Rehabilitation Following Articular Cartilage Repair Surgery

Kevin E Wilk, DPT, PT, FAPTA

**Introduction**

- Most challenging of all lesions to successfully treat
- Not sexy concepts – not bejazz
- Just basic science principles that the surgeon & rehab specialist must adhere to
- Unforgiving structure
- Career injury / Life altering lesions

**Rehab Plays a Key Role in Ultimate Outcome**

**Medial Meniscus Allograft with Microfracture**

- 30 yo female

- 12/26/08: 1cm x 15mm
- 7/30/09: healing - painful

**Articular Cartilage Function Overview**

- Provides a low friction, resilient, weight bearing surface
- Absorbs mechanical shock - load
- Coefficient of friction 15 times less than that of ice on ice

Mankin '71

**Cartilage Development & Aging**

**Immature Cartilage**
- Blue-white color
- Thick
- Increased cellularity
- Many mitotic figures
- Higher water content
- Higher PG content
- Lower collagen content

**Mature Cartilage**
- Thinner
- Less cellular
- Mitotic activity ceases
- Lower water content
- Lower PG content
- Higher collagen content
**Nutrition**

- Cartilage avascular → Diffusion
- Immature: Underlying bone and synovial fluid
- Adult: Synovial fluid

**Obstacles to Cartilage Repair**

- Hypocellular
- Avascular
- Chondrocytes “imprisoned” in matrix

**History**

- Often an Associated Ligamentous injury
- Pain
- Swelling
- Catching
- Locking

**Surgeical Options for Localized Articular Cartilage Lesions**

- Arthroscopic lavage
- Arthroscopic debridement
- Arthroscopic abrasion chondroplasty
- Microfracture or picking
- Osteochondral autograft transfers
- Autologous chondrocyte implantation

Which procedure is best???

**Candidates for Cartilage Restoration**

- Pre-articrlar full-thickness lesion
- Contained lesion
- “Big enough yet small enough”
- Ligamentously stable
- Satisfactory alignment
- Functioning meniscus

- Age < 40??
- BMI Reasonable
- Non - Smoker

- Compliant patient with realistic expectations

Rehab Must Match the Surgery
The Treatment Algorithm: Cartilage Repair Centers
Smaller, Less Complex, Less Invasive

- Small < 2 cm² Defect
- Failure
- Low Demand Patient
- OATS
- ACI
- Failure
- Marrow Stimulation
- Chondroplasty
- Failure
- Age > 40
- MS
- OATS
- ACI

Factors
- Size
- Age
- Social
- Activity
- Genetic
- Complacency

Articular Cartilage Lesions
Rehabilitation Concepts

- Successful rehabilitation requires knowledge of:
  1. Biology of articular cartilage
     - factors influence healing & repair
     - such as motion, compression, etc.
     - nutrients
     - protection, shear & compression

TIBIOFEMORAL COMPRRESSIVE LOADS

- Level walking: 3.4 x BW  
  Morrison J Biomech  ’70
- Up ramp: 4.5 x BW
- Down ramp: 4.5 x BW
- Up stairs: 4.8 x BW
- Down stairs: 4.5 x BW
- Rise from chair: 3.2 x BW  
  Dumbleton Biomech  ’72
- Knee bend: 4.2 x BW  
  Ellis J Biomech Eng  ’84

The Treatment Algorithm: Cartilage Repair Centers
Larger, More Complex, More Invasive

- Larger > 2 cm² Defect
- Failure
- Low Demand Patient
- ACI
- Allograft
- Failure
- 3-3 cm² MS, OATS
- ACI
- Failure
- Redo ACI
- Allograft

