Articular Cartilage

Robert C. Manske, PT, DPT, MEd, SCS, ATC, CSCS
Professor and Chair
Wichita State Department of Physical Therapy
Via Christi Health, Wichita, KS

Why Worry About Cartilage?

Estimated 385,000 procedures to repair articular cartilage defects in US in the year 1995

Poor Outcomes

- 231 patients; 4 year follow-up
- SF-36, KOOS, Lysholm, WOMAC and IKDC
- Poor functional outcome most highly correlated by articular cartilage status, especially PF
- Women significantly worse outcomes than males
- Meniscal treatment did not significantly affect scores.


Incidence

- Retrospective review
- 7 surgeons – practiced for min 7 yrs
- 25,124 knee arthroscopies
- Chondral lesions in 19,827 (63%)
- Mean of 2.7 articular injuries per knee


Incidence

- Between years 1989 – 2004
- Average age 39

http://www.bidmc.harvard.edu

Incidence

Classification
- Localized osteochondral or chondral lesion in 10,130 cases (67%)
- Osteoarthritis in 4311 cases (29%)
- Osteochondritis dissecans in 332 cases (2%)


Incidence

Location
- Most common
  - Patellar articular surface (36%)
  - Medial femoral condyle (34%)
- Least common
  - Medial tibial plateau (6%)


Incidence

Other concomitant injuries
- Medial meniscus tear (37%)
- ACL injury (36%)

Incidence

The “Ideal” patient for cartilage surgery is younger than 45 years old, has an isolated deep cartilage lesion, especially asymptomatic with no other associated lesions and no signs of osteoarthritis.


Articular cartilage damage found in 63% of patients undergoing knee arthroscopy.

Chondral or osteochondral damage found in 610 of 1000 (61%) of patients undergoing knee arthroscopy. Most common location MFC!


Incidence General Population

12% incidence in general population.

Common lesion
- Articular cartilage injury
- Young active individuals (mid 20’s)
- Also seen in older (40’s)
- Successful treatment delicate balance of activities and applied stresses

Mechanism of Cartilage Injury
- Direct blunt trauma
  - Striking joint on helmet or hard surface
- Indirect impact loading
  - Blow to bone
- Torsional loading
  - During tackle
  - Planting and cutting

Following ACL Injury
- 42 knees in 40 patients
- Acute isolated ACL injury
- 14 conservative
- 28 reconstruction
- T2 mapping MRI
- TOI, yearly for 11 years

Following ACL Injury

- All had cartilage damage at TOI
- Size of bone marrow edema pattern correlated with amount of cartilage loss during first 3 years
- Adjusted risk for cartilage loss for year 1
  - Doubled for MFC, Lateral compartment
  - Tripled for patella
- Years 7-11
  - LFC 50x baseline
  - Patella 30x baseline
  - MFC 19x baseline


Tibiofemoral Joint

- Most commonly, articular lesions are located in the area that contacts the tibia between 30-70° of knee flexion.


Tibiofemoral Joint

- Medial femoral condyle most common location for full-thickness focal chondral defects


Articular Cartilage

- Provides a wear resistant, accommodative surface
- Capable of withstanding high compressive and shear loads during weight bearing activities
- Has low coefficient of friction which allows ease of movement between joint surfaces

Articular Cartilage

- Functions to attenuate force and reduce friction
- A viscoelastic material
  - "Visco" - fluid squeezed out
  - "Elastic" - recovers to its resting length after deformation
- Designed to tolerate intermittent compression and shear forces
- Thickness varies from joint to joint and is thickest at PFJ
- Often worn down faster than it can repair itself

Histologic Characteristics

- Essentially no blood or lymph vessels; or nerve fibers
- Nutrition via imbibition
- Cartilage contents:
  - 70-80% Water
  - 10-20% Dry Weight
  - 10-15% Proteoglycans and non-collagenous proteins
  - 10-15% Collagen
Histologic Characteristics

- Chondrocytes (2% of total volume) synthesize collagen, non-collagenous proteins and proteoglycans (PTG's)
- Collagen and PTG's I° building blocks of cartilage
- Give cartilage its form and stiffness

Histologic Characteristics

- Water binds to PTG aggregate which gives cartilage its stiffness and allows it to attenuate force
- With ageing – Decrease in PTG content; resulting in less binding sites for water

Hyaline Cartilage Zones

- **Superficial zone (10-20%)**
  - Consists of “lamina splendens” layer
  - Tightly packed collagen fibers parallel to articular surface
  - Cellular layer of flattened chondrocytes.
  - Protect deeper layers from shear
Hyaline Cartilage Zones

- **Transitional or Middle zone (40-60%)**
  - Composed of spherical chondrocytes, PTG's, and obliquely oriented collagen fibers that primarily resist compressive forces
  - Serves as transition zone between deep and superficial.

- **Deep zone (30%)**
  - Collagen fibers and chondrocytes oriented perpendicular to articular surface
  - Resists compressive loads.

