ACL Reconstruction: The MOON Group: What does Data Show?

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Disclosures Kurt P Spindler

1. **Current FUNDING**
   a. NIH R01 = MOON (K Spindler – PI)
   b. NIH R01 = MeTeOR study (J Katz - PI)
   c. NIH R01 = ACLR Healing (B Fleming- PI)
   d. NIH RO1 = ACL Healing (M Murray – PI)
   e. Unrestricted Educational Gifts
      • DonJoy
      • AOSSM = MARS
   f. Research Grant: Smith & Nephew Calaxo
   g. Research Grant: Arthritis Foundation

2. **Patent:** Intra-articular Healing Ligaments

3. **Consultant:** NFL, Service Excellence, Mitek

4. **Scientific Advisory Board:** Cytori
KP Spindler and RW Wright:
Anterior Cruciate Ligament (ACL)

Normal ACL  ACL Tear  Scope ACL Tear
Medial and Lateral Meniscus

- Normal meniscus
- Bucket handle MM
- Partial LM tear

Articular Cartilage

- Normal LFC
- Focal defect LFC
- Normal MFC
- Early GII Chondromalacia MFC

MOON ACLR Multicenter Cohort:

1. Patient-Reported Outcomes and Failure

2. Specialized Cohort: Initiation and Predictors of OA

1. 20+ Year Development & History MOON

2. NIH Initial 2 Year Follow-up ('06 - '10) & Competitive Renewal 6 Year F/U ('10 - '15)
   Competitive Supplement add 1241 ('13 - '15)
   Competitive Renewal 10 Year F/U ('15 - '20)

3. Why MULTICENTER?
   a. Sample size Outcomes events occur < 10% of time
   b. Timeliness obtain relevant results within years
   c. Generalizability to treatment of ACL tears
# Site Support Staff

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If you are looking for information on the Scientific Validity MOON Group and its studies on inter-rater agreement, systematic reviews, and agreement among surgeons, this is a comprehensive summary:

1. Inter-rater Agreement of Meniscus Tears and Treatment. Dunn, AJSM, 2004
2. Inter-rater Agreement of Articular Cartilage Classification. Marx, AJSM, 2005
4. Intra- & Inter-surgeon Agreement on ANATOMIC Femoral and Tibial Tunnels ACLR. McConkey AJSM 2012 & Wolf AJSM 2013

To establish the consistency of measurements and techniques across 7 sites, multiple validity studies have been performed.
Intra- and Inter-Surgeon Agreement
ACLR Tunnel Placement
McConkey AJSM 2012 & Wolf AJSM 2013

1. **Intra & Inter-surgeon variability**
   a. 12 surgeons - 6 knees: **CADAVER**
   b. Tunnels reproducible across technique and experience
   c. Statistical differences, but doubt clinically relevant

2. **Intra & Inter-surgeon variability**
   a. 8 Surgeons @ 4 sites: **PATIENTS**
   b. Small variations between and among surgeons
   c. Statistical difference, but doubt clinically relevant

Figure C.4.8 ACL Tunnel Aperture Overlap Maps for the patient dataset depicting the likelihood of ACL tunnel placement on a native tibia bone surface organized by surgeon. Eight surgeons are depicted.
## Entire MOON (PRO) Cohort F/U

<table>
<thead>
<tr>
<th>Enrollment Years</th>
<th>N</th>
<th>2 Years</th>
<th>6 Years</th>
<th>10 Years</th>
<th>PRO Forms</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002-2003</td>
<td>1080</td>
<td>85%</td>
<td>83%</td>
<td>82%</td>
<td>KOOS</td>
</tr>
<tr>
<td>2004-2005</td>
<td>1217</td>
<td>82%</td>
<td>82%</td>
<td>‘04 = 81%</td>
<td>IKDC</td>
</tr>
<tr>
<td>2007-2008</td>
<td>1250</td>
<td>81%</td>
<td>81%</td>
<td></td>
<td>Marx</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>3547</td>
<td>85%</td>
<td>82%</td>
<td>82%</td>
<td>SF-36</td>
</tr>
</tbody>
</table>

>90% f/u failure and additional surgery (via phone)
MOON NESTED Cohort 2 Yr f/u
(Standing MTP XR for JSN)

<table>
<thead>
<tr>
<th>Enrollment Years</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completed ONSITE</td>
<td>59</td>
<td>21</td>
<td>67</td>
<td>68</td>
<td>55</td>
<td>47</td>
<td>317</td>
</tr>
</tbody>
</table>

