Introduction: RTP after Cartilage Repair

• Multiple Factors influence selection of Cartilage Repair technique
  • Characteristics of Defect(s)
  • Age of patient
  • Concomitant Pathology
  • Level of Sports Participation
  • Prior Treatment
  • Goals and Expectations

• Cartilage repair is a physiologically slow process
• Durability of repair depends on quality of repair tissue
• Rehabilitation is integral to maturation of repair tissue and final outcome
Factors Influencing Cartilage Repair Outcomes

• Defect Characteristics
  • Size
    • Size < 2 cm²
    • Size ≥ 2 – 4 cm²
  • Location(s)
  • Containment

• Patient Characteristics
  • Duration of Symptoms
  • Prior Treatment(s)
  • Age
  • Activity Level
  • Expectations and Goals

Factors Influencing Cartilage Repair Outcomes

• Concomitant Knee Pathology
  • Tibio-Femoral Malalignment
  • Patellofemoral Maltracking
  • Ligament Deficiency
  • Meniscus Deficiency

• Rehabilitation Compliance
  • Mechanical Over-Loading and Under-Loading are detrimental to cartilage restoration

• Avoidance of Preventable Complications
  • Periosteum vs. Absorbable Collagen Membrane
  • RTP before tissue healing
Cartilage Treatment Concepts

- Palliative →
  - Arthroscopic Debridement

- Reparative →
  - Microfracture/Marrow Stimulation

- Substitutive →
  - Osteoarticular Transfers, Autograft and Allograft

- Regenerative →
  - ACI/MACI/Scaffold/MSC

Rehabilitation after Cartilage Repair
Advancing Understanding

- Mechanical forces affect proteoglycan turnover and synthesis
- Cyclic Loading enhances proteoglycan synthesis and stiffens cartilage
- Continuous trend to earlier weight bearing in cartilage repair 11-12 wks → 5-6 wks
- Rehabilitation provides conducive mechanical environment for cartilage maturation and remodeling
Autologous Chondrocyte Implantation
Post-Operative Repair Process

**Proliferation**
- 0-6 weeks
- Cells attach to bone

**Transition**
- 7-12 weeks
- Repair tissue spongy, compressible

**Remodeling**
- 12-36 weeks
- More matrix, organization

**Maturation**
- Up to 1-2 years
- Stiffness approaches native cartilage

Pre-Op  5 months  1 year  3 year

Rehabilitation Comparison

<table>
<thead>
<tr>
<th>Activity</th>
<th>Microfracture</th>
<th>Osteochondral Grafting (Autograft)</th>
<th>Autologous Chondrocyte Implantation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Passive Motion (CPM)</td>
<td>Immediately post-operative 6-8 hours per day Up to 8 weeks</td>
<td>Immediately post-operative</td>
<td>6-8 hours post-operative 8-12 hours per day Up to 6 weeks (at least 2)</td>
</tr>
<tr>
<td>Non-Weight-Bearing</td>
<td>Not specified</td>
<td>Weeks 0-2</td>
<td>Weeks 0-2</td>
</tr>
<tr>
<td>Protected Weight-Bearing</td>
<td>Weeks 0-8</td>
<td>Weeks 2-8</td>
<td>Weeks 2-7</td>
</tr>
<tr>
<td>Full Weight-Bearing</td>
<td>Weeks 6-8</td>
<td>At week 8</td>
<td>By weeks 8-9</td>
</tr>
<tr>
<td>Normal Daily Activities</td>
<td>Weeks 6-8</td>
<td>At 3 months</td>
<td>Gradually increased through weeks 6-12</td>
</tr>
<tr>
<td>Low Impact Activities</td>
<td>At 3 months</td>
<td>At 3-4 months</td>
<td>At 6 months</td>
</tr>
<tr>
<td>High Impact Activities (running, aerobics)</td>
<td>Not Specified</td>
<td>At 4-5 months (OAT5) At 6-7 months (Mosaicplasty)</td>
<td>At 9-12 months</td>
</tr>
<tr>
<td>Return to Sports (high impact, pivoting activities)</td>
<td>At 4-6 months</td>
<td>At 5-6 months (OAT5) At 9 months (Mosaicplasty)</td>
<td>At 12-18 months</td>
</tr>
</tbody>
</table>
Principles of Articular Cartilage Loading

