Rehabilitation Following Articular Cartilage Repair Surgery

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Faculty Disclosure:

- Theralase Laser – Medical Advisory Board
- LiteCare Laser – Consultant
- AlterG – Medical Advisory Board
- Intelliskin USA – Medical Advisory Board
- Zetrotz Medical – Medical Advisory Brd
- Throw Like A Pro – Co-Owner
- Dr PRP – Rehab Advisor
- Educational Grants:
  - Empi Medical
  - Joint Active System
  - ERMJ
  - Bauerfeind Brace
- 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

Promote Healing
Do not Overload Healing Tissue
Rehab Articular Cartilage

Motion, Motion, Motion

- Low intensity
- Long duration

Articular Cartilage Rehabilitation

Motion is Lotion

TIBIOFEMORAL COMPRESSIVE 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

Overview

Kaufman, AJSM 1991  
isokinetic 600/sec 550 4x BW
Kaufman, AJSM 1991  
isokinetic 300/sec 550 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
“It hurts after I exercise !!!”

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

Treat the Joint !!!
Not Just an Isolated Injury

Biology of the Rehab Program
### Tibiofemoral Compressive 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 COMPRESSIVE LOADS

<table>
<thead>
<tr>
<th>Study</th>
<th>Condition</th>
<th>Speed</th>
<th>Angle</th>
<th>Factor</th>
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<td>isokinetic 60°/sec</td>
<td>55°</td>
<td>4x</td>
<td>BW</td>
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</tbody>
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### 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 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 4 cm² = moderate
  - > 4 cm² = large

Outerbridge System

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

Orthopedics 1997;20:525-538

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 Chondroitin Sulfate
  » 317 Glucosamine & CS
  » 318 Celecoxib
• Treatment plan for 24 weeks
• Able to take up to 400 mg actaminophen for pain
• Primary outcome 20% reduction in knee pain

Figure 1. Rates of a Primary Response in the Five Groups at 4 and 24 Weeks.
A primary response was defined as a 20 percent decrease in the summed score for the pain subscale of the Western-Ontario and McMaster Universities Osteoarthritis Index.
Knee Bracing for the Osteoarthritis 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 poor, 39% pain w/ 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

Surgical Techniques for Articular Cartilage Lesions
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

Rehab Following Microfracture

Protection Phase (week 0-8)

- 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 (no restrictions)
- 43% Previous activity level (few restrictions)
- 14% Level of participation decreased

Steadman JR et al: J Orthopaedics '98

Mithoefer, 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 surgerical 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/m
  - 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 AUTOGRAFT TRANSFER

Donor Sites

REHABILITATION FOLLOWING OSTEOCHONDRAL AUTOGRAFT 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 (1/2 - 3/4 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

• 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
**REHABILITATION FOLLOWING OSTEOCHONDRAL AUTOGRRAFT PROCEDURE**

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

Autologous Chondrocyte Transplantation

Femoral Condyle OCD Trochlea

Autologous Chondrocyte Implantation Indications
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 26-52)

- 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
All Defects
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
Hybrid Procedure: OCT & De Novo

DeNovo NT

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 !!