Medical Art Prosthetics: Composite Polymers

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Client: Mr. Gregory Gion

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Problem Statement

- Prostheses achieve adequate levels of realism and comfort, but have significant issues:
  - Expensive fabrication
  - Wear and tear
    - Loss of material
    - Discoloration
- **Goal:** Devise a fabrication method using alternative polymers to change the surface properties of the prosthesis while maintaining the desirable properties
  - Increase durability
  - Decrease coefficient of friction
  - Maintain aesthetics

Figure 1: Recreation of a missing finger[1]

1. Gion, G., MMS, & CCA. (n.d.). Home. Retrieved February 10, 2018, from http://www.medicalartprosthetics.com/

Background

- **Client:** Mr. Gregory Gion, BA, BS, MMS
  - Founder of Medical Arts Prosthetics, LLC
  - Maxillofacial prosthetist
  - Specializes in anaplastology and artistic recreation of skin aesthetic on prostheses

Mr. Gregory Gion, BA, BS, MMS[1]

1. Gion, G., MMS, & CCA. (n.d.). Home. Retrieved February 10, 2018, from http://www.medicalartprosthetics.com/

Design Specifications

- **Design Specifications**
  - Budget: $500
  - Must look life-like
  - Increase tear strength
  - Lower μ than current silicone models
  - Decrease wear rate
  - Exhibit UV resistance
  - Not affect color accuracy or appearance

Figure 2: Recreation of a missing finger[1]

1. Gion, G., MMS, & CCA. (n.d.). Home. Retrieved February 10, 2018, from http://www.medicalartprosthetics.com/

Motivation

- Aid in patient integration into society
- Undergo deformation and discoloration
- High cost → Insurance replaces every 5 yrs → requires longevity of device

Figure 3: Fungal growth on a silicone prosthetic[2]

Figure 4: Recreation of a missing finger[1]

1. Gion, G., MMS, & CCA. (n.d.). Home. Retrieved February 10, 2018, from http://www.medicalartprosthetics.com/
2. A. Udagama, "URETHANE-LINED SILICONE FACIAL PROSTHESES," Journal of Prosthetic Dentistry, vol. 58, no. 3, pp. 351-354, Sep 1987.

Materials and Methods: Sample Fabrication

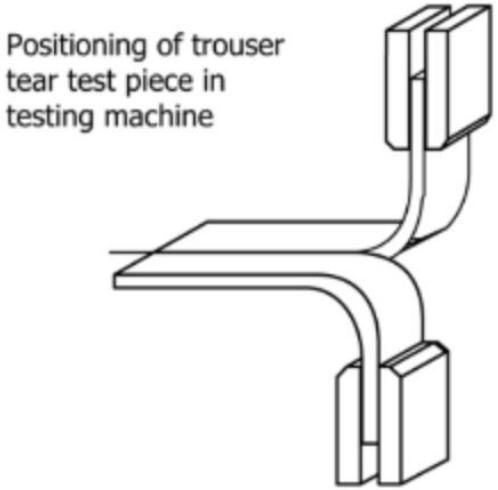
- Silicone Elastomer A & B (RTV-4420)
- Polyurethane (SC-92)
- Sofreliner (T) Primer
- Pasteur Micropipette
- Pressure Generator + Airbrush
- Hot Plate
- Vacuum Chamber

- PU diluted into 30:70 (v/v) water:PU
  - sprayed 5 times into petri dish covers
  - allowed to cure via drying on hot plate
  - 100 µL primer applied to each sample via paintbrush
  - 50 minute wait time and 50:50 (m/m) silicone A:B added onto primed PU

