Osteochondral Knee Injuries

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PGY-4
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Articular Cartilage

- Complex, layered structure
- Viscoelastic material
  - Resist shear forces
- Variable loadbearing
  - Range of motion
  - Position
- Essential role
  - Reduction of stress on subchondral bone
  - Minimize friction with motion
- Structure and organization
Articular Cartilage: Composition

- Extracellular matrix (95% volume)
  - Type II collagen fibers
    - V, VI, IX, and XI
  - Sulfated proteoglycans
  - Negatively charged carboxyl and sulfate groups
    - High affinity for water
    - Maximal volume expansion
  - Other components: biglycan, decorin, fibromodulin, fibronectin, lipids and link proteins
Articular Cartilage: Composition

- Chondrocytes (2% volume)
  - Mesenchymal stem cell origin
  - Matrix synthesis
    - Anaerobic
  - Arrangement -> zones
    - Superficial
    - Transitional
    - Deep
    - Calcified cartilage
Articular Cartilage: Zones

<table>
<thead>
<tr>
<th>Layer</th>
<th>Width (um)</th>
<th>Characteristic</th>
<th>Orientation</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gliding (Superficial)</td>
<td>40</td>
<td>↓ Metabolic</td>
<td>Tangential</td>
<td>Shear</td>
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<tr>
<td>Transition (middle)</td>
<td>500</td>
<td>↑ Metabolic</td>
<td>Oblique</td>
<td>Compression</td>
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<tr>
<td>Radial (deep)</td>
<td>1000</td>
<td>↑ Collagen size</td>
<td>Vertical</td>
<td>Compression</td>
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<tr>
<td>Tide mark</td>
<td>5</td>
<td>Barrier</td>
<td>Tangential</td>
<td>Shear</td>
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<tr>
<td>Calcified</td>
<td>300</td>
<td>Hydroxyapatite</td>
<td></td>
<td>Anchor</td>
</tr>
</tbody>
</table>
Osteochondral Injury

• Epidemiology
  – True incidence unknown
    • Noyes et al – 5%-10% young pts with traumatic hemarthrosis
    • Curl et al – 63% patients undergoing arthroscopy
      – Grade IV – 19% in all patients
        » 5% in younger patients
  – Cause worse symptomatic scores
Patient History

- Acute vs chronic
- Traumatic event: sports/accident
- Prior surgery: meniscus or ligament
- Current symptoms
  - Activity related pain and swelling
    - Typically impact exercises
  - Pain localizes to effected compartment
  - Occasional synovitis
  - Mechanical symptoms
    - Crepitus
Physical Exam

• Complete knee exam
  – Ligament stability
  – Alignment
  – Patella tracking

• Common findings
  – Effusion
  – Quadriceps atrophy
  – Tenderness to palpation in affected compartment
  – Painful weight-bearing
  – Motion preserved
  – Fragments
    • Mechanical symptoms
Imaging

• Radiographs
  – Weightbearing AP in extension and 30 degrees flexion (joint space)
  – Flexion Lateral View (PF articulation)
  – Skyline (Patella tilt)
  – Weightbearing long-leg alignment
    • Stress on repair

• CT or CT Arthrogram
  – Evaluate bone loss
  – Measure TT-TG
Imaging

• MRI
  – Most sensitive for focal defects
    • Fat-suppressed T2, proton density, T2 fast spine-echo
      – Improved sensitivity
  – Delayed gadolinium-enhancing MRI for cartilage and T2 mapping
    • Estimate joint cartilage glycosaminoglycan
    • Monitor level of healing
Outerbridge Classification

- Grade 0: Normal
- Grade I: Cartilage with softening and edema
- Grade II: Partial-thickness defect with fissures on the surface that do not reach subchondral bone or exceed 1.5cm in diameter
- Grade III: Fissuring to the level of subchondral bone in an area with a diameter of >1.5cm
- Grade IV: Exposed subchondral bone
International Cartilage Repair Society Classification

- Grade 0: Normal Cartilage
- Grade IA: Softening or Fibrillations
- Grade IB: Superficial Fissuring
- Grade II: Less than half the cartilage depth
- Grade III: More than half the cartilage depth, and:
  A: Not to the calcified layer
  B: To the calcified layer
  C: To the subchondral bone
  D: Blisters
- Grade IV: Osteochondral lesion violating the subchondral plate
  A: Superficial
  B: Deep
Natural History

- Juvenile OCD lesions -> much better prognosis than adult lesions
  - Good prognostic factors: Open physes, medial femoral condyle
  - 80% of adults develop OA if no treatment initiated
    - Poor prognosis
  - Lateral condyle lesions provide worse subjective scores