**Weight Bearing Loading**

- Load but don’t overload, Use but don’t overuse

---

Principles of Articular Cartilage Loading

**Resume Activity and RTP**

- Return to sports activity criteria: all ≥ 90%
  - Quad/Hamstring Strength Index
  - Single Leg Hop Tests
  - KOS-ADL Scale
- On Field/Sport Assessment
  - no pain or swelling
  - Self Agility Full Speed ➔ Unopposed Practice ➔ Opposed Practice Drills ➔ Full Scrimmage (RTP)
Cartilage Repair Procedures
Average Time to Return to Play

- **Autologous Chondrocyte Implantation**
  - 12-18 months
  - **Larger Lesions**
  - **Slower Return**
  - **Best Durability of Repair**

- **OATS Allograft**
  - 9-12 months

- **OATS Autograft**
  - 6-9 months

- **Microfracture**
  - 4-6 months

- **Chondroplasty**
  - 3-4 months

**Predictors of Outcomes**

**Articular Cartilage Defects**

**Return to Play**: Most ideal with
- Younger Athletes, Higher skill level
- Duration of Symptoms < 1 year
- Smaller Lesions
- Quicker RTP with MFx, OATS autograft but only for smaller lesions (<2 cm²)
- Larger lesions better with ACI or OATS Allograft
- ACI has best durability and longest rehab
- Longer-term Preoperative Symptoms: creates an adverse intra-articular environment for cartilage repair
Predictors of Outcomes
Articular Cartilage Defects

RTP Decision Making:

Short Term:
- Higher probability for RTP w/OATS Auto vs. MFx, but both work for small lesions
- Less RTP in NFL w/ MFx vs. Chondroplasty
- Mithoefer showed decline in sports participation and performance in MFx athletes after 18 mos.
- For focal lesions > 2 cm². Microfracture and OATs showed significantly worse clinical outcomes and lower return to high level sports compared to smaller lesions < 2 cm²

Long Term:
- 87% of ACI treated professional Soccer players remained at their previous sports level at average 52 mos. F/U
- For ACI, no influence on lesion size and clinical outcome or return to sport indicating that this is clearly the better first option for larger lesions
- Higher Tegner scores after ACI than MicroFx as well as higher good to excellent treatment success in professional athletes and adolescent athletes 72-95%

Mithoefer AJSM 34, 2006; Mithoefer AJSM 33, 2005; Mithoefer AJSM 33, 1147, 2005;

Gudas Arthroscopy 21, 2005; Mithoefer AJSM 34, 2006; Marcacci Arthroscopy 21, 2005;
RTP after Cartilage Procedures

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients F/U os.</th>
<th>Time to RTP</th>
<th>RTP @ same or &gt; level</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chondroplasty</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Scilia et al | 52 pts. 70 mos. | 8.2 mos. | 67% | • Starting players more likely to RTP (11.6 games/season)  
• 4.4% less likely to RTP with Microfracture  
• No correlation with age, location of defect, position |

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients F/U mos.</th>
<th>Time to RTP</th>
<th>RTP @ same or &gt; level</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microfracture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gudas et al</td>
<td>60 pts. 37 mos.</td>
<td>4-6 mos. (ave 6.5 mos.RTP)</td>
<td>93% OAT 52% MFx</td>
<td>• 15 (52%) MF patients returned to sports activities at the preinjury level at an average of 6.5 mos. (4-8 mos.)</td>
</tr>
<tr>
<td>Gudas et al</td>
<td>60 pts. 125 mos.</td>
<td>4-6 mos.</td>
<td>75% OATS 37% MFx</td>
<td>• OATs technique allowed higher rate of return, longer maintenance at the preinjury level at 10 yr. F/U</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients F/U mos.</th>
<th>Time to RTP</th>
<th>RTP @ same or &gt; level</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microfracture (Continued)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Mithoefer et al, Microfracture in High Impact Sports, AJSM 2006 | 32 pts. 24 mos. | 4-6 mos. | 44% RTP and 25% at same level | • After initial improvement, score decreases were observed in 47% of athletes  
• Best for < 40 yrs, < 2 cm², < 1 yr symptoms, no prior surgery |
| OATS Allograft | | | | |
| Shaha et al; AJSM 2013 | 38 pts. 47 mos. | 9-12 mos. | 29% | • 42% unable to return to duty, only 5.3% at preinjury level |
| Krych et al; AJSM 2012 | 43 pts. 30 mos. | 9-12 mos. | 79% | • Age > 25, pre-op symptoms > 1 yr negatively affected RTP  
• 75% Recreational, 23% Collegiate athletes |
### RTP after Cartilage Procedures (Continued)