- **Calcified layer**
  - Tidemark that separates subchondral bone from calcified cartilage
  - Provides complex adhesive properties of cartilage to bone
Outerbridge Classification

- 0 – Normal cartilage
- I – Softening and swelling
- II – Partial thickness defect, fissuring < 1.5 cm in diameter
- III – Fissures that reach subchondral bone > 1.5 cm in diameter
- IV – Exposed subchondral bone

The Problem with Articular Cartilage
Cartilage

- Undergoes same necrotic phase as normal tissue
- If subchondral plate not disrupted the inflammatory phase almost absent
- Process of transudation, exudation, and hematoma formation absent
- No fibrin clot for scaffold

No new repair cells – task falls on chondrocytes

- Chondrocytes are metabolically active but are incapable of producing required repair products
- If injury extends through subchondral bone all 3 phases are stimulated
- Underlying bone excellent source of new blood vessels and primitive cells for differentiation and modulation to fibroblasts or chondrocytes

Without penetration of subchondral bone, the absence of an intrinsic vascular system prohibits an injury to articular cartilage from inciting the commonly observed vascular response

Cartilage Injury

- Loading of articular surfaces causes movement of fluid within the matrix
- This dampens and distributes loads within the cartilage and the subchondral bone


Cartilage Injury

- Done slowly – cartilage can deform and matrix absorbs force sparing injury
- Done rapidly – matrix absorbs more stress
- If stress great enough matrix ruptures, cells are damaged and injures subchondral bone


Cartilage Injury

- Blunt trauma can damage articular cartilage and calcified zone-subchondral bone region
- Yet – leave articular surface intact!

Cartilage Injury

- Loss of PTG’s or an alteration of structure can occur before signs of cartilage injury occur following even impact loading.


- Loss of matrix PTG’s will decrease cartilage stiffness and increases its permeability.
- Increases risk and susceptibility to injury.


Cartilage Fibrillation

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Chondrocytes require nutrients that are absorbed via diffusion from synovial fluid.

Synovial membrane lines the surface of the joint capsule and secretes synovial fluid.

Joint motion is necessary for diffusion of nutrients and pressures from synovial fluid and across the synovial surface of the joint capsule.

Degeneration or necrosis of cartilage occurs with prolonged compression or immobilization.
Theories on Articular Cartilage Nutrition
- Possible because there is no anatomical barrier between fluid and cartilage
- Solutes have been shown to pass freely
- Articular cartilage cannot survive without synovial fluid

Joint Movement
- Healthy joint deprived of movement, fluid becomes stagnant and nutrients depleted
- Movement and intermittent loading create a pumping action
- As cartilage is compressed, fluid squeezed out and metabolic waste removed
- When load is removed, nutrient rich synovial fluid is reabsorbed in cartilage

Joint Unloading
- Ten patients required 6-8 weeks of unloading (NWB)
- Quantitative T1rho and T2 imaging
  - Prior to surgery
  - Immediately after NWB
  - 4 weeks of FWB

Joint Unloading

- Increase in T1rho and T2 relaxation time maps for all femoral and tibial compartments noted post NWB.
- All values returned to near baseline values after 4 weeks FWB.


Joint Unloading

- Changes appear to be to proteoglycan content and more localized to load bearing regions.
- There is a reversibility of compositional fluctuations.

Symptoms of Unhealthy Cartilage

- Stiffness
- Swelling
- Pain
- Muscle Guarding
- Crepitis
Rehabilitation Dilemma

- Importance of cartilage undisputed
- Avascular nature complicates pathology*
  - No real hemorrhage or fibrin clot formation – no inflammatory response
- Minimal potential for regeneration

PROMOTE HEALING: DO NOT OVERLOAD TISSUE


Successful Rehab Requires Knowledge of:

- Science of articular cartilage, factors that influence repair and degradation
- Specific surgical variables
  - Nature of lesion (acute vs. chronic)
  - Location of defect (MFC, LFC, MTP, LTP, Trochlea, Patella)
  - Size of defect
  - Depth of defect

Successful Rehab Requires Knowledge of:

- Exact surgical procedure
  - Tailor to exact surgical procedure
- Specific patient variables
  - Age
  - Desired activity level
  - Occupation
Primary Goals

- Return to full weight bearing
- Restitution of ROM
- Restoration of muscle strength
- Recovery of neuromuscular control

Factors Affecting Outcomes

- Patient specifics
  - Age
  - Goals
    - Patient specific
  - Activities
  - BMI
  - General health
    - Smoker
    - Diabetic
  - Patient motivation

Principles of Rehabilitation

- Individualized
- Create healing environment
- Normalize knee biomechanics
- Reduce pain and inflammation
- Restore soft tissue balance
- Restore muscle function
- Restore proprioception
- Restore neuromuscular control
- Controlled and progressive loading
- Patient compliance
- Team approach
Principles of Rehabilitation

- Age?
- Buckwalter JOSPT 1998
  - Gradual degeneration of tissue matrix
  - Reduction in load bearing capacity
  - Poorer prognosis if age > 40, overweight or smoker
  - Motivation to return to prior level of function

