Properties of Ligamentous and Tendinous Tissues

Deformation Force
(Sress or Load)

Change in Tissue Length
(Strain or % Deformation)

2x cross sectional area

x cross sectional area

slope

x length

2x length

Deformation Force
(Sress or Load)

Change in Tissue Length
(Strain or % Deformation)
Ligament Injury

- Ligament - fibrous dense connective tissue - binds bones
  - injuries to these structures may be a precursor to osteoarthritis
  - has functional subunits that tighten or loosen depending on joint position
  - is not densely innervated or densely vascularized
    - do contain some blood vessels and nerves in outer covering (epiligament)
    - do contain proprioceptors
    - do transmits pain signals via type C fibers
  - in bone-ligament-bone structures, ligament is the weakest link
    - weakest near ligament insertion (adolescent & osteoperotic exceptions)
  - ligaments are not readily weakened by inactivity (takes many weeks)
    - ligaments show only a 10% - 20% u in tensile strength with exercise
  - It is currently not known whether any modalities aid in ligament healing
  - surgical repair not done unless ends are significantly far apart
    - length of repair scar does not affect final functionality or tensile strength
      - unless ends are far apart:  r extra-long scar r d joint stability & u joint laxity
    - ACL tears most often result in ends unopposed r surgery required
  - surgical repair restores only about 80% - 90% of original tensile strength
Functional Sub-units of the Lateral Collateral Ligament - Left Knee
Ligament Sprain

- Ligament sprain classifications
  - grade I - slight incomplete tear - no notable joint instability
  - grade II - moderate / severe incomplete tear - some joint instability
    - one ligament may be completely torn
  - grade III - complete tearing of 1 or more ligaments - obvious instability
    - surgery usually required

- In most cases, more than 1 ligament share loads around a joint
  - most sprains involve more than one ligament - example: ankle
    - most common sprain: ankle inversion accompanied by plantar flexion
      - primary ligaments: anterior talofibular and calcaneofibular ligaments
    - if sprain is severe, “backup” structures may sometimes be involved
      - backup structures: posterior talofibular ligament & peroneal tendons
    - most common knee sprain: valgus force to knee r medial collateral tear
      - backup structure: anterior cruciate (cruciates blood supply inferior to collaterals)
  - joint instability in knee sprain likely to be evident only in injury position
  - repeat injuries not only tear healed areas but backup structures as well
    - prevention of re-injury is of critical importance
Important Structures of the Ankle

- lateral malleolus
- anterior tibiofibular ligament
- anterior talofibular ligament
- navicular
- cuneiforms
- phalanges (distal, middle, proximal)
- metatarsals
- calcaneofibular ligament
- calcaneus
- peroneal tendons
- posterior talofibular ligament
- tibiocalcaneal ligament
- tibiotalar ligament
- tibionavicular ligament
- 1st metatarsal
- 1st cuneiform
- navicular
- talus
- medial malleolus
- calcaneus
- achilles tendon
- fibula
# Ligament Healing

<table>
<thead>
<tr>
<th>Stage</th>
<th>Pathology - Healing</th>
<th>Treatment Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inflammatory</strong></td>
<td><em>Intra-articular injury</em></td>
<td>RICE (Protect &amp; Immobilize &lt;48 hrs)</td>
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<tr>
<td>(days 0 - 4)</td>
<td>intra-articular pressure &amp; hemarthrosis</td>
<td>Immobilize (r d osteoarthritis)</td>
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<tr>
<td><strong>Extra-articular injury</strong></td>
<td>subcutaneous hematoma</td>
<td>NSAID drugs</td>
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<tr>
<td></td>
<td>Fibrin clot is formed in ligament tears in minutes</td>
<td>light passive ROM exercise (&gt;48 hrs)</td>
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<tr>
<td></td>
<td>exercises that “cross” the joint</td>
<td>exercises that “cross” the joint (straight leg raises for ACL injury)</td>
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<tr>
<td><strong>Fibroplastic</strong></td>
<td>fibroblasts &amp; angiogenic cells r scar matrix</td>
<td>progress to full active ROM exercise</td>
</tr>
<tr>
<td>Proliferation</td>
<td>macrophages remove damaged ligament debris</td>
<td>resistance &amp; weight bearing exercise</td>
</tr>
<tr>
<td>(day 4 - weeks)</td>
<td>“decent” tensile strength within 3 weeks</td>
<td>u intensity of all types of exercises</td>
</tr>
<tr>
<td></td>
<td>“decent” tensile strength within 3 weeks</td>
<td>biomechanical evals began at 3 wks</td>
</tr>
<tr>
<td><strong>Remodeling</strong></td>
<td>u density of scar matrix</td>
<td>progression of activity</td>
</tr>
<tr>
<td>Maturation</td>
<td>replacement of initial or inferior collagen tissues</td>
<td>(u intensity &amp; duration)</td>
</tr>
<tr>
<td>(weeks to years)</td>
<td>u strength of molecular bonds of scar matrix</td>
<td>near maximum strength reach within 1 year</td>
</tr>
<tr>
<td></td>
<td>** but not back to 100% of original**</td>
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</tbody>
</table>