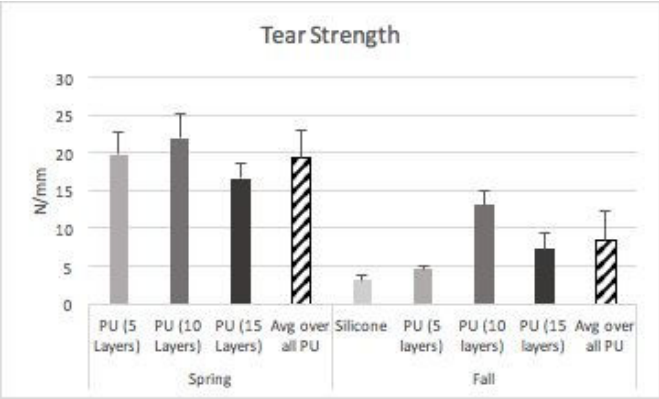
Figure 5: Sample fabrication schematic

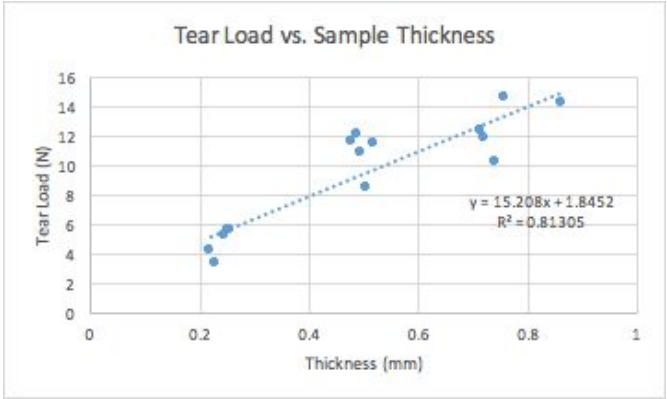
Tear Resistance Test (from ASTM D1938)

1. Prep sample and make cut ⅔ of the way across center
2. Separate samples at rate of 20mm/min in MTS machine
3. Obtain load, displacement, and time values from test
4. Peak load normalized to sample thickness is considered the tear strength

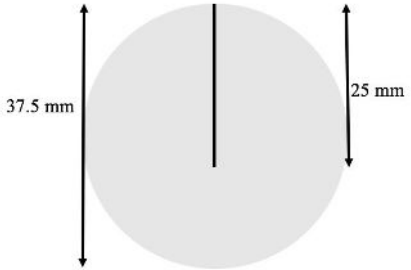


Tear Resistance Test: Data Summary



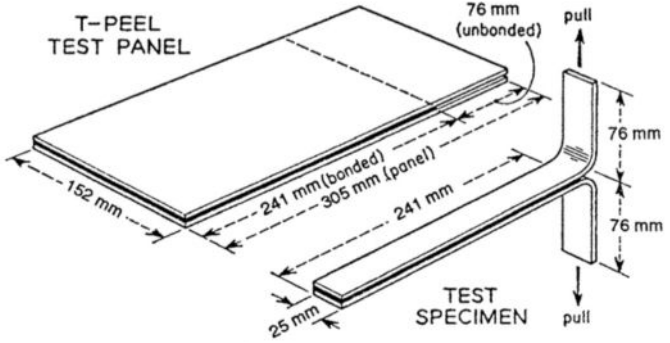


- PU tear strength was shown to be significantly greater than silicone. However, results between studies remain inconsistent
- A mostly linear trend between sample thickness and peak load was obtained



Adhesive Strength Test (from ASTM D1867)

1. Fabricate a rectangular PU bound to silicone specimen with unbound ends
2. Separate ends of the sample at 25.4 mm/min
3. Obtain load, displacement, and time values
4. Plot in MATLAB to determine mean peel strength



Adhesive Strength: Test Data Summary

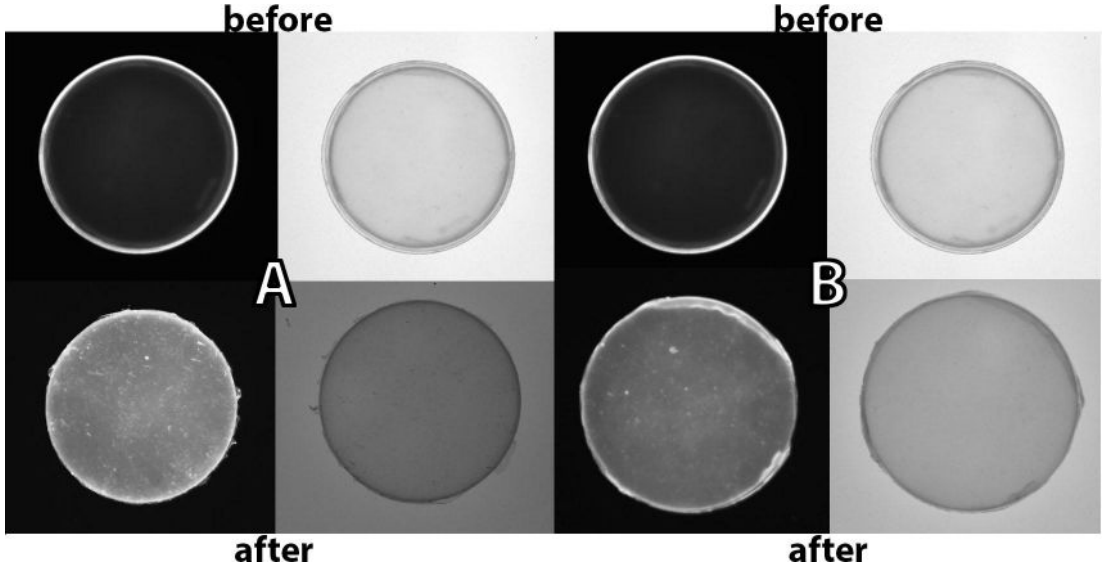
Adhesive Strength Testing Results	
Adhesive Strength Testing	**Results**
Peak Load	6.648 ± 4.928 N
Peak Peel Strength	0.960 ± 0.709 N
Mean Peel Strength	0.626 ± 0.502 N

