Biomechanics of Tissue Healing and Its Relationship to Therapeutic Exercise

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What is Injury?

• *Damage caused by physical trauma sustained by tissues of the body* (Whiting WC, Zernicke RF 2008)
  - Contributing factors (age, gender, nutrition, genetics, fatigue, environment, equipment, disease, previous injury, pain, skill level, anthropometric variability, fatigue)

• Injury types
  - Primary vs. secondary
  - Acute vs. chronic
  - Microtrauma vs. macrotrauma
  - Compensatory
Framework for Therapeutic Exercise Prescription

1. Tissue Healing
2. Mobility
3. Initiate Performance, Stabilization and Motor Control
4. Improve Performance
5. Advance Coordination and Skill

Adapted from Anemaet, 2017
Framework 1: Tissue Healing

Stages of Tissue Healing
1. Inflammatory Response **
2. Proliferation (Repair)
3. Remodeling (Maturation)
Physiology of Tissue Healing: Inflammatory Response

1. Inflammatory Response (Whiting WC, Zernicke RF 2008)
   - Generalized response to injury
   - Occurs in *all* cases, regardless of tissue affected
   - Can lead to damage if not controlled
     - Blocks proliferation / remodeling
   - Clinically: *rubor et tumor cum calore et dolore / functio laesa*
     - Redness
     - Swelling
     - Heat
     - Pain
   * * 5th SIGN: Functional Loss
Physiology of Tissue Healing: Inflammatory Response

1. Inflammatory Process/Response
   • NOT active healing
   • Exudate (fluid and plasma proteins) brought to area to initiate healing
     • Fluid/swelling caused by exudate may contribute to pain
     • Serves several positive functions
   • Chemotaxis
     • Phase controlled by chemical mediators
     • Phagocytes
     • Macrophages, neutrophils
   • Pain/impaired movement from altered chemical state:
     • Irritates nerve endings
     • Increased tissue tension from edema or joint effusion
     • Muscle guarding (body’s way of immobilizing a painful area)
Physiology of Tissue Healing: Inflammatory Response – Clinical Implications

• GOALS
  • Control excessive inflammation
  • Decrease pain
  • Protection of injured tissue
  • Facilitate wound healing
  • Maintain integrity/function of associated areas
  • Improve proprioception
  • Target compensations
  • Client education

• First 2-4 days after injury; up to 4-6 days, unless injury is perpetuated
• Send signals to fibroblasts
• Tissues go into proliferation phase
2 Options: Regenerate or Repair

• Regenerate new tissue
  ** OR **

• Repair it
  • Fill with scar tissue – connective tissue
  • Start in 24 hrs
  • Fibroblasts come into the area
  • Synthesize proteins (proteoglycans, elastins, collagen) responsible for repair
Skeletal Muscle Injury (Whiting WC, Zernicke RF 2008)

• Impact Injury
  • Direct compressive Impact (contusion/intramuscular hemorrhage)

• Exercise-induced Injury (DOMS)
  • Connective/contractile tissue disruption after exercise
  • Muscle tenderness, stiffness, restricted ROM
  • Especially after eccentric muscle action in contractile tissue
  • Symptoms and metabolic events similar to acute inflammation (Close GL, et.al., 2005)

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TABLE MOUNTAIN
Skeletal Muscle Injury (Whiting WC, Zernicke RF 2008)

- **Acute Muscular Strain**
  - Tendon – connects skeletal muscle to bone
  - Strain - damage to a musculotendinous unit
    - Overstretch a passive muscle
    - Dynamically overload an active muscle (in concentric or eccentric action)

- **Severity of tissue damage**
  - Magnitude of force
  - Rate of force application
  - Strength of the musculotendinous structures
  - Categorize
    - Mild: min structural disruption/rapid return to normal function
    - Moderate: partial tear in mm tissue, pain, some loss of function
    - Severe: complete or near-complete tissue disruption/functional loss/hemorrhage/swelling
Tissue Healing in Skeletal Muscle

Regeneration vs. repair depends on:

1. Extent of injury / deep?
   - Sarcolemmas sheath intact?
   - If endomysium is damaged, no regeneration!
   - Fill with connective tissue scar
   - Decrease efficiency/strength