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients F/U mos.</th>
<th>Time to RTP</th>
<th>RTP @ same or &gt; level</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mithofer et al; AJSM 2005, Soccer Players</td>
<td>45 pts. 50 mos.</td>
<td>12-24 mos., 14 mos. high level</td>
<td>80%</td>
<td>• Most successful in younger competitive athletes with less than 1 yr symptoms, of those RTP 87% maintained level &gt; 4 yrs</td>
</tr>
<tr>
<td>Mithofer et al; AJSM 2005, Young Athletes</td>
<td>20 pts. 48 mos.</td>
<td>12-18 mos., 15 mos. Ave.</td>
<td>96%</td>
<td>• All with &lt; 1 yr symptoms returned to pre-injury level but only 33% with &gt; 1 yr of symptoms • Ave size 6.4 cm², 60 % with open growth plates</td>
</tr>
<tr>
<td><strong>MACI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zak et al: AJSM, 2012, Matrix ACI</td>
<td>70 pts 60 mos.</td>
<td>12-18 mos.</td>
<td>74% RTP Pre-injury level</td>
<td>• Third generation ACI with mid-term results very consistent with 1⁰ ACI</td>
</tr>
</tbody>
</table>

### Return to Play

**Cartilage Procedures Meta-Analysis**

<table>
<thead>
<tr>
<th>STUDY</th>
<th># PTS</th>
<th>F/U</th>
<th>RTP or Full Duty</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Meta-Analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systematic Review, 20 studies, Mithofer et al, AJSM 2009</td>
<td>1363 pts.</td>
<td>&gt; 3 yrs</td>
<td>Varies by Technique</td>
<td>• Younger athletes, smaller defects, shorter pre-operative symptom duration, high skill level = HIGHEST RTP • <strong>Highest Rate RTP:</strong> OATS Autograft • <strong>Best Longevity:</strong> ACI • Worst rates of RTP after long duration of pre-op symptoms resulting from adverse environment for cartilage repair • Age threshold about 30 years old</td>
</tr>
</tbody>
</table>
Arthroscopic Debridement, Chondroplasty Return to Play

Return to Play after Chondroplasty of the Knee in National Football League Athletes. Scillia et al; AJSM 2015;43:663-8. Level 4 Case Series

- 54 knees (52 patients) underwent arthroscopic chondroplasty
- 67% return to regular season NFL game play @ avg. of 8.2 months
- With Concomitant Microfracture players **4.4x less likely to return to NFL** than those who did not undergo procedure

Arthroscopic Debridement, Chondroplasty Return to Play

- No significant correlation of RTP to age, lesion size, location, position played, draft round selection  
  * Age did not make difference
- Playing >11.6 games/season → 4.7x more likely RTP  
  *Better players more able to return
- Athletes who RTP compared with player of similar level prior to surgery
  - 56 fewer games
  - 3.3 fewer seasons
  - 3.2 fewer games/ season  
  *Decreased Duration of Career
Arthroscopic Microfracture
Return to Play

- 32 pts with single lesions; F/U 2 years after Microfracture (Steadman Technique)
- 44% able to regularly RTP in high impact, pivoting sport and 25% (8 pts) RTP at same level
- Return to sport significantly higher in patients:
  - < 40 years old
  - Defect size < 2cm²
  - Pre-op symptoms < 1 year
  - No Prior Surgery

Osteoarticular Autograft Transfers
Return to Play
A Prospective Randomized Clinical Study of Mosaic Osteochondral Autologous Transplantation Versus Microfracture for the Treatment of Osteochondral Defects in the Knee Joint in Young Athletes. Gudas R. et.al.: Arthroscopy 2005:21:1066. Level 1 RCT

- 60 athletes (24.3 yrs) with symptomatic cartilage lesions randomized to undergo OATs or MF. F/U 37 mos.; ICRS, Tegner, MRI.; same post-op rehab protocol
- 26 (93%) OAT patients and 15 (52%) MF patients returned to sports activities at the preinjury level at an average of 6.5 mos. (4-8 mos.)