UV Degradation Test: ASTM D1148

1. Samples placed under RSM Type 275 W, 125 V sun-lamp bulb contained in metal housing test chamber
2. Sample exposed to radiation for lamp from 0 to 340 hours and imaged at 10 hour intervals
3. Degree of discoloration is rated against control group and original sample images, samples were analyzed qualitatively and quantitatively using a light box colorimeter

UV Degradation Test: Data Summary

- Observed degradation of PU coating on side of samples
- No visual discoloration under natural light
- Light box imaging showed 20% darkening from t=0 to t=340 hr
- Fluorescent imaging showed further degradation and formation of white spots on surface of sample
- Results showed 50% less degradation compared to strictly silicone sample

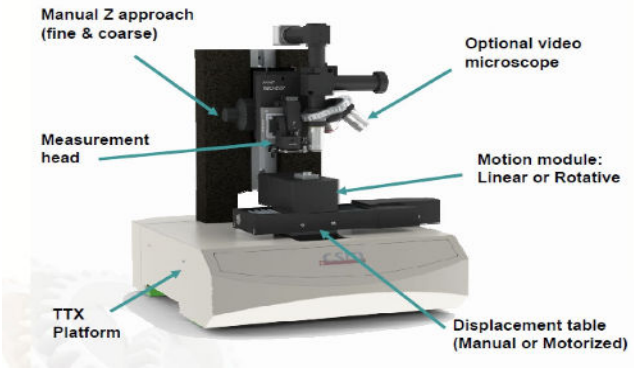


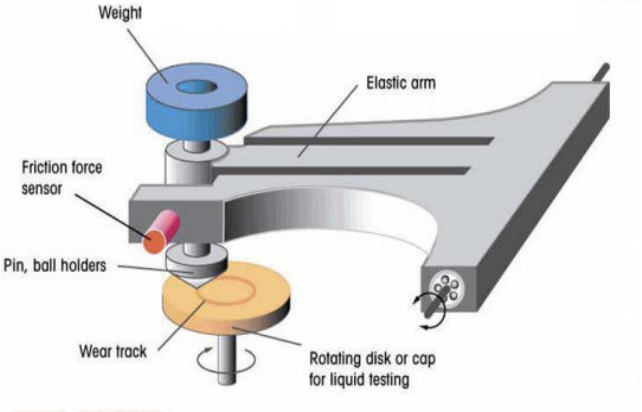
Tribology: Coefficient of Friction and Wear

- Sample mounted on linear Nano Tribometer
- Nano Tribometer set to oscillate at 50, 20, 10 μN to maintain full range of motion of the probe
- Device returns friction and penetration depth, allowing for determination of the CoF and wear rate based on the following relationship:

