Advances in Knee: Patellofemoral Instability, ACL Reconstruction and Meniscal Repair

Saturday, May 11, 2013

Pre-Course

www.isakos.com/2013congress
May 11, 2013

Dear Colleagues,

On behalf of the course chairs, we welcome you to Toronto and to the ISAKOS Pre-Course: Advances in Knee: Patellofemoral Instability, ACL Reconstruction and Meniscal Repair.

The Advances in Knee Pre-Course aims to improve the understanding and treatment of the knee through a unique combination of didactic sessions and live surgical demonstrations. Focusing on the diverse topics of Patellofemoral Instability, ACL Reconstruction and Meniscal Repair, this Pre-Course will encourage presentations with a high level of evidence, debates on controversial subjects, and increased audience participation. This course will include didactic presentations in the morning, and Surgical Demonstrations with Debates in the afternoon. Topics of presentation include Pediatric ACL, ACL Revision, Osteoarthritis, Total Knee Arthroplasty, Acute Dislocation, Recurrent Instability, and MPFL.

We have assembled an international faculty, including experts from around the world, presenting on their areas of expertise. We thank them in advance for their time and their presentations.

Thank you in advance for your participation, and we hope you find the ISAKOS Pre-Course: Advances in Knee: Patellofemoral Instability, ACL Reconstruction and Meniscal Repair to be a valuable educational experience.

Best Regards,

Allen Anderson, MD, USA
Willem van der Merwe, MBChB, FCS, SA Ortho, SOUTH AFRICA
David Parker, FRACS, AUSTRALIA
ISAKOS Congress 2013: Pre-Course
Advances in Knee: Patellofemoral Instability, ACL Reconstruction and Meniscal Repair
May 11, 2013 • Toronto, Canada

Pre-Course Chairs
Allen Anderson, MD, USA
Willem van der Merwe, MBChB, FCS, SA Ortho, SOUTH AFRICA
David Parker, MBBS, BMedSci, FRACS AUSTRALIA

Faculty
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Elizabeth Arendt, MD USA
Constance Chu, MD USA
Mark Clatworthy, FRACS NEW ZEALAND
Myles Coolican, FRACS AUSTRALIA
David Dejour, MD FRANCE
Christopher Dodd, FRCS UNITED KINGDOM
Lars Engebretsen, MD, PhD NORWAY
Pieter Erasmus, MB.Ch.B.M.Med SOUTH AFRICA
Julian Feller, FRACS AUSTRALIA
Peter Fowler, MD, FRCSC CANADA
Freddie Fu, MD USA
Christopher Harner, MD USA
Ryosuke Kuroda, MD JAPAN
Paul Marks, BA, MD, FRCSC CANADA
Philippe Neyret, MD FRANCE
Frank Noyes, MD USA
Elvire Servien, MD, PhD, Prof FRANCE
René Verdonk, MD, PhD BELGIUM
Stewart Walsh, FRACS NEW ZEALAND
Andy Williams, MB BS, FRCS, FRCS (Orth.) UNITED KINGDOM
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<thead>
<tr>
<th>Pre-Course Chairs</th>
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<tbody>
<tr>
<td>Anderson, Allen F.</td>
<td>3b - Depuy Mitek, Orthopediatrics; 8 - Associate Editor, American Journal of Sports Medicine and Online Journal of Sports Medicine; 9 – Chair, Knee Committe ISAKOS</td>
</tr>
<tr>
<td>Parker, David Anthony</td>
<td>2 - Smith &amp; Nephew, Arthrex</td>
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<td>Van Der Merwe, Willem Mare</td>
<td>2 – Phizer, Arthrex, Tornier; 3b – Arthrex, Tornier; 6 – Arthrex, Tornier; 7 – Arthrex, Tornier</td>
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<tr>
<td>Amis, Andrew A.</td>
<td>1 – Corin, SIW; 2 - Smith &amp; Nephew; 3c - Corin; 7 - Corin, Smith &amp; Nephew, Stryker, Mathys; 8 - Knee, Knee Surgery, Sports Traumatology &amp; Arthroscopy; Medical Engineering and Physics</td>
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<td>Arendt, Elizabeth A.</td>
<td>3b - Tornier; 7 - Several (list available on request)</td>
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<td>Clatworthy, Mark</td>
<td>2 - DePuy, Arthrex</td>
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<td>Coolican, Myles Raphael James</td>
<td>5 - Zimmer; 9 – Director, Sydney Orthopaedic Research Institute; Member, Orthopaedic Sports Medicine Committee of ISAKOS</td>
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<td>Dejour, David Henri</td>
<td>1 - Tornier, SBM</td>
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<td>Dodd, Christopher</td>
<td>1 - Biomet Inc.; 2 - Biomet Inc.; 3b - Biomet Inc.; 5 - Biomet, Stryker, DePuy; 7 - Oxford University Press</td>
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<td>Engebretsen, Lars</td>
<td>2 - Arthrex, Smith &amp; Nephew; 8 - BJSM, AJSM, KSSTA, JBJS (Am), SJMSS; 9 - ESSKA</td>
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<td>Fu, Freddie H.</td>
<td>1 - ArthroCare - fund deposited to Univ of Pittsburgh Account; 3a - Gordon Fu, Stryker employee (son); 8 – Editor, Operative Techniques in Orthopaedics</td>
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<td>Harner, Christopher D.</td>
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<td>Kuroda, Ryosuke</td>
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<td>Matthews, Hilary</td>
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<td>Warden, April</td>
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**CME Hours**
The ISAKOS Sports Rehabilitation Concurrent Course: Global Perspectives for the Physical Therapist and Athletic Trainer is planned and implemented in accordance with the essential areas and policies of the Accreditation Council for Continuing Medical Education (ACCME) through joint sponsorship.

**CME Accreditation**
This activity has been planned and implemented in accordance with the Essential Areas and policies of the Accreditation Council for Continuing Medical Education (ACCME) through joint sponsorship of the American Academy of Orthopaedic Surgeons (AAOS) and the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS).

The AAOS is accredited by the ACCME to sponsor continuing medical education for physicians.

The American Academy of Orthopaedic Surgeons designates this live activity for **AMA PRA Category 1 Credits™**. Physicians should only claim credit commensurate with the extent of their participation in the activity.

