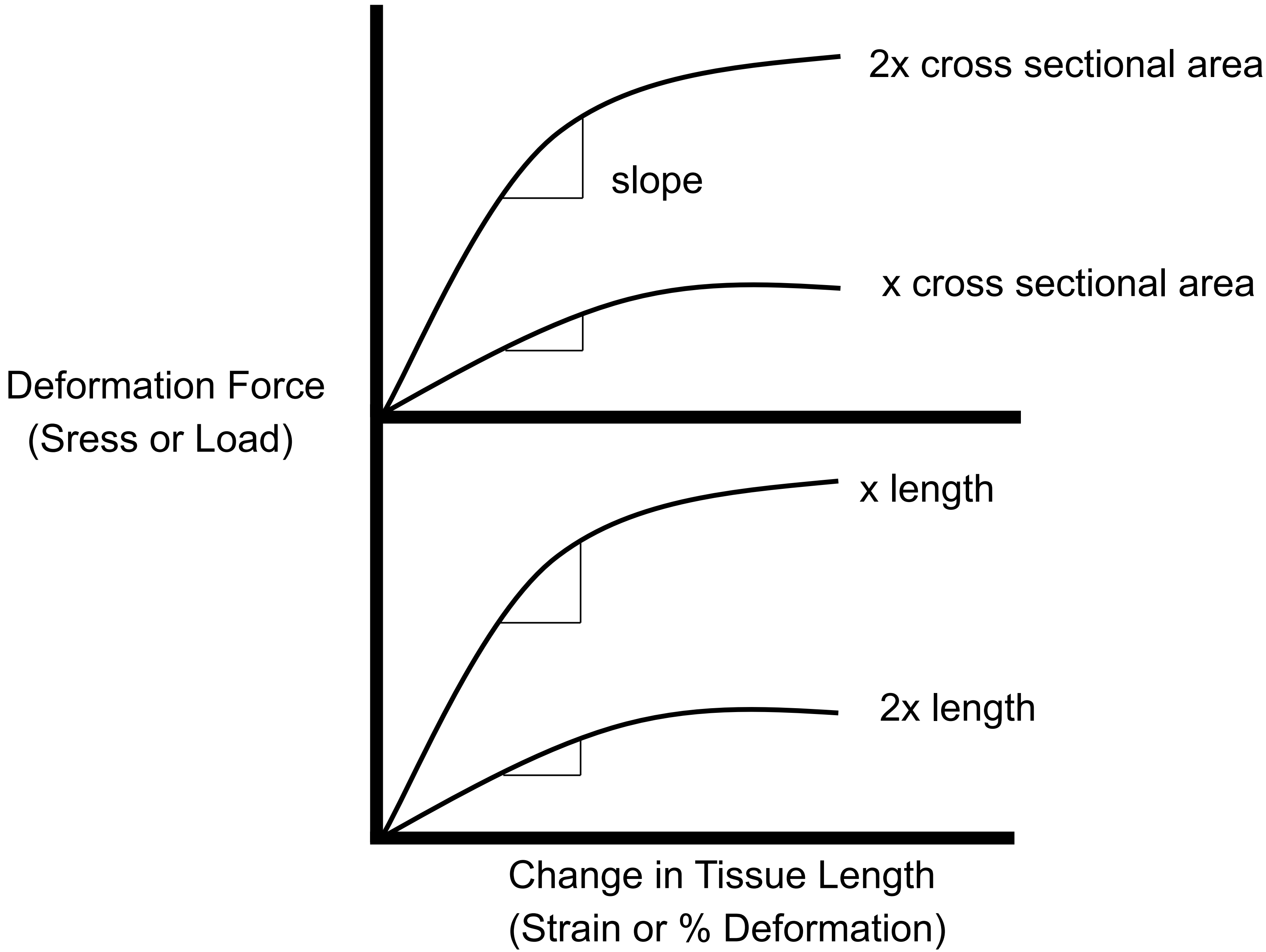
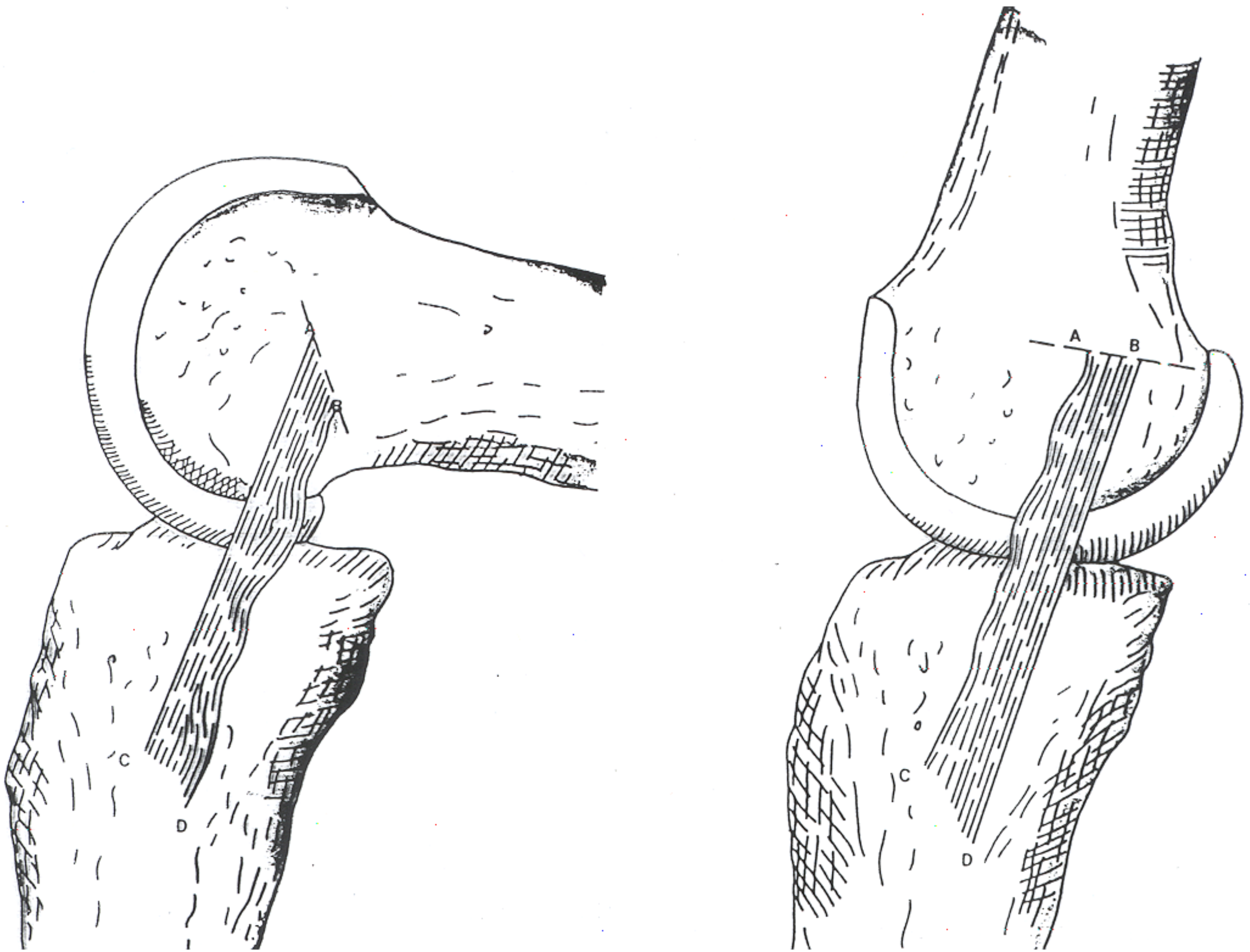
Properties of Ligamentous and Tendinous Tissues