2. Inflammatory Phase – determines amount of regeneration
   - Macrophage > neutrophils
   - Clean up area/signal fibroblasts
     - Macrophages – life span 1-3 years
     - Neutrophils - life span 1-2 days
   - Macrophages
     - Too many fibroblasts = fibrotic scar tissue forming
     - Too many macrophages = CT, collagen, scar tissue instead of mm
Tissue Healing in Skeletal Muscle

3. Regeneration of contractile elements

(Kolt & Snyder-Mackler, 2003)

- Activation/proliferation of satellite cells
- Ruptured muscle fibers retract
- Fill gap with blood
- Cytokines released – attract leukocytes/macrophages
  - Remove necrotic tissue
  - Mediate satellite proliferation through chemotaxis
  - Lasts 5-7 days after injury
- Maturation of myofibers occurs at ~14 days

Kolt & Snyder-Mackler, 2003
Tissue Healing in Skeletal Muscle

Two processes during muscle regeneration

1. Regeneration of myofibrils
2. Production of scar tissue

• Immobilization (Lehto, et.al., 1985) = Few inflammatory cells
• Early exercise (Lehto, 1985) produced dense scar tissue, increased fat deposits
• With excessive scar tissue, tissue extensibility is reduced
Tissue Healing in Skeletal Muscle
Clinical Implications

• Mobilizing muscle early after injury strengthens tissue more quickly, BUT:
  • Density of connective tissue acts as barrier preventing myofibrils from joining
  • Barrier might affect muscle activation patterns
  • Predispose area to recurring injury
  • Scar tissue affects extensibility of tissues
  • Muscle atrophy source of structural weakness in the muscle
  • Short period of immobilization required, but not prolonged!
  • Rat model: 3-5 days of immobilization

• Age of the species is an important factor influencing the regenerative process (Borisov, 1999)
  • Increased age = less satellite cells
  • Effectiveness of phagocytosis of macrophages is slowed
  • Few growth factors
Tissue Healing in Skeletal Muscle
Clinical Implications

- **Immobilized muscle**
  - Inactive muscle undergoes rapid change in structure, and thus function
    - Atrophy
    - Protein synthesis decreases/protein degradation increases
    - Muscle in shortened state – 30% decrease in net weight (rat, 3 days immob)
    - Most affected if in shortened position
    - Decrease in muscle activation (50% of controls, gastroc - in shortened position x 4 wks)
  - Can intermittent lengthening (stretching) minimize a loss of sarcomeres in series when muscle is immobilized in a shortened position (Williams, 1990)
    - Rats immobilized x 2 weeks; Sarcomeres decreased by 19%
    - ROM reduced by 41% in animals that weren’t stretched
    - 30 min stretching/day sufficient to prevent loss of sarcomeres and maintain ROM at control levels
- **Rate of stretching** (Simpson, et.al., 1996)
  - Rabbit tibial osteotomies – lengthened at different rates
  - Rates too high: significant increase in connective tissue, damaged muscle fibers; mod increase in CT
  - Low levels of lengthening: sarcomeres added to muscle fibers as expected, min increase in CT

**TAKE HOME: Low Load, Prolonged Stretch**
Tissue Healing in Skeletal Muscle
Clinical Implications

• Need to provide rest soon after injury
• Max, ~3-5 days
  • Limited scar tissue laid down
  • Scar tissue less dense
  • Regenerating myofibrils can penetrate tissue more easily
  • More normal muscle performance achieved
Tissue Healing in Skeletal Muscle
Clinical Implications

• Control inflammation, as muscle heals
• Increased inflammation = incr phagocytic cells (macrophages/neutrophils)
  • More macrophages = increased fibrosis/scar tissue
• HOW?
  • Modalities
    • Game Ready
    • Ice (use wet, thin towel between skin and ice pack)
    • Laser
Tissue Healing in Skeletal Muscle Clinical Implications

• Are surgeons bandaging post op?
  • Education
  • How long?
  • Gentle remobilization

• Exercise - facilitate muscle function
  • Protect regenerating muscle cells
  • Mild/light contraction (not stressing newly regen cells)
  • No high strain/stress on new cells so don’t ‘pull them apart’
  • Inflammation and pain is your guide – allow dog to ‘cheat’ during exercise
  • Gradual progression of forces, TO TOLERANCE
    • Light contraction – muscle pump/increased circulation/remove phagocytic, inflam cells from the injured area
    • PROM – mid range, WITHIN PAIN TOLERANCE (2-3x/day)
    • Joint compressions
    • Muscle ‘flickers’
Bone Injury (Whiting WC, Zernicke RF 2008)

