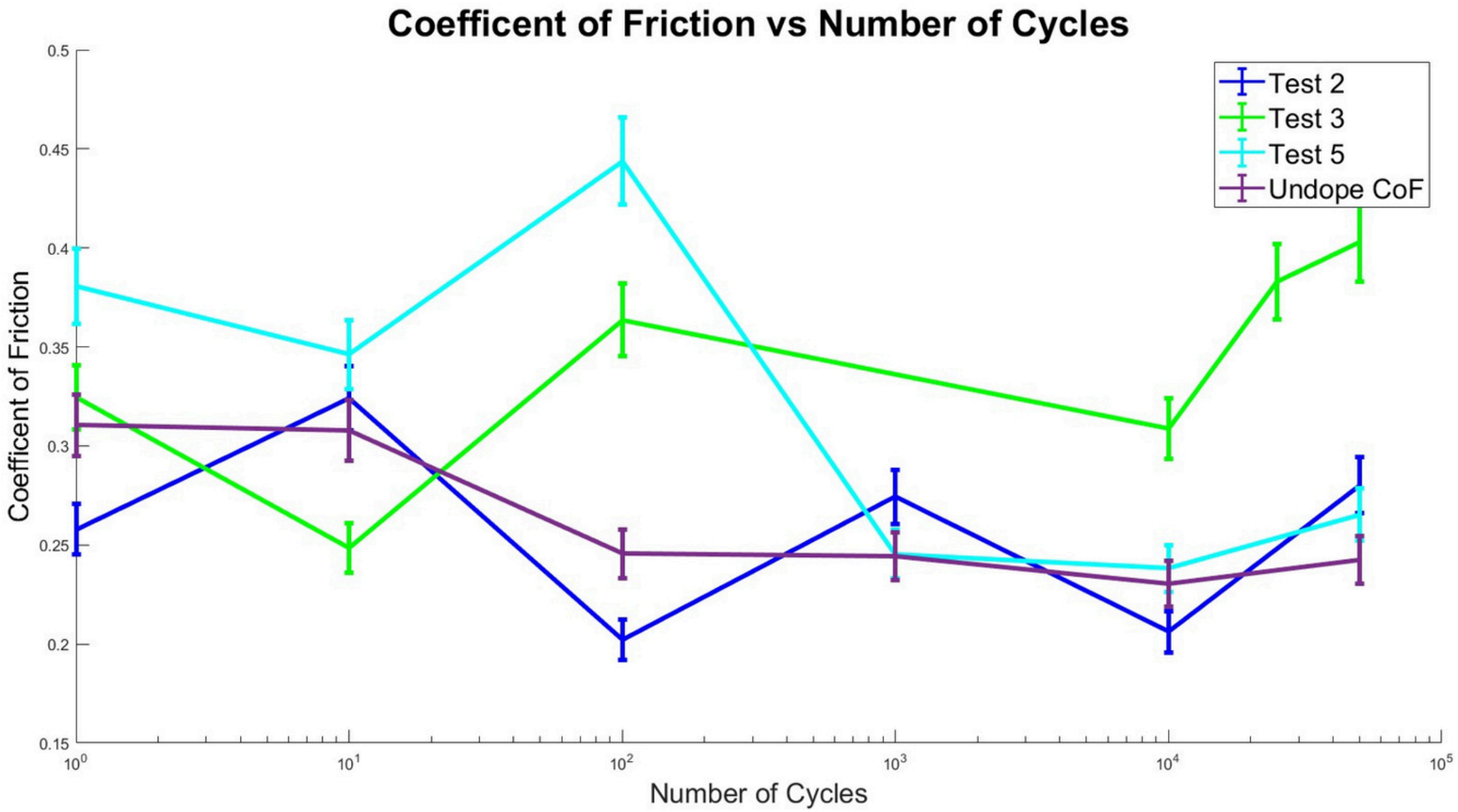
Figure from S. J. Harris and G. G. Krauss, "Improved technique for measuring the ball volume removed in a ball-on-disk test," Tribology Letters, vol. 10, no. 3, pp. 187–188, Apr. 2001, doi: 10.1023/A:1009014524815.