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

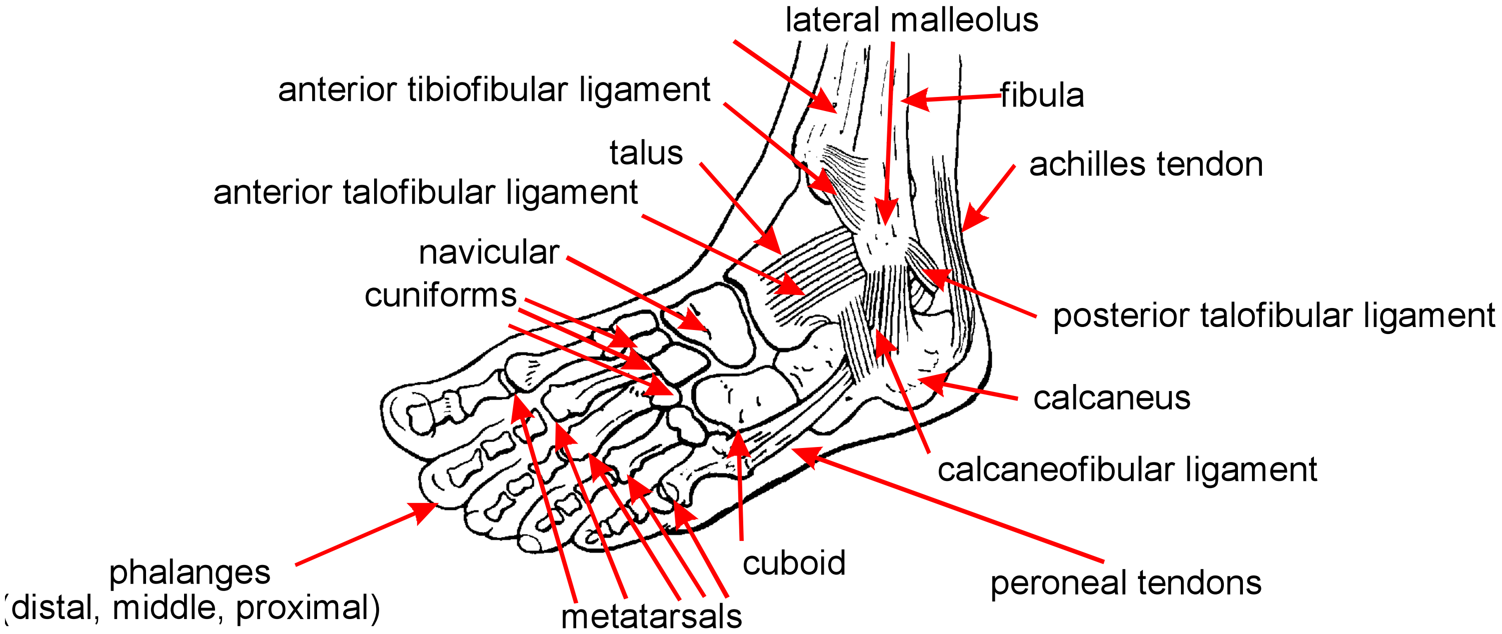
Functional Sub-units of the Lateral Collateral Ligament - Left Knee