**Course Objectives**
Upon completion of this course, participants should be able to:
- Aim to improve the understanding and treatment of the knee
- Evaluate clinical cases and practice evidence-based, informed orthopedic care.
- Demonstrate the application of current techniques, procedures and research
- Identify and analyze current research data pertaining to the knee
Agenda
ISAKOS Congress 2013: Pre-Course
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PRE-COURSE AGENDA

8:00 - 8:02  Introduction  
  Chair: Allen Anderson, MD USA  
  David Parker, MBBS, BMedSci, FRACS, AUSTRALIA  
  Willem Van Der Merwe, MBChB, FCS, SA Ortho, SOUTH AFRICA

8:00 - 8:40  Session I: Pediatric ACL  
  Moderator: Willem Van Der Merwe, MBChB, FCS, SA Ortho, SOUTH AFRICA

  8:02 – 8:10  Conservative Management  
  Lars Engebretsen, MD, PhD NORWAY

  8:10 - 8:20  Physeal Sparing Reconstruction  
  Allen Anderson, MD USA

  8:20 - 8:30  Transphyseal Reconstruction  
  Stewart Walsh, FRACS NEW ZEALAND

  8:30 - 8:40  Discussion & Case Presentations  
  Allen Anderson, MD USA  
  Lars Engebretsen, MD, PhD NORWAY  
  Stewart Walsh, FRACS NEW ZEALAND

8:40 - 9:20  Session II: Revision ACL  
  Moderator: Willem Van Der Merwe, MBChB, FCS, SA Ortho, SOUTH AFRICA

  8:40 - 8:50  Can Failure of ACL Reconstruction be Prevented  
  Ryosuke Kuroda, MD JAPAN

  8:50 - 9:00  Indications and Techniques for Revision of ACL Reconstruction  
  Christopher Harner, MD USA

  9:00 - 9:10  Sports Specific ACL Reconstruction  
  Andy Williams, MB BS, FRCS, FRCS (Orth.) UNITED KINGDOM

  9:10 - 9:20  Discussion & Case Presentations  
  Christopher Harner, MD USA  
  Ryosuke Kuroda, MD JAPAN  
  Andy Williams, MB BS, FRCS, FRCS (Orth.) UNITED KINGDOM

9:20 - 10:00  Session III: ACL & Osteoarthritis  
  Moderators: Willem Van Der Merwe, MBChB, FCS, SA Ortho, SOUTH AFRICA  
  Paul Marks, BA, MD, FRCS, CANADA

  9:20 - 9:30  Osteoarthritis After ACL Injury & Reconstruction: Can We Prevent It?  
  Constance Chu, MD USA

  9:30 - 9:40  Treatment of ACL Pathologic Laxity, Malalignment and Unicompartmental Osteoarthritis  
  Mark Clatworthy, FRACS NEW ZEALAND

  9:40 - 9:50  ACL Reconstruction with Unicompartmental Knee Replacement  
  Christopher Dodd, FRCS UNITED KINGDOM

  9:50 - 10:00  Discussion & Case Presentations  
  Constance Chu, MD USA  
  Mark Clatworthy, FRACS NEW ZEALAND  
  Christopher Dodd, FRCS UNITED KINGDOM
### ISAKOS Congress 2013: Pre-Course
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<th>Time</th>
<th>Session</th>
<th>Description</th>
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<tr>
<td>10:00 - 10:15</td>
<td>Break</td>
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<tr>
<td>10:15 - 11:30</td>
<td><strong>Session IV: Patellofemoral Instability</strong></td>
<td><strong>Moderator:</strong> David Parker, MBBS, BMedSci, FRACS, AUSTRALIA</td>
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<td>10:15 - 10:22</td>
<td>Biomechanics of Patellofemoral Instability</td>
<td>Andrew Amis, PhD, DSc UNITED KINGDOM</td>
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<td>10:22 - 10:29</td>
<td>Imaging of the Patellofemoral Joint and Assessment of Instability</td>
<td>Myles Coolican, FRACS AUSTRALIA</td>
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<td>10:29 - 10:39</td>
<td>Management of Acute Dislocation</td>
<td>Elizabeth Arendt, MD USA</td>
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<td>10:49 - 10:56</td>
<td>Tibial Tubercle Osteotomy: Techniques Used in Instability</td>
<td>Elvire Servien, MD, PhD, Prof FRANCE</td>
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<td>10:56 - 11:03</td>
<td>MPFL Reconstruction: Indications &amp; Technique</td>
<td>Pieter Erasmus, MB.Ch.B.M.Med SOUTH AFRICA</td>
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<td>11:03 - 11:10</td>
<td>Trochleoplasty: Indications &amp; Technique</td>
<td>David Dejour, MD FRANCE</td>
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| 11:10 - 11:30 | Discussion & Case Presentations | Andrew Amis, PhD, DSc UNITED KINGDOM  
Elizabeth Arendt, MD USA  
Myles Coolican, FRACS AUSTRALIA  
David Dejour, MD FRANCE  
Pieter Erasmus, MB.Ch.B.M.Med SOUTH AFRICA  
Julian Feller, FRACS AUSTRALIA  
Elvire Servien, MD, PhD, Prof FRANCE |
| 11:30 - 12:10 | **Session V: Meniscus** | **Moderator:** Allen Anderson, MD USA |
| 11:30 - 11:40 | Current Concepts in Meniscal Repair | René Verdonk, MD, PhD BELGIUM |
| 11:40 - 11:50 | Meniscal Transplantation: The University of Pittsburgh Experience | Christopher Harner, MD USA |
| 11:50 - 12:00 | Meniscal Transplantation Combined with ACL Reconstruction | Frank Noyes, MD USA |
| 12:00 - 12:10 | Discussion & Case Presentations | Christopher Harner, MD USA  
Frank Noyes, MD USA  
René Verdonk, MD, PhD BELGIUM |
| 12:10 - 1:10 | Lunch | Lunch |
| 1:10 - 2:55 | **Session VI: Live Surgical Demonstrations: Patellofemoral Instability** | **Moderators:** David Parker, MBBS, BMedSci, FRACS, AUSTRALIA  
Peter Fowler, MD, FRCSC, CANADA |
1:10 - 1:40 MPFL Reconstruction
    Pieter Erasmus, MB.Ch.B.M.Med SOUTH AFRICA
1:40 - 1:55 Discussion & Case Presentations
    Andrew Amis, PhD, DSc UNITED KINGDOM
    Elizabeth Arendt, MD USA
    Myles Coolican, FRACS AUSTRALIA
    Pieter Erasmus, MB.Ch.B.M.Med SOUTH AFRICA
1:55 - 2:40 Tibial Tubercle Osteotomy for Patella Alta Combined with Trochleoplasty for Dysplasia
    David Dejour, MD FRANCE
2:40 - 2:55 Discussion & Case Presentations
    David Dejour, MD FRANCE
    Pieter Erasmus, MB.Ch.B.M.Med SOUTH AFRICA
    Julian Feller, FRACS AUSTRALIA
    Elvire Servien, MD, PhD, Prof FRANCE
2:55 - 3:05 Break
3:05 - 4:40 Session VII: Live Surgical Demonstrations: ACL
    Moderators: Willem Van Der Merwe, MBChB, FCS, SA Ortho, SOUTH AFRICA
    Paul Marks, BA, MD, FRCSC, CANADA
3:05 - 3:40 Double Bundle ACL Reconstruction
    Freddie Fu, MD USA
3:40 - 3:55 Discussion & Case Presentations
    Constance Chu, MD USA
    Lars Engebretsen, MD, PhD NORWAY
    Freddie Fu, MD USA
    Ryosuke Kuroda, MD JAPAN
    Stewart Walsh, FRACS NEW ZEALAND
3:55 - 4:25 Extraarticular Reconstruction
    Philippe Neyret, MD FRANCE
4:25 - 4:40 Discussion & Case Presentations
    Mark Clatworthy, FRACS NEW ZEALAND
    Christopher Dodd, FRCS UNITED KINGDOM
    Christopher Harner, MD USA
    Philippe Neyret, MD FRANCE
    Andy Williams, MB BS, FRCS, FRCS (Orth.) UNITED KINGDOM
4:40 - 5:30 Session VIII: Live Surgical Demonstrations: Meniscal Root Tear
    Moderators: Allen Anderson, MD USA
    René Verdonk, MD, PhD BELGIUM
4:40 - 5:20 Medial Meniscal Root Tear
    Christopher Harner, MD USA
5:20 - 5:30 Discussion & Case Presentations
    Christopher Harner, MD USA
    Philippe Neyret, MD FRANCE
    Frank Noyes, MD USA
    René Verdonk, MD, PhD BELGIUM
Session I