Factors
- Size
- Age
- Social
- Activity
- Genetic
- Patient Expectations

Promote Healing
Do not Overload Healing Tissue

TIBIOFEMORAL COMPRRESSIVE LOADS

- Kaufman, AJSM 1991
  - isokinetic 60°/sec 55° 4x BW
  - isokinetic 30°/sec 55° 3.5x BW
- Ericson, AJSM 1986
  - cycling 1.2x BW
- Morrison, J Biomech
  - level walking 3.4x BW
- Dahlkurst, Eng Med’82
  - squat – ascent 140° 5.0x BW
  - squat – descent 140° 5.6x BW
- Nisell, AJSM 1989
  - isokinetic 30°/sec 65° 9.0x BW
Articular Cartilage Lesions

Rehabilitation Concepts

- Successful rehabilitation requires knowledge of:
  2: Specific surgical variables
    » nature of lesion (acute, chronic)
    » location of lesion (femur, trochlea, patella)
    » size of defect
    » depth of lesion
    » WB area**
Rehab Articular Cartilage

Rehab Specifics

Patellofemoral Lesions
- Motion
- Flexibility (Q, G/S)
- Patella position
  - Correct tilt
  - Control PFJR
- Treat above & below
  - Hip control
  - Pelvic control
  - Foot/ankle position

Tibiofemoral Lesions
- Motion, motion, motion
- Control WB forces
- Shock absorbers (Q)
- Location of lesion
- Control WB forces
- Slow to run, plyos

Articular Cartilage Lesions

Classification

- Size of lesion
  - Smaller lesions are “shouldered” and may not progress.
- Size Classification
  - < 2 cm² = small
  - 2 to 5 cm² = moderate
  - > 5 cm² = large

Outerbridge System
- Grade I - softening
- Grade II - fibrillation
- Grade III – fissuring to bone
- Grade IV - full thickness
  Orthopedics 1997;20:525-538

Orthopedics 1997:20:525-538
Articular Cartilage Lesions

Diagnostic Concepts

• Successful recognition of articular cartilage lesion on MRI
• Variables:
  » Location
  » Size
  » Exact of lesion
  Mair:
  Potter:
  Graf:

Articular Cartilage Lesions

Rehabilitation Concepts

• Successful rehabilitation requires knowledge of:
  3: Exact surgical procedure
    » tailor rehab to procedure
  4: Specific patient variables
    » age, activity level
    » LE alignment
    » Concomitant injuries
    » Meniscus

Articular Cartilage Lesions

Rehabilitation Concepts

• Successful rehabilitation requires knowledge of:
  5: Phases of articular cartilage healing
    • Four Phases of Healing
      – Proliferation Phase
      – Transitional Phase
      – Remodeling Phase
      – Maturation Phase

Rehab Articular Cartilage

Motion, Motion, Motion

• Low intensity
• Long duration

Articular Cartilage Rehabilitation

Phases of Articular Cartilage Healing

Four Biological Phases

I: Proliferation – Protection Phase
  » First 6-8 weeks of healing
  » Cell multiply & produce matrix
II: Transitional – Protection Phase
  » Weeks 8-12/16
  » Repair tissue is spongy, delicate phase
III: Remodeling – Functional Phase
  » Weeks 12/16 - 32
  » Remodeling to articular(fibrocartilage)
IV: Maturation Phase (8-18> months)
  » Fibrocartilage matures, increases in strength, etc.
Glucosamine Supplements

- Glucosamine & Chondroitin Sulfate treatment is NOT a new concept
- These products have been widely used in Europe & Asia for several yrs
- Interest in the USA
  - 1977 book entitled “The Arthritis Care” recounted authors’ experience with G & CS
  - Declared it useful – rapid interest
  - In 2000, $640 million supplement sales
  - Alternative Medicine & Veterinary

Knee Bracing for the Osteoarthritic Knee Patient

Crenshaw et al: Clin Orthop ‘00
Essentials to Cartilage Restoration

- Alignment:
- Unload the involved compartment
- Normalize the biomechanics

Surgical Techniques for Articular Cartilage Lesions

Microfracture

Articular Cartilage Procedures
Rehab Following Microfracture
Protection Phase (week 0-8)

