Rehabilitation Following Articular Cartilage Repair Surgery

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2017 Chicago Sports Medicine Symposium

Faculty Disclosure:

• Theralase Laser – Medical Advisory Board
• LitoCure Laser – Consultant
• AlterG – Medical Advisory Board
• Intelliskin USA – Medical Advisory Board
• Zetroz Medical – Medical Advisory Board
• Throw Like A Pro – Co-Owner
• Dr PRP – Rehab Advisor
  » Empi Medical
  » Joint Active System
  » ERMI
  » Bauerfeind Braces
• Book Royalties:
  » CV Mosby, Lippincott, Human Kinetics
Rehab Articular Cartilage

Introduction

- One of the most challenging of all lesions to successfully treat
- Athletes — Active People
  - Not sexy concepts — no bejazz
  - Just basic science principles that the surgeon & rehab specialist must adhere to
- Unforgiving structure
- Career threatening injury
- Life altering lesions

Rehab Plays a Key Role in Ultimate Outcome

Surgerical Options for Localized Articular Cartilage Lesions

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

Rehab Must Match the Surgery
Articular Cartilage Lesions
Rehabilitation Concepts

- Successful rehabilitation requires knowledge of:
  1. Biology of articular cartilage
     - Factors influence healing & repair
     - Motion, compression, loading, etc.
     - Nutrition
     - Protection: shear & compression

**What's Good for Articular Cartilage**

**Promote Healing**
- Exercise
- Nutritious diet

**Do not Overload Healing Tissue**
- Avoid high-intensity activities
- Limit overload on injured tissue
Rehab Articular Cartilage

Motion, Motion, Motion

- Low intensity
- Long duration

Articular Cartilage Rehabilitation

Motion is Lotion

TIBIOFEMORAL COMPRESSION 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*

TIBIOFEMORAL COMPRESSION LOADS

Overview

- **Kaufman, AJSM 1991**  
  - Isokinetic 60°/sec 550° 4 x BW
  - Isokinetic 30°/sec 550° 3.5 x BW
- **Ericson, AJSM 1986**  
  - Cycling 1.2 x BW
- **Morrison, J Biomech**  
  - Level walking 3.4 x BW
- **Dahlkurst, Eng Med’82**  
  - Squat – ascent 140° 5.0 x BW
  - Squat – descent 140° 5.6 x BW
- **Nisell, AJSM 1989**  
  - Isokinetic 30°/sec 65° 9.0 x BW
“It hurts after I exercise !!!”

Don’t do that !!!
Let’s find a form of exercise for you to do !!!
Proprioception & NM Control

Progressive WB Loading
<table>
<thead>
<tr>
<th>Activity</th>
<th>Load Multiplier</th>
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</thead>
<tbody>
<tr>
<td>Level walking</td>
<td>3.4 x BW</td>
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<tr>
<td>Up ramp</td>
<td>4.5 x BW</td>
</tr>
<tr>
<td>Down ramp</td>
<td>4.5 x BW</td>
</tr>
<tr>
<td>Up stairs</td>
<td>4.8 x BW</td>
</tr>
<tr>
<td>Down stairs</td>
<td>4.5 x BW</td>
</tr>
<tr>
<td>Rise from chair</td>
<td>3.2 x BW</td>
</tr>
<tr>
<td>Knee bend</td>
<td>4.2 x BW</td>
</tr>
</tbody>
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Morrison J Biomech '70
Dumbleton Biomech '72
Ellis J Biomech Eng '84
### TIBIOFEMORAL COMPRESSIVE LOADS

<table>
<thead>
<tr>
<th>Study</th>
<th>Exercise</th>
<th>Speed</th>
<th>Angle</th>
<th>BW Multiplier</th>
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<tbody>
<tr>
<td>Kaufman, AJSM 1991</td>
<td>isokinetic 60°/sec</td>
<td>55°</td>
<td>4x</td>
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</tbody>
</table>