Pediatric ACL
The Current Evidence for Treatment of ACL Injuries in Children Is Low

A Systematic Review

Håvard Moksnes, PT, MSc, Lars Engebretsen, MD, PhD, and May Arna Risberg, PT, PhD

Investigation performed at the Norwegian Research Centre for Active Rehabilitation, Department of Sports Medicine, Norwegian School of Sport Sciences, Oslo, and the Orthopaedic Department, Oslo University Hospital, Oslo, Norway

Background: There is no consensus on the management of anterior cruciate ligament (ACL) injuries in skeletally immature children, and the methodological quality of published studies is questionable. The transphyseal reconstructions, physeal-sparing reconstructions, and nonoperative treatment algorithms that are advocated have little support in the literature. The purpose of this study was to systematically review the methodological quality of the literature on the management of ACL injuries in skeletally immature children.

Methods: We performed a literature search with use of PubMed to identify prospective or retrospective studies whose primary aim was to assess the outcome after operative or nonoperative treatment of ACL injuries in skeletally immature children. To be included in the analysis, a study had to have a mean duration of follow-up of at least two years and a minimum of ten children in the study had to be verified to be skeletally immature. The methodological quality of the included studies was evaluated with use of the Coleman Methodology Score.

Results: No randomized controlled trials, two prospective cohort studies, and twenty-nine retrospective studies met the inclusion criteria. The Coleman Methodology Score averaged 44.7 ± 9.2 out of 100 (range, 28 to 62). The methodological deficiencies were most evident with regard to the number of included children, the study design, and the description of rehabilitation protocols, outcome criteria, and outcome assessments.

Conclusions: Caution is necessary when interpreting the results of studies on the treatment of ACL injuries in skeletally immature children because of widespread methodological deficiencies. There is a need for appropriately sized prospective studies and detailed descriptions of rehabilitation programs.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

The increased focus on the health benefits of regular physical activities highlights the importance of youth participation in sports. However, there is a concern that participation in sports exposes children to musculoskeletal injuries that may negatively influence their long-term health. During the past two decades, there have been an increasing number of studies on anterior cruciate ligament (ACL) injuries in skeletally immature children. The main dilemma is whether surgical treatment can provide an adequate functional outcome without harming the physis or whether nonoperative treatment should instead be advocated until skeletal maturity is reached. Nonoperative management has been associated with an increased risk of secondary injuries and future disability. Two recent publications, a systematic review and a meta-analysis, have concluded that surgical treatment is safe and provides a good functional outcome. Although concerns have been raised regarding the quality of studies on this topic, the methodological quality of these studies has not been assessed.

In the present study, we review the literature on the treatment of ACL injuries in skeletally immature children with use of the Coleman Methodology Score, which has recently...
been used to evaluate the methodological quality of studies on a variety of other orthopaedic treatments.\textsuperscript{10-17}

Materials and Methods

To be eligible for inclusion, published studies had to be randomized controlled trials, prospective studies, or retrospective studies on operative or nonoperative treatment of an intrasubstance ACL injury in skeletally immature children. In addition, the study population had to have a minimum of ten children who were verified to be skeletally immature, and the mean duration of follow-up had to be at least two years. Studies had to be in English, German, or a Scandinavian language.