Wear Volume Results

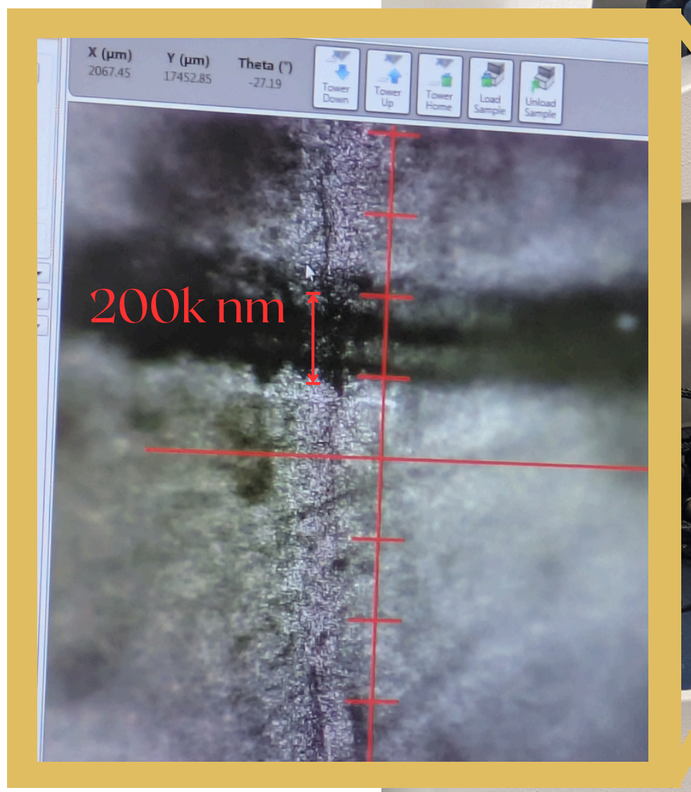


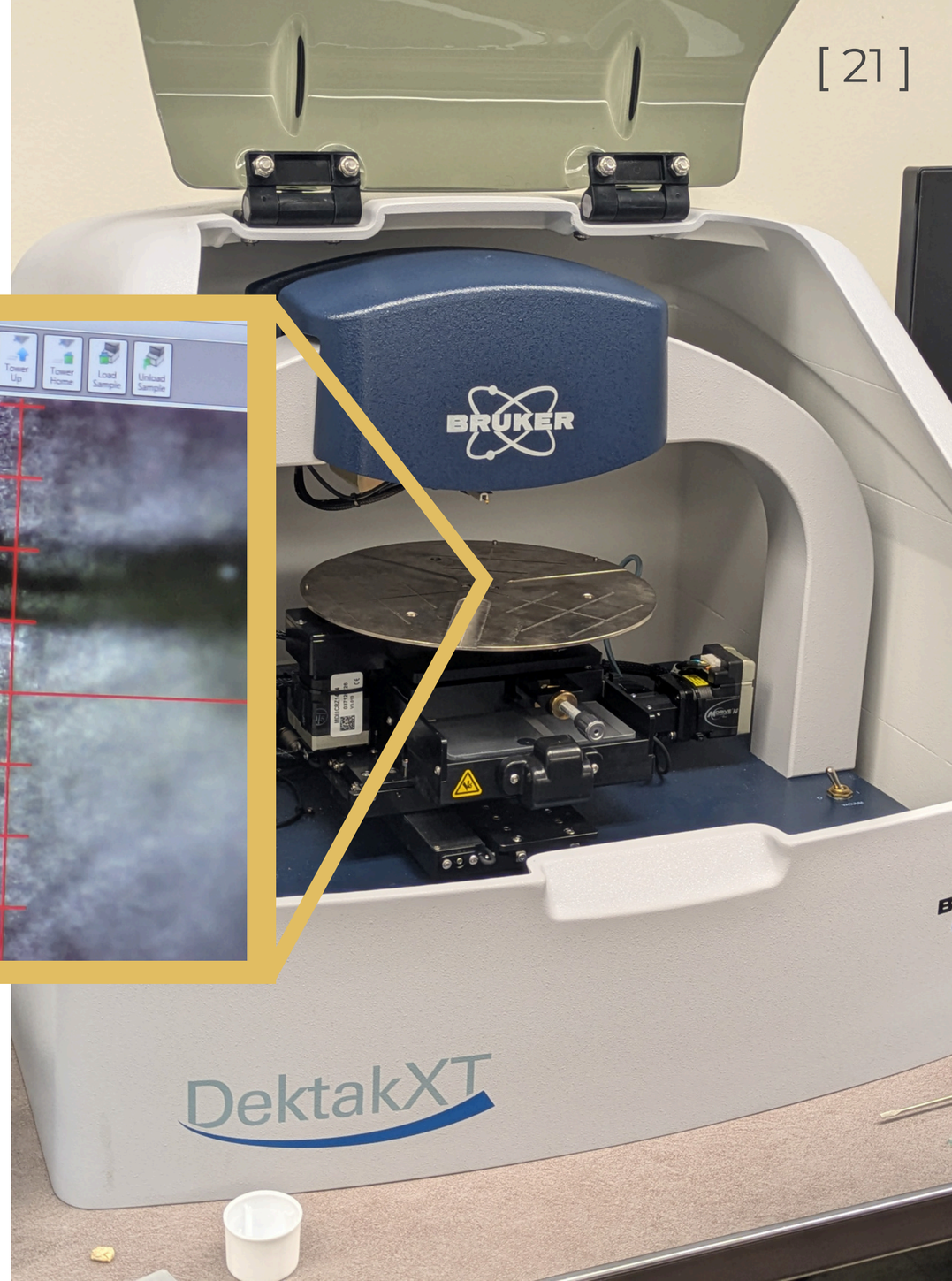
Average Abrasiveness Results



Dektak

- Profilometer that provides information on topography
  - Measures displacement as a function of position
  - Can create a height vs. 1D position graph
  - Sample moves with respect to the tip and traces a line forward
- Varied force and time across desired areas