**Onsite:** MTP standing XR for joint space measurements
KT-1000 AP laxity & independent blinded PE
Patient-Reported Outcomes (KOOS, Marx, etc.)
Functional HOP testing
<table>
<thead>
<tr>
<th></th>
<th>Is <strong>Age</strong> a risk factor for ACLR failure?</th>
<th>Yes: increased failure of ACLR in younger individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Is <strong>Gender</strong> a risk factor for future activity after ACLR?</td>
<td>Yes: lower activity level (Marx) in females</td>
</tr>
<tr>
<td>3</td>
<td>Is <strong>Baseline Activity</strong> Level a risk factor for future activity after ACLR?</td>
<td>Yes: higher activity level in individuals with higher baseline activity level</td>
</tr>
<tr>
<td>4</td>
<td>Is <strong>BMI</strong> a risk factor for ACLR activity and patient-reported outcome (PRO)?</td>
<td>Yes: higher BMI predicts lower activity and worse outcomes</td>
</tr>
<tr>
<td>5</td>
<td>Is <strong>Smoking</strong> a risk factor for ACLR activity and PRO?</td>
<td>Yes: lower activity level and worse outcomes</td>
</tr>
<tr>
<td>6</td>
<td>Is <strong>Education</strong> a risk factor for ACLR outcome?</td>
<td>Yes: less education years worse outcome</td>
</tr>
</tbody>
</table>
## PATIENT RISK FACTORS ON ACLR OUTCOME: INJURY EXTENT

<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Is a Grade 1 or 2 MCL injury a risk factor for ACLR outcome?</td>
<td>No: Not a risk factor</td>
</tr>
<tr>
<td>2</td>
<td>Is a LCL injury a risk factor for ACLR outcome?</td>
<td>Yes: More symptoms in individuals with LCL injury</td>
</tr>
<tr>
<td>3</td>
<td>Is a Medial Meniscal repair a risk factor for ACLR outcome?</td>
<td>Yes: worse outcome with repairs</td>
</tr>
<tr>
<td>4</td>
<td>Is a Lateral Meniscal repair a risk factor for ACLR outcome?</td>
<td>No: lateral meniscal repair same as no lateral meniscal tear</td>
</tr>
<tr>
<td>5</td>
<td>Is an Articular Cartilage injury a risk factor for ACLR outcome?</td>
<td>Yes: worse outcomes with Grade III/Grade IV chondromalacia</td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>What is the risk of ACLR graft failure at 2 years?</td>
<td>Autograft: 1-6% Allograft: 2-20%</td>
<td></td>
</tr>
<tr>
<td>What is the best graft source (autograft or allograft)?</td>
<td>Lower failure AUTOGRAFT especially Younger (see Figure 1)</td>
<td></td>
</tr>
<tr>
<td>What is the reoperation rate for failure of meniscus repair during ACLR?</td>
<td>4-6%</td>
<td></td>
</tr>
</tbody>
</table>