Search Strategy and Study Selection

Two systematic searches were performed with use of PubMed, and studies published between 1966 and May 2011 were included. The search strategies are shown in the Appendix. The first search (search #13 in the Appendix) aimed to identify studies on surgical treatment of ACL injury in skeletally immature children, and the second search (search #14 in the Appendix) aimed to identify studies on nonoperative and postoperative rehabilitation after ACL injury in this population. The abstracts of the identified studies were reviewed independently by two of the authors to assess eligibility. If an abstract did not provide sufficient information, the full text of the article was reviewed. Additionally, the reference lists of included studies were reviewed to identify additional studies that had not been found through the initial searches. Inclusion of the studies was determined by consensus between the two reviewers. The full text of the included articles was retrieved and assessed for methodological quality. Each included study was categorized, on the basis of the primary treatment described, as involving (1) transphyseal reconstruction, (2) physeal-sparing reconstruction, or (3) nonoperative treatment.

Study Quality Assessment

The Coleman Methodology Score\textsuperscript{12} was used to assess the methodological quality of the included studies. This instrument consists of two parts with seven and eleven criteria, respectively, and the total score can range from 0 to 100. Part A has a maximum possible score of 60, and part B has a maximum score of 40 (see Appendix). A high score indicates a study with few confounding factors or other biases. The criteria for the Coleman Methodology Score were developed on the basis of the CONSORT (Consolidated Standards of Reporting Trials) statement.\textsuperscript{12,18}

In the present study, some of the scoring criteria in part A were modified: (1) the study size (question 1) was altered from the number of tendons to the number of patients; (2) the mean duration of follow-up (question 2) was altered to the minimum duration of follow-up, and the corresponding time criteria were changed from more than twenty-four months to more than five years, from between twelve and twenty-four months to between two and five years, and from less than twelve months to less than two years; (3) the type of study (question 4) was modified to include case series, which were assigned a score of 0 (the same score as retrospective cohort studies); and (4) the description of rehabilitation (question 7) was modified to omit compliance with rehabilitation from the scoring criteria. No modifications were made to the criteria in part B. The studies were scored independently by the reviewers, and any scoring discrepancies were discussed until consensus was achieved.

Source of Funding

This study was funded by the authors’ institutions (the Norwegian School of Sport Sciences and Oslo University Hospital).

Results

A flow diagram of the study selection process is shown in Figure 1, which is based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) statement.\textsuperscript{11,13}
The systematic search on operative treatment identified 209 potentially eligible abstracts, and twenty-one of the studies were included. The search on rehabilitation identified twenty-two abstracts, and one of the studies was included. Nine additional studies were identified from manual searches of journals and the reference lists of the included studies and were also included.

Two of the thirty-one included studies were prospective cohort studies, and the remaining twenty-nine (94%) were retrospective studies; no randomized controlled trials were identified. The total number of participants in the included studies was 966, and the mean number of children per study was 31.2 (range, ten to ninety-four). The nineteen studies on transphyseal reconstruction had a mean of thirty-five children (range, ten to ninety-four), the eight studies on physeal-sparing reconstruction had a mean of twenty-nine children (range, twelve to fifty-seven), and the four studies on nonoperative treatment had a mean of seventeen children (range, twelve to twenty-six). The characteristics of all included studies are presented in the Appendix.

Methodological Quality
The results of the study quality assessments are presented in Table I. None of the studies fulfilled all of the criteria, and the mean Coleman Methodology Score (and standard deviation) was 44.7 ± 9.2. The lowest score was 28, and the highest was 62. The mean score was 23.3 ± 7.1 for part A and 21.4 ± 4.9 for part B. The mean scores for the individual sections are shown in Table II. The highest mean scores in part A were for “diagnostic certainty” (4.8 out of 5) and “description of treatment given” (4.3 out of 5), and the lowest score was for “type of study” (0.6 out of 5). The highest score in part B was for “description of

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<th>No. of Patients</th>
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<td>Steadman (2006)</td>
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<td>3.3 (2.2-5.0)</td>
<td>22.0</td>
</tr>
<tr>
<td>Bonnard (2011)</td>
<td>57</td>
<td>P</td>
<td>12.2 (6.8-14.5)</td>
<td>5.5 (2.0-14.0)</td>
<td>29.0</td>
</tr>
<tr>
<td>Woods (2004)</td>
<td>13</td>
<td>N</td>
<td>13.8 (11.0-16.0)</td>
<td>5.8 (1.8-24.5)</td>
<td>23.0</td>
</tr>
<tr>
<td>Couvoisier (2011)</td>
<td>38</td>
<td>T</td>
<td>14.0 (11.0-15.0)</td>
<td>3.0 (2.0-4.0)</td>
<td>26.0</td>
</tr>
<tr>
<td>Lipscomb (1986)</td>
<td>24</td>
<td>P</td>
<td>13.5 (10-15)</td>
<td>2.9 (2.0-5.0)</td>
<td>26.0</td>
</tr>
<tr>
<td>Aronowitz (2000)</td>
<td>21</td>
<td>T</td>
<td>13.4 (11-15)</td>
<td>2.1 (1.0-5.0)</td>
<td>29.0</td>
</tr>
<tr>
<td>Seon (2005)</td>
<td>11</td>
<td>T</td>
<td>14.7 (13.1-15.5)</td>
<td>6.5 (3.8-10.9)</td>
<td>22.0</td>
</tr>
<tr>
<td>Marx (2009)</td>
<td>55</td>
<td>T</td>
<td>13.4 (8.4-16.6)</td>
<td>3.2 (1.0-7.5)</td>
<td>27.0</td>
</tr>
<tr>
<td>Kopf (2010)</td>
<td>14</td>
<td>T</td>
<td>14.4 (11-16)</td>
<td>7.0 (1.9-11.1)</td>
<td>15.0</td>
</tr>
<tr>
<td>Anderson (2004)</td>
<td>12</td>
<td>P</td>
<td>13.3 (std. dev., 1.3)</td>
<td>4.1 (2.0-8.1)</td>
<td>22.0</td>
</tr>
<tr>
<td>Mizuta (1995)</td>
<td>18</td>
<td>N</td>
<td>12.8 (10-15)</td>
<td>4.3 (0.8-8.3)</td>
<td>17.0</td>
</tr>
<tr>
<td>Aichroth (2002)</td>
<td>45</td>
<td>T</td>
<td>13 (11-15)</td>
<td>4.1 (1.0-8.0)</td>
<td>30.0</td>
</tr>
<tr>
<td>McIntosh (2006)</td>
<td>16</td>
<td>T</td>
<td>13.6 (11-14)</td>
<td>3.4 (2.0-9.3)</td>
<td>15.0</td>
</tr>
<tr>
<td>Edwards (2001)</td>
<td>20</td>
<td>T</td>
<td>13.7 (11-15)</td>
<td>2.8 (1.4-7.4)</td>
<td>19.0</td>
</tr>
<tr>
<td>Gaulrapp (2006)</td>
<td>53</td>
<td>T</td>
<td>13.9 (9-16)</td>
<td>6.5 (3.0-11.0)</td>
<td>19.0</td>
</tr>
<tr>
<td>Streich (2010)</td>
<td>31</td>
<td>T</td>
<td>11 (9-12)</td>
<td>5.8 (3.4-7.1)</td>
<td>21.0</td>
</tr>
<tr>
<td>Henne (2009)</td>
<td>56</td>
<td>T</td>
<td>12.4 (5.0-16.8)</td>
<td>2.3 (1.0-6.8)</td>
<td>17.0</td>
</tr>
<tr>
<td>Gebhard (2006)</td>
<td>40</td>
<td>P</td>
<td>11.9 (7-14)</td>
<td>2.8 (1.1-17.0)</td>
<td>14.0</td>
</tr>
<tr>
<td>Micheli (1999)</td>
<td>17</td>
<td>P</td>
<td>11 (2-14)</td>
<td>5.5 (2.1-14.0)</td>
<td>22.0</td>
</tr>
<tr>
<td>McCarroll (1994)</td>
<td>60</td>
<td>T</td>
<td>13.7 (13-15)</td>
<td>4.2 (2.0-7.0)</td>
<td>17.0</td>
</tr>
<tr>
<td>Arbes (2007)</td>
<td>20</td>
<td>T</td>
<td>13.9 (9-15)</td>
<td>5.4 (0.5-10.5)</td>
<td>10.0</td>
</tr>
<tr>
<td>Graf (1992)</td>
<td>12</td>
<td>N</td>
<td>14.5 (11.7-16.3)</td>
<td>Minimum, 2.0</td>
<td>13.0</td>
</tr>
</tbody>
</table>