Principles of Rehabilitation

- Location
  - Weight bearing surface
    - Caution weight bearing
  - Patella or trochlea
    - Caution sheer forces
  - Size and depth
    - Larger lesions
    - Slower rehab
    - Poorer prognosis

Principles of Rehabilitation

- Facilitation healing process
- Avoid immobilization
  - Decreased proteoglycan content
  - Weakening of cartilage

Return to Sports

- Cross sectional study
- 15 patients – isolated ACL reconstruction compared to age match controls
- 3T MRI assessment
  - 3-D volume/thickness
  - Biomechanical mapping
  - Function – deformation and recovery after 30-min run


Return to Sports

- No volume or thickness difference 5 months associate with increased thickness, increased deformation and delayed recovery with running.
- Increased thickness due to water accumulation
- Swollen tissues presented at abnormal T2 images
- Early signs of OA
- Earlier the return to sports during the first year the more fragile the articular cartilage


Return to Sports

- At 6 months – cartilage following ACL surgery showed diminished quality and in vivo resiliency compared with controls
- Delayed recovery might induce maintained deformation and dehydration of cartilage
- Detrimental in high impact sports

Gamut of Treatment Options

Conservative Treatment

- Case series
- 48 patients with full thickness articular cartilage lesions
- Lysholm score < 75
- 3 month active rehab program

Conservative Treatment

**Program**
- CV training
- Hip strengthening
- Knee strengthening
- Neuromuscular training


Conservative Treatment

**Outcomes**
- Tested pre and post
  - Knee injury and osteoarthritis outcome score
  - IKDC 2000
  - Isokinetic strength
  - Hop tests


Conservative Treatment

- Adherence rate 83%
- 4 patients could not do program due to pain and symptoms
- All others saw improvements in all outcomes

Surgical Treatment

Replacement

Bone Marrow Stimulation

Abrasion
Drilling
Microfracture

Surgical Treatment

Replacement

Bone Marrow Stimulation

Osteochondral
Autologous/Allograft
Transplant Surgery (OATS)

Surgical Treatment

Replacement

Bone Marrow Stimulation

Regenerative

Autologous Chondrocyte Implantation
Articular Cartilage Repair
Procedures

Chondroplasty and Abrasion
Arthroplasty

Articular Cartilage Injury
- If injury doesn’t extend to subchondral region, there is limited capacity for repair
- When injury extends to vessels in the subchondral region, a clot forms
- Inflammatory and undifferentiated cells migrate into it and commence repair process
Articular Cartilage Injury

- New matrix framework has insufficient proteoglycans, type II collagen, and adhesive molecules.
- Hyaline cartilage high in type II collagen
- Repair tissue fibrocartilage – primarily type I collagen
- Causes marked differences in structural properties
- Lacks organization into the layered structure of articular cartilage
- Chondral repair tissue is often of intermediate composition and structure between hyaline and fibrocartilage


Articular Cartilage Injury

- Does not bond to surrounding hyaline cartilage
- Subchondral bone does not form an impermeable barrier, allowing fluid exudation
- Repair tissue lacks durability of original tissue


Articular Cartilage Injury

- Compared to original tissue – the repair tissue has:
  - Inferior stiffness
  - Inferior resilience
  - Poorer wear characteristics
Arthroscopic Abrasion Arthroplasty

- Introduced approximately 30 years ago
- Modification of Magnusson “house cleaning” procedure with extensive debridement and Insall-Pirdie open drilling of subchondral bone plate

Arthroscopic Abrasion Arthroplasty

- Superficial scraping of sclerotic lesion with curette or burr until bleeding occurs
- Remove entire layer to enhance clot attachment
  - Generally 1-3 mm of subchondral bone
- Clot initially forms into fibrous tissue and eventually fibrocartilage

Friedman et al

- Retrospective study
- 110 patients arthroscopic debridement
- 73 abrasion arthroplasty
- Mean F/U 1 year
- Results based on pre-operative complaints of pain, swelling, buckling, function

Friedman et al

- Abrasion arthroplasty group
  - 60% improved
  - 34% no change
  - 6% worse
  - 83% still had pain
- 1 P/O hemarthrosis
- 2 biopsies during 2nd surgery for continued pain


Friedman et al

- Conclusions
  - Need further studies to check repair tissue after prolonged use
  - Only offer arthroscopic debridement as an intermediary step, not to replace osteotomy or replacement


Bert and Maschka

- Retrospective review
- 59 patients – arthroscopic abrasion arthroplasty and debridement
- 67 had arthroscopic debridement only
- F/U 5 years
- Unicompartmental OA only
- Used HSSKSS and radiological assessment

Bert and Maschka

- Abrasion and Debridement
  - 51% good to excellent
  - 16% fair
  - 53% poor; 50% or poor made worse
  - 22% had TKR within 1 year