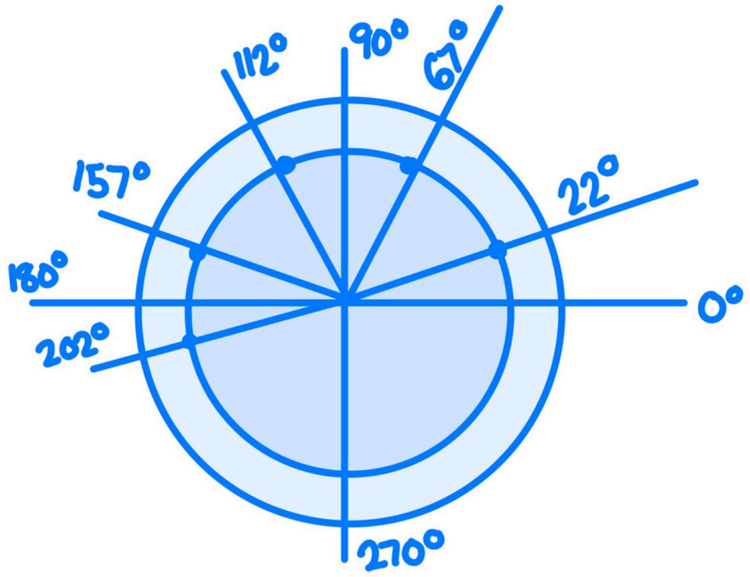


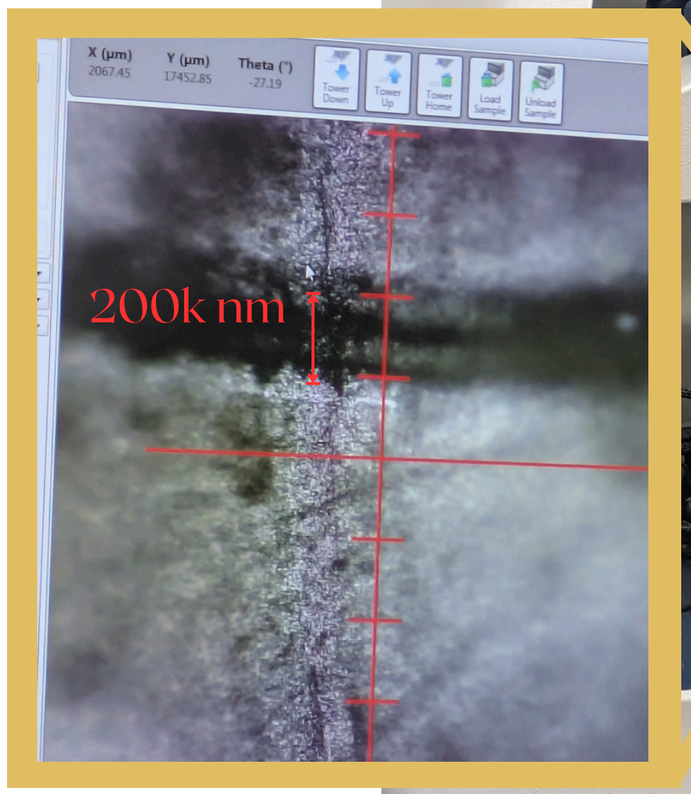