* T = transphyseal reconstruction, P = physeal-sparing reconstruction, and N = nonoperative treatment.
subject selection process” (12.8 out of 15). Table III compares the Coleman scores of the three different treatment algorithms. The study by Liddle et al. had the highest Coleman score. That study involved prospective follow-up of seventeen children who had undergone identical ACL reconstructions with a transphyseal technique and hamstring tendon grafts. The study also reported specifically on the postoperative rehabilitation program and secondary injuries, and it used adequate outcome measurements. The two studies by Kocher et al. and the recent study by Nikolaou et al. had the next-highest scores. The studies by Kocher were performed with identical designs and are good examples of how retrospective studies can have a sound methodological design. The 2005 study involving physeal-sparing reconstruction and the 2007 study involving transphyseal reconstruction had clear inclusion criteria, relatively large homogenous populations (forty-four and fifty-nine children, respectively), and a treatment algorithm based on physiological maturity and knee function.

### TABLE II Coleman Methodology Score, Mean Section Scores

<table>
<thead>
<tr>
<th>Section Score (Maximum)</th>
<th>Mean</th>
<th>Range</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part A (60)</td>
<td>23.3</td>
<td>10-37</td>
<td>7.1</td>
</tr>
<tr>
<td>1. Study size—number of patients (10)</td>
<td>3.5</td>
<td>0-10</td>
<td></td>
</tr>
<tr>
<td>2. Minimum follow-up (5)</td>
<td>1.3</td>
<td>0-2</td>
<td></td>
</tr>
<tr>
<td>3. Number of different treatment procedures included (10)</td>
<td>5.8</td>
<td>0-10</td>
<td></td>
</tr>
<tr>
<td>4. Type of study (15)</td>
<td>0.6</td>
<td>0-10</td>
<td></td>
</tr>
<tr>
<td>5. Diagnostic certainty (5)</td>
<td>4.8</td>
<td>0-5</td>
<td></td>
</tr>
<tr>
<td>6. Description of treatment given (5)</td>
<td>4.3</td>
<td>0-5</td>
<td></td>
</tr>
<tr>
<td>7. Description of preop. and postop. rehabilitation and/or conservative treatment (10)</td>
<td>2.9</td>
<td>0-10</td>
<td></td>
</tr>
<tr>
<td>Part B (40)</td>
<td>21.4</td>
<td>11-30.5</td>
<td>4.9</td>
</tr>
<tr>
<td>Outcome criteria (10)</td>
<td>4.7</td>
<td>0-10</td>
<td></td>
</tr>
<tr>
<td>8. Outcome measures clearly defined (2)</td>
<td>1.7</td>
<td>0-2</td>
<td></td>
</tr>
<tr>
<td>9. Timing of outcome assessment clearly stated (2)</td>
<td>0.2</td>
<td>0-2</td>
<td></td>
</tr>
<tr>
<td>10. Use of outcome criteria that has reported good reliability (3)</td>
<td>2.0</td>
<td>0-3</td>
<td></td>
</tr>
<tr>
<td>11. Use of outcome with good sensitivity (3)</td>
<td>0.9</td>
<td>0-3</td>
<td></td>
</tr>
<tr>
<td>Procedure for assessing outcomes (15)</td>
<td>3.9</td>
<td>0-15</td>
<td></td>
</tr>
<tr>
<td>12. Subjects recruited (5)</td>
<td>0.5</td>
<td>0-5</td>
<td></td>
</tr>
<tr>
<td>13. Investigator independent of surgeon/therapist (4)</td>
<td>0.3</td>
<td>0-4</td>
<td></td>
</tr>
<tr>
<td>14. Written assessment (3)</td>
<td>2.4</td>
<td>0-3</td>
<td></td>
</tr>
<tr>
<td>15. Completion of assessment by subjects themselves with minimal investigator assistance (3)</td>
<td>0.7</td>
<td>0-3</td>
<td></td>
</tr>
<tr>
<td>Description of subject selection process (15)</td>
<td>12.8</td>
<td>8-15</td>
<td></td>
</tr>
<tr>
<td>16. Selection criteria reported and unbiased (5)</td>
<td>4.8</td>
<td>0-5</td>
<td></td>
</tr>
<tr>
<td>17. Recruitment rate reported (≥80% = 5; &lt;80% = 3) (5)</td>
<td>4.5</td>
<td>3-5</td>
<td></td>
</tr>
<tr>
<td>18. Eligible subjects not included in the study satisfactorily accounted for (5)</td>
<td>3.4</td>
<td>0-5</td>
<td></td>
</tr>
<tr>
<td>Total score (100)</td>
<td>44.7</td>
<td>28-62</td>
<td>9.2</td>
</tr>
</tbody>
</table>