- Debridement
  - 66% good to excellent
  - 15% fair
  - 21% poor; 86% of poor made worse
  - 15% had TKR within 1 year


Radiologically
- 51% of abrasion knees had increased joint space
- 31% had found no change or worsening
- 20% of knees with satisfactory clinical results had further collapse on x-ray
- Concluded debridement alone better than abrasion

Arthroscopic Lavage and Debridement
Lavage and Debridement

- PWB or WBAT for 1-2 weeks
- Full passive knee extension
- Gradual restoration of knee flexion usually 0-135° by weeks 2-3
- PROM, AAROM and AROM (unloaded) immediately postoperative
- Emphasis on isometric and OKC exercises initially
- Gradually progress to CKC exercise

Lavage and Debridement

- Moderate impact loading 6-8 weeks
- Progress to high impact loading 8-12 weeks


180 patients
Random assignment
- Lavage alone
- Debridement and lavage
- Placebo surgery


Patients and assessors of outcome were blinded to treatment group assignment
Outcomes assessed multiple time frames up to 24 months
5 subjective self-reported scales
- 3 scales for pain
- 2 scales for function


At no point did intervention groups report less pain and better function than placebo

Patterns of Arthroscopy in US
- Descriptive epidemiology study
- ABOS database of 6 month case logs
- Those sitting between 1999-2009
- # cases of arthroscopy for knee OA
  - Max 2001=1621 cases
  - 2009 = 966


Patterns of Arthroscopy in US
- Total number of cases per surgeon
  - 2003 = 11.9
  - 2009 = 8.6
- As a % of total orthopedic caseload
  - 2003 = 9.9
  - 2009 = 6.2


Patterns of Reimbursement
- Cohort study
- Florida State Ambulatory Surgery database
- Knee arthroscopy from 2000-2008 for patients with and without OA
- 49% decrease in age and sex adjusted population based rate of knee arthroscopy

Patterns of Reimbursement

- 12.3 per 100,000 in 2000
- 6.3 per 100,000 in 2008
- Arthroscopy for knee OA significantly decreased for both private and public insurance


The NEW ENGLAND JOURNAL of MEDICINE

A Randomized Trial of Arthroscopic Surgery for Osteoarthritis of the Knee


- Single center, randomized, controlled trial of arthroscopic surgery
- Group assignment random
  - Surgical lavage and debridement and physical and medical therapy
  - Physical and medical therapy alone

- **Outcomes**
  - WOMAC scores at 2 year follow-up
  - Short Form - 36

- **Findings**
  - Analysis of scales at interim visits and at end of 2 years did not show additional benefit of arthroscopic surgery


**Mosaicplasty & Osteochondral Autograft/Allograft Transplantation Surgery (OATS)**
Mosaicplasty

- Using a collection of small osteochondral cylinders inserted side by side
- Better represents the radius of curvature of the normal articular surface
- Advantage is placement of spongy bone into spongy bed of recipient

Mosaicplasty

- Fibrocartilage forms around cylinders of graft

Mosaicplasty

- Surgical site is retracted to remove any loose cartilage. The edges of the cartilage are brought back to right angles and any detached cartilage is removed.
Mosaicplasty

- Then the base of the lesion is abraded to viable sub chondral bone.

Mosaicplasty

- Under direct visualization the first tunnel is drilled perpendicular to the surface of the condyle using an appropriate drill bit. Depth of tunnel will vary depending on pathology; 15 mm for cartilage repair, 20-25 mm for OCD.

Mosaicplasty

- The graft is then harvested from the medial rim of the femoral trochlea, away from the weight-bearing areas with a tubular chisel of the same diameter as the drill bit used to prepare the hole for the recipient site.
Mosaicplasty

- The chisel must be carefully positioned perpendicular to the cartilage surface. Chisel is driven by a hammer to the desired depth, avoiding any overheating that could put the viability of the graft in harm.

- Recipient hole is dilated. Cylindrical graft is inserted into the hole using a graduated harvesting tamp enabling the graft to be inserted to the desired depth so that the surface of the graft is level with the adjacent hyaline cartilage.

- The grafts should cover at least 70% of the cartilage defect.
- Graft appearance after procedure

- Graft after procedure
- Graft 6 months after procedure

Fresh Osteochondral Allograft Transplantation
Larger lesions (> 2.5 cm²) difficult to treat
Marrow stimulating techniques and ACI do not always restore bony condylar architecture
Defect filled with single plug from cadaver
  - No donor site morbidity
  - Incorporation of allograft bone

Supply & Demand
  - Bottleneck
  - Limited supply of grafts
  - Only from young donors
  - Intact articular surface
  - Many grafts initially fail safety due to viral or bacterial contamination

Ideal procedure to revise failed cartilage repair procedures
Especially when changes in subchondral bone are present
Subchondral cysts
Persistent bone marrow edema
**Weight bearing**

- Relatively fast
- WBAT if single graft
- Multiple plugs may need protection for ~ 6 weeks
- ROM not restricted
- Brace optional
- Stationary bike as soon as pain allows