• Bone
  • Structural support/protection
  • Facilitates movement
  • Site for hematopoiesis and mineral storage
  • Compromised osteocyte performance - jeopardize structural integrity of affected bone/skeletal system

• Bone injuries
  • Osteopenia – loss of bone tissue (puppies)
  • Osteoporosis – porous bone; more or larger holes
  • Osteonecrosis – cessation of blood flow
  • Fracture
    • Most common injury in bone
    • Break in structural continuity
    • May be used to describe disruption to cartilage and epiphyseal plate
Tissue Healing in Bone  (Whiting WC, Zernicke RF 2008)

3 Phases of Fracture Healing:

1. **Inflammation**
   - Hematoma (pool of blood) – immediate response at fracture site
   - 3 days – mesenchymal cells produce fibrous tissue at fracture ends
     - Outer layer forms new periosteum
     - First 3 days – stable (don’t tend to displace) and unstable fractures (slip after reduction/immobilization) react the same
     - 3-5 days after fracture, degree of stability influences subsequent healing steps
       - Stable Fx – well vascularized
       - Unstable Fx – not well vascularized
     - Osteoblasts form new trabeculae
       - Stable Fx – new bone forms along periosteal surface; spanning fracture site
       - Unstable Fx - new bone does NOT span the fracture line (delayed or malunion)
   - Day 9 – cells invade in gap between the bony ends
     - Macrophages – remove cell and matrix debris
     - Fibroblasts – generate structural matrix for cells/vessels
     - Capillaries
   - 2 weeks post fx – osteoblasts begin bone deposition
Tissue Healing in Bone

2. **Bony union across fractured ends**
   - Partial repair
   - Initial callus forms on bone ends
   - Occurs by ~3 weeks
   - Minimal movement at fracture site
   - Xray – fracture line still visible
   - Good stability by ~6 weeks
   - Partial weightbearing
   - 3-6 weeks

3. **Callus Remodeling**
   - No movement at fracture site
   - No fracture line on radiographs
   - Begins as soon as the fracture site gains stability
   - Osteoclasts – resorbs old bone
   - Osteoblasts – deposit new bone
   - Bone is fully repaired
   - Good stability
   - 6-12 weeks
Tissue Healing in Bone

• Primarily remodeling and regeneration
  • No permanent scar / ‘scar’ gets ‘reabsorbed’
  • Big Difference
    • Not same vascularity as muscle
    • A lot of vascularity.lot of blood vessel response
Tissue Healing in Bone
Clinical Implications

- **1-2 weeks – woven bone and chondrocytes form callous**
  - Any bone movement/loading will tear apart that woven bone and hyaline cartilage
  - Keeps callous from forming

- **Reparative Phase – (2-6 weeks)**
  - Controlled stress - begin GENTLE loading
    - Callous replaced w lamellar/trabecular bone over those 4 weeks
    - Bone is ready to accept low loads
    - Get calcification - How much depends on the load
      - WOLFF’s Law – bone forms in response to pressure on bone
      - If no forces on a bone during 2-6 weeks, not heal as well, quickly or strongly

- **Remodeling Phase**
  - At 6-12 weeks, bone near full strength
  - Hyaline/woven bone replaced w trabecular bone
  - Osteoclasts resorb the trabecular bone
  - Remodel occurs up to 5 years
  - Gradual return to full activity after hard callous formation
Tendon Injury

Tendon

- Force transfer from skeletal muscle to bone
  - 3 zones:
    - Body of tendon
    - Osteotendinous junction – connections of tendon to bone
    - Myotendinous junction – connections with muscle

- Act proprioceptively
  - Shock absorbers
  - Energy storage sites – act as springs to store energy during locomotion
  - Enhances athletic function

- Injury can restrict or prevent normal movement and function

- Types of tendon injury
  - Direct insult – laceration
  - Indirect – excessive tensile loads
Tendon Injury

• **Strain:** injury to musculotendinous unit
  • Categorized by severity of injury (similar to skeletal muscle)
    • Mild: min structural disruption, local tenderness, minimal functional deficit
    • Moderate: partial structural defect, visible swelling, marked tenderness, some loss of stability
    • Severe: complete structural disruption, marked tenderness, functional deficits that usually require corrective surgical intervention