• Full passive knee extension immediately
• Immediate motion: 0-45°
  + Week 1: 0-90
  + Week 2: 0-105
  + Week 4: 0-125
• Motion exercise hourly (use opposite leg)
• CPM use 6-8 hours per day
• No brace, may use elastic compression sleeve or wrap for swelling

Weight bearing progression:
✓ NWB 2-4 weeks or (NWB for 4-6 wks)
✓ 25% BW week 6-7
✓ 50% BW weeks 7-8
✓ FWB week 8-9
*Depends on location & extent of lesion (size)

• OKC exercise for 5-6 weeks
• CKC leg press at week 4-5
• Bicycle once ROM permits (low resistance/seat)

Rehab Following Microfracture
Transitional Phase (week 8-14)

• Full weight bearing week 8
• Full ROM week 6-7
• Initiate functional rehab drills
• Pool exercise program
  » Control joint compressive/shear forces
  » Consider orthotics or brace
• Gradually increase walking program

• Full passive knee extension immediately
• Immediate motion: 0-45°
  + Week 1: 0-90
  + Week 2: 0-105
  + Week 4: 0-125
• Motion exercise hourly (use opposite leg)
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• OKC exercise for 5-6 weeks
• CKC leg press at week 4-5
• Bicycle once ROM permits (low resistance/seat)
Rehab Following Microfracture
Maturation Phase (week 14-22)

- Progress strengthening exercises
  » Progress CKC exercises
  » Lunges, squats, step-overs, etc
- Progress functional drills, proprioception
- Stretching & flexibility drills
- Progression in functional activities

Rehab Following Microfracture
Return to Activity Phase (week 22-26)

- Continue strengthening & flexibility exercises
- Continue bicycle program
- Functional activities:
  ✓ Low impact: week 16-20
  ✓ Moderate impact: week 22-26
  ✓ High impact: week 26-34

Rehabilitation Microfracture
Rehab Overview

- Drop locked brace crutches
- Full passive extension
- CPM - motion
- Immediate PROM
- Lots of motion, motion…
- EMS to quads
- Progress to CKC
- Running: week 16-20

Microfracture Results

- 86% normal/near normal knee function
- 43% Previous level of activity (no restrictions)
- 43% Previous activity level (few restrictions)
- 14% Level of participation decreased
  Steadman JR et al: J Orthopaedics ‘98

MITHOEFEFER, WILLIAMS, WARREN: AJSM ‘06

- Microfracture surgery on 32 high impact pivoting athletes (?)
- 66% reported good-excellent results
- 44% returned to impact sports
- After initial improvement – scores decreased in 47% of the athletes
- Return to sports significantly higher with:
  » Athletes 40 yrs of age or less
  » Lesion size 200mm2
  » Pre-Operative symptoms less than 12 months
  » No prior surgical intervention
Mithoefer, Williams, Warren: JBJS ‘06

- Femoral chondral microfracture in 48 pts.
- Minimum FU 2 years results:
  - 67% good – excellent results
  - 25% fair results
  - 8% poor results
- Best results observed in patients:
  - Lower body mass index (BMI) worse results BMI >30kg/m²
  - Good fill grade of defect on MRI
  - Shorter duration of symptoms
- MRI on 24 knees – 54% good repair – tissue fill
  - 29% moderate fill
  - 17% poor tissue repair & fill

Mosaicplasty
Osteochondral Autograft Transfer

OSTEOCHONDRAL AUTOGRAFT TRANSFER

- Articular cartilage & subchondral bone plug harvested from NWB
- Osteochondral plugs
- Various diameters 2.5 - 10 mm
- Insert plugs into defect
- Rehabilitation variables:

OSTEOCHONDRAL AUTOGRAFT TRANSFER

Donor Sites
REHABILITATION FOLLOWING OSTEOCHONDRAL AUTOGRRAFT PROCEDURE

Protection Phase (Week 0 - 8)