**Healed Ligament never attain pre-injury tensile strength due to:**

- d # of hydroxypyridinium cross linkages in collagen
- u quantity of type V (inferior) collagen r d collagen fibril diameter
- u amount of fat cells, blood vessels, loose & disorganized collagen in the scar
Immobilization vs. Mobilization: A Fine Line

Effects of immobilization on injured ligamentous tissue

**GOOD**
- less ligament laxity (lengthening)
- decreased risk of osteoarthritis

**BAD**
- less overall strength of ligament repair scar
- protein degradation exceeds protein synthesis resulting in collagen quantity
- production of inferior tissue by blast cells
- resorption of bone at site of ligament insertion
- decreased tissue tensile strength (50% in 6 - 9 weeks)

Benefits of mobilization (movement) on injured ligamentous tissue

- ligament scars are wider, stronger, and are more elastic
- Better alignment / quality of collagen
Ligament Repair Surgery (ACL)

Suture anchor placed in condyle of femur in and through the site of normal ACL origin.

Ends of ACL approximated using the sutures from the anchor.

A clot of the patient's own blood is formed and attached to the suture site.
ACL Re-construction Surgery

Harvest of Ligament Replacement from donor site (Patellar Tendon)

Hamstring Tendons are Becoming More Preferable

Grafting of Replacement Into Holes Drilled into the Femur & Tibia
Tendon Rupture

- Tendon - dense regular tissue attaching muscle to bone
  - forces of 2000 psi have been recorded in the human achilles (running)
  - max tensile strength is 4X max force production in muscle
- Tendon rupture - most often seen in Achilles
  - Age 30, blood flow d in an area 2-6 cm above calcaneal insertion
    - most tears occur here
  - tendon can still function with as little as 25% of the fibers intact
  - tears due to steroid injection abuse occur 2 - 4 weeks after last injection
  - complete tendon rupture diagnosed via the following symptoms
    - palpable & sometime visible gap above calcaneous
    - excessive passive dorsiflexion
    - absence of plantar flexion when calf muscle squeezed (Thompson test)
Tendon Rupture

- Tendon rupture treated with casting or surgery (usually both)
  - surgery is best when tear is complete
    - results in maximal restoration of both optimal length and tensile strength
    - after surgery foot is immobilized in plantar flexed position
    - at 4 weeks, foot is brought to neutral position & re-casted
    - at 6 weeks, cast is removed & gentle weight bearing & ROM exercise begins
    - bounding type exercises begin no earlier than 12 weeks
  - casting alone is best in partial tears & in older non-competitive athletes

Surgical Repair of Achilles Tendon Using Bunnell Cross-stitch Sutures to Approximate the Fibers
Bone Fractures

• Most fractures occur to the shaft of long bones
• Bone is well vascularized and highly innervated
• Heals relatively rapidly when ends are well approximated (6 weeks or less)
• Healed bone often stronger than original due to external calcification
Fracture Types

**simple (closed)** - little or no bone displacement

**compound** - fracture ruptures the skin & bone protrudes

**green stick** - occurs mostly in children whose bones have not calcified or hardened

**transverse** - crack perpendicular to long axis of the bone - displacement may occur

**oblique** - diagonal crack across the long axis of the bone - u chance of displacement

**spiral** - diagonal crack involving a "twisting" of the bone about the longitudinal axis
  (occurs in skiing when bindings are too tight)

**comminuted** (blowout) - "crushing" fracture - more common in elderly - may require screws, rods, & wires - may cause permanent discrepancy in leg length

**impacted** - one end of bone is driven up into the other - may result in length discrepancy

**depressed** - broken bone is pressed inward (skull fracture)

**avulsion** - fragment of bone is pulled away by tendon (Hip flexors, adductors)
Points to Remember with Regard to Fracture Healing

- Fractures are treated by reduction (realignment) & immobilization
- In most cases, simple fractures heal completely in approximately 6 - 8 weeks
  - bones of elderly heal slower because of poor circulation

- Two types of bone healing: Primary & Secondary (both usually occur at some level)
  - **Primary** - healing without external fibrocartilagenous callus formation
    - Seen with rigid (exact) internally or externally fixated reductions
    - Similar to haversian remodelling (normal homeostatic bone metabolism)
    - Rate of healing the same as secondary bone healing
  - **Secondary** - healing with a small gap between bone ends
    - External fibrocartilagenous callus forms, leaving area of u' girth upon healing
Steps in Fracture Healing