- 60 athletes (24.3 yrs) with symptomatic cartilage lesions randomized to undergo OATs or MFx. F/U 10.4 yrs ICRS, Tegner, MR.
- OATs vs. MFx same post op rehab, NWB 4 wks, RTP 4-6 mos.
- Over 50% failure by 36 mos. in MFx group

Osteoarticular Autograft Transfers Return to Play


- OAT groups had 75% continued RTP at same level vs 37% in MFx group maintained @ 10 yrs (from prior evaluation at 3 yrs.)
- MRI and Radiographs showed 25% of OATS and 48% MFx groups had Mild DJD at 10 yrs.
Osteochondral Allograft Transfer
Return to Activity & Play

Return to an Athletic Lifestyle After Osteochondral Allograft Transplantation of the Knee. Shaha et al, AJSM 2013  Level 4 Case Series

• 38 pts with OATS Allograft; F/U 3.9 years, Active Duty Military Personnel, Ave. Size 4.89cm²
• 29% (11/38) able to return to full duty
• 5.3% returned to preinjury level
• 42% separated from service with medical discharge
• All showed graft healing, No revisions, No effect of concomitant procedures

Osteochondral Allograft Transfer
Return to Play

Return to an Athletic Activity after Osteochondral Allograft Transplantation in the Knee. Krych et al, AJSM 2012  Level 4 Case Series

• 43 athletes treated with OATS Allograft for chondral defects, Ave. Size 7.25cm², Ave F/U 2.5 years
• 75% Recreational, 23% Collegiate athletes
• 79% (34/43) able to return to preinjury level of sport
• Risk factors for not RTP:
  • > 25 years old
  • > 12 months duration of pre-op symptoms
Autologous Chondrocyte Implantation
Return to Play

Articular Cartilage Repair in Soccer Players with Autologous Chondrocyte Implantation. Mithöfer, Peterson Mandelbaum, Minas, AJSM 2005  Level 4 Case Series

• 45 soccer athletes treated with ACI for chondral defects, Ave. Size 5.7cm², Ave F/U 3.5 years, 35% multiple defects
• 96% of adolescents reported good or excellent results by Tegner and Lysholm scores
• 96% RTP at high impact sports, 60% to an athletic level equal or higher than pre-injury
• RTP correlated with shorter pre-op symptoms and a lower number of prior operations.
• All adolescents with symptoms ≤12 months RTP pre-injury level whereas only 33% with preoperative symptom longer than 12 months returned to play

Risk factors for not RTP:
• > 25 years old
• > 12 months duration of pre-op symptoms

Autologous Chondrocyte Implantation
Return to Play

Functional Outcome of Knee Articular Cartilage Repair in Adolescent Athletes. Mithöfer, Minas, Peterson, Yeon, Micheli; AJSM 2005  Level 4 Case Series

• 20 adolescent athletes treated with ACI for chondral defects, Ave. Size 5.7cm², Ave F/U 4.0 years
• 83% of high level players RTP and 16% recreational players RTP (33% of total players)
• 80 RTP at same or higher level and 87% maintained level of play for an ave. 4.4 years post-op
• Risk factors for not RTP:
  • > 25 years old
  • > 12 months duration of pre-op symptoms
RTP after Cartilage Repair 2015

**Summary**

- Cartilage lesions requiring treatment shorten high level athletic careers
- RTP most ideal with:
  - Younger Athletes
  - Higher skill level
  - Duration of Symptoms < 1 year
  - Smaller Lesions
- Faster RTP with Microfracture, OATS autograft but only for smaller lesions (<2 cm²)
- ACI has best durability and longest rehab

---

RTP after Cartilage Repair 2015

**Summary**

- Larger lesions better treated with ACI or OATS Allograft and still have RTP
- Longer-term Preoperative Symptoms: creates an adverse intra-articular environment for cartilage repair with diminished results
- Cartilage lesions requiring treatment shorten high level athletic careers
RTP after Cartilage Repair 2015

**Summary**

- Despite the often inadequate treatment options for the all too frequent cartilage injuries in athletes, RTP is still feasible in the majority of cases.
- Understand what the literature demonstrates (pros and cons) and don’t put square pegs in round holes (it only makes it worse). Manage Expectations.
- We need to continue to strive to do better for our patient athletes.

**Thank You!**
RTP after Cartilage Procedures: References