### TABLE III Coleman Methodology Score According to Treatment Algorithm *

<table>
<thead>
<tr>
<th>Section score (Maximum)</th>
<th>Transphyseal (N = 19)</th>
<th>Physeal Sparing (N = 8)</th>
<th>Rehabilitation (N = 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part A (60)</td>
<td>23.6 (10-37)</td>
<td>25.4 (14-34)</td>
<td>18.0 (13-23)</td>
</tr>
<tr>
<td>Part B (40)</td>
<td>21.0 (11-27.5)</td>
<td>21.1 (11-28.5)</td>
<td>23.8 (15-30.5)</td>
</tr>
<tr>
<td>Outcome criteria (10)</td>
<td>4.8 (0-7)</td>
<td>4.2 (0-8.5)</td>
<td>5.5 (0-10)</td>
</tr>
<tr>
<td>Procedure for assessing outcomes (15)</td>
<td>3.4 (0-11)</td>
<td>4.5 (0-12)</td>
<td>4.5 (0-15)</td>
</tr>
<tr>
<td>Description of subject selection process (15)</td>
<td>12.7 (8-15)</td>
<td>12.4 (8-15)</td>
<td>13.8 (10-15)</td>
</tr>
<tr>
<td>Total score (100)</td>
<td>44.6 (31-62)</td>
<td>46.4 (33-60)</td>
<td>41.8 (28-49.5)</td>
</tr>
</tbody>
</table>

*Values are given as the mean, with the range in parentheses.*
study by Nikolaou et al. involved ninety-four skeletally immature children who underwent transphyseal reconstruction with good results as assessed with use of functional questionnaires and return to sports. In these four highest-rated studies, 4.2% (nine) of the 214 grafts sustained a rerupture, and growth disturbance was reported in 0.5% (one) of the patients. Furthermore, 47% (101) of the patients had 104 concomitant meniscal injuries, 67% (seventy) of which were treated with surgical repair. The meniscal repair failed during the follow-up period in 14% (ten) of those patients. However, only 10% (three) of the thirty-one included studies included validated outcome measures, such as magnetic resonance imaging (MRI) or arthroscopy, for evaluating secondary meniscal tears or cartilage injuries.

**Treatment Algorithms and Rehabilitation**

Eleven of the nineteen studies on transphyseal reconstruction used hamstrings tendons, two used bone-patellar tendon-bone autograft, four used diverse techniques, one used bone-patellar tendon-bone allograft, and one used Achilles tendon allograft. The eight studies on physeal-sparing reconstruction involved different surgical methods. Three of the four studies on nonoperative treatment included a description of an unambiguous algorithm involving primary nonoperative treatment, with optional delayed surgical treatment, in all subjects. None of the studies on nonoperative treatment provided well-described rehabilitation protocols. Rehabilitation guidelines were adequately described in only 3% (one study) of the thirty-one included studies. Rehabilitation was inadequately described in 58% (eighteen) of the studies and not described in 96% (twelve). Two studies (6%) included functional preoperative outcome measurements, whereas the remaining twenty-nine studies (94%) did not include any data on baseline or pretreatment knee function.

**Discussion**

This systematic review illustrates that studies on the treatment of skeletally immature children with ACL injury have major deficiencies with regard to methodological quality. Thirty-one studies with a total of 966 children were included, but none were randomized controlled trials, two had a prospective study design, and the remaining twenty-nine had a retrospective design. The included studies had a mean Coleman Methodology Score (and standard deviation) of 44.7 ± 9.2 out of a maximum possible score of 100, which suggest that the knowledge base for the management of ACL injuries in skeletally immature children is weak. The present review showed that the published studies have major weaknesses in methodological quality, particularly with regard to study size, study design, and the description of rehabilitation protocols (in part A of the Coleman score) and with regard to the assessment of knee function with adequate measurement tools (in part B of the Coleman score).

The Coleman score evaluates the quality of studies with regard to study design (part A) and the assessment of outcomes, recruitment, and compliance (part B). The included studies had a mean score 23.3 ± 7.1 out of 60 on part A and 21.4 ± 4.9 out of 40 on part B, suggesting that the main deficiencies regarding methodological quality in the literature on the management of ACL injuries in the skeletally immature population involved study design (part A).

Coleman et al. reported a mean Coleman score of 37.3 ± 15.9 for studies on the outcome of surgical treatment of patellar tendinopathy, and Watsend et al. reported a mean score of 52.1 ± 14.0 for studies on posterior cruciate ligament tears. Note that the “operation-specific” nature of Coleman scores for different procedures means that this score should not be used to compare the methodological quality of studies of different medical conditions, and that was not a goal of the present study. To our knowledge, the highest Coleman scores reported are from studies on different techniques of microfracture cartilage repair and collagen meniscus implantation, with mean scores of 58.2 ± 3.6 and 67.1 ± 18.6, respectively. In 2005, Jakobsen et al. evaluated the quality of studies on cartilage repair and found a mean Coleman score of 43.5 ± 12.5, with scores of 35.7 ± 9.3 for part A and 7.8 ± 4.7 for part B. Øiestad et al. reported a mean modified Coleman score of 52.2 ± 13 out of 90 for studies involving long-term follow-up of adults with ACL injuries; the mean score was 31.1 ± 9.6 out of 50 for part A and 21.1 ± 6.9 out of 40 for part B. Comparison of the mean Coleman score for the studies in the present review with the scores in the previous studies shows the methodological quality of the studies on treatment of ACL injuries in skeletally immature children to be among the lowest reported. The main difference between the present systematic review and the other reviews is in part A, suggesting that greater attention in future research should be focused on designing adequately sized prospective studies.

