Dental Polymers

Lecture #18
Teeth

- Humans go through 52 teeth in the course of a lifetime
  - 20 “baby” teeth
  - 32 “permanent” teeth
- Molars can have contact pressure as great as 25 k.s.i.
Tooth

- **Enamel**
  - Hardest material in human body
  - Hydroxyapatite (97%)
  - Enamelin (3%)

- **Dentin**
  - Supports enamel
  - 72% hydroxyapatite
  - Vulnerable to infection and decay
  - Sensitive to hot and cold

- **Pulp/nerve**
  - Most active living part of tooth
  - Veins, arteries, nerves, lymph passages

- **Root**
  - Fully below gum line
  - Attach tooth to jaw by means of periodontal membrane
Dental Materials

- Dental materials
  - All items used in tooth repair or replacement
  - Cover broadest range of materials in any one chemical industry

- Multidisciplined
  - Organic, inorganic, physical, bio-, and polymer chemistry
  - Metallurgy, adhesion, materials science, and coatings technology
Dental Polymers

- Most successful, but not oldest group of polymers are the acrylic resins – methyl methacrylate and its derivatives
- Early dentures
  - Carved ivory
  - “Vulcanite” rubber dentures
Acrylic Polymers

- First used in 1937
- Originally injection molded into a pre-cast gypsum mold.
- Later replaced by a heat curable mixture

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\text{-} & \quad \text{-} \\
\text{C} & \quad \text{C} & \quad \text{C} & \quad \text{CH}_2 \\
\text{COOCH}_3 & \quad \text{COOH} \\
\end{align*}
\]

\[n\]

Poly(methyl methacrylate)
Modifications to Acrylic Resins

- Cross-linking monomers to prevent crazing (formation of microcracks) on repair
  - Ethylene dimethacrylate
- Co-polymerization with other acrylics for better durability
- Internal pigmentation for shade control
- Inclusion of chopped fibers for characterization by vein simulation – more “natural” appearance
- Grafting with rubbery polymers for better impact resistance
## Typical Physical Properties of Denture Base Polymers

<table>
<thead>
<tr>
<th>Property</th>
<th>PMMA/HC</th>
<th>PMMA/SC</th>
<th>VMMA</th>
<th>Pour Resin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength (MPa)</td>
<td>48-62</td>
<td>--</td>
<td>52</td>
<td>--</td>
</tr>
<tr>
<td>Compressive strength (MPa)</td>
<td>76</td>
<td>--</td>
<td>70-76</td>
<td>--</td>
</tr>
<tr>
<td>Tensile elongation (%)</td>
<td>1-2</td>
<td>1-1</td>
<td>7-10</td>
<td>1-2</td>
</tr>
<tr>
<td>Impact strength (kg•m/cm)</td>
<td>0.19</td>
<td>0.11</td>
<td>0.44</td>
<td>0.11-0.22</td>
</tr>
<tr>
<td>Transverse deflection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3500g (mm)</td>
<td>2.0</td>
<td>&lt;1.5 @</td>
<td>1.9</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2500g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5000g (mm)</td>
<td>4.0</td>
<td>&lt;4.5 @</td>
<td>3.9</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4000g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of thermal expansion ($^\circ$C$^{-1} \times 10^{-6}$)</td>
<td>81</td>
<td>--</td>
<td>71</td>
<td>--</td>
</tr>
<tr>
<td>Water sorption (mg/cm²)</td>
<td>0.7</td>
<td>&lt;0.8</td>
<td>0.26</td>
<td>&lt;0.8</td>
</tr>
<tr>
<td>Solubility (mg/cm²)</td>
<td>0.04</td>
<td>&lt;0.04</td>
<td>&lt;0.04</td>
<td>&lt;0.04</td>
</tr>
</tbody>
</table>
Crown/Bridge

- Introduced shortly after full denture use
  - First use full crowns and facings cemented to natural teeth
  - Poor abrasion caused the use of metals such as Au and Co-alloys

Au prosthesis with acrylic crown & bridge resin
Acrylic Resin Teeth

- Injection molded
  - Failed
    - Crazing
    - Complete disintegration
- Now powder/liquid dough process
  - Cross-linked with ethylene dimethacrylate or allyl methacrylate for shade control
- For better wear, inclusion of up to 50% microfine silica (40 nm)
Restoratives

- Amalgams
  - Alloy powder
    - Mostly silver and tin
    - May also include copper, zinc, or gold
  - Mercury
    - 75% of all restorations, $10^8$ amalgams/yr.
  - Mercury poisoning?
    - Debated pro & con
  - Ugly, don’t match tooth color
Composite Restoratives

- Methacrylate with filler
  - E-glass fibers
  - Soda lime glass beads
  - Calcium phosphate
  - Fused silica
  - Li alumniosilicate glass ceramic
  - Al silicates
  - Ba boroniosilicates
  - Crystalline quartz
  - Calcium silicate
  - Pyrogenic silicas

- Suffer from finishing problems
  - Polishing produces rough surface
  - Plaque adhesion

- Current UV- or visible light curing restoratives
Other Uses

- **Facings**
  - Pre-formed facings bonded to fractured, deformed, or discolored enamel surface

- **Orthodontics**
  - Bonding of orthodontic device to tooth enamel
Other Polymers

- Gutta percha
  - Poly-trans isoprene
  - Endodontic points for root canal
- Cellulose
  - Moisture absorbents
- Silicones, polysulfides, and polyethers
  - Crown and bridge impressions