  - $K = V/(F*s)$

K = wear rate
V = worn volume
F = normal force
S = sliding distance

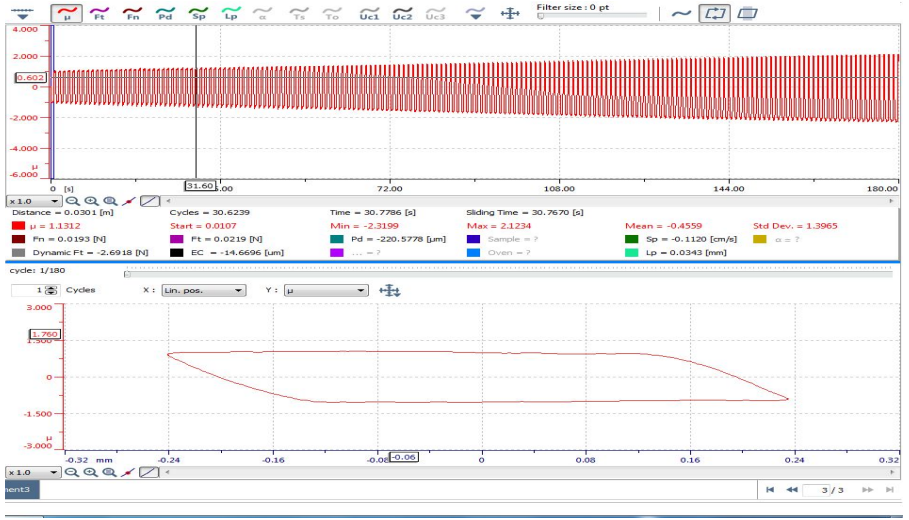




Tribology: Coefficient of Friction Summary

20mN Normal Load: Raw data output (PU)

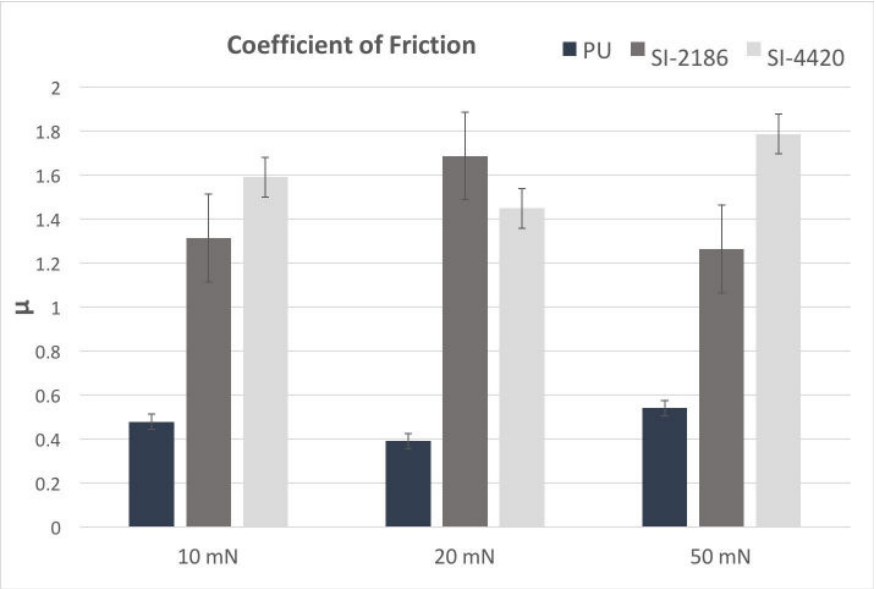
20mN Normal Load: Raw data output (Silicone)



- Friction values are positive and negative because the probe moves in an oscillatory manner
- Hysteresis curve is indicative of the coefficient of friction value recorded during each iteration

Coefficient of Friction: Data Summary

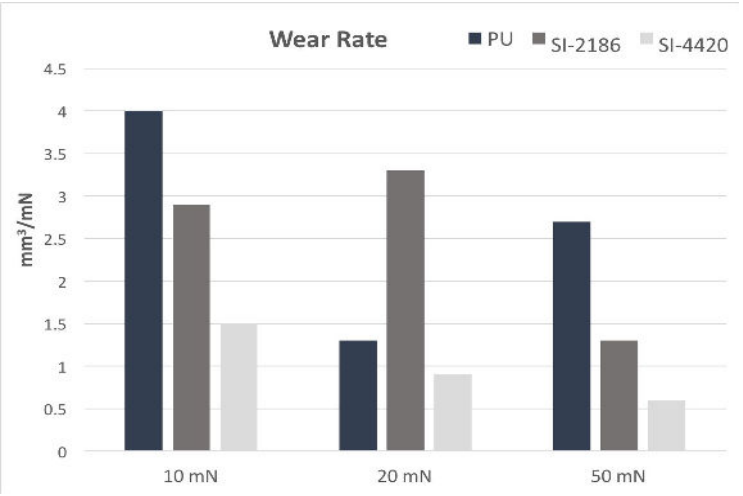
Coefficient of Friction (CoF) of Polyurethane and Silicone			
Normal Load	PU	SI-2186	SI-4420
10mN	0.478	1.312	1.590
20 mN	0.390	1.687	1.449
50 mN	0.540	1.263	1.787