**Return to athletic activity following OAT in knee**

- Case series
- 43 athletes
- Average age (32.9 years)
- Outcomes
  - KOOS
  - IKDC
  - Marx Activity Rating Scale
  - Cincinnati Sports Activity Scale Scores


- Average 2.5 years limited return to sport possible in 38/43 (88%)
- Full return to pre-injury level in 34/43 (79%)
- In these 34 – return to sport was 9.6 +/- 3.0 months
- Age > 25 years and symptoms > 12 months negatively affected ability to return to sports

Autologous Chondrocyte Implantation (ACI)

- Advanced cell-based orthobiological technique used for treatment of chondral injuries to the knee.
- Used since 1987
- Performed on more than 12,000 patients internationally

ACI

Rehabilitation guidelines based on:

- Expert opinion
- Animal studies
- Basic science
- Clinical biomechanics


Rehabilitation after Autologous Chondrocyte Implantation

- In general,... Rehab should address impairments and functional limitations without jeopardizing healing of the lesion.


Rehabilitation after Autologous Chondrocyte Implantation

- Classic description is termed autologous chondrocyte transplantation (ACT)
- Ideal patient young, otherwise healthy knee

Autologous Chondrocyte Implantation

- 37 patients: Ave age 47.8 yrs
- 37 patients: Ave age 31.0 yrs
- 24 month follow-up
- IKDC, Lysholm, Cincinnati sports scale, Tegner


- Sig increase in funct. - early as 6 months
- Non significant - but slight tendency for better clinical outcome in younger group


ACT Surgical Steps

- First stage is arthroscopic evaluation
- Assess containment, depth an potential bone loss
- Biopsy performed from superomedial edge of trochlea or the lateral edge of intercondylar notch

ACT Surgical Steps

- Total volume of biopsy should be approximately 200-300 mg
- 3 “Tic-Tac”-sized fragments


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ACT Surgical Steps

- **Second Procedure**
  - Arthrotomy
  - Preparing defect
  - Periosteal harvesting


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ACT Surgical Steps

- **Second Procedure**
  - Suturing periosteum over defect
  - Testing for water tightness
  - Fibrin glue sealant
  - Chondrocyte implantation
  - Wound closure
  - Rehabilitation

Disadvantages

- Chondrocyte leakage
- Dedifferentiation of phenotype (cells grown in monolayer initially)
- Uneven distribution
- Periosteal detachment
- Periosteal hypertrophy


ACI

- Used for larger lesions (> 2 cm²)
- Ideal for symptomatic well-contained chondral or shallow osteochondral defects measuring 2-10 cm²
- May be used as secondary procedure after 1 or more failed alternative cartilage repair procedures.
ACI
- Still 2nd surgery procedure.
- Culture time initially 6-8 weeks.
- Now 3-4 weeks.
- Minimum 3 weeks needed after initial surgery.
  - Replace synovial fluid
  - Portal healing
  - Analgesia/anesthetic recovery


Periosteal patch (First Generation)
- Smokers - poor-quality periosteum
- Obese patients – large amounts of adherent adipose tissue to separate from periosteum
- Patch that is 2mm larger than the defect is harvested to allow for slight shrinkage after detachment

Periosteal patch (First Generation)
- Periosteal hypertrophy
- More commonly on patella
- ? Due to stimuli of higher shear forces


Periosteal patch (First Generation)
- Most common complication with 1st generation periosteal patch (36%)

Bartlett W et al. JBJS Br. 2005
Henderson I, et al. JBJS Br. 2004
Micheli LG, et al. CISM. 2001
Niemeyer P, et al. AJSM. 2008
Zeifang F, et al. AJSM. 2010

Other Complications
- Patellar hypertrophy

Other Complications
- Malfusion
- Insufficient regeneration
- Delamination


Collagen Membrane - 2nd Generation
- Bilayer porcine collagen membrane
- Membrane eventually degraded by enzymatic digestion
- 2 surfaces
  - External – strong barrier
  - Inner – porous stimulates cells to produce cartilage-specific matrix molecules

2nd Generation
- Collagen membrane
- Reduced amount of graft hypertrophy
- 87% good to excellent results

CCI

- Expanded population of chondrocytes that express a marker predictive of the capacity to form hyaline-like cartilage in vivo
- Optimized cartilage cell batches


Matrix Induced ACI – 3rd Generation

- Full thickness chondral defects of knee
- 2-stage procedure
- Initial harvest of healthy cartilage
- Isolation and expansion of chondrocytes ex vivo
- Re-implantation of cells over site

Matrix Induced ACI – 3rd Generation

- MACI has become an established technique for repair of full-thickness chondral defects of the knee


Matrix Induced ACI

- Incidence of graft hypertrophy with MACI
- 25% with postoperative course of 1 year
- Occurred most commonly in first year and regressed by year 2.
- Excessive growth of regenerative cartilage tissue

ACI vs Microfracture

- Knutsen et al: MF preferred over ACI
- Saris et al: ACI preferred over MF
- Basad et al: ACI preferred over MF for larger lesions


ACI – Outcomes

- 1st generation ACI
- 42 patients/45 knees
- Outcomes
  - ICRS score
  - IKDC score
  - Tegner score
  - Lysholm score
  - Stanmore functional rating


ACI – Outcomes

- 96 month follow-up
- Significant increase in all scores were found
- Only 5/45 required further surgery
- Degeneration or partial detachment

ACI – Re intervention?