1.) Inflammatory Phase

- Bleeding from bone, bone periosteum, & tissues surrounding the bone
  - formation of fracture hematoma & initiation of inflammatory response
- Induction (stimulus for bone regeneration) - caused by:
  - d Oxygen r bone necrosis (fractured bone becomes hypoxic immediately)
  - disruption of & creation of new bioelectrical potentials
- Inflammatory response - lasts between days 2-9 following injury:
  - phagocytes & lysosomes clear necrosed bone and other debris
  - a fibrin mesh forms and “walls off” the fracture site
    - serves as “scaffold” for fibroblasts and capillary buds
  - capillaries grow into the hematoma
    - in a fracture, the new blood supply arises from periosteum
      - normally 3/4 of blood flow in adult bone arises from endosteum
      - in children, normal blood flow already comes from preisoteum r u healing
2.) Fibrocartilagenous callus Formation

- Lasts an average of 3 weeks
- Fibroblasts and osteoblasts arrive from periosteum & endosteum
- Within 2-3 days, fibroblasts produce collagen fibers that span the break
  - This tissue is called Fibro-Cartilagenous Callus and serves to “splint” the bone
  - FCC is formed both in and around the fracture site
  - Osteoblasts in outer layer of FCC begin to lay down new hard bone
  - In a non-immobilized fracture, the FCC has poor vascularization
    - Poor vascularization leads to poor bone production and incomplete periosteum at repair site
Steps in Fracture Healing

3.) Hard Boney Callus Formation & Ossification

- Weeks to months
- Fracture fragments are joined by collagen, cartilage, & then immature bone
  - Osteoblasts form trabecular bone along fracture periphery (external callus)
  - Trabecular bone is then laid down in the fracture interior (internal callus)
- Ossification (mineralization) starts by 2-3 weeks & continues for 3-4 months
  - Alkaline phosphatase is secreted by osteoblasts
    - blood serum levels serve as an indicator of the rate of bone formation

- In non-Immobilized fractures, more “cartilage” than bone is laid down
  - this must later be replaced by normal cancellous bone
    - results in a longer healing time and fractured area remains weak for a longer period
- Fractures should be reduced (immobilized) within 3-5 days
4.) Bone Remodeling

- Months to years (mechanically stable at 40 days)
- Excess material inside bone shaft is replaced by more compact bone
- Final remodeled structure is influenced by optimal bone stress
Bioelectricity and Fracture Healing

Bioelectric Factors in Bone Repair & Nonunion Fractures

- Areas of growth & repair in fractures have shown to be electronegative
  - play a major role in induction
  - stimulate osteoblast activity
- compression of fractured bone ends seems to u electronegativity
  - u electronegativity r u rate of hard bone deposition
  - strong case for using internal or external fixator

Non-union fractures (fractures that fail to heal within 5 months)

- caused by excessive age, contamination (infection), motion at fracture site
- treatment 1. electrical stimulation (20 amps for 12 weeks)
  - implantation of electrodes in the fibrous tissue at fracture site or under skin
- treatment 2. bone grafting
  - harvesting small quantities of bone from a non-critical area (ex: pelvis)
  - implanting the harvested bone at non-union fracture site
Immobilization: Cast Disease

- Most changes are reversible
- Muscle Atrophy
- Reduced calcium content in surrounding bone
- Resorption and weakening of tissues at sites of ligament attachments
- No stress forces on an immobilized joint → thinning of articular cartilage
- Adhesions → joint stiffness
- Loss of peripheral autonomic vascular control → hair loss → shiny mottled skin
- Sensory dissociation (light touches interpreted as painful)
Therapeutic Implications for Treating Fractures

- Active ROM exercises to joints above and below immobilized region
- Resistive ROM exercises to muscle groups that are not immobilized
- Once the cast or immobilization device has been removed:
  - gentle but progressive resistance exercises of all immobilized joints
  - evaluate strength of joint(s) and compare to non-injured counterparts
  - return to vigorous activity only after strength discrepancy $\leq 15\%$
Factors Enhancing Bone Healing

- Youth
- Early Immobilization of fracture fragments
- Maximum bone fragment contact
- Adequate blood supply
- Proper Nutrition
  - Vitamines A&D
- Weight bearing exercise for long bones in the late stages of healing
- Adequate hormones:
  - growth hormone
  - thyroxine
  - calcitonin
Factors Inhibiting Bone Healing

- Age
  - Fractured Femur Healing Time
    - infant: 4 weeks
    - teenager: 12 to 16 weeks
    - 60 year old adult: 18 to 20 weeks

- Extensive local soft tissue trauma

- Bone loss due to the severity of the fracture

- Inadequate immobilization (motion at the fracture site)

- Infection

- Avascular Necrosis