2488 Primary ACLR >92% f/u @ 2 years
# RETURN TO SPORTS, ACTIVITY LEVELS, AND SPORT OUTCOME INSTRUMENTS (IKDC & KOOS)

<table>
<thead>
<tr>
<th></th>
<th>Will I be able to <strong>return to sports?</strong></th>
<th><strong>Unknown</strong> except FB &amp; Soccer</th>
</tr>
</thead>
</table>
| 2 | What are my chances to return to play American **Football?** | High School ~70%  
College ~70%  
50% cited fear as critical factor for not returning |
| 3 | What are my chances to return to play **Soccer?** | ~70%  
Males more likely to return than females to RTP |
<p>| 4 | What will my future <strong>activity level</strong> be after ACLR based on the Marx Activity Scale? | <strong>Decreased activity</strong> with a 4 point loss on the Marx activity scale at 2 years. |
| 5 | What will my future patient-reported outcome on the <strong>KOOS?</strong> | <strong>Improved</strong>, but not normal |
| 6 | What will my future patient-reported outcome be after ACLR based on the <strong>IKDC?</strong> | <strong>Improved</strong>, but not normal |</p>
<table>
<thead>
<tr>
<th></th>
<th><strong>What causes knee pain at time of surgery for ACLR?</strong></th>
<th><strong>KOOS Pain Subscale</strong></th>
<th><strong>KOOS ADL Subscale</strong></th>
<th><strong>KOOS QoL (Knee Related Quality of Life)</strong></th>
<th><strong>SF-36 PCS (physical function)</strong></th>
<th><strong>SF-36 MCS (mental function)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BMI, female gender, older age, and LCL injury</td>
<td>Improved outcomes with higher baseline scores, lower BMI, non-smoker, and untreated lateral meniscal tears.</td>
<td>Improved outcomes with lower education, medial meniscal repair, grade IV MFC, MTP, LTP, grade III LTP, MTP, revision ACLR</td>
<td>Improved outcomes with Higher baseline score, non-smoker, untreated LM tear</td>
<td>Improved outcomes with higher baseline score, lower BMI, younger age, excised or untreated LM tear</td>
<td>Improved outcomes with higher baseline score, higher baseline Marx</td>
</tr>
<tr>
<td>2</td>
<td>Bone bruise not associated with pain after ACLR</td>
<td>Poorer outcomes with lower education, medial meniscal repair, grade IV MFC, MTP, LTP, grade III LTP, MTP, revision ACLR</td>
<td>Poorer outcomes with lower education, contralateral ACLR, medial meniscal repair, no lateral meniscal tear, Grade III/IV trochlea, revision ACLR</td>
<td>Poorer outcomes with lower education, contralateral ACLR, MM repair, grade IV MFC, LFC or MTP, revision ACLR</td>
<td>Poorer outcomes with revision ACLR, lower education, smoker, grade III/IV LTP</td>
<td>Poorer outcomes with less education, smoker/quit</td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>2 years</td>
<td>6 years</td>
<td>Median time to event:</td>
<td>(See Figure 1 for Individual Risk)</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------------------------------------------</td>
<td>---------</td>
<td>---------</td>
<td>-----------------------</td>
<td>-------------------------------------</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>What is the risk of ipsilateral knee ligament reconstruction failure at 2 years?</td>
<td>4.9%</td>
<td>7.7%</td>
<td>17.1 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>What is the risk of an ACL tear in the normal contralateral knee at 2 years? 6 years?</td>
<td>2.5%</td>
<td>6.4%</td>
<td>27.3 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>What is my risk of infection after ACLR?</td>
<td>0.4%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>What is the risk of surgery for arthrofibrosis?</td>
<td>4.1%</td>
<td>5.4%</td>
<td>13.1 months (cyclops), 2.2 months (MUA), 18.2 months (synovectomy)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>What is my risk of meniscal repair failure?</td>
<td>4% re-operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>What is my risk of hardware removal?</td>
<td>0.6%</td>
<td>1.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. 1512 ACLR with 85% min 6 yr f/u with multivariable statistical modeling Marx Outcome

2. Marx activity (scale 0-16) $t_0=12$, $t_2=9$, $t_6=7$

3. Proven Predictors of MARX Athletic activity
   a. Age
   b. Gender
   c. BMI
   d. Smoking
   e. educational status
   f. revision ACLR
   g. time from surgery
   h. Grade 4 CM MFC
   i. Competition level
   j. specific sport
Marx Activity @ 2 & 6 Years

1. NOT significant predictors Marx!
   a. meniscus injury and treatment
   b. autograft choice
   c. Grade 1-4 CM at surgery except MFC
Cost-Effectiveness Analysis of Early Reconstruction versus Rehabilitation & Delayed Reconstruction for ACL Tears

Data Sources: KANON RCT & MOON

Markov Decision Modeling

Costs based 2012 US

SF-6D (component of SF-36)

RESULTS: Early ACLR results had both:
- increase 0.30 QALYs (Quality adjusted life years)
- lower cost $1797 (2012$) Threshold 17% failure

Societal Point of view – early ACLR is more cost effective and preferred strategy
Baseline Predictors of Health-Related Quality of Life After ACLR A Longitudinal Analysis of a Multicenter Cohort at Two and Six Years

*Dunn JBJS Am April 2015*

1. Data MOON 2002-2004 = 1512 ACLR
2. Follow-up = 93% with Multivariable Analysis
3. ACLR effect size 1.2 for PCS score SF-36
4. Mean utility gained at six years after ACL reconstruction was 5.3 quality-adjusted life years (QALYs)
5. Identified predictors Better and Worse PCS SF-36 which similar to KOOS & IKDC
Prospective Analysis of 2488 Primary ACLR From the MOON Cohort Risk Factors and Predictors of Subsequent ACL Injury in Either Knee After ACLR (Kaeding April AJSM 2015)

1. MOON AOSSM Presented 2014
2. 2488 Primary ACLR
3. 92.7 % f/u @ 2 years
4. AVOID failure by NOT using allografts high school and college!
5. RESULTS: *Age* and *activity* were predictors of increased risk of both ipsilateral and contralateral ACL tear

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**Ipsilateral ACLR Graft failure**

![Graph showing the relationship between age and probability of retained ACL graft](image)

- **BTB**
- **Hamstring**
- **Allograft**
Factors Associated with Infection Following Anterior Cruciate Ligament Reconstruction