Methodological deficiencies in the included studies were found in five criteria in particular: “study size,” “type of study,” “description of rehabilitation protocols,” “outcome criteria,” and “procedure for assessing outcomes.” The main limitation involving study size and study type was the lack of randomized controlled trials and prospective studies. Thus, there is a need to perform high-quality prospective observational studies on this patient population that describe treatment algorithms, interventions, and outcomes in detail. Manchikanti et al. emphasized that the results of observational studies are particularly valuable for investigating questions regarding etiology, prognosis, and estimates of potential risks. Furthermore, prospective long-term observational studies are suitable for detecting rare or late adverse effects of interventions, and they are more likely to provide an indication of what is accomplished in daily health care practice. Therapeutically, randomized controlled trials should be performed to compare the effects of different interventions. We recognize that there are practical and ethical limitations because of the low number of pediatric ACL injuries, but well-planned multicenter studies with uniform inclusion criteria and outcome measures should be performed.

The rehabilitation programs, including exercises and progression milestones, were also not well described in the majority of the included studies. Postoperative restrictions involving weight-bearing and knee motion were provided in some studies, but rehabilitation protocols describing exercise selection, dose, progression, and criteria for return to sports on the basis of functional performance were not.
The primary purpose of the published studies was to describe and evaluate surgical techniques. The majority of the studies had adequate descriptions of the surgical techniques, as reflected by the mean score of 4.3 out of 5 for the Coleman criterion “description of treatment given.” Although the focus was on the surgical technique, the Coleman score highlights the importance of describing rehabilitation programs because of the known impact of rehabilitation on the functional outcome after orthopaedic surgical treatments. In future studies, there should be an increased focus on describing and assessing compliance with the rehabilitation programs to enhance the strength and clinical relevance of the results.

The major deficiencies involving outcome criteria were the absence of predefined and homogeneous timing of follow-up assessments and the lack of validated outcome measures with good sensitivity. All of the studies except the two with a prospective design had large variations in the time between inclusion or surgical treatment and the follow-up assessment, which significantly reduces the generalizability of the reported results. Additionally, 90% (twenty-eight) of the thirty-one included studies did not document adequate outcome measures for assessing secondary meniscal tears or cartilage injuries at the time of follow-up. Because arthroscopy or MRI was not included in the follow-up examinations, only secondary injuries that were treated during the follow-up period were documented in those studies. Thus, the number of secondary injuries may be underestimated in the published studies on surgical as well as non-operative treatment and should be interpreted with caution.

Outcome measures with good sensitivity are also needed for young children with ACL injuries; although there is a need for reliable and validated self-reported questionnaires, none of the questionnaires that are frequently used have been validated in this population. There have been conflicting reports on how the International Knee Documentation Committee (IKDC) subjective knee evaluation form (2000 version) is understood by children. Good reliability, validity, and responsiveness have recently been reported for the newly developed Pedi-IKDC. Most of the studies in the present review used functional questionnaires, but few studies included performance-based outcome measures. Furthermore, the majority of studies included radiographs as an outcome measure, although only sixteen (52%) received points for having sufficient radiographic evaluations including standing longitudinal radiographs (question 11), which are a requirement for examining lower limb alignment and growth disturbances. MRI has been suggested to be a good radiation-free method to determine skeletal maturity in the future, although further validation of this measure is needed.

Single-leg hop tests are reliable outcome measures for healthy adults and adults who have undergone ACL reconstruction. Single-leg hop tests are recommended in combination with isokinetic strength measurements for functional evaluation of knee stability and ability to return to sports. Additionally, isokinetic strength measurements have been documented to be reproducible and reliable in children six to fifteen years of age, and they are the preferred outcome measure for evaluation of quadriceps and hamstring muscle strength. Three (10%) of the thirty-one included studies used performance-based functional outcome measures to evaluate knee function at the time of final follow-up.

In the outcome assessment portion of the Coleman score, only three (10%) of the thirty-one studies received points for reporting consecutive recruitment of patients (question 12); in the other twenty-eight studies, medical records or surgeon files had been searched to identify skeletally immature children with ACL injuries. Additionally, only two (6%) of the studies included received points for using investigators who were independent of the surgeon or therapist (question 13). Furthermore, only seven (23%) of the studies included a clear statement that completion of the written assessments were performed by the patients themselves with minimal investigator assistance (question 15). Ultimately, reporting following the guidelines in the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement is essential to enable other researchers and clinicians to compare results.

We recognize that the present review has limitations. The electronic search was performed with use of only one database; however, because of the small number of published studies and the few research centers publishing on the topic, we are confident that all relevant studies have been included. An important caution should be noted: although the methodological quality of the published studies was low, that does not mean that the quality of the treatments given in the studies was equally low. The purpose of this paper was not to assess the effect of the treatments applied. Because of the low methodological quality, clinicians and researchers should practice caution when deciding on the treatment recommendations to be given to skeletally immature children who have sustained an ACL injury. There are no studies with solid scientific evidence that can justify advising one treatment algorithm over others. The child and parents should be individually assessed and informed on the basis of a clinical examination, imaging, performance-based functional testing, and an initial rehabilitation program before conclusive advice on treatment of an ACL injury in a skeletally immature patient is provided.

In conclusion, this systematic review demonstrated that the methodological quality of the current literature on treatment of skeletally immature children with ACL injuries was generally low, as measured with use of the Coleman Methodology Score. The four studies with the highest scores reported good functional results with a low rate of growth disturbance. More attention should be paid to methodological quality when designing, performing, and reporting studies on treatment of skeletally immature children with ACL injuries. Particular attention should be given to the design of prospective studies, the inclusion of homogeneous populations, detailed reporting of rehabilitation protocols, and the use of adequate outcome measures.

Appendix

Tables summarizing the Coleman Methodology Score, the included studies, and the number of studies identified...
References


PHYSEAL SPARING ACL RECONSTRUCTION OF THE PEDIATRIC KNEE

Allen F. Anderson, M.D.
Nashville, Tennessee

I. Introduction
- ACL tears in children have been reported with increasing frequency \(^1\text{--}^\text{10}\)
- When a child or adolescent presents with a torn ACL, the physician is faced with a dilemma
- A non-operative approach may result in meniscal and articular cartilage damage \(^1\text{,}^4\text{--}^6\) and surgery may cause iatrogenic growth disturbance \(^3\text{,}^4\text{,}^7\text{--}^9\)
- The treating physician must understand normal growth and development, the natural history of ACL tears, the risk factors for iatrogenic growth disturbance and the treatment options.