• Brace locked during ambulation (2 - 4 weeks)
• WB progression
  » NWB for 2-4 weeks
  » PWB (toe-touch) weeks 3 - 6
  » PWB (½ - ¾ BW) weeks 5 – 8
  » FWB with control weeks 8

• ROM progression
  » Week 1: 0 - 90°
  » Week 2: 0 - 105°
  » Week 3: 0 - 115°
  » Week 6: 0 - 125°
  ROM as tolerated

• Strengthening program, isometrics, SLR, OKC exer.
• Mini-squats week 5
• Leg press week 3-4
• Bicycle (when ROM permits)
• Gradual return to functional activities

Transitional Phase (Week 8 - 14)

• Full WB week 8
• Knee ROM: 0 - 135°
• Initiate CKC and functional activities (step-ups, lunges, balance drills, proprioceptive)
• Pool program - progress
• Gradually increase functional exercises & activities

Maturation Phase (Week 16 - 24)

• Progress all strengthening exercises
  » Control excessive shear & compression
• Progress walking, bicycle program
• Light activities (week 16-20)
• Continue flexibility, ROM exercises

Return to Activity Phase (Week 22-32)

• Continue strengthening and flexibility exercises, bicycle
• Functional activities:
  » Low-impact: 4 - 4½ months
  » Moderate-impact: 5-6 months
  » High-impact: 6 - 9 months
Mosaicplasty in Athletes

- 78 athletes with minimum 3 year f/u
  - 64% returned to same level of play
  - 19% returned to lower level of play
  - 17% no sports post-op
  - 8% worse following surgery
- Of 78 athletes, 43 had some OA changes pre-op
- Picture 1 yr post-op — Hangody et al, reported at 2001 AAOS

Hangody, Fules: JBJS (A): '03

- 831 patients mosaicplasty on knee joint
- Long term follow-up results:
  - 92% good – excellent result femoral condyle
  - 87% good- excellent result tibial plateau
  - 79% good – excellent on patellar defects
  - 3% donor site morbidity
  - 4 deep infections
  - 36 post-operative painful hemarthrosis

Hangody, Fules: JOSPT '06

- 831 patients mosaicplasty on knee joint
- Long term follow-up results:
  - 92% good – excellent result femoral condyle
  - 87% good- excellent result tibial plateau
  - 79% good – excellent on patellar defects
  - 94% good – excellent talar surfaces
- 69 of 89 underwent 2nd look arthroscopy – exhibited congruent gliding surfaces, survival of hyaline cartilage, and filling in of defect

Allograft Osteochondral Grafts

- Isolated defects
  - Patella, femoral condyle, tibia
- Large or small
- Defect filled with single plug from cadaver bone
  - No donor site morbidity

Allograft Osteochondral Grafts

- Allograft tissue takes longer to heal
- Longer recovery
- Little risk
  - Viral transmission < 1:1,000,000
- No donor site morbidity
- Good results in > 85% at 5 years
Autologous Chondrocyte Implantation

**Indications**
- Advancing Indication: Patella
  - Facet vs diffuse patellar involvement
  - Aggressive treatment of underlying instability or malalignment

**Femoral Condyle**
- OCD
- Trochlea

Cartilage “Transplant”
Rehab Following ACI
Protection Phase (Week 0-8)

- ROM guidelines
  - 1st 24 hours: CPM/Motion ??
  - Day 2-3: ROM 0-45
  - Gradual increase ROM 0-90
  - Week 4: 0-105
  - Week 6: 0-125
  - Week 8: 0-135
- CPM – 6-8 hours/day
- Full passive knee extension

Rehab Following ACI
Protection Phase (Week 0-8)

- Weight bearing progression:
  - NWB for 2 weeks
  - TTWB for 4 weeks
  - FWB at 8 weeks
- Brace locked full extension during ambulation & sleep
- Ambulation in unlocked brace at 8 weeks
Rehab Following ACI
Protection Phase (Week 0-8)

