Development of a Low-Cost Low-Force Mechanical Testing Device and its Application in Measuring Mechanical Properties of Polyelectrolyte Capsules for Engineered Tissue Assembly

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Opportunity and Significance
Tissue engineered muscle is a promising approach to restoring function in cases of volumetric muscle loss due to congenital defects, trauma, or cancer resection. We previously developed polyelectrolyte GAG-chitosan microcapsules as a platform for modular tissue engineering. In this study, we explored how the addition of photocrosslinkable acrylate groups to chitosan affect the mechanical properties of the GAG-chitosan polyelectrolyte membranes found in microcapsules. To quantify the membrane's mechanical properties and the effects of photocrosslinking, we measured the burst strength of the spherical polyelectrolyte capsules using a low-load mechanical testing system designed and assembled in house from commercially available components. The system was used to record rupture strength of individual capsules under conditions of uniaxial compression.

Technical Objectives
• To develop a low-cost low-force mechanical testing device
• To evaluate the effect of the degree of substitution of GMA-chitosan on the burst strength of the GAG-GMA-chitosan capsules.

Materials and Methods

- Glycidyl Methacrylate
- Glycidyl Methacrylated Chitosan
- Photoinitiator solution is added.
- Long-wave UV light is applied for 6 minutes.
- Microcapsules are washed with saline and surface-stabilized with PGA.
- Photoinitiator solution is added.
- Long-wave UV light is applied for 6 minutes.

GMA/Chitosan = 0.05 w/o UV
GMA/Chitosan = 0.10 w/o UV
GMA/Chitosan = 0.15 w/o UV
GMA/Chitosan = 0.20 w/o UV

0.5 mL GAG is extruded into rapidly spinning GMA/CTS bath.

Low-Force Mechanical Testing Device

- Linear Actuator (LAC) was purchased from ACTUONIX
- LAC provides uniaxial compression
- Velocity of LAC may be controlled
- USB ports are located on electrical box of LAC and load cell.
- The load cell records electrical impulses produced when LAC makes contact with load cell, once it is brought down.
- Readings from load cell and control of LAC is possible through USB interface; information is recorded in Excel spreadsheet.
- Average microcapsule diameter is 3mm.
- Device was made for under $300.

System at Work

- 3-mm microcapsule is placed on load cell.
- LAC is brought down; microcapsule is crushed.
- LAC is released.

Results

<table>
<thead>
<tr>
<th>GMA/Chitosan</th>
<th>Mean Burst Load (g)</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05 w/o UV</td>
<td>28.4 ± 10.0 g</td>
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</tr>
<tr>
<td>0.10 w/o UV</td>
<td>34.2 ± 10.0 g</td>
<td></td>
</tr>
<tr>
<td>0.15 w/o UV</td>
<td>44.2 ± 10.0 g</td>
<td></td>
</tr>
<tr>
<td>0.20 w/o UV</td>
<td>59.7 ± 10.0 g</td>
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Summary

• Control capsules (no GMA) burst at average of 22.3 g.
• Gratting of GMA increased burst strength to average of 40.0 g regardless of degree of substitution.
• Photocrosslinking of GMA-containing capsules further increased burst strength from 34.2 g for 0.05 GMA/Chitosan up to 82.0 g for 0.2 GMA/Chitosan ratio.

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