- Concomitant meniscal injury
  - 6.5% volumetric loss of articular cartilage per year
Natural History

- **Superficial lesion**
  - Injure chondrocytes -> decreased proteoglycan concentration
    - Increased force transmission to subchondral bone
  - Avascular repair
    - Response is to increase synthesis of matrix macromolecules
    - Cannot restore surface

- **Full-thickness lesions**
  - Hematoma -> stem cell migration -> synthesis of Type I collagen
    - Some low impact joint motion required for chondrocytes
    - TGF-B, BMP, IGF, FGF -> influence migration and proliferation
Non-operative Treatment

• First line of treatment for mild symptoms
  – Rest
  – NSAIDs
  – Unloading bracing
  – Physical therapy
    • Patellofemoral strength
    • Four-way hip program

• Controversial
  – Corticosteroid injections
  – Hyaluronic acid
  – Glucosamine
Operative Treatment

**Indications**

- Grade III or IV
- Symptomatic
  - Weight-bearing pain
  - Swelling
  - Mechanical symptoms
- Correlated exam
- Failed conservative treatment
- Cooperative patient
  - Realistic expectations
  - Post-operative protocols
- Correctable articular co-morbidities

**Contraindications**

- Smokers
- BMI > 35
- Inflammatory conditions
- Advanced degenerative changes
  - >50% joint space narrowing
- Uncorrected Articular Comorbidity
  - Knee misalignment
  - Meniscal deficiency
  - Ligamentous laxity
Operative Consideration

• Considerations prior to surgical treatment
  – Conservative Trial and Effectiveness
  – Patient Age
  – Defect Chronicity
  – Prior Treatments
  – Possible Contraindications
  – Defect Size
  – Defect Location
Surgical Technique Options

• Debridement with chondroplasty
• Primary fixation of unstable fragments
• Marrow stimulation techniques
  – Microfracture
• Osteochondral autograft
  – Mosaicplasty
• Osteochondral allograft transplantation
• Autologous chondrocyte implantation (ACI)
  – Matrix-associated autologous chondrocyte implantation (MACI)
• Patellar cartilage unloading procedures
<table>
<thead>
<tr>
<th><strong>Small defects (&lt;2-4cm²)</strong></th>
<th><strong>Large defects (&gt;2-4cm²)</strong></th>
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<tbody>
<tr>
<td>• Microfracture</td>
<td>• Osteochondral allograft</td>
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<tr>
<td>– Medium sized lesions</td>
<td>– Simpler rehab</td>
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<tr>
<td>– No substantial bone loss</td>
<td>– Wait for donor</td>
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<tr>
<td>– Lower demand patient</td>
<td>• Autologous chondrocyte implantation (ACI)</td>
</tr>
<tr>
<td>• Osteochondral autograft</td>
<td>– Multiple lesions</td>
</tr>
<tr>
<td>– Very small lesions</td>
<td>– Full-thickness cartilage surrounding</td>
</tr>
<tr>
<td>– Bone loss</td>
<td>– Complex rehab</td>
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<tr>
<td>– High demand athletes</td>
<td>– Long delay to return to sports</td>
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<tr>
<td>• Debridement</td>
<td>• Matrix-associated autologous chondrocyte implantation</td>
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</table>
Surgical Debridement

- Removal of loose flaps/fragments
  - Relieve mechanical symptoms

- Indications
  - Short term relief (50%-70%)
  - First line treatment prior to extensive procedure

- Rehabilitation
  - Physical therapy for quad strength
  - Return to activity as tolerated

- Prognosis
  - Kirkley et al (2008) – No affect on progression to OA vs sham surgery
Primary Fixation

- Fixation of osteochondral fragment
  - Requires adequate subchondral bone
- Absorbable or nonabsorbable screws
  - Nonabsorbable headless screws require removal
- Prognosis
  - Excellent results in OCD lesions (skeletally immature)
Microfracture

• Overview
  – Allow marrow elements into defect
  – Single-stage, arthroscopic procedure
  – Performed after ligamentous repair

• Technique
  – Creation of stable cartilage margin
  – Removal of calcified cartilage layer
Microfracture

- Awl penetration of subchondral bone
- 3-4mm bridge to prevent fractures
- Check for bleeding bone
- Mesenchymal clot fills defect
- Proper stimulation leads to fibrocartilage repair tissue
  - Type 1 collagen
  - Random orientation
  - Non-homogenous matrix
Microfracture

- **Contraindications**
  - Very large defects
  - Defects lacking surrounding shoulders
  - Patellar defects (due to high shear forces)