Brophy JBJS Am March 2015

1. Data MOON 2002-2005 = 2198 ACLR
2. Follow-up > 85% with Multivariable analysis
3. Infection was defined as an ACLR required postoperative surgical irrigation and debridement.
4. Overall rate infection = 0.77%
5. Diabetes significant increased risk OR = 18.8
6. Autograft BTB significantly lower risk infection than Autograft HG or Allografts
Meniscus treatment and age associated with narrower radiographic joint space width 2 to 3 years after ACLR: data from the MOON onsite cohort (Jones, M Osteoarthritis and Cartilage 2015)

1. Measure joint space width min 2 yr after primary ACLR within MOON nested cohort
   Normal and untreated small stable tear not different

2. Medial meniscus repair significantly more narrowing than normal untreated; however, medial meniscus repair was significantly less narrowing than excision

3. Caveat: repair based primarily on tear type and vascularity thus surgeon cannot switch from excision to repair

N=261 ACLR @2.5 yrs

![Graph showing joint space narrowing (JSN) for different meniscus treatments: Normal Meniscus, Untreated Tear, Meniscus Repair, Meniscectomy. The graph illustrates that excision causes more narrowing than repair, which in turn causes more narrowing than untreated tears.]
Powerful Role **AGE** in JSW MOON ORBITS

Jones, M Osteoarthritis & Cartilage 2015
KOOS Pain as a Marker for Significant Knee Pain Two and Six Years after Primary ACLR: A MOON Prospective Longitudinal Cohort Study

Wasserstein Osteoarthritis & Cartilage 2015

1. Data MOON 2002-2005 = 1761 Primary ACLR
2. Follow-up @ 6 years > 86% with Multivariable analysis
3. Significant Knee PAIN present 9-39% ACLR 6yrs
4. Dominant risk factor is a Second Surgery either revision or simple scope
5. Demographics and articular cartilage and meniscus injury also influenced knee pain but to a lesser extent then second surgery
Can MOON Evaluate: ELITE Athlete or Why Revision ACLR Worse Outcomes

1. Elite athlete: NO!
   - inadequate sample size

2. Revision ACLR = NO!
   - Worst Predictor of Outcome!
   a. MARS was born to evaluate predictors (84 surgeons, 53 sites have enrolled 1200)
   b. Funded NIAMS PI: Rick Wright MD
   c. >80% 2 yr f/u in Fall 2013
   d. AOSSM Award paper submitted 11/1/13 results presented AOSSM 2014
MOON Publications


MOON Publications


37. Jones, M et.al Meniscus Treatment and Age-associated with narrower radiographic joint space width 2-3 years after ACLR: Data from the MOON onsite cohort Osteoarthritis and Cartilage OAC 2015

38. Brophy, RH et.al Diabetes and not using Bone-Tendon-Bone autograft increase the risk of Infection after ACLR JBJS Am 2015

39. Wasserstein, D et.al The KOOS Pain as a Marker for Significant Knee Pain Two and Six years after Primary ACLR: MOON prospective longitudinal cohort study OAC 2015
Outcome Concepts are NOT New!

1. Katzenstein 1908: long-term f/u
2. Codman 1925: “end result”
**Right Idea = Men Repair & 7 yr F/U**

1. **Katzenstein in 1908!**
   a. First successful meniscus repair 
      Berlin, Germany
   b. Reviewed long-term meniscus excision = varus and arthritis
   c. Advocated Knee Surgery
      • Preop Quad therapy
      • NO immobilization
   d. 7 cases @ 1-7 yr f/u

2. **Courtesy Hans Paessler**
   Germany March 2006

**Historical Note. Moritz Katzenstein: The Father of Meniscus Repair Surgery**

_Hans H. Paessler, Kurt Franke, and James Gladstone_
End Result or Outcomes Not NEW

E.A. Codman

- “Father” of shoulder surgery
- Published “The Shoulder” in 1934
- Proponent of outcome studies
- Performed first rotator cuff surgery
- Described partial rotator cuff tears in 1934
- Died a pauper with an unmarked grave

Courtesy Jed Kuhn

Cleveland Clinic Sports Health
Outcomes Legend in Our Time!

1. Dr. Sandy Kirkley
2. MPH Outcomes
3. Published 39 papers (8 RCTs)
4. Tragic death @ 41
5. Member & Mentor to MOON
6. Orthopaedic Surgeon
7. Outcomes Researcher
8. Mother
9. She was RIGHT – EBM and Outcomes will become basis of Orthopaedic Decision Making
Grant Funding and Gifts
Thank-You!

Cleveland Clinic Main Campus  
Sport Health Garfield Heights