II. Normal growth and development
- The consequences of iatrogenic growth disturbance are greater in younger children. Consequently, the choice of treatment is influenced by maturity.
- The physician must know the chronologic age, skeletal age, and physiologic age.
- For large populations, chronologic age is an excellent predictor of skeletal maturity; however, patients may show a significant variance from the average.
- Skeletal age may be predicted by radiographs\(^11\) and physiologic age by Tanner staging of skeletal maturation\(^12\).

- Tanner staging

<table>
<thead>
<tr>
<th>Stage</th>
<th>MALE</th>
<th>FEMALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I I.</td>
<td>Stage I prepubescent</td>
<td>No pubic hair</td>
</tr>
<tr>
<td>Stage II</td>
<td>Minimal pubic hair</td>
<td>Breast buds</td>
</tr>
<tr>
<td>Stage III</td>
<td>Pubic hair over penis</td>
<td>Enlargement of breast</td>
</tr>
<tr>
<td></td>
<td>Voice changes</td>
<td></td>
</tr>
<tr>
<td>Stage IV</td>
<td>Adult pubic hair</td>
<td>Areola enlargement</td>
</tr>
<tr>
<td></td>
<td>Axillary hair</td>
<td></td>
</tr>
<tr>
<td>Stage V post pubescent</td>
<td>As adult</td>
<td>As adult</td>
</tr>
</tbody>
</table>

- The distal femur and proximal tibial physes are the most rapidly growing
- The peak height velocity for males is 13 to 15 years of age (average 13.5 years), and it rarely occurs before Tanner stage IV. For females, the peak height velocity occurs in Tanner stage III between 11 and 13 years of age (average 11.5 years). The peak height velocity for females precedes menarche by approximately one year.
• Pritchett\textsuperscript{13} reported that the distal femur grows at 1.3 cm per year, until the last two years of growth, when the growth rate drops to .65 cm per year. The rates of proximal tibial growth are .9 cm per year and in the last two years, .5 cm per year.

• The greatest concern for iatrogenic growth disturbance is not leg length discrepancy, but angular deformity. An over-the-top femoral groove may result in a valgus/flexion deformity of the distal femur. Damage to the anterior tibial physis may result in recurvatum. In a worse case scenario, Wester, et al,\textsuperscript{14} estimated that a 14-year-old boy with 2 cm of remaining distal femoral growth could develop a 14 degree valgus deformity with a lateral femoral epiphysiodesis, or an 11 degree recurvatum with a partial tibial arrest.

III. Natural History
• The natural history of ACL tears in children and adolescents is generally poor. Patients often experience recurrent instability, meniscal damage and sports-related disability.\textsuperscript{2,5,6,10,15, 26, 27}

IV. Risk Factors for Iatrogenic Growth Disturbance
• There is a significant deficiency in the age-specific basic science on physeal injuries.
• Transphyseal drill holes –
  - Destruction of 7\% of the cross sectional area of the physis causes growth disturbance\textsuperscript{16}
• Soft tissue through transphyseal drill holes –
  - Guzzanti, et al\textsuperscript{17} found that 2 of 21 tibias in an animal model developed a Valgus deformity and one was shorter
  - They recommended evaluation of the % of damage to the physis
  - Houle, et al\textsuperscript{18} found 8 of 11 growth arrests in an animal model. Larger drill holes caused greater deformity. Soft tissue grafts across the physis offered no protection. Drill holes should not involve more than 1% of the physeal area
  - Babb, et al\textsuperscript{19} found that use of a tendon autograft did not prevent a bony bar.
    - Mensenchymal stem cells, however, prevented growth arrest
      - Stadelmaier, et al\textsuperscript{20}
      - Fascia lata autograft prevents physeal arrest
      - Janarv, et al\textsuperscript{21}
        - Destruction of 7-9\% of the physis caused growth disturbance - No growth disturbance in injuries of 4-5\% of the physeal area
        - Soft tissue across the physis prevents a bony bar formation
        - Yoo, et al
          - 5/43 (11.6\%) of adolescents had a focal bone bridge after transphyseal reconstruction. The authors thought that transphyseal reconstruction was not a benign procedure that could be applied safely to younger children with substantial growth remaining.
• Graft tension
  - Edwards, et al\textsuperscript{22} tensioned grafts at 80N in an animal model and found growth disturbance
- The physes are sensitive to compression (Hueter-Volkman principle)
- Chudik, et al\textsuperscript{23} performed ACL reconstructions using Transepiphyseal, transphyseal, and over the top femoral holes. They found that the Transepiphyseal technique was more anatomic and caused less growth disturbance.

\begin{itemize}
  \item **Conclusions**
  \begin{itemize}
    \item Drill hole size is important
      \begin{itemize}
        \item 3-4\% or less of the cross sectional area
        \item Drill perpendicular and central rather than peripheral
      \end{itemize}
    \item Soft tissue grafts across the physis offer protection, although the results of animal studies are mixed
    \item The physes are sensitive to compressive forces. Therefore, do not over tension the graft
    \item The tibial physis is probably more vulnerable than the femoral physis.
  \end{itemize}
\end{itemize}

V. **Treatment Options**

- Non-operative. Despite poor results, many surgeons still advocate a non-operative approach to avoid iatrogenic bone growth disturbance.
- Extraarticular procedures. Others have recommended a primary repair or extraarticular procedures. Unfortunately, the results of these procedures have been no more successful in children than adults.
- Modified physeal sparing procedures
  - Parker, et al\textsuperscript{24} used hamstrings through the tibial groove and over the top.
  - Kocher, et al\textsuperscript{7} used an iliotibial band over the top and through the knee. If the over the top position is used, avoid rasping, which may damage the perichondral ring of LaCroix.

Anatomic ACL reconstruction is the standard of care now. Why should children be treated differently?

- Transepiphyseal