### Articular Cartilage Lesions

**Rehabilitation Concepts**

- Successful rehabilitation requires knowledge of:
  - **2: Specific surgical variables**
    - Type of lesion (acute, chronic)
    - Location of lesion (femur, trochlea, patella)
    - Size of lesion
    - Depth of lesion
    - WB area**
Rehab Articular Cartilage
Rehab Specifics

Patellofemoral Lesions
- Motion
- Flexibility (Q, G/S)
- Patella position
  » Correct tilt
  » Control PFIR
- 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 4 cm² = moderate
  ✓ > 4 cm² = large

Articular Cartilage Lesions

Classification

Outerbridge System

✓ Grade I - softening
✓ Grade II - fibrillation
✓ Grade III – fissuring to bone
✓ Grade IV - full thickness

Orthopedics 1997;20:525-538

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 status
    • Nutrition
    • Smoking
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

Articular Cartilage Lesions
Rehabilitation Concepts

• Successful rehabilitation requires knowledge of:
  6: Weight Bearing Concepts
    ✔ Control WB forces
    ✔ Especially stairs, uneven surfaces, prolonged WB
    ✔ Concerned regarding compression, shear, rotation forces
Marder, Hopkins, Timmerman: *Arthroscopy '05*

- Effects of WB on the recovery following microfracture of MFC or LFC
- 50 patients were Rx with Microfracture
- Mean age 39.7 (16-66 yrs)
- Group I: NWB & CPM for 6 weeks
- Group II: WBAT & no CPM
  - Lysholm scores higher in group II (WBAT)  
  - No stat sign diff between the 2 groups

Song, Dong, Li et al: ‘14

- Drilled full thickness defect in patellar groove in 40 male rats
- Randomized into 4 groups:
  - No exercise group (SED)  
  - no exercise in 2 weeks (2W)  
  - no exercise 4 weeks (4W)  
  - no exercise 8 weeks (8W)
  - Best results: 4 week group eval at 10 & 14 wks  
  - Worst results – 2 weeks group (histochemistry scores)

**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


- 1583 patients with symptomatic knee OA
  mean age 59 yrs (65% females)
- Excluded 1655 patients for various reasons
- Treatment groups:
  - 313 placebo
  - 317 Glucosamine
  - 318 Chonoin Sulfate
  - 317 Glucosamine & CS
  - 318 Celecoxib
- Treatment plan for 24 weeks
- Able to take up to 400 mg acetaminophen for pain
- Primary outcome 20% reduction in knee pain
Knee Bracing for the Osteoarthritic Knee Patient

Hewitt, Noyes, Barber, Heckmann: Orthop '98

- 18 patients symptomatic medial OA
- Before bracing 78% reported knee as fair to poor, had pain with ADL’s
- Following 9 weeks of bracing: 33% rated knee as fair to poor, 39% pain with ADL’s
- Asymptomatic walking tolerance increased from 51 min to 139 min following 1 yr


- 119 patients randomly assigned to one of 3 groups: neoprene sleeve, valgus brace, control group
- Assessed pain, stair climbing, 6 minute walking test, quality of life
- Tested after 6 months of wear
- Significant reduction in pain, 3.3 x reduction with brace group
- Braced out performed neoprene or control
Essentials to Cartilage Restoration

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

Articular Cartilage Surgery & Outcomes

- Yanke, Cole: Orthopedics ’14
- Cvetanovich, Riboh, Tilton, Cole: AJSM ’17
- Oliver-Welsh, Griffith, Meyer, Cole: Ortho ’16
- Chalmers et al: Cartilage ’13

- Weight bearing progression:
  - NWB 2-4 weeks
  - 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**

*Protection Phase (week 0-8)*

- Full passive knee extension immediately
- Immediate motion: 0-60° (tolerance)
  - 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

**Rehab Following Microfracture**

*Transitional Phase (week 8-16)*

- Full weight bearing week 8
- Full ROM week 6-7
- Initiate functional rehab drills
- Emphasize hips, core, quads
- Pool exercise program
  - Control joint compressive/shear forces
  - Consider orthotics or brace
- Gradually increase walking program
Rehab Following Microfracture

