Medical Art Prosthetics: Composite Polymers

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**Client:** Mr. Gregory Gion

**Advisors:** Dr. Tracy Puccinelli, Mr. Russ Haas
Overview

▪ Problem Statement
▪ Background
▪ Design Specifications
▪ Motivation
▪ Materials and Methods
▪ Tear Abrasion Test
▪ UV Degradation Test
▪ Adhesive Strength Test
▪ Management Plan
▪ Budget
▪ Future Recommendations
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

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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 protheses

Design Specifications

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

Figure 2: Recreation of a missing finger

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

Figure 4: Recreation of a missing finger

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

<table>
<thead>
<tr>
<th>Adhesive Strength Testing</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Load</td>
<td>6.648 ± 4.928 N</td>
</tr>
<tr>
<td>Peak Peel Strength</td>
<td>0.960 ± 0.709 N</td>
</tr>
<tr>
<td>Mean Peel Strength</td>
<td>0.626 ± 0.502 N</td>
</tr>
</tbody>
</table>
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:

\[ K = \frac{V}{(F \times s)} \]

- \( K \) = wear rate
- \( V \) = worn volume
- \( F \) = normal force
- \( S \) = sliding distance
Tribology: Coefficient of Friction Summary

- 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

<table>
<thead>
<tr>
<th>Normal Load</th>
<th>PU</th>
<th>SI-2186</th>
<th>SI-4420</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mN</td>
<td>0.478</td>
<td>1.312</td>
<td>1.590</td>
</tr>
<tr>
<td>20 mN</td>
<td>0.390</td>
<td>1.687</td>
<td>1.449</td>
</tr>
<tr>
<td>50 mN</td>
<td>0.540</td>
<td>1.263</td>
<td>1.787</td>
</tr>
</tbody>
</table>

- 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
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.

\[
K = \frac{V}{(F \times s)}
\]

### Wear Rates of Polyurethane and Silicone (1x10^{-8})

<table>
<thead>
<tr>
<th>Normal Load</th>
<th>PU</th>
<th>SI-2186</th>
<th>SI-4420</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mN</td>
<td>4</td>
<td>1.3</td>
<td>2.7</td>
</tr>
<tr>
<td>20mN</td>
<td>2.9</td>
<td>3.3</td>
<td>1.3</td>
</tr>
<tr>
<td>50mN</td>
<td>1.5</td>
<td>0.9</td>
<td>0.6</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Material</th>
<th>Product Number</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicone Elastomer</td>
<td>A-RTV-20</td>
<td>$41.95</td>
</tr>
<tr>
<td>Silicone Elastomer</td>
<td>A-2186-F</td>
<td>$139.95</td>
</tr>
<tr>
<td>Sofreliner Tough Primer 10ML</td>
<td>76750186</td>
<td>$46.00</td>
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<tr>
<td>Single Component Aliphatic Water-Based Coating (Polyurethane)</td>
<td>SC-92</td>
<td>$54.00</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Miscellaneous</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping and Handling and Tax</td>
<td>~ $10.00</td>
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<tr>
<td>Final Poster</td>
<td>~ $30.00</td>
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</tbody>
</table>

- **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
Acknowledgements

- Ahmet Deniz Usta
- Dr. Tracy Puccinelli
- Mr. Russ Haas
- Mr. Gregory Gion
References

Thank you!

Questions?