- Risk factors
- 413 patients: Over follow-up up of ~5 years (88 required surgery)


Postoperative Weightbearing

- How best to progress weight bearing
- RCT
- 63 patients: 31 Accelerated; 32 Traditional
  - Accelerated FWB @ 8 weeks
  - Traditional FWB @ 11 weeks


Postoperative Weightbearing

- Outcomes
  - KOOS
  - SF-36
  - VAS
  - 6-min walk test
  - Knee ROM pre, 3, 6, 12, 24 months, 5 years after surgery
  - MRI 3, 12, 24 months and 5 years

Postoperative Weightbearing

- VAS different (less) pain at 5 years accelerated
- No other differences
- Accelerated safe and effective


- VAS different (less) pain at 5 years accelerated
- No other differences
- Accelerated safe and effective

- 31 patients following MACI
  - Accelerated WB – FWB at 6 weeks
  - Delayed WB – FWB at 10 weeks
- Assessment 3 m, 2 yrs, 5 yrs
- MRI – bone edema and effusion
- KOOS, Tegner scores


- Decline in cartilage MRI scores both groups
- Significant increase in bone edema at 2 and 5 years but no group differences
- Associations between bone edema and pain was noted

Factors Predictive of Outcomes


Return to Sports

- 70 patients
- Mean age of 34.9
- Evaluated 5 years after MACI
- Subjective clinical scores
  - KOOS-Sport
  - Noyes


Return to Sports

- Able to do regular sports activities
  - Cycling
  - Running on flat ground
- 74.3% returned to at least pre-injury level of activity

MACI Outcomes
- Case series
- 21 patients
- Outcomes
  - KOOS
  - IKDC
  - Modified Cincinnati scores
  - MRI


MACI Outcomes
- Significant improvements for all KOOS subcategories within 1 year – maintained through 5
- Failure in 9.5% of patients
- Complete filling of defect (82%) and integration (82%) were seen in most patients
- *Signs of subchondral bone edema still present in 47% at 5 years*


MACI Outcomes
- 44 consecutive patients
- Mean age 33.5
- Better scores if wait > 12 months to return to impact sports
- Longer recovery time – better outcomes up to 2 years post surgery

MACI Outcomes
- Case series
- 47 consecutive patients
- Assessments
  - Pre
  - 3 months
  - 12 months
  - 24 months


MACI Outcomes
- Clinical and statistical significant improvements over all times


Biological Basis for Rehab
- 4-6 weeks characterized by cell adhesion, filling defect and production of specific matrix markers.

Biological Basis for Rehab
- **Initial few weeks** material is consistency of fluid-like
- **Shear forces extremely deleterious**
- **PROM – CPM, manual**


Biological Basis for Rehab
- **Cryotherapy**
  - Increased joint temperatures stimulates proteolytic enzymes and cytokines
  - Harmful to cartilage


Biological Basis for Rehab
- **Cryotherapy**
  - Affects postoperative pain
  - Joint effusion

Biological Basis for Rehab

- **Cryotherapy**
  - Decreased need for pain medication
  - Edema control??


Biological Basis for Rehab

- **Weeks 4-6 through 12**
  - Chondrocyte differentiation
  - Collagen II framework built up
  - Proteoglycan form cartilage matrix
  - Cartilage now has spongy consistency


Biological Basis for Rehab

- **3-6 months**
  - Cartilage resembles gelatin

- **6 months**
  - Soft plastic

**Clinical Importance**

- Cartilage remodeling of newly formed tissue may take time
- At least 18 months after surgery

Clinical Importance

- Amounts of hyaline as time with time intervals
- Continuous remodeling – may become more hyaline with time
- Length of training?


ACI after Microfracture

- Significantly higher failure rates and inferior clinical outcomes compared with ACI as first line of treatment.


ACI after Microfracture

- Thickening of subchondral plate after microfracturing makes articular cartilage more susceptible to damage from shear forces.
- Violation of subchondral bone might convert chondral problem into osteochondral problem.