• **Tendinopathy** Scott A, et.al., JOSPT, 2015
  • Chronic exposure to volumes/magnitudes of loading beyond physiological capacity
    • Tension
    • Compression
    • Friction
  • Cumulative cycles of injury, inflammation and repair – often subclinical
  • Leads to pain/swelling (tendinopathy)
  • Injury-repair evolves gradually over time
  • Slow resolution/inability to return to full activity
Tendon Injury

Tendinopathy - Pathomechanics Scott A, et.al., *JOSPT*, 2015

- Cycle of chronic and acute-on-chronic pain
  - Poorly healed
  - Deconditioned tendon
  - Failed attempts to return to activity
- End result of overuse = result of repeated release of inflammatory and reparative mediators (PGE2)


Tissue Healing in Tendons

- Repair of tendons is never complete! (Frank et al., 1999)
- Repaired tendons only return to 70-80% of original strength (Leadbetter, 1993)
- Poor healing response
- Replace Type III collagen with Type I collagen
- Inflammation
  - Initial response of all tissues to injury
  - Start of the reparative process
- Musculotendinous overuse affects the enthesis
  - Cause bone-tendon zone to become abnormally organized
  - Abnormalities in the fibrocartilage (thickening, mineralization)
Tendon Injury

Tendinopathy - Structural Changes  

- Thicker tendon
- Reduced energy-storing capacity  
- Higher strains for the same load
- Decline in structural and material properties
- Reduced load-bearing capacity  
Tendon Injury

• Effect of Exercise on tendons (Maffulli & King, 1992)
  • Increases CSA, collagen fiber thickness, cellularity of tendons in young animals
  • Results vary, species to species
  • Adult animals – improve tensile strength, total weight of collagen, without increase in tendon area (Kannus et.al., 1997; Maffulli & King, 1992)
  • Fine line between load stimulating positive cellular response (incr collagen synthesis, size and number of fibrils, and thus tensile strength) and load triggering degrading response (Frank & Hart, 1990)
Tissue Healing in Tendons
Clinical Implications

• Days 1-5: Inflammatory response, blood clotting (Enwemeka, 1989)
• GAGs, collagen synthesis
  • Restore integrity of tendon matrix
  • Week 1 - Avoid additional tissue damage
    • Day 7: increased ground substance, disorganized fibrils
    • Rest
    • Ice
    • Immobilization
• Weeks 2-3
  • By Day 18: inflammatory cells are no longer present
  • Low loads help align new fibers and strengthen repairing tendon
    • Exercise
    • IASTM
    • Bracing
  • Stretching and activation of muscle-tendon unit may prevent excessive muscle atrophy and joint stiffness
• 3+ Weeks
  • Injury - 4 weeks: fibronectin present, as template for reparative tendon (Williams, et.al., 1984)
  • Progressively increase stress on tendon to optimize tissue healing
Ligament Injury

- Ligament – connective tissue that joins one bone to another
- Resist excessive movement or dislocation
- ‘Passive joint stabilizers’
  1. Attachment of articulating bones to one another across a joint
  2. Guidance of joint movements
  3. Maintenance of joint congruency
  4. Position sensors for joints
  5. Ligament Injury
- Injury to ligament, compromises:
  - Stabilization
  - Ability to control joint movements
  - Proprioceptive function
- Know extent of the injury
  - Determine proper management
  - Amount of recovery time and functional loss
  - Insufficient recovery time – chronic
  - Acute ligamentous rupture
Tissue Healing in Ligaments

• Similar in structure / heal similarly
  • Tendons – mm to bone
  • Ligaments – bone to bone

• Do not regenerate; heal by repair – so primarily have scar tissue responsible for the repair

• Precursor cells to tendon – tenoblasts, from injured end of a tendon

• Proliferation of fibroblasts

• Tenoblasst/fibroblast for collagen form fibrils
Tissue Healing in Ligaments

- Ligaments are sensitive to training and disuse
- **Long-term immobilization** (Noyes, et.al., 1974; Woo et.al., 1987)
  - Immobilization degrades collagen
  - Ligament atrophy
  - Reversible
  - Exercise hastens recovery
  - Respond to appropriate amount of mechanical loading
  - Synthesize collagen
  - Increase strength
  - Too much loading detrimental, esp if joint is unstable
Tissue Healing in Ligaments
Clinical Implications