- Results demonstrate a significantly lower CoF for the PU coated samples than either Silicone varian
- Reduce the likelihood of sample catching on fabrics and different textures

Tribology: Wear Rate Summary

Wear Rates of Polyurethane and Silicone ($1x10^{-8}$) [=]			
Normal Load	PU	SI-2186	SI-4420
10mN	4	1.3	2.7
20 mN	2.9	3.3	1.3
50 mN	1.5	0.9	0.6



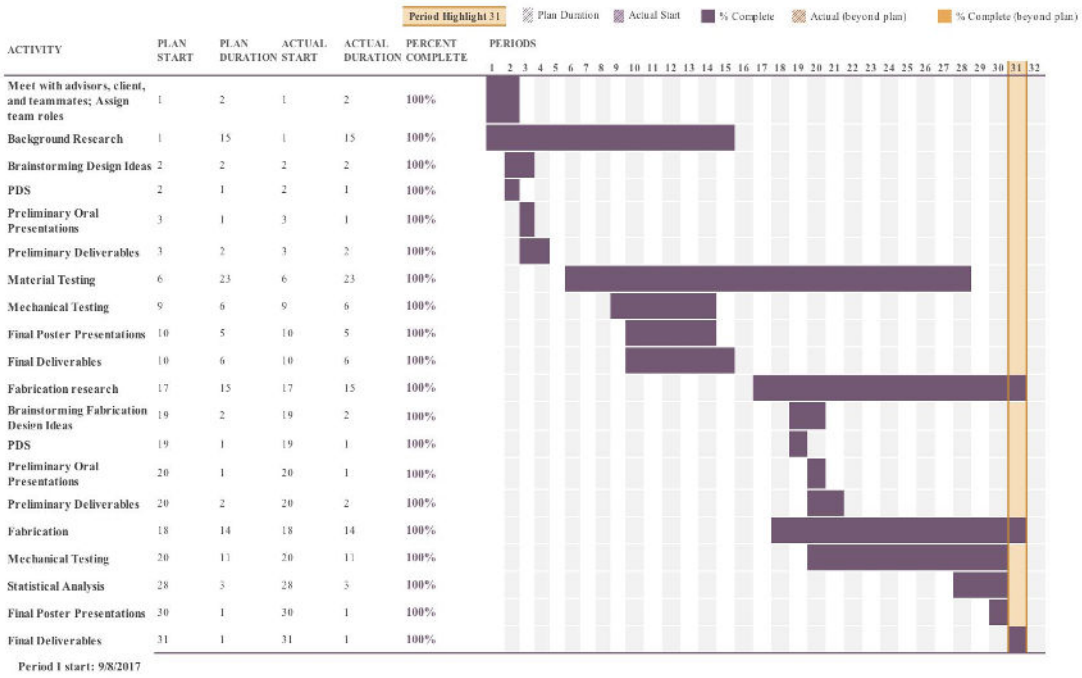
$K = V/(F*s)$

- All materials exhibited elastic deformation during testing, hence volume loss could not be adequately derived
- Penetration values do not accurately reflect respective wear rates
- Rather, these values are indicative of the elastic modulus of each material → PU coated samples were found to be more elastic

Management Plan

- **Fall 2017**
  - Meet with client and advisors
  - Background research
  - Design development
  - Material and mechanical testing

- **Spring 2018**
  - Fabrication research
  - Design Development
  - Mechanical testing
  - Fabrication
  - Characterization and statistical analysis
  - Working prototype



Budget

Material	Product Number	Cost
Silicone Elastomer	A-RTV-20	$41.95
Silicone Elastomer	A-2186-F	$139.95
Sofreliner Tough Primer 10ML	76750186	$46.00
Single Component Aliphatic Water-Based Coating (Polyurethane)	SC-92	$54.00

Miscellaneous	Cost
Shipping and Handling and Tax	~ $10.00
Final Poster	~ $30.00

- **Total Spent:** $321.90
- $178.10 **under budget**

Future Recommendations

- More complete UV testing and analysis using colored silicone
- Optimization of the fabrication method for use by an anaplastologist
- Perform aesthetic finger prosthetic clinical trial utilizing this method to assess performance over time during daily use
- Further testing with color retention after PU coating in addition to testing into the ease of coloring PU

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Thank you!

Questions?