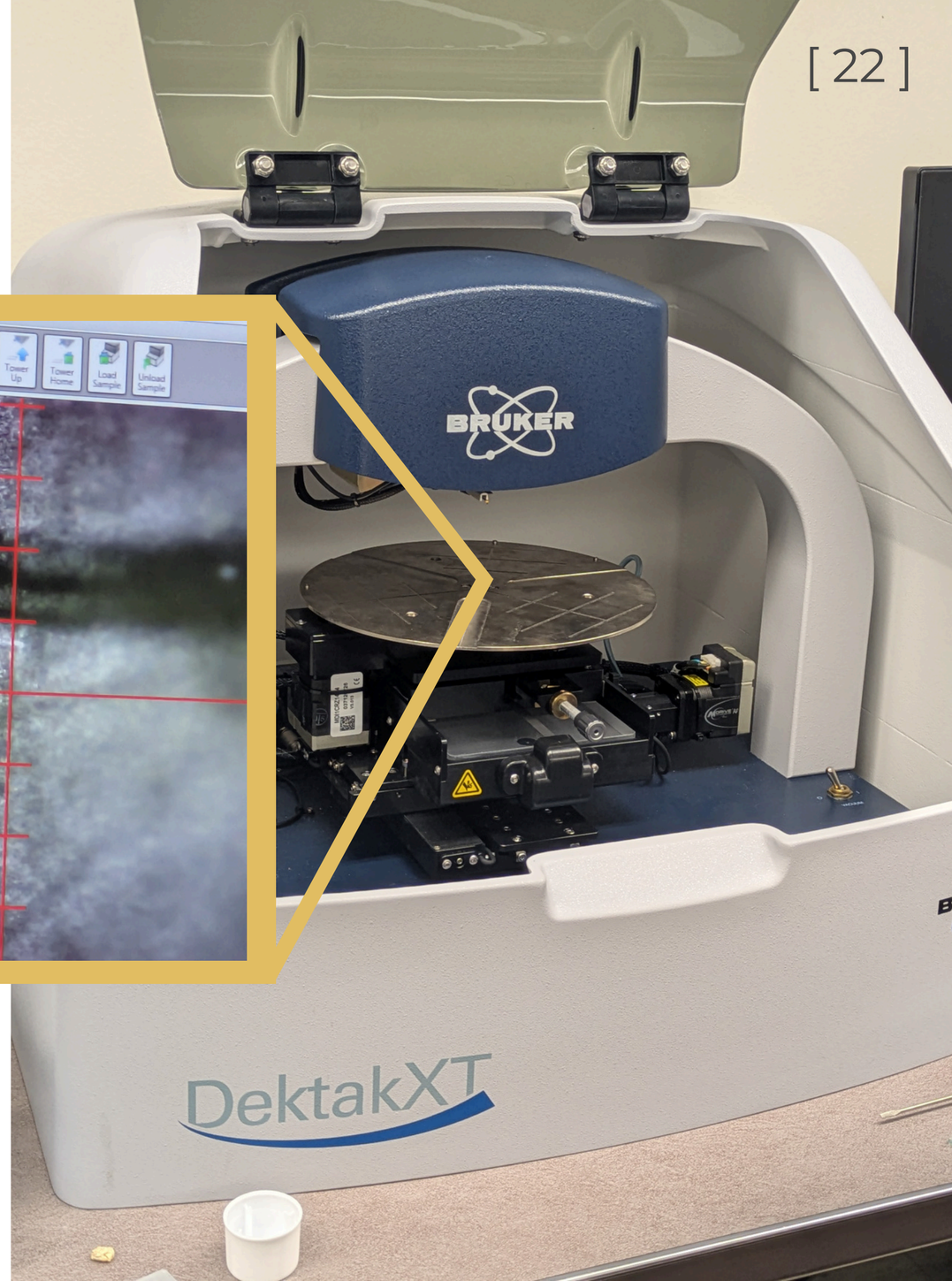
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Dektak