• 3 phases – biological responses following ligamentous injury (Frank, 1996)
  1. Bleeding/inflammation
  2. Active repair with proliferation of bridging materials
  3. Remodeling

• Acute management of ligamentous injury has significant effect on outcome of rehabilitation (Oakes, 1991)

• R.I.C.E. (0-3 days)
  • Uncontrolled bleeding/edema
  • Abnormal collagen fiber arrangement
  • Hypertrophic, painful scar

Oakes BW, 1992
Tissue Healing in Ligaments
Clinical Implications

- First 3 weeks – initial healing
  - Early mobilization is detrimental to collagen orientation
  - Surgery/complete tear – immobilize
  - Partial tear – decreased stress
- > 3 weeks (3-10 weeks, up to 16 weeks)
  - Mobilization increases tensile strength of the repairing ligament
  - Begin movement
  - Gradual increase in load, but not full load
- Remodeling Phase
  - Week 6 – Week 26, up to 1 year
  - High risk for reinjury if too much load/stress and is too sudden

Oakes BW, 1992
Tissue Healing in Cartilage

• Technically heals same way – inflammation, proliferation, remodeling
• But avascular!
• Minimal initial vascular response - so no large inflammatory response to help it heal
• Precursor cells
  • Chondrocytes, divide - so have possibility for regeneration or repair
  • Increase proteoglycan production – aid in tissue healing; but healing is SLOW
  • Can take years to heal
• OA – keep putting stresses on it in the process; never makes it to healing
• Continue reinjuring
Tissue Healing in Cartilage
Clinical Implications

- May never heal
- Takes a LONG time – months to years
- Unloaded motion is BEST! – stimulate synovial fluid movement without putting compressive forces on the cartilage that could damage it
- Unloaded/open chain – aid in healing it
- Best healing
  - In periphery of cartilage /along edges
  - Amount of healing, depends on depth of injury
  - The DEEPER the injury (full thickness), the better the healing
    - More likely to damage subchondral bone below the cartilage with deep injury
    - Pulls in right cells to help cartilage heal
Tissue Healing in Nonmusculoskeletal Injury

- Skin and nervous tissue
- Secondarily affected to MSK tissue

SKIN
- Body’s outermost defense
- Pathology
  - Abrasion – scraping away of superficial skin layer; usually mechanical
  - Blister – fluid-filled; caused by heat, chemical, mechanical
  - Contusion – bruise; direct impact
  - Puncture – penetration depth
  - Laceration – jagged tearing of the skin
- Venous vasculature close to dermis, thus significant hemorrhage
- Minimize scarring
- 10-14 days
Tissue Healing in Nonmusculoskeletal Injury

NERVOUS TISSUE

• Often debilitating dysfunction
• Brain, supraspinal structures, spinal cord/nerves, peripheral nerves
• Reduce/eliminate sensory and/or motor function
• Chemical, thermal, ischemic, mechanical means
• Mechanical
  • Entrapment
    – Entrapped in a confined anatomical space/between anatomical structures
    – Impingement of nervous tissue
  • Trauma
    – Direct mechanical insult or forces indirectly applied from surrounding structures
    – 3 principal loading types:
      • Compressive: pressure on the nervous tissue
      • Tensile: tissue elongation/stretch injury
      • Shear: friction-related
Tissue Healing in Nonmusculoskeletal Injury

NERVOUS TISSUE

- Temporarily block nerve signal conduction or sever (partial/full) axon
  - Wallerian Degeneration
    - Injury to the axon, leading to degeneration (axon and myelin sheath disintegrate)
    - Regenerate or cell death
- IVDD
  - Rotational body movements
  - Shear stress in annular fibers
  - Leads to tears, weakness in annular layers
  - Compression squeezes nucleus pulposus into area of annular weakness
  - Herniated disc impinges on adjacent structures – primarily on nerve root/spinal cord
    - Inflammation
    - Irritation of nerve root
    - Pain / referred pain
    - Local muscle spasms
    - Zygapophyseal joint pathology; loss of ROM
Tissue Healing in Nonmusculoskeletal Injury

