Principle of Screw and Plate Fixation & Mechanical Behavior of Implant Materials
Roles of Implants

• Add stability
  – Fracture fixation
  – A plate used after osteotomy

• Replace damaged or diseased part
  – Total joint replacement

• Healing stimulants
Advantages of Internal Fixation

• No casts
  – Prevent skin pressure and fracture blisters
  – No scars
• No complications of bed rest
  – Important for the elderly
• Early motion
  – Avoid stiffness
  – Enhance fracture healing
  – Prevent muscle atrophy
Principles of Fixation

• Rigid fixation
  – Stress distribution
  – Fracture stability
• Compression
  – Stability
• Primary healing
  – Membranous bone repair
**Biomechanics of Dynamic Compression Plate (DCP)**

- Designed to compress the fracture
  - Offset screws exert force on specially designed holes in plate
  - Force between screw and plate moves bone until screw sits properly
  - Compressive forces are transmitted across the fracture

[Diagram showing the beginning and end result of the dynamic compression plate process.](ttb.eng.wayne.edu/~grimm/ME518/L19F3.html)
DCP (Cont’d)

- Alternate embodiment:
  - External compression screw control

- Additional pictures of internal plate
Plate Placement

- Lateral cortex
- Flexural rigidity
  - $E \times I$
- Depends on direction of loading
  - Area moment of inertia
**Plate and oblique fracture**

A: For ONLY torsional loads: 45° to long axis

B: For ONLY bending loads: Parallel to long axis

Realistically: loads in both directions will be applied: Divide angle between long axis and 45°
**Dynamic Hip & Condular Screw Indications (DHS)**

- **Fractures of the proximal femur**
  - Intertrochanteric fractures
  - Subtrochanteric fractures
  - Basilar neck fractures
- **Stable fractures**
- **Unstable fractures in which a stable medial buttress can be reconstructed**
- **Provide controlled collapse and compression of fracture fragments**

**Sliding Compression Screw Devices**

- Screw in center of femoral head (proximal fragment)
  -Slides through barrel attached to plate
    - See yellow arrow
  - Essential to obtain max hold capacity in head of femur

- Plate is attached to bone (distal fragment) by screws
  - Screw threads designed to allow optimum fracture compression and hold
Sliding Screw Plate Angle

• 135° Plate Angle
  – For anatomic reduction
  – Less force working across sliding axis than higher angle plates
    • Prevents impaction
  – Used effectively in stable fractures
    • Controlled collapse is not important
**Sliding Screw Plate Angle**

- **150° Plate Angle**
  - For unstable fractures
  - Mechanically, it is desirable to place sliding device at as high angle as clinically possible while still maintaining placement of device in center of head
  - Technically surgeon cannot place sliding device at high angle in small hip or in hip with varus deformity
DHS Technique

- Incisional line
  - Red = conventional
  - Green = minimal access
- Procedure is monitored by x-ray image intensifier

**DHS Targeting Device**

- Aligns guide pin
- Under the vastus lateralis
- Wedged in upper part
  - Between vastus and femoral shaft

DHS Guide Pin

• Guide pin is inserted
  – Centered in the femoral neck

**DHS Axial Screw**

- Axial screw is inserted with an extension
  - Extension to guide the barrel of plate
- Slot along screw fits a longitudinal ridge inside barrel prevents rotation, allows axial compression only

DHS Plate

• Plate against femoral shaft
  – Shaft screws are inserted

DHS Problems

• With the plate attached to the bone
  – Bone below the plate is at an increased risk of a stress fracture

• Quality of bone is important
  – Procedure will vary among patients with healthy or osteoporotic bone
Materials

Composite

Metal: Rough & Polished

Polymer

Ceramic

http://www.me.udel.edu/~advani/research_interest/implants.htm


http://www.orthopedictechreview.com/issues/sep00/case15.htm
Bio Materials

• Synthetic materials
  – Non viable material
  – Interacts with biological systems
    • Corrosion
    • Debris
  – To augment or replace tissues and their functions
Types of materials

- Metals
- Composites
- Polymers
  - Polyethylene (PE)
  - Silicone
- Ceramics
- Bone cement (PMMA)
- Biodegradable
<table>
<thead>
<tr>
<th>Metals</th>
<th>Titanium</th>
<th>Cobalt-chromium-molybdenum</th>
<th>Stainless Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Make-up</td>
<td>$\text{Ti}_6\text{Al}_4\text{V}$</td>
<td>30-60% Co 20-30% Cr 7-10% Mo</td>
<td>Cr, Ni, Mo Cr: oxide layer when dipped in Nitric acid (reduced corrosion)</td>
</tr>
<tr>
<td>Young’s Modulus</td>
<td>110 GPa</td>
<td>200 GPa</td>
<td>190 GPa (used with cement)</td>
</tr>
<tr>
<td>Benefits</td>
<td>Yield strength; Ti &gt; Stainless Steel</td>
<td>Stronger and more corrosion resistant than stainless steel; Excellent resistance to fatigue, cracking, and stress</td>
<td>Strong, cheap, relatively biocompatible; annealed, cold worked or cold forged; relatively ductile-contouring of plates and wires</td>
</tr>
<tr>
<td>Uses</td>
<td>Cementless joint replacements (total knee arthroplasty); Fracture fixation devices</td>
<td>Total joint arthroplasty (usually fixed with cement); Need to be inserted with a lower modulus polymer cement for fixation to prevent stress shielding of surrounding bone</td>
<td>Rarely used in new designs in joint replacement; Fracture fixation devices</td>
</tr>
<tr>
<td>Problems</td>
<td>Poor wear characteristics *varies with smooth or porous surface</td>
<td>Co, Cr, Mo known to be toxic in ionic form; High modulus *varies with smooth or porous surface</td>
<td>Excessively corrosive in some cases Susceptible to fatigue cracking Very high modulus PMMA cement may cause fracture or tissue reaction</td>
</tr>
</tbody>
</table>