- Traveled in 45-degree intervals around the tracks to average width and depth





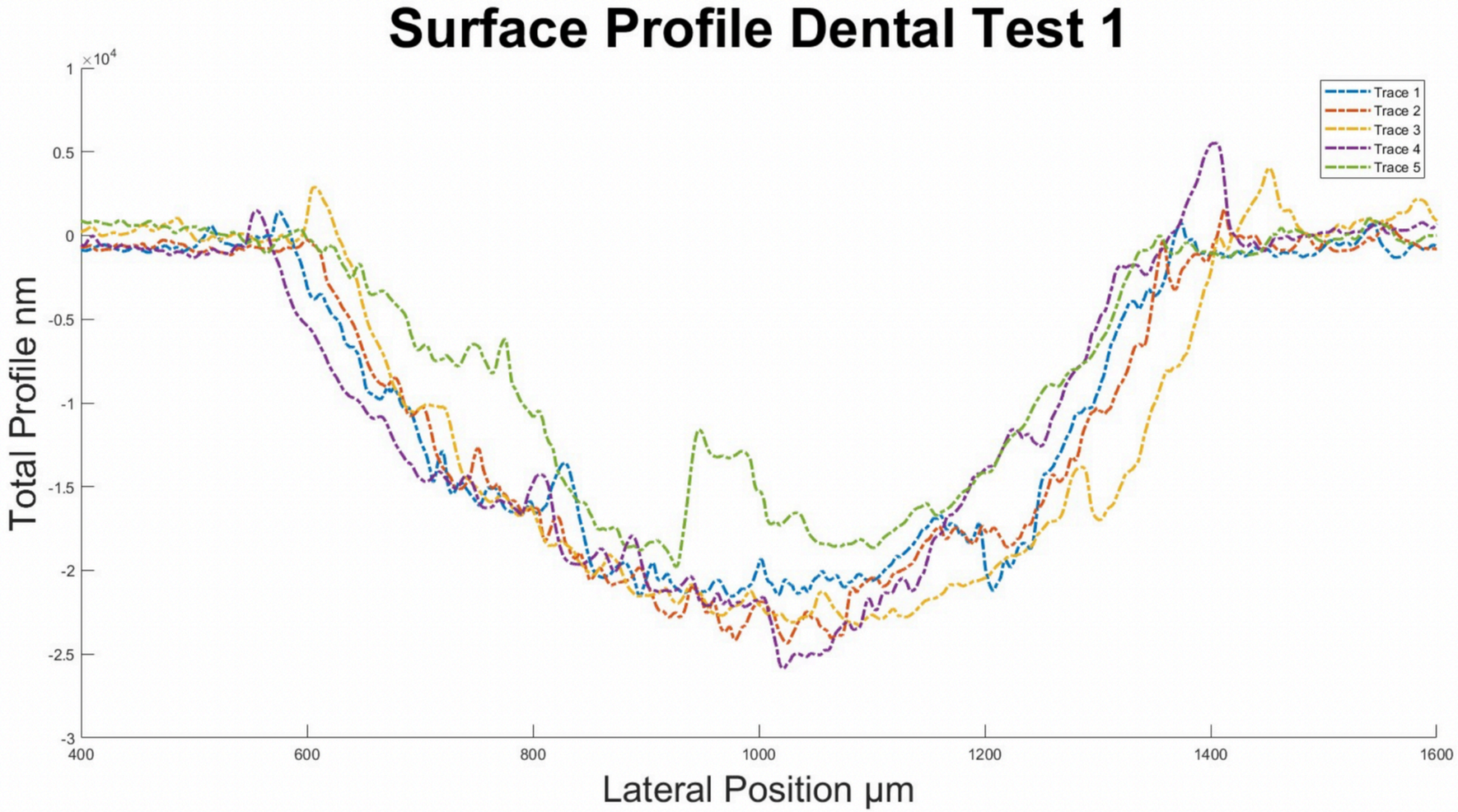


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Surface Profiles, Dental Test 1