**NERVOUS TISSUE**

* Secondary Issues
  * Reflex muscle guarding
    - Prolonged muscle contraction in response to painful stimulus
    - Underlying tissue / referred pain source
    - Splints the injured tissue against movement
    - Ceases when painful stimulus is relieved
  * Intrinsic muscle spasm
    - Metabolic changes that occur when mm is in continued state of contraction
    - Pain from altered circulatory and metabolic environment
    - Self-perpetuating; regardless of whether primary lesion that caused the initial guarding is still irritable
    - Also response to: prolonged period of immobilization, direct trauma, viral infection
  * Muscle weakness
    - Decrease in strength of contraction of muscle
    - Result of systemic, chemical, local lesion of a nerve of CNS or PNS or myoneural junction; inactivity; direct trauma to the muscle
Principles for Dosing

• Exercise Prescription
  • Proper amount of correct activity to achieve best benefit?
  • Efficient, benefit the quickest, prescribe accurately to achieve goals and get best outcome
  • Put thought into it!
  • ALWAYS ask yourself ‘WHY?’
  • Does it work for the patient?
    • Right amount of right activity for best benefit
    • Home setting, age of client (not just the patient!)
Assessing Tissue Healing

1. Load/overload **
   • Based on time frames for healing
2. Specificity
3. Variation
   • Comes later (2-3 weeks down road)
Principle #1: Load vs. Overload

• Amount of stress on body/system during exercise

• **Determined by what time frame you’re in for healing**

• Load determines how successful the outcome will be
  • Too much / too little – takes longer or don’t get right outcome

• Load vs overload
  • Load – putting stress on body
  • Overload – gradual increase stress on the body/system
Overload

• Increase demands; body generates greater force to get adaptive response
  • Ex: increase weight to get more strength

• Overload – NOT just in terms of strengthening
  • Applies to all types of exercise
  • Applies to all systems of the body
    • Aerobic exercise
    • Balance
Overload

• Overloading body systems is accomplished in diff ways
  • Most often think: Increase load/resistance/distance you perturbate them, or balance
  • Can do more sets of an exercise
  • Longer duration of an exercise (5 vs 15 min)
  • Change speed – slow or fast/decrease the speed
  • Change rest periods – reduced rest period times/rests between exercises (not as much recovery time)
  • Alter number of reps
  • Combination of these

** Bottom line: Cause increase in demand on the body system you want to change
Principle #2: Specificity

- Adaptations to your exercise/training is specific to the stimulus you apply
- Also translates into other activates that they may do; related gains
- Get adaptations outside of the way that you train
  - Exercise prescription - design to target something specifically
  - Ex: Strength vs. Power
    - Strength to transfer sit – stand
    - But not power (ability to use that strength quickly)
  - What do you want to improve/accomplish?
    - Body system: soft tissue, CV, ROM, proprioception
    - Action: strength, power, aerobic capacity, endurance, improve static or dynamic balance, speed
Principle #3 - Variation

• Later stage: 2-5 weeks (proliferation stage)
• Change variable(s) in your parameters over time
  • Gain optimal training stimulus
  • Trick body – think introduce a new exercise
  • Body will adapt to this ‘new’ exercise
  • Change velocity, intensity, rest periods, etc

• Overload vs. Variation
  • Overload – just increase the exercise
  • Variation – change the exercise; trigger adaptations

• If don’t change exercise –
  • Begin to see smaller gains; not as much as in prior weeks/initially
  • Want max gains every single week/visit
  • Gains diminish/plateau – reached max potential
    • Body made all adaptations/recognizes that exercise
    • Body says I have to do something different here
  • Variation: allows body to jumpstart the adaptations
Exercise parameters – “FITTT” Parameters

• **F**requency - # sessions/period of time they do it over
• **I**ntensity – how much load/overload, # of reps, # sets, # holds
• **T**ime (Duration) – time within the session/overall time – # days, weeks, months
• **T**ype of exercise – isometric, isotonic, CV, balance
Exercise parameters – “F.I.T.T”

• Avoid complete/continuous immobilization (Cyriax, 1982; Salter, 1993; Salter, 1999; Wynn Parry & Stanley, 1993)
  • Adherence of developing fibrils
  • Weaken connective tissue
  • Changes in articular cartilage

• Influence development of organized scar through passive movements

• Tissue-specific movements
  • Prevent abnormal adherence
  • Avoid disruption of the scar

• Intensity (dose)
  • Gentle to avoid detaching fibrils from healing site
  • No pain
  • Do not reinjure tissue
  • Depends on severity of lesion
  • ANY movement TOLERATED at this stage is beneficial
  • DO NOT increase pain or inflammation
  • Active movement contraindicated at lesion site
  • Active movement appropriate in adjacent regions – maintain integrity, address compensations, increase circulation and lymph
Exercise for Tissue Healing