Maturation Phase (week 16-24)

- Progress strengthening exercises
  - Progress CKC exercises
  - Bicycle, bridging, leg press, hip ER/IR, lateral slides, step downs, balance, endurance
- Progress functional drills, proprioception
- Stretching & flexibility drills
- Progression in functional activities

Rehab Following Microfracture

Return to Activity Phase (week 24/26 & >)

- 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

**PF Rehab Overview**

- Drop locked brace crutches limited time
- Full passive extension
- Patella protection program
- Immediate PROM
- Lots of motion, motion…
- EMS to quads
- Progress to CKC
- Running: when ready
Microfracture Results

- 86% normal/near normal knee function
- 43% Previous level of activity \(\text{(no restrictions)}\)
- 43% Previous activity level \(\text{(few restrictions)}\)
- 14% Level of participation decreased

\textit{Steadman JR et al: J Orthopaedics '98}

\textbf{Mithoefer, Williams, Warren: AJSM '06}

- Microfracture surgery on 32 high impact pivoting athletes \(\text{(?)}\)
- 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
Femoral chondral microfracure 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 >30 kg/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

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

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 - 4
  » PWB (½ - ¾ BW) weeks 4 – 6
  » FWB with control weeks 6 - 8
REHABILITATION FOLLOWING OSTEOCHONDRAL AUTOGRAFT PROCEDURE
Protection Phase (Week 0 - 8)

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

REHABILITATION FOLLOWING OSTEOCHONDRAL AUTOGRAFT PROCEDURE
Protection Phase (Week 0 - 8)

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

REHABILITATION FOLLOWING OSTEOCHONDRAL AUTOGRAFT PROCEDURE
Transitional Phase (Week 8 - 16)

• 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 24-32)

- 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

Osteochondral Allograft
Frank, Lee, Levy, Cole: AJSM ‘17

- 224 consecutive patients OATS (allograft)
- Minimum of 2 yrs follow up
- Mean age 32.7 yrs
- 87% survival rate at 5 yrs post operative
- 82% experienced significant improvement
- 18% failure rate
- 37% re-operation rate

Autologous Chondrocyte Transplantation

Indications

- Femoral Condyle
- OCD
- Trochlea
Autologous Chondrocyte Implantation

*Advancing Indication: Patella*

- Facet vs diffuse patellar involvement
- Aggressive treatment of underlying instability or malalignment

Cartilage “Transplant”
ACI and Meniscal Transplantation

**Indications**

- Symptomatic, younger pts, < 50 yrs, s/p total or near total meniscectomy
- Minimal radiographic degenerative changes
- Grade I-II (III) Chondromalacia, or correctable chondral defect
- Stability, Alignment optimized

**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)

• 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)

• 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 16-26)

- 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 26-32)

- 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</th>
<th>1 Year</th>
<th>2 Year</th>
<th>3 Year</th>
<th>4 Year</th>
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<td>71</td>
<td>54</td>
<td>32</td>
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<tr>
<td>Patient</td>
<td>11</td>
<td>74</td>
<td>79</td>
<td>9.3</td>
<td>8.9</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Excelle
nt
Very
Good
Good
Fair
Poor
Cartilage “Transplants”

- Isolated defects
  - Patellar defects not as successful as femoral
- Small risk of donor site morbidity
- No risk of viral transmission
- Prolonged healing process
  - 12-18 months for full healing
  - Limited activities during this period
- Must have intact menisci

*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)

Adult vs Juvenile Cells
Juvenile cells have better biosynthetic activities
DeNovo NT

Hybrid Procedure: OCT & De Novo

Allograft Osteochondral Transplantation
- Large articular lesion especially if subchondral bone missing

Courtesy: Dr Parker
Articular Cartilage Rehabilitation
Rehab Following Surgery

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

Long Term Results

Thank You !!