Dental Test 1: Represents Fully-Doped Disks with No Gradient. Outermost ring

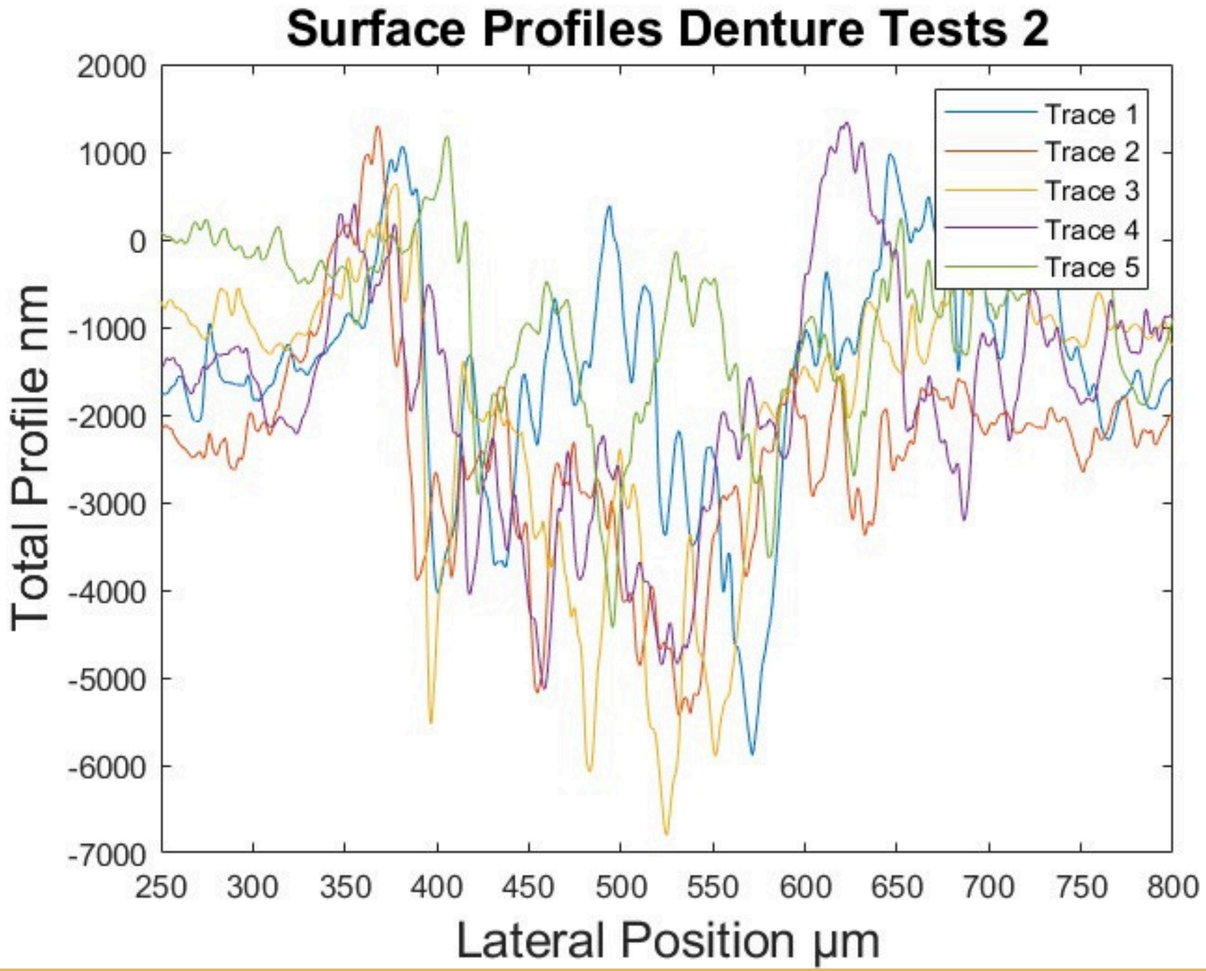




Surface Profiles, Dental Test 2

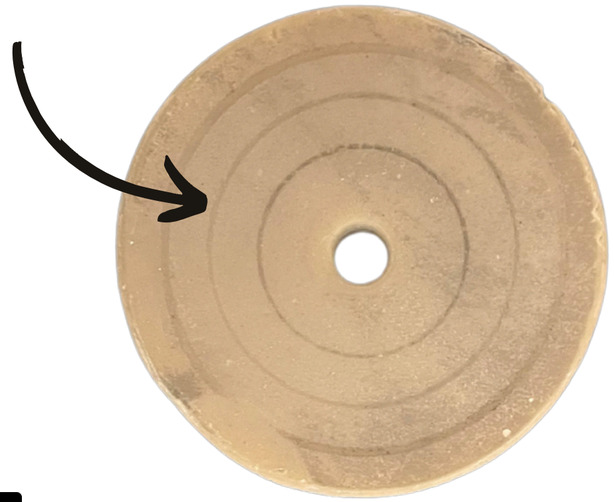
Dental Test 2:
Represents Fully-Doped Disks with No Gradient.
Inner ring