- **Rehabilitation**
  - Toe-touch weight bearing x6 weeks
  - Motion with possible CPM

- **Complications**
  - Subchondral cyst formation (~50%)
  - Compromises future procedures
Microfracture Results

- Steadman et al *JKS* 2014
  - 20 elite alpine skiers at 2 year follow-up
    • 19/20 returned to competitive skiing
    • Average time to return 13.4
    • Patient satisfaction high

- Steadman et al *JKS* 2014
  - 22 patients under 19 years old at 2 year follow-up
    • Average Lysholm score – 90
    • Median patient satisfaction 10/10

- Mithoefer et al *AJSM* 2009
  - Review of 28 studies with average f/u 41 months
    • Initial improvement seen in all studies
    • Long term durability questioned
    • Defect fill on MRI variable
Osteochondral Autograft/Mosaicplasty

• Overview
  – Replace defect on weight-bearing surface with autograft from minimal weight-bearing surface
    • Medial trochlear ridge
    • Lateral trochlear ridge
    • Intercondylar notch
    • Sulcus terminalis (lateral femoral condyle)

• Indications
  – Small lesions in patients attempting to get back to sports earlier
  – Can use multiple plugs for larger defects
Osteochondral Autograft/Mosaicplasty

- **Technique**
  - Recreate curvature of lesion
  - Sizing of defect
  - Harvester selected
    - 10mm to 15mm length
  - Recipient hole created
    - Slightly smaller than graft
  - Graft slowly introduced into recipient site through harvester
    - Oversized tamp used to seat graft
    - Slightly recessed preferred over proud
    - <2mm
  - Can fill plugs with synthetic back-fill
Osteochondral Autograft/Mosaicplasty

• Pearls
  – Peripherally uncontained defects can compromise plug stability
  – Deep defects and AVN require very long plugs that are difficult to harvest and implant
  – Patellar lesions are controversial
    • Thin transplanted cartilage
Osteochondral Autograft/Mosaicplasty

• Rehab
  – Weight-bearing lesion dependent
    • Small lesion -> full weight-bearing
  – CPM controversial

• Complications
  – Plug Necrosis
  – Cyst formation in plugs
  – Cartilage degeneration plugs
Osteochondral Autograft/Mosaicplasty

• Results
  – Hangody et al *AJSM* 2010
    • Case series of 354 patients followed for an average 9.6 years
      – Good to excellent results in 91% (femoral), 86% (tibial), and 74% (patellofemoral)
      – Graft harvest pain in only 5%
      – Only slight deterioration in athletic group
  – Solheim et al *Knee* 2013
    • Case series of 73 patients with median age of 34
      – 40% of patients had a Lysolm score <64 (poor) at long term (>10 yrs) follow-up
        » Risk factors - older than 40, women, defects larger than 3cm
Osteochondral Autograft/Mosaicplasty

• Comparative Results
  – Ulstein et al *KSSTA* 2014
    • 25 patients randomized to either osteochondral autograft or microfracture
      – Median follow-up: 9.8 years
      – No significant difference in Lysholm, KOOS, muscle strength, radiographs
  – Krych et al *JBJS* 2012
    • OAT mosaicplasty (48) compared with microfracture (48)
      – No significant difference SF-36, daily living score, IKDC
      – OAT group significantly improved Marx Activity Rating at all time points
        » Better overall athletic ability
  – Gudas et al *Arthroscopy* 2013
    • 102 patients with ACL reconstruction and medial femoral condyle lesion
      – IKDC scores better in OAT group then microfracture or debridement
      – No articular damage at time of reconstruction did best
  – Gudas et al *Arthroscopy* 2005
    • OAT superior to microfracture in young athletes
      – HSS and ICRS scores
      – Cartilage repair assessment
      – 93% vs 52% return to pre-injury activity level
Autologous Chondrocyte Implantation

- Two-staged, cell-based technique for medium to larger full-thickness lesions
- Stable rim of intact bone to support graft
- Bone grafting may be necessary for lesions deeper than 8mm
Arthroscopic cartilage biopsy
  - Identify and size the defect
    - Kissing lesions
    - Lesion containment
  - Full-thickness harvest from superolateral aspect of notch or medial aspect of proximal trochlea
    - 5mm wide x 10mm long
    - 200mg to 300mg
  - Sterile transport medium for culturing

Autologous Chondrocyte Implantation
Autologous Chondrocyte Implantation

- Cartilage production
  - Enzymatic degradation to 300,000 cells
  - Amplification to 12 million cells per 0.4ml
  - Up to 48 million cells obtain
  - Process takes approximately 6 weeks
    - 2 weeks for cryopreservation
Autologous Chondrocyte Implantation

