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OSTEOTOMY AND DEFORMITY CORRECTION TECHNIQUES
Objectives

- Fracture healing biology
- Osteotomy techniques
- Ring fixator techniques & biomechanics
Fracture Healing

4 general types of bone repair

- **Endochondral bone repair**
  - callus, secondary bone healing
  - interfragmentary motion

- **Primary bone repair**
  - direct contact repair
  - absolute stability / no fracture gap

- **Gap repair**
  - direct repair
  - stable fixation / small gap

- **Distraction osteogenesis**
  - callotasis
  - slow distraction of fracture gap

The route of repair is dependent on the mechanical environment
## Mode of healing and mechanics

<table>
<thead>
<tr>
<th>FIXATION:</th>
<th>plating</th>
<th>external fixation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Plating diagram" /></td>
<td><img src="image" alt="External fixation diagram" /></td>
<td><img src="image" alt="External fixation diagram" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FLEXIBILITY:</th>
<th>Non-Locked</th>
<th>Locked</th>
<th>ExFix</th>
<th>Ilizarov</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Flexibility scale" /></td>
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<tr>
<th>HEALING:</th>
<th>primary</th>
<th>secondary, with callus</th>
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Fracture Healing

Stability of fracture determines the morphology of healing

<table>
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<tr>
<th>Primary / Gap Healing</th>
<th>Callus Healing</th>
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<tbody>
<tr>
<td>Perfect Reduction</td>
<td>Functional reduction</td>
</tr>
<tr>
<td>Absolute Stabilization</td>
<td>Flexible fixation</td>
</tr>
<tr>
<td>IFM &lt;0.15 mm</td>
<td>IFM = 0.2 – 1 mm (^3); &gt; 10 mm (^4)</td>
</tr>
<tr>
<td>Interfragmentary Compression</td>
<td>Dynamization (^4)</td>
</tr>
</tbody>
</table>

Mechanical environment and healing

Rigid Fixation
Primary healing
No Callus

Non-rigid Fixation
Secondary healing
Callus

Excessive motion
Nonunion
Hypertrophic callus

Nirula, World J Surgery, 2009
Secondary Healing

**Inflammatory Stage**

- Hematoma is formed and *inflammation* occurs (potential disruption of healing by NSAIDs)
- Hematoma is a source of signaling molecules critical to the healing cascade
- Necrosis of the bone ends
Secondary Healing

[Diagram of secondary healing]

Soft callus formation

- Cartilage is formed in the fracture site
- Bone begins to form directly, mostly along the periosteum
- Vascular ingrowth begins to occur
- Disruption of blood supply (e.g. smoking) at this stage delays healing
- Micromotion at the fracture site is vital to soft callus formation
Secondary Healing

Hard callus formation

- Cartilage deposited at the fracture site begins to calcify
- Calcification continues until the bone ends are united
- Woven bone is deposited at the fracture site
- Blood supply continues to improve

Grabber et al. J Trauma, 1985
Secondary Healing

Remodeling

- Hard callus (both the external bridging callus and the medullary callus) is remodeled into mature bone

Grabber et al. J Trauma, 1985
Flexible plating with motion-lock screws = abundant callus formation
What is the ideal choice?

- Patient: age, health, vascular supply
- Surgical environment: sterility, radiography
- Resources: plates, nails, external fixation
- The Times They are a-Changin’
  - Bob Dylan 1964
Osteotomy Techniques

- Percutaneous
- Preserve periosteal blood supply
- Technique varies with location
  - Multiple Drill Hole: diaphyseal, dense bone
  - Gigli: metaphyseal, soft bone
- Performed after frame application
- Latency period: 7-14 days
Multiple Drill Hole osteotomy

- 1 cm anterior longitudinal incision
- Careful periosteal elevation
- 4.8 mm drill hole: one anterior hole—several posterior holes
- 10 mm sharp osteotome
- Complete with 90 deg turn of osteotome
- Requires rod/strut removal to complete
SAGITTAL PLANE DEFORMITY

Anatomic axis

10° Recurvatum CORA

ADTA 80°
Surgical Treatment
Gigli saw osteotomy

- 2 transverse incisions, 1 cm each
- Careful periosteal elevation
- Pass suture - done prior to frame app
- Saw passed with suture
- May include fibula - distal supra-malleolar
- Rods/struts remain intact
- Compress 1-2 mm
Proximal Tibia Gigli
Distal Tibia Gigli
Low distal tibia Gigli
41 yo oral surgeon
10 months later
1.5 year follow-up
Bilat tibia, femur, foot, >350 lb
Tib-Calc Fusion, Tibia Lengthening
Fibula Osteotomy

- May use small sagittal saw
- Multiple drill hole technique with 2.0 drill or 1.8 wire
- Rarely remove section
- Done prior to frame application
Dome Osteotomy

- Open procedure
- Acute correction with internal fixation
- Frontal or sagittal plane deformity <12 deg, with minimal translation
- Most common in distal tibia or distal femur
Equal Tibia and Fibula
Equal Tibia and fibula
Follow-up
What’s a stable ring fixator?

- Pain-free
- Balanced
- Weight-bearing
- Optimal environment for healing
Ring fixation mechanics

- Cyclic axial micromotion promotes bone healing, only if it’s not excessive or absent (about 1 mm)
- Translational shear inhibits bone healing
- Bending less clear (inhibitive)
- Goal- low axial stiffness, high bending, translational and torsional stiffness (Ilizarov)
What creates a strong frame?