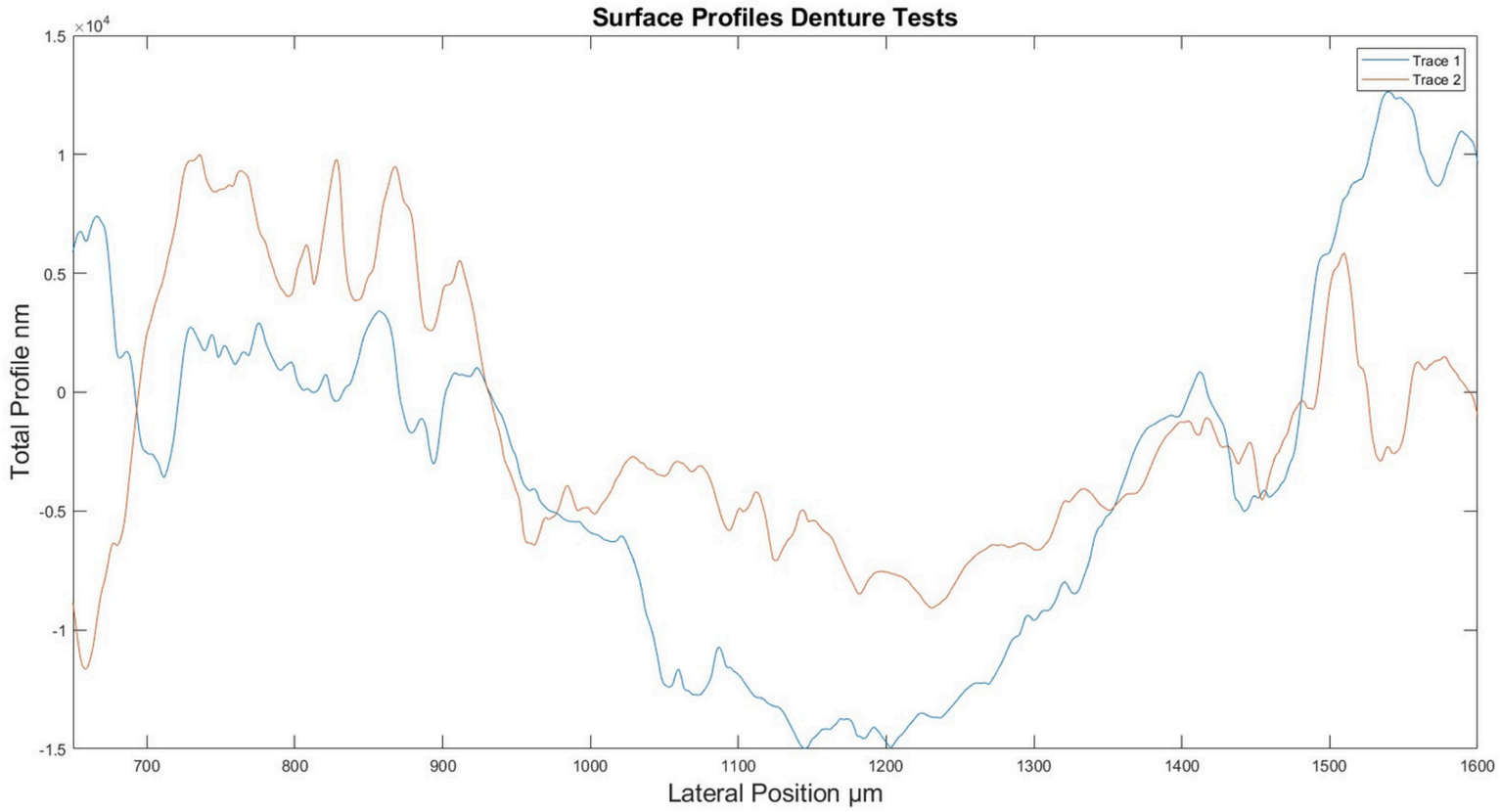




Surface Profiles, Dental Test 3

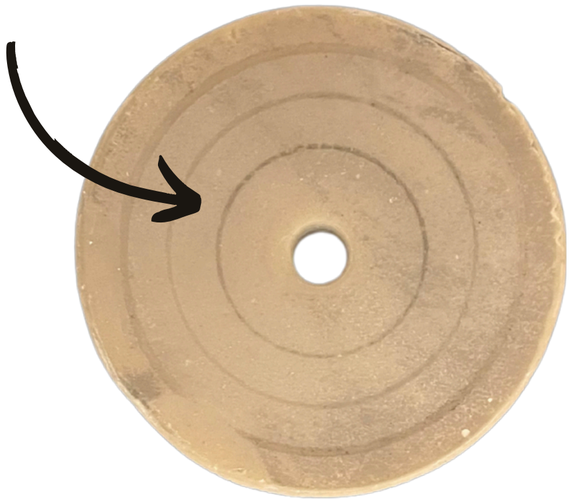
Dental Test 3:
Represents Gradient
Disk
Middle ring