- Autologous chondrocyte implantation
  - Limited medial or lateral parapatellar arthrotomy
  - Defect preparation
    - Sharp debridement with intact shoulders
    - Do not remove subchondral bone (only calcified cartilage)
      - Limit bleeding -> limited dilution
    - Size is templated for patch cover
Autologous Chondrocyte Implantation

- Patch cover
  - Periosteal patch (1st gen) or collagen membrane (2nd gen)
    - Proximal medial tibia
  - Patch placed over defect and trimmed
    - 6-0 resorbable suture
    - Knots tied on patch side (3, 6, 9, 12 o’clock)
    - Suture line waterproofed with fibrin glue
      - Tested for defects with saline
  - 18-gauge angiocatheter introducer
    - Slowly fill with chondrocytes
    - Seal remainder of patch
Autologous Chondrocyte Implantation

• Rehabilitation
  – Proliferation (weeks 1-6)
    • Vulnerable to shear and compressive forces
    • CPM used for 6-8 hours a day
      – Degree of motion dependent on location of defect
    • Toe-touch weight bearing
  – Transition (weeks 7-12)
    • Gradually progress to full weight bearing
    • Closed chain exercises
  – Remodeling (>12 weeks)
    • Progressive strength training
    • Proprioceptive exercises
    • No cutting sports for 18 months
Autologous Chondrocyte Implantation

- Peterson et al. *AJSM* 2010
  - 224 patient replies to multiple outcome surveys
    - Mean follow-up 12 years
    - 74% reported better or same scores compared to previous years
    - 92% satisfied, would repeat surgery

- Biant et al *AJSM* 2014
  - 104 patients underwent ACI (85 with collagen patch) with minimum 10 year follow-up
    - 26% failure rate, mean at 5.7 years
    - 73 patients with viable graft
      - 63% excellent result, 25% good, 8% fair, 4% poor
      - 98% overall satisfaction rate

- Niemeyer et al *Int Ortho* 2014
  - Matched-pair analysis of 1st generation vs 2nd generation with minimum 10 year follow-up
    - Significant better Lysholm and IKDC in 2nd generation
Matrix-induced Autologous Chondrocyte Implantation

• Considered third generation of cartilage repair
• Culturing of chondrocytes on to a scaffold
  – Biodegradable type I or II collagen membrane
• Can be done arthroscopically
• Graft lays within defect
  – Secured within defect with fibrin glue
  – Sutures or anchors can be used for additional support
Matrix-induced Autologous Chondrocyte Implantation

• Clinical results
  – Marlovits et al AJSM 2012
    • Case series of 21 patients
      – Significant improvements in KOOS, IKDC, Tegner at 5 years
      – Subchondral edema on MRI for 47% of patients
  – Similar results throughout the literature

• Comparison to ACI
  – Nawaz et al JBJS 2014
    • 869 patients with mean follow-up of 6.2 years
    • 380 with ACI, 519 with MACI
      – No difference in survivorship of graft
      – Functional and pain scores were better in MACI group than ACI group
  – Bartlett et al JBJS Br 2005
    • Prospective, randomized trial of 91 patients
    • No significant difference
      – Clinical scores, arthroscopic findings, biopsy, graft hypertrophy
Comparative Results

• Basad et al *KSSTA* 2010
  – Randomized trial of 40 MACI vs 20 microfracture with two year follow-up
    • Significant improvement in both groups
    • MACI superior at 2 year follow-up
      – Lysolm
      – Tegner
      – ICRS patient
      – ICRS surgeon

• Kon at al *AJSM* 2011
  – Cohort study of 41 semipro/pro soccer players
  – Second generation vs microfracture
    • Microfracture median time to return:  8 months
    • 2\textsuperscript{nd} gen ACI median time to return: 12.5 months
    • Subjection scores: similar at 2 years
      – Decline in microfracture scores over time
ACI vs Mosaicplasty

- Bentley et al. JBJS (Br) 2003
  - 100 total patients with symptomatic articular cartilage defect
  - Majority posttraumatic, avg defect size 4.66cm²
  - Avg age 31.3 years
  - Mosaicplasty: 42 patients; ACI: 58 patients
    - ACI: 88% excellent or good results
    - Mosaicplasty: 69% excellent or good results
    - 1 yr arthroscopy: ACI 88% vs MS 34% excellent or good repairs
Osteochondral Allograft Transplantation