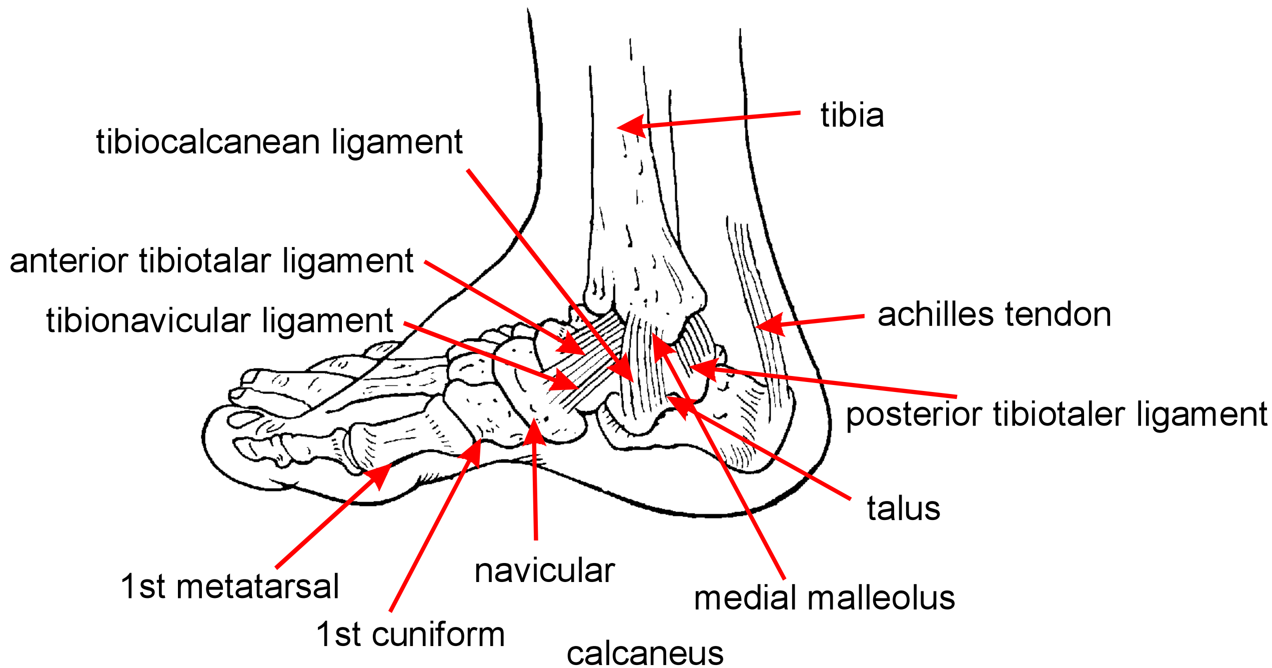


Ligament Sprain

- 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





Ligament Healing

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

<u>Healed Ligament never attain pre-injury tensile strength due to</u>:

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

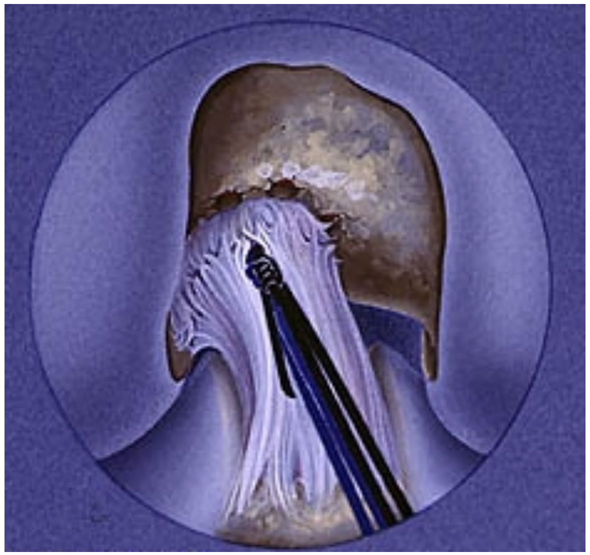
Immobilization vs. Mobilization: A Fine Line

- <u>**Effects of immobilization on injured ligamentous tissue**</u>
  - **GOOD**
    - **less ligament laxity (lengthening)**
    - **d risk of osteoarthritis**
  - **BAD**
    - **less overall strength of ligament repair scar**
    - **protein degradation exceeds protein synthesis r net d in collagen quantity**
    - **production of inferior tissue by blast cells**
    - **resorption of bone at site of ligament insertion**
    - **d tissue tensile strength (50% in 6 - 9 weeks)**
- <u>**Benefits of mobilization (movement) on injured ligamentous tissue**</u>
  - **ligament scars are wider, stronger, and are more elastic**
  - **Better alignment / quality of collagen**

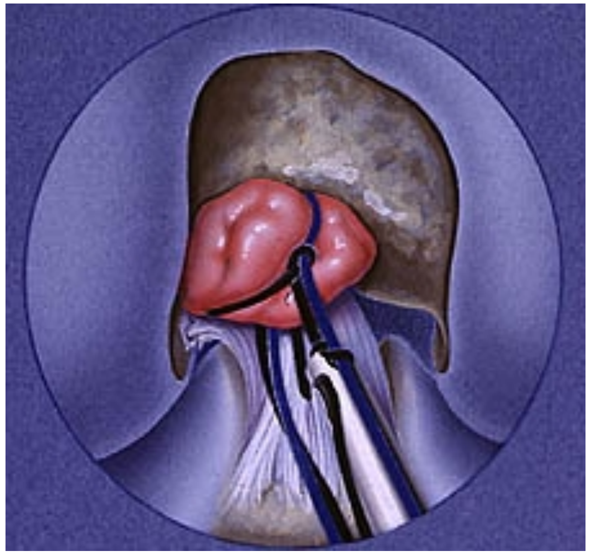
Ligament Repair Surgery (ACL)