Microfracture

- A biological response is stimulated by penetration of the subchondral plate
Microfracture

An ideal treatment for cartilage injury should:

- Technically simple to perform
- Arthroscopic
- Low patient morbidity – min. incision
- Cost effective
- Long-term success rate
- Burn no bridges

Microfracture Advantages

- Less heat necrosis than drilling
- Provides rough surface for blood clot to attach – “superclot”
- Maintain subchondral plate
- Allow access to mesenchymal stem cells rather than mature chondrocytes

MICROFRACTURE

NOT THIS IS

Tissue Replacement Tissue Repair
Considerations
- Age of patient
  - Adolescence
  - Middle age
  - Geriatric
- Axial alignment
  - Varus/valgus
  - Recurvatum
  - Instabilities

Indications
- Full thickness lesion
  - Weight bearing surface tibia or femur
  - Contact lesion on PF joint
  - Unstable cartilage overlying subchondral bone
  - Degenerative changes with normal axial alignment


Ideal Indications
- Focal grade III or IV articular surface lesions without bone loss that are surrounded by normal articular cartilage in a young patient.

Considerations

- Activity level
  - Professional
  - Recreational
  - Vocational
- Demands and expectations
  - Impact vs non impact sports
  - Time for recovery
  - Realistic expectations

Contraindications

- Subchondral bone loss
- Axial misalignment
- Noncompliant patient
- Partial-thickness defects
- Systemic immune-mediated disease
- Disease-induced arthritis
- Cartilage disease

Microfracture Technique

- Surgical awl to penetrate subchondral bone
- Create 3-4 perforations per cm²
- Depth of 2-4 mm
- Should access underlying bone, releasing blood and mesenchymal cells


- 24 full thickness chondral defect on MFC
- Sheep model
- Small diameter awl 1.0mm
- Larger diameter awl 1.2mm
- Control
- Assessment 6 months after surgery


Microfracture Technique

- Compared to control both groups improved
- 1.0 mm awl improved overall repair and surface grading better than 1.2mm awl

Microfracture Technique

- When see fat droplets coming from marrow cavity
- Creates bleeding response to form "superclot" over chondral defect


WB Guidelines (0 - 6 Weeks)
Femoral Condyle/Tibial Plateau

<table>
<thead>
<tr>
<th>Surgery Day</th>
<th>NWB-TTWB</th>
<th>NWB-ATTWB</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>Full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1-2</td>
<td>Week 3-4</td>
<td>Week 5-6</td>
<td>Week 7</td>
<td>Week 8</td>
<td>Week 9</td>
<td>Week 10</td>
</tr>
</tbody>
</table>

WB Guidelines (0 - 6 Weeks)
Patella or Trochlea

<table>
<thead>
<tr>
<th>Surgery Day</th>
<th>WBAT</th>
<th>Full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1-2</td>
<td>Week 3-4</td>
<td>Week 5-6</td>
</tr>
</tbody>
</table>
First Post-operative visit

- Assess brace status – trochlear groove or combined
- Assess weight bearing compliance
- Assess fit of crutches (don’t count on medical staff)
- Educate of polar pak/theracool

Clinical Assessment

- Swelling
- Patellar mobility
- Quad tone/SLR
- Extension/flexion ROM per MD
- Treat limitations listed above

Important factors

- Weight bearing status
  - NWB 6-8 weeks if condyle/plateau lesion
  - WBAT if trochlear groove
- CPM machine
  - Performed 6-8 hours per day every day
  - 1 complete cycle of motion each/min
  - Ranges of 20-80° or 30-70°
CPM
- Enhances nutrition and metabolic activity of articular cartilage
- Stimulate the pluripotential mesenchymal cells to differentiate into articular cartilage rather than fibrous tissue or bone
- Accelerates healing of both articular cartilage and periarticular tissues


CPM
- Cyclical pumping moves synovial fluid which nourishes articular cartilage
- Physical exercise increases amount of synovial fluid
- Hemarthrosis cleared 2x as fast with CPM
- Prevents adhesions
- Minimal compressive forces if passive


Rehabilitation of Microfracture
- CPM
  - Use 6 hours per day x 8 weeks
  - Full-thickness cartilage defects
  - Resulted in enhanced gross healing of lesion viewed by post surgery arthroscopy
  - 85% satisfactory results with CPM
  - 55% satisfactory results without CPM

Post Operative ROM

- Week 1: 0-90
- Week 2: 0-110
- Week 3: 0-125
- Home CPM 6-8 hours day
- Knee sleeve or compression to minimize swelling

Post Operative Braces

- None for isolated condylar or plateau lesion
- 8-10 weeks for trochlear groove or combined etiology knees
- Graduated unlocking progression at appropriate time frames

Edema Management

- Polar Pak with continuous flow bladder
- Compression stocking; tube-grip
- Ace bandage use
- Continuous icing for 1st 7-10 days
- Education of patient critical
Rehabilitation of Microfracture

Weeks 0-6

- Brace
- Some recommend brace regardless of location.
  - Tibia or condyle in full extension
  - PF/Trochlear groove lesion allow 0-20 or 0-30 degrees ROM stop


Rehabilitation of Microfracture

Weeks 0-6

- PWB 4-6 weeks, initially toe touch (<5.0 lbs) then progress to 50%, then 75% BW
- *15% WB first 6 weeks
- Some advocate NWB for 6-8 weeks
- Full passive knee extension*
- Gradually increase knee flexion ROM
- Full knee ROM at 3-4 weeks