- Strengthening exercises
  - Electrical muscle stimulation quads
  - Quad sets & SLR (flexion)
  - Hip abd/adduction
  - AROM knee ext (week 3)
  - Bicycle (ROM permits)
    - Light resistance
  - Pool program

Rehab Following ACI
Transitional Phase (Week 8-16)

- Discontinue locked brace week 6 -8
  - Motion in brace week 8
- Weight bearing progression:
  - Week 6: 50% BW
  - Week 8: 100% BW with crutch
- Progress to CKC functional exercises
- Initiate proprioception drills
- Pool program week 4-5 (incision determines)
- Walking program (week 8-10)

Rehab Following ACI
Maturation Phase (Week 16-24)

- Full non-painful ROM
- Progress strengthening program
  - Light resistance
  - Control shear & compression
  - Emphasize bike, CKC and pool exercises
- Progress stretching exercises
- Increase walking & functional activities

Rehab Following ACI
Functional Activities (Week 26-52)

- Progress functional activities:
  - Low impact activities: 5-6 months
  - Moderate impact activities: 6-9 months
  - High impact activities(?): 9-12 months

Autologous Chondrocyte Implantation
Modified Cincinnati Rating Scale: 7/95 to 12/00

<table>
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<tr>
<th>All Defects</th>
<th>Pre-Op N=111</th>
<th>1 Year N=71</th>
<th>2 Year N=54</th>
<th>3 Year N=32</th>
<th>4 Year N=21</th>
<th>5 Year N=8</th>
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<td>5.9</td>
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<td>8.1</td>
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<td>6.1</td>
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<td>5.0</td>
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<td>5.9</td>
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<td>1.0</td>
<td>1.3</td>
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Autologous Chondrocyte Implantation
Modified Cincinnati Rating Scale
Patella/Trochlea/MFC Defects

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<th>Patella/Trochlea/MFC Defects</th>
<th>Pre-Op N=15, 27, 48</th>
<th>1 Year N=9, 14, 31</th>
<th>2 Year N=6, 8, 23</th>
<th>3 Year N=2, 5, 14</th>
<th>4 Year N=2, 4, 8</th>
<th>5 Year N=1, 3</th>
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Peterson, Minas: CORR '00

- 92 patients underwent ACI; F/U 2-9 yrs
- Good to excellent results
  » 92% isolated femoral condyle
  » 67% multiple lesions
  » 89% OCD
  » 65% patella
- Repair tissue biopsy “hyaline-like”

Mithofer, Peterson, Mandelbaum: AJSM '05

- 45 soccer players under ACI surgery of the knee
- 72% returned to competitive play
- 80% of the players returned to pre-surgery level
- Average length of play – 52 months following surgery

Autologous Chondrocyte Implantation (2nd generation)

- Alternative flap to periosteum
- Scaffold to avoid flap
- All implants in place at 1mo (MRI)

CaReS®: Matrix imbedded ACI

Autologous Chondrocyte Implantation (2nd generation)

- Cultured or minced articular cartilage
  » One or two stages
  » Autologous (MACI, CAIS, NeoCart)
  » Allograft juvenile (DeNovo NT)

DeNovo NT

Hybrid Procedure: OCT & De Novo

Adult vs Juvenile Cells
Juvenile cells have better biosynthetic activities
Allograft Osteochondral Transplantation

- Large articular lesion especially if subchondral bone missing

Articular Cartilage Rehabilitation
Rehab Following Surgery

- Delicate balance of forces & applied stress
- Motion to stimulate healing / repair
- Control shear & compression forces
- Rehab varies based on surgery & lesion
- Monitor signs & symptoms closely
- Progress slowly & sequentially to recondition cartilage
- Caution: repetitive high impact loading till ??

Thank You!!

Long Term Results