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 patients own blood is formed and attached to the suture site

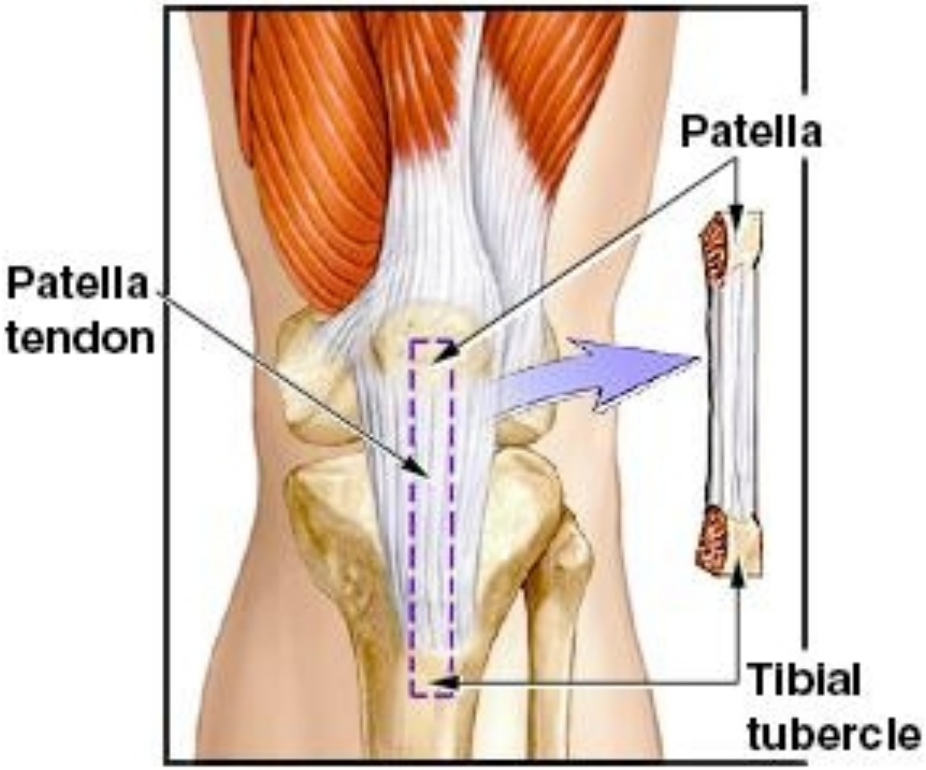


ACL Re-construction Surgery

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



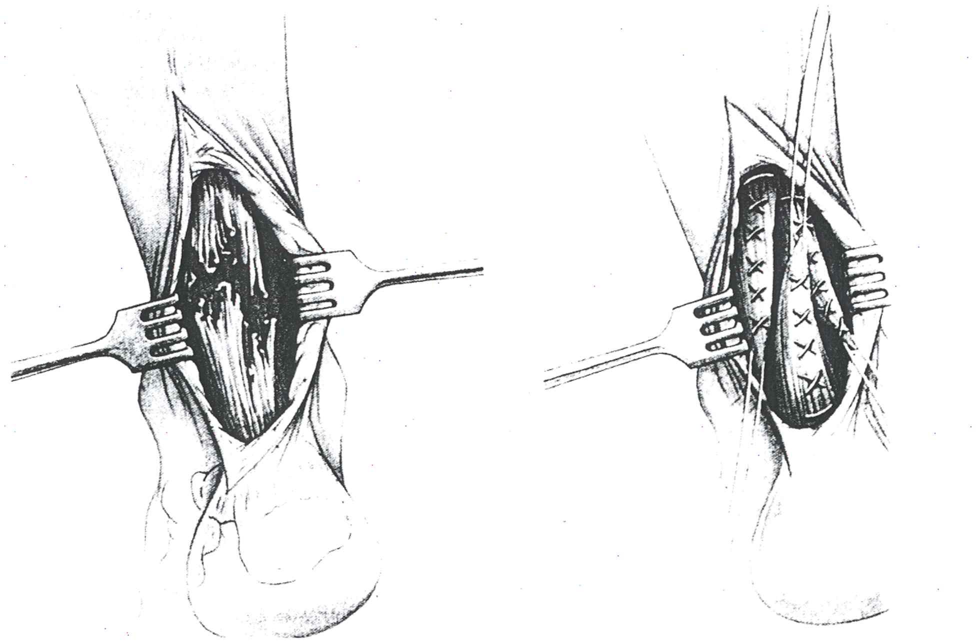
Tendon Rupture

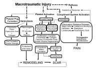
- **Tendon - dense regular tissue attaching muscle to bone**
  - **forces of 2000 psi have been recorded in the human achilles (running)**
  - **max tensile strength is 4X max force production in muscle**
- **Tendon rupture - most often seen in Achilles**
  - **Age 30, blood flow d in an area 2-6 cm 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-stich Sutures to Approximate the Fibers




Macrotraumatic Injury
Reflexes
Platelet Activation
Compliment System Activation
Platelet Plug Formation
Hemostasis
Growth Factors
PAIN
REMODELING
SCAR

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 haversion 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**

Steps in Fracture 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 r d bone production r 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 trabelcular 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