- The combination of the frame and the fixation
- “Frame stability”
  - rings or ring blocks
  - wires and half pins
  - connections of wires and half-pins to the rings
  - connections b/t rings (rods or TSF struts)
Ideal Ring Fixator

- Maximum rigidity to prevent shearing motion at fracture site
- Controllable axial stiffness to optimize IFM throughout healing
- Minimal soft tissue violation
- Maintenance of strength throughout treatment

Watson, Mathias, Maffulli: 2000 U of Aberdeen, Scotland
Rings

- Ring sizing is very important (#1)
- Gasser (1990), Bronson (1998): Most important factor in overall frame stiffness
- 2 cm soft tissue clearance (anticipate swelling)
- TSF allows for multiple ring sizes
- Typically, use the smallest possible (exceptions)
Rings

- Bone position: central optimum, but eccentric OK
- Orthogonal to limb segment: helpful for connections
- Long unsupported distances: consider a dummy ring
- Partial rings: greater plastic deformation with wire tensioning and less stiff than complete rings (Cross et al., Am J Vet Res, 2004)
Enclose the foot ring
Single ring

- # of wires, half pins per ring
  - Metaphysis – 4 to 5 fixation points, varies from 1-3 wires, 2-3 half pins
Ring Block concept

- The portion of a frame attached to a bone/limb segment
- Often 2 rings connected by 4 threaded rods
- To optimize stability: min of 4 points of fixation (2-3 per ring), fix the near and far ends of segment
- Short metaphyseal segments: one ring with 3-5 fixation points
Ring Blocks

- Strength increases
  - rings are closer to the bone (2 cm clearance)
  - # of rings
  - # of threaded rods between rings
Ring Blocks

- More stability $\rightarrow$ nonunions, unstable fracture patterns, fusions, obesity, neuropathy
- Less stability $\rightarrow$ lengthening
- Medium $\rightarrow$ transport, stable fracture
Connecting rings to bone

Pins and wires
Wires

- Traditional Ilizarov fixation
- 1.8 mm (1.5mm in small applications)
- Provides stable fixation in small bone segments, osteopenia, neuropathic, metaphyseal, feet
- Useful for achieving orthogonal ring application: reference wire for reference ring
Reference ring - wire
Wires

- To increase frame stability:
  - Increase wire diameter, number, tension, crossing angle (ideal 90, aim for 60)
  - Opposing olive wires (rule of thumbs for deformity correction)
  - Olive wires can be used to pull or move bone segments
  - Drop wires
Drop Wires
Increases with wire tension

- Metaphyseal bone 90-110 kg
- Diaphyseal bone 110-130 kg
- Drop wires/metatarsal 50-90 kg
Wire Tension

- Loss of tension occurs:
  - Rapid reduction in wire tension (25+%-75%)
  - Clamping wire squeezes it (toothpaste out of tube) → plastic deformation. More with cannulated
  - Wire slippage thru bolts. Most with Russian. Best tighten to 14Nm (bolt failure near 20). Most likely cause. Strut torque wrench=5.6Nm
  - Cyclic axial micromotion is preserved due to wire recoil with loading
  - Re-tensioning wires not supported experimentally
Wire Insertion Technique

- Bicortical
- Avoid dense bone
- Use saline sponge to cool
- No paralytics
- No tourniquet
- Tap or oscillate wire thru far tissues
- Joints at end of range
Half Pins

- Use began with Ilizarov methods due to wire issues: pain, infection, soft tissue issues, etc.
- Typically used in diaphyseal bone.
- Rigidity: $1w+3p > 3p (5\text{mm}) > 1w+2p (5\text{mm})$
Half Pins

- To increase stability with half pins:
  - Increase diameter (bending and torsion = r4) – core diameter if threads outside of bone
  - Sizes range from 4 to 6 mm (< 1/3 bone diameter)
  - Increase number
  - Crossing angle/divergence
  - Pin Spread (near/far)
Smallest diameter outside of bone determines stiffness. Therefore, if pin threads out of bone, bending stiffness $\alpha$ core diameter.
Half Pin frame connections

- Rancho cubes
- Half pin fixation bolts
- Angled clamps
- Mix
Half Pin Insertion Technique

- Irrigation during drilling
- Drilling technique
- Always bicortical
- Avoid sclerotic bone
- No tourniquet
Half Pin Insertion Technique
Safe Half Pin Locations-Tibia

- Bicortical
- Lateral
- Medial
- Anterior
- Posterior
Steerage Pins

- Lowenberg et al, 2008, CORR: Correlation of shear to compression for progressive fracture obliquity
  - Synthetic tibia fracture model to assess fracture line migration with multiple frame configurations
  - Only parallel oblique half pins limit motion with loading from 40-60 degrees fracture obliquity = shear becomes compression
  - All are good below 30 degrees
Ring Block Fixation: Wires vs. Pins

  - Compared 3 four ring constructs sawbone model
  - Two 90° wires/ring (8 wires); two 90° 5 mm pins/ring (8 pins); three 6mm pins 60 ° divergent per block(6 pins)
  - Rigidity: wire< 5mm pins = 6 mm pins
  - Bottom Line: consider divergent half pins in tibia
SUMMARY: Fixation Basics

- Start with the “Rule of two’s”
  - 2 cm soft tissue clearance
  - 2 rings/segment (ring block)
  - 2 points fixation/ring
  - 2x2 connecting rods (except tsf struts)

- Recent mechanical studies
  - Three divergent 6mm half pins per bone segment
  - Steerage pins for oblique fractures

- Preoperatively plan using mechanical principles