Rehabilitation of Microfracture

Weeks 0-6

- Full passive knee extension*
- Flexion contracture will result in gait abnormalities and PF pain/symptoms


Rehabilitation of Microfracture
Weeks 0-6

- Generous PF mobilizations
- Instruct in home program of self PF mobs
- Performed periodically (5-6 x/day) at home

Rehabilitation of Microfracture
Weeks 0-6

- Emphasize ROM (controlled loading) passive and active assisted
  - Isometrics progressing to limited arc isotonics
  - Isometrics
    - Towel roll under knee for biofeedback
    - E-stim if having trouble eliciting
    - Multiple-angle isometrics when ROM improved
  - CKC ex’s bike and pool

Rehabilitation of Microfracture
Weeks 0-6

- MUST KNOW LOCATION OF LESION
- Imperative so that therapist can avoid angles that engage the articular cartilage lesion
- *Especially important for those that have undergone PF microfracture
Rehabilitation of Microfracture
Weeks 0-6
- 4-8 weeks: Hyaline-like tissue also present within the lesion
- 6 weeks: Limited chondral repair and ongoing re-sorption of subchondral bone
- By 12 weeks: Defects completely filled


Rehabilitation of Microfracture
Weeks 6-12
- Restoration of ROM and Gait
- When SLR without pain/extensor lag – p/o brace DC’d
- May use knee sleeve with ADL’s
- Weight-bearing varies with location
- Typically at 6 weeks fibrocartilage should have started to fill in defect

Rehabilitation of Microfracture
Weeks 6-12
- Typically full ROM achieved by or before 12 weeks
Rehabilitation of Microfracture
Weeks 6-12

TF EXERCISE BIOMECHANICS

OKC knee extension
- Compressive loads greatest from 60-90 degrees
- Shear greatest at 0-40 degrees


CKC knee extension
- Shear and compression greatest at 60-100 degree arc


SAFE EXERCISES

CKC leg press 0-60 degrees
- Low-load high rep
Rehabilitation of Microfracture
Weeks 6-12
- **UNSAFE EXERCISES**
- PF Joint – OKC knee extensions are not used until after 3 months due to high PF forces

Rehabilitation of Microfracture
Weeks 6-12
- **SAFE EXERCISES**
  - Mini squats 0-45
  - Graduated step up program

Rehabilitation of Microfracture
Weeks 12-18+
- Dedicated to restoration of strength
- CKC now 0-80 degrees
- Assess quality and control of movement rather than simply amount of weight
- Slowly begin OKC
  - Start initially in 90 to 40 degree arcs
  - Closely monitor signs of pain or swelling
Rehabilitation of Microfracture
Weeks 12-18+
- 16 weeks perform:
  - Forward step down test
  - Isokinetic test at 180 and 300 degrees/s
  - Goal of 85% limb symmetry


Rehabilitation of Microfracture
Weeks 12-18+
- Moderate impact loading at 16 weeks
- If meet criteria for strength, ROM and clinical exam may begin jogging on TM
- Progress to high impact loading 20-26 weeks

Complications
Infection

DVT

Contracture/Scar

Adhesion/Arthrofibrosis

No studies on rates following articular cartilage procedures

ACL surgery between 0.14 and 1.7%

Most symptoms present within one week

Secondary occurrence around two months


Infection

- Fever
- > edema or swelling than typical
- > complaints of pain than normal
- Localized warmth and decreased motion
- Diagnosis through lab cultures of aspirated joint fluid
DVT

- Not been studied in articular cartilage population
- Incidence without prophylaxis after total joint knee surgery ~ 85%
- Arthroscopy with prophylaxis ~9.9%


DVT

**Risk factors**

- Obese
- Smoke
- Hormone replacement
- Age >65
- Venous insufficiency
- Prior history of DVT


Scar Tissue Adhesions

**Arthrofibrosis**

- More common after open procedures
- Careful monitoring of ROM
- Scar tissue and surrounding soft tissue mobilization as soon as possible
- Modalities as need to break up scar tissue
Outcomes

- 24 NBA players between 1997-2006
- First seasons before and after surgery
- 8/24 (33%) never returned
- 14/24 returned for > 1 season


- Points scored
- Minutes played
- 8.15 x less likely to remain in NBA

- 25 professional football players
- 76% returned to football following microfracture


- Significant improvements in knee scores
- Regardless of postoperative rehabilitation
- Maximum of 2 cm lesions


- 86% of patients able to return to previous level of sports after microfracture for traumatic defects

- Improved subjective scores
  - Lysholm
  - IKDC
  - Tegner improved at 2 years, but declined @ 72 months
  - Hop test normal in 70%


ALWAYS RESPECT THE ARTICULAR CARTILAGE!
THANK YOU!

Robert C. Manske, PT, DPT, SCS, ATC, CSCS
Professor
Department of Physical Therapy
Wichita State University
Via Christi Outpatient Sports and Orthopedic Rehab
Wichita, Kansas
Robert.manske@wichita.edu