  - r Fractures should be reduced (immobilized) within 3-5 days

Steps in Fracture Healing

- **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**

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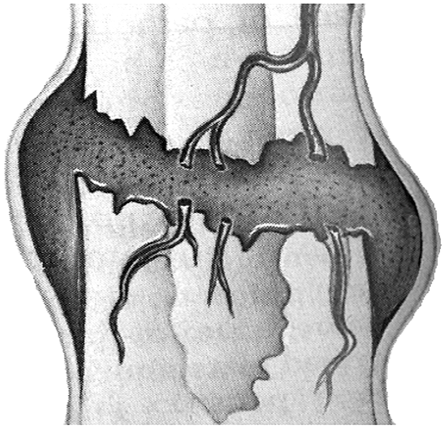

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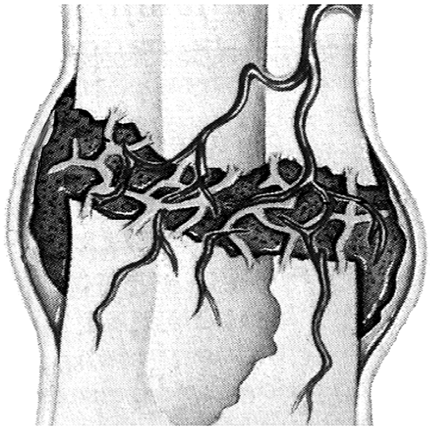

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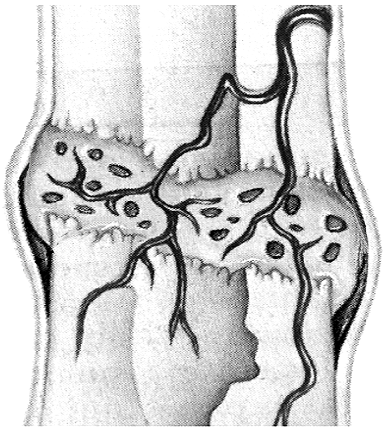

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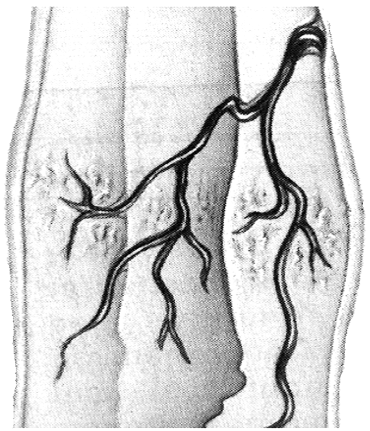

Bioelectricity and Fracture Healing

- **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
- d calcium content in surrounding bone
- resorption and weakening of tissues at sites of ligament attachments
- no stress forces on an immobilized joint r thinning of articular cartilage
- Adhesions r joint stiffness
- loss of peripheral autonomic vascular control r 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 discrepency $\leq$ 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**