PROTECTION PHASE (Kisner & Colby, 2002)

1. Educate the client
   • Anticipated recovery time - how long, how often, how much
   • Protection, with appropriate functional activity
   • Precautions:
     • Proper dose rest and movement
     • Too much movement – increased pain/inflammation
   • Contraindications:
     • Stretching
     • Resistance exercises at site of inflamed tissue (Zohn & Mennell, 1976)

2. Control effects of inflammation
   • Control pain, edema, spasm
   • Immobilize – short term
     • Rest, splint, orthotic, taping
   • Modalities
     • Cryotherapy – Game Ready
     • Laser
Exercise for Tissue Healing

PROTECTION PHASE (Kisner & Colby, 2002)

3. Promote early healing and prevent deleterious effects of rest
   - Manual therapy (Grade I-II joint mobilizations)
   - Massage
   - Passive movement; joint compressions; muscle setting – with caution
   - Target compensations
Exercise for Tissue Healing

4. Most effective exercise: light mm contraction
   - Is muscle contraction beneficial for muscle healing?
     - Mechanotransduction (Kahn, 2016) – deforming the muscle, small deformation causes biochemical signals to go off, in addition to increased blood flow/mm pumping
     - Brings right cells to the region to continue/improve healing
   - Isometric ‘flickers’/muscle setting
   - Isometric = small mid-range contraction
     - Different from PROM!
   - Turn mm on/off very quickly = <1 sec on/<1 sec off
   - Short contraction time – limits # of motor units that are recruited = lower intensity
   - NOT STRENGTHENING / not strong mm contraction
   - ‘Muscle pump’: remove edema/increase circulation
   - Just remove inflammation / help tissue heal / bring good blood supply
   - Typical prescription – 10-20 flickers, 3-4 times/day – to tolerance
   - More you do it, more it removes edema
Exercise for Tissue Healing

• Frequency – 3-4 times/day, to tolerance
• Intensity – light
• Time (Duration) – until inflammation is reduced (2-3 days) –
  • Normal inflammation should be under control in 3 days
  • If goes beyond 2 weeks, then it becomes chronic inflammation
• Type - isometric
Exercise for Tissue Healing

5. PROM exercise
   a. Safe to begin as soon as pain allows post-op
   b. Within the limit of pain
   c. Facilitate tissue healing
   d. Improves fluid dynamics
   e. Maintains nutrition within joints
   f. Avoids problems with joint fibrosis
      * Wright RW et.al., J Knee Surg, 2008
   g. Mid-range Motion
   h. Range gained due to decreased pain, swelling, muscle guarding
   i. Avoid soft tissue and joint stresses
   j. Maintains mobility (joints, ligaments, tendons, muscles)
      * Decreases pain by movement of the joint
      * Signals other tissue healing cells to come to the area
   k. Early motion = reduces pain, decreases adverse changes in articular cartilage,
      prevents capsular contraction
      * Cascio BM, et.al., Clin Sports Med, 2004
Joint Compressions - Standing
Joint Compressions - Sidelying
Weight Shifts
Muscle ‘Flickers’

• If painful, bring floor to limb
Quad Resistance

Sidelying - antigravity
Case Example of Exercise for Tissue Healing

TPLO Patient

Questions to Ask, BEFORE you see the patient:
1. What type of surgery? What tissues are involved?
2. How long ago?
3. Who did the surgery?
4. How much OA in the joint
Case Example of Exercise for Tissue Healing: TPLO Patient

Subjective:
- Medical history
- Prior level of activity
- Current level of activity
- Medications
- How long was he lame before he had the surgery?
- How did it happen?
- Stairs in the home
- Other dogs
- Concomitant issues

Objective:
- Posture, conformation
- Incision
- Flexibility
- Gait
- Functional Movements
- Limb circumference (muscle mass, edema)
- Palpation – atrophy, heat, tone, spasm, trigger points, tenderness
- Screen – ROM
- Home environment
- Compensation – evaluate nose to tail!
  - 1/10 pelvic rotation
  - ‘Crabs’ to affected side
  - Tight hamstrings? – increased stifle flexion at a walk with CCLR
  - Spasm – Sartorius, rectus femoris, etc. (sustained stress due to surgical procedure)
  - Reactivity/discomfort on spinal palpation
Case Example of Exercise for Tissue Healing: TPLO Patient