• Implant fully developed tissue capable of withstanding normal load transmission
  – Mature matrix, cartilage bone interface
  – Chondrocytes are immunoprivileged
  – Allograft bone heals by creeping substitution
    • Most critical step
    • Greater bone edema caused by immune response
  – Risk of HIV transmission 1/1.6 million
  – Graft viability
    • 98% at 7 days
    • 70% at 28 days
Osteochondral Allograft Transplantation

- **Technique**
  - Pre-operative X-rays to size
  - Arthrotomy – possible patella subluxation
  - Defect preparation
    - Reamer over guide wire to healthy cancellous bone
    - Depth dependent on bone quality
    - Depth in four quadrants measured
  - Transplantation
    - Reamer/trimming to same size plug
    - Marked for orientation
    - Hand-pressed fit (no tamp used)
    - Screws or pins to supplement as needed
Osteochondral Allograft Transplantation

- **Challenges**
  - Trochlea/patella complex anatomy
    - Difficult to match sulcus anatomy
  - Diffuse patella damage
    - Patellar allograft resurfacing
    - Allograft replaces entire surface
    - Fixation obtained with AP screws
Osteochondral Allograft Transplantation

• Rehab
  – Weight bearing determined by lesion size to protect graft
    • Patellofemoral joint -> WBAT in extension
  – Range of motion determined by lesion location
  – Progression to weight-bearing and exercises similar to other rehab protocols

• Complications
  – Graft availability
    • Size mismatches
  – Worse results in large, bipolar lesions
    • Increased age
Osteochondral Allograft Transplantation

• Clinical results
  – Raz et al *JBJS* 2014
    • 58 patients, allograft to distal femur, lesions larger than 3cm in diameter
      – Mean 21.8 year follow-up
      – 13/58 required additional surgery
        » 9 TKA
      – Survival rates
        » 91% - 10yrs, 84% - 15yrs, 69% - 20yrs, 59% - 25yrs
        » Mean modified HSS score 86 at 15 years
  – Shaha et al *AJSM* 2013
    • 38 athletes at single military institution, mean f/u 4.1 years
    • Analysis of isolated chondral injury
      – Rate of return to full duty – 33.3%
      – Rate of return to sport level – 7.4%
    • Predictors: Branch of military and occupation
  – Krych et al *AJSM* 2012
    • 43 athletes (mostly recreational) at 2.5yr
    • Concomitant injuries included
      – 79% returned to pre-injury level
      – Return to sport – 9 months
      – Age >25 and pre-op duration of symptoms negative predictors
Osteochondral Allograft Transplantation

• Glenn et al *AJSM* 2006
  – Canine study osteochondral autograft vs allograft
    • MRI studies at 3 and 6 months – no difference
    • Biomechanical testing – no difference
    • Normal cartilage structure for both

• Jamali et al *CORR* 2005
  – 20 knees, patellofemoral joint only
    • 5/20 failed
    • If incorporated, improved clinical scores
      – 4/15 – no radiographic arthritis
      – 6/15 – minimal radiographic arthritis
Patellofemoral Compartment

- All techniques less successful compared to tibiofemoral compartment
- Tracking must be corrected first
- Microfracture results varied
- ACI, following tracking correction, has emerged as procedure of choice
  - 80% good or excellent results
## Summary

<table>
<thead>
<tr>
<th></th>
<th>Microfracture</th>
<th>Mosaicplasty</th>
<th>ACI</th>
<th>Allograft</th>
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</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td>No donor morbidity</td>
<td>Mature hyaline cartilage</td>
<td>No size limitation</td>
<td>No size limitation</td>
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<tr>
<td></td>
<td>Arthroscopic</td>
<td>Bone-bone healing</td>
<td>Hyaline-like cartilage</td>
<td>Mature hyaline cartilage</td>
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<td>Quick return to sports</td>
<td>Autologous tissue</td>
<td>Simple rehab</td>
</tr>
<tr>
<td><strong>Disadvantage</strong></td>
<td>RTS (6-9mo)</td>
<td>Miniopen</td>
<td>Arthrotomy</td>
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<td>Fibrocartilage</td>
<td>Donor site morbidity</td>
<td>Complex rehab</td>
<td>Graft availability</td>
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<td>RTS (12-18mo)</td>
<td>RST (9-12mo)</td>
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<td>Cost</td>
<td>Graft mismatch</td>
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<td>Cost</td>
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Conclusion

- Common injury, but not all symptomatic
- Attempt non-operative treatment first
- Multiple surgical options available
  - Patient factors
    - Age, BMI
  - Surgical factors
    - Lesions size, location, concomitant injury
- Correct concomitant deformities
- Patient education/expectations