Biomechanics Review

Part 1

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Quick Mechanical Physics Review

• **Force:** The action of one object onto another that results in a change of motion or shape

• Forces that act on a body can also be called loads
  – Newtons are the Units

• Types
  – Linear: A force that goes along the axis of movement
  – Rotational: a force that revolves around the axis or results in rotational motion
Linear Forces

• Perpendicular forces to an axis are known as **normal** forces.
• **Tangential** forces are parallel to the axis
• Compression is a negative change in length or shorter
• Tensile forces are a positive change in length or longer
Rotational Forces

• **Moment/Torque**: The rotational effect of a force a distance away from a point
  – Newton * Meters
  – $M = F \times D$

• Moment: force parallel to long axis

• All forces occur about an axis
Elasticity

- Elasticity is the ability of an object to return to its original shape after a force has been removed and is measured from the stress and strain observed on an object.

- Stress
  - The pressure of the force applied on an area
  - Units: Pascal (Pa = N/m^2)
Elasticity Continued

• Strain
  – Changes in length of an object due to stress
  – Strain is the \( \frac{\text{Change in Length}}{\text{Original Length}} \)
  – Strain is normally given as a percent

Before Force

After Force

Original length
5 cm

Change in Length
0.5 cm

\[ Strain = \frac{0.5 \text{ cm}}{5 \text{ cm}} = 0.1 = 10\% \]
Stress-Strain Curve

• Young’s modulus (Elastic Modulus or $E$) is the slope of the linear portion of the curve or elastic region
  – $E = \text{Stress}/\text{Strain}$
• The larger the $E$ the stiffer the material and the more force is required to cause a deformation in the object
• The stress-strain curve will be the same for each elastic material independent of its shape
Important Places on the Curve

- **Yield Point/Elastic Limit**: the level of strain that is the point where the deformation changes from elastic to plastic
- **Ultimate Strength**: the highest stress observed on the material
- **Breaking Point/Failure Point**: the point where the strain will cause a break in the material
- **Elastic vs. Plastic Deformations**: non-permeant vs. permeant deformations
Elasticity Continued

• Elastic Properties:
  – Endurance Limit: Stress level at which a material can be cyclically loaded an infinite number of times without failing
  – Fatigue Failure: Number of cycles to material failure at a specific stress level

• Material Properties
  – **Brittle**: A material that experiences little plastic deformation before it fails
  – **Ductile**: A material that experiences large plastic deformations before it fails
  – **Toughness**: A material that can absorb more energy (area under the curve) prior to failure (resistance to failure)
  – **Weakness**: A material that can absorb little energy (area under the curve) prior to failure (prone to failure)

• Materials can have different combinations of properties:
  – Ex. Flexible, Brittle, Strong vs. Stiff, Ductile Strong
Curves of Materials of Mixed Properties

Elastic materials are not confined to one material property. Often a material will have a mix and this makes some materials better for certain implants than others.
# Common Orthopedic Materials

## Young’s Modulus

<table>
<thead>
<tr>
<th>Material</th>
<th>Xs Stiffer than Cortical Bone</th>
<th>Xs Stiffer than Cancellous Bone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic (Al2O3)</td>
<td>18-22x</td>
<td>21-41x</td>
</tr>
<tr>
<td>Alloy (Co-Cr-Mo)</td>
<td>10-13x</td>
<td>11-24x</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>10-11x</td>
<td>11-20x</td>
</tr>
<tr>
<td>Titanium</td>
<td>5-5.5x</td>
<td>5.7-10.3x</td>
</tr>
<tr>
<td>Matrix Polymers (Collagen)</td>
<td>0.24-0.59x</td>
<td>0.28-1.1x</td>
</tr>
<tr>
<td>PMMA (Bone cement)</td>
<td>0.087-0.167x</td>
<td>0.1-0.31x</td>
</tr>
<tr>
<td>Polyethylene (UHMWPE)</td>
<td>0.0432-0.0518x</td>
<td>0.0497-0.0963x</td>
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