Client Education

a. Time frame for bone healing
b. Towel Walk (on slippery surfaces)
c. PROM
d. Modalities (ice-T.I.D.)
e. Suture removal in 10-14 days (appointment needed)
f. Schedule follow-up appointment (3wks)
g. Leash walk-short distances, short lead--monitor dog’s response (comfort stiffness)
h. Avoidance of explosive activities (running, jumping, playing)
i. Problems to note: persistent edema; acute pain identified by sharp yelps/cries; change in the usage of the affected limb; licking incision site
Goals: Stifle Rehabilitation - Acute

- Reduce pain/edema
- Improve ROM
- Improve flexibility
- Improve weightbearing
- Joint position sense
- Correct compensations
Case Example of Exercise for Tissue Healing: TPLO Patient

**Post-Op Week 1**

1. Multiple short walks (‘potty breaks’ only) on a short lead, 3-5x per day. This should not be a consistent pace. Allow your dog to stop and sniff around.

2. Passive ROM (10-15 reps) 1-2x/day-slowly – hip, stifle, hock

3. Joint compressions

4. Modalities as appropriate
   a. Massage
   b. Ice (15 min.) 1-2x/day-after PROM and walks

5. Problems to note: persistent edema; acute pain identified by sharp yelps/cries; change in usage of the affected limb and/or licking incision site – call your veterinarian immediately
Case Example of Exercise for Tissue Healing: TPLO Patient

Post-OP Weeks 2-4

1. Multiple short ‘potty’ walks on a short lead, 3-4 times per day. This should not be a consistent pace. Allow your dog to stop and sniff around.

2. Ice (10-15 min.) 2 times/day-after walks – use a wet, thin kitchen towel between the skin and ice pack.

3. Scar massage – perpendicular to the length of the incision.

4. Gradually progress therapeutic activities
   a) Stop PROM / Massage
   b) Weight shifts
   c) Muscle flickers
   d) Quad resistance; repeat 3-5 times, to tolerance

5. Problems to note: persistent edema; acute pain identified by sharp yelps/cries; change in usage of the affected limb and/or licking incision site – call your veterinarian immediately.
Case Example: Post hemilaminectomy

• Standing exercises – in standing, shift weight side to side and front to back; repeat 3-5 times daily, 3-4 times daily
  • FEET FLAT
  • Square stance

• Quad resistance: In standing, pull his left hip back and slowly drag your hand down his leg, encouraging him to pull (flex) his hip forward

• 3-legged standing - lift up each hind leg. Allow him to support his weight for as long as he can – or until he ‘sinks’. Repeat for each leg 3-5 times, or until fatigued. The amount of time can be increased as he is able.

• Joint compressions – in standing, feet flat, gently compress over her pelvis until she ‘sinks’, stand and repeat 3-5 times daily
Case Example: Post hemilaminectomy

- Stand and support – keeping his feet flat (not knuckled). Weight shift onto hindlimbs – back and forth and side to side. Repeat ~5-10 times, or until fatigued.

- Attempt 1-legged standing, left and right pelvic limbs, until she ‘sinks’. Lift and repeat 5-10 times or until fatigued.

- Rotation schedule – rotate Sassy every 2-4 hours on to her opposite side. Support her rear when turning her, careful not to let her flop around.

- Gently place Sassy over the peanut to support her weight several times throughout the day. While in this position:
  - Stand and support – keeping her feet flat (not knuckled). Weight shift onto hindlimbs – back and forth and side to side. Repeat ~5-10 times, or until fatigued.
  - Joint compressions – with feet flat, gently oscillate compressions over her pelvis to encourage weightbearing.
  - Proprioceptive training – rub Sussy’s rear paws over the ‘nubs’ on the balance disc for 20-30 seconds.
Summary of Tissue Healing Exercise
Acute Phase

• NOT trying to improve performance
• NOT increase how far they can move
• NOT improve CV capacity
• GOALS
  • Decrease pain/edema
  • Increase circulation
  • Increase synovial fluid production/movement
• Painfree
• Prescribe at LOW intensity (feel like they aren’t doing anything)
• Short duration
• High frequency
• As active as possible, within pain tolerance