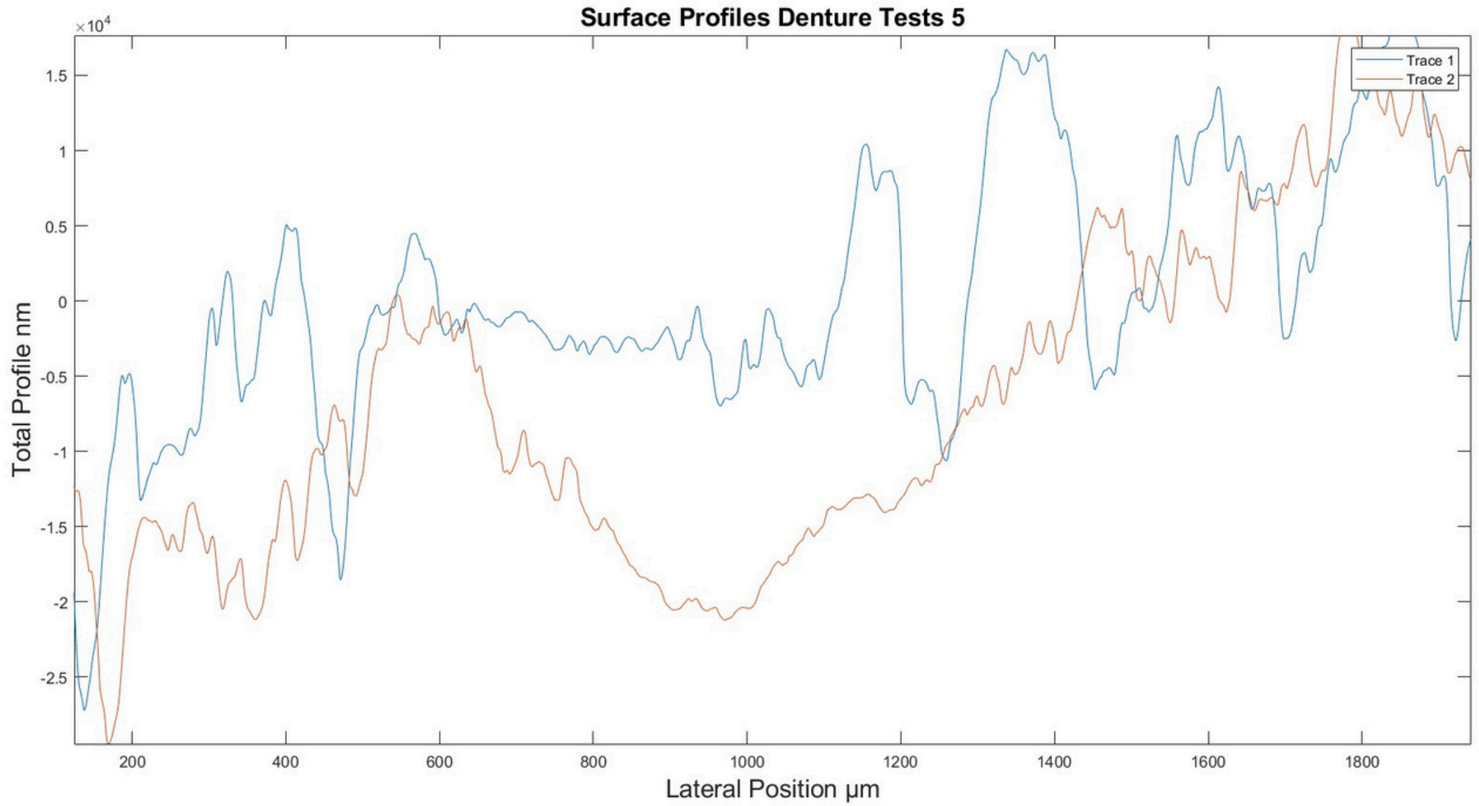




Surface Profiles, Dental Test 5

Dental Test 5:
Represents Gradient
Disk
Inner ring





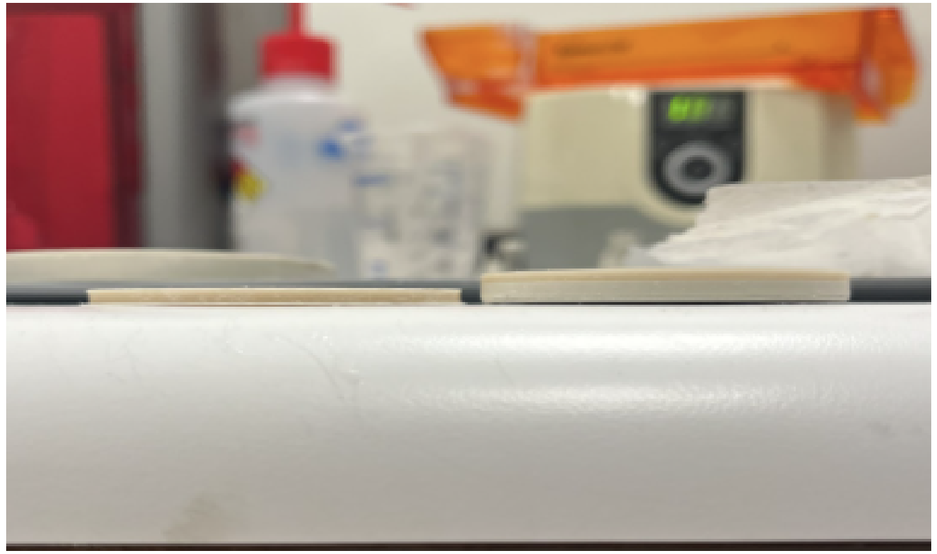
Conclusion

We are seeing a change in wear resistance and abrasiveness over a range of trials using the UMT. Our preliminary results suggest that top-layer doping decreases wear resistance and increases the coefficient of friction.

Challenges

Changing dental resin formulations between layers resulted in delamination, which is why we chose to do a gradual gradient.

The build plate caused surface roughness, which made the baseline conditions of the bottom and top surfaces different.



Future Works

- Different Resin Formulations - Metal Additives, Alumina Additives, Ceramic Mixing
- Futher Investigating Different Gradient Distributions of Porcelain
- Further Surface Modifications - Patterning
  - The next talk is a pilot study of patterning porcelain-doped surfaces on dental resin disks!

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
- Sprague Summer Research Funding from Harvey Mudd College

Summary

Thank you! Questions?