http://www.engr.sjsu.edu/WofMatE/projects/srproject/srproj3.html#overview
Composites

• Manufactured in several ways
  – Mechanical bonding between materials (matrix and filler)
  – Chemical bonding
  – Physical (true mechanical) bonding

• Young’s modulus = 200 GPa

• Benefits
  – Extreme variability in properties is possible

• Problems
  – Matrix cracking
  – Debonding of fiber from matrix

• Examples: concrete, fiberglass, laminates, bone
Ceramics

• Materials resulting from ionic bonding of
  – A metallic ion and
  – A nonmetallic ion (usually oxygen)
• Benefits
  – Very hard, strong, and good wear characteristics
  – High compressive strength
  – Ease of fabrication
• Examples
  – Silicates, Metal Oxides - Al2O3, MgO
  – Carbides - diamond, graphite, pyrolyzed carbons
  – Ionic salts - NaCl, CsCl, ZnS
Ceramics (cont’d)

• Uses
  – Surface Replacement
  – Joint Replacement

• Problems
  – Very brittle & Low tensile strength
    • Undergo static fatigue
  – Very biocompatible
  – Difficult to process
    • High melting point
    • Expensive
Polyethylene

• Ultra high molecular weight (UHMWPE)
• High density
  – Molecular weight 2-6 million
• Benefits
  – Superior wear characteristics
  – Low friction
  – Fibers included
    • Improve wear properties
    • Reduce creep
• Used
  – Total joint arthoplasty
Bone Cement

• Used to fill gaps between bone and implant
• Example: total hip replacement
  – If implant is not exactly the right size, gaps are filled regardless of bone quality
Bone Cement

• Polymethylmethacrylate
• Mixed from powder polymer and liquid monomer
  – In vacuum
    • Reduce porosity
    • Increase strength
  – Catalyst (benzoyl peroxide) may be used
• Benefits
  – Stable interface between metal and bone

http://www.totaljoints.info/bone_cement.htm
Bone Cement (cont’d)

• Problems
  – Inherently weak
    • Stronger in compression than tension
    • Weakest in shear
  – Exothermic reaction
    • May lead to bone necrosis
  – By handling improperly or less than optimally
    • Weaker
  – Extra care should be taken to
    • Keep debris out of the cement mantle (e.g., blood, fat)
    • Make uniform cement mantle of several mm
    • Minimize voids in the cement: mixing technique
    • Pressurize
Biodegradable materials

• Fixation of horizontal maxillary osteotomies
  – Totally biodegradable self-reinforced polylactide (SRPLLA) plates
  – Pins
    • Poly-p-dioxanone (PDS)

• Benefits
  – Gradual rate of absorption
    • Allows an optimal transfer of support to bone as it heals
Mechanical Properties of IM

• As Implant materials have to function as bones, the mechanical properties of interest are
  – Elastic modulus
  – Ultimate tensile strength

• They are listed in order of increasing modulus or strength

(in next 2 slides)
Elastic Modulus in increasing order of strength

1. Cancellous bone
2. Polyethylene
3. PMMA (bone cement)
4. Cortical bone
5. Titanium alloy
6. Stainless steel
7. Cobalt-chromium alloy
Ultimate Tensile Strength in increasing order of strength

1. Cancellous bone
2. Polyethylene
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4. Cortical bone
5. Stainless steel
6. Titanium alloy
7. Cobalt-chromium alloy
Young’s Modulus

Interactive Figure

http://www-materials.eng.cam.ac.uk/mpsite/interactive Charts/stiffness-cost/NS6Chart.html
Additional Resources

The End
Fracture Blisters

- Blisters on swollen skin overlaying a fracture
  - Most often at tibia, ankle or elbow
  - Appear within 24-48 hours of injury
- Complicate or delay surgical treatment if present preceding care
  - No adverse affects if they appear following treatment

**Varus Deformity at the knee**

A. “A medial inclination of a distal bone of a joint from the midline”
   - Can occur at any joint; Knee shown

B. Before correction

C. After corrective implants

http://www.wheelessonline.com/o12/74.htm  
http://www.hyperdictionary.com/medical  
Oteotomy

- Removal of a wedge of bone to correct a (varus) deformity
  - High Tibial Osteotomy

Proximal Femur (Hip) Fractures

- Risk of fracture effected by
  - Age
  - Gender
  - Geographic location/Ethnicity
  - Mental capacity
  - Bone strength
  - Pre-existing medical conditions

http://www.orthoteers.co.uk/Nrujp-ij33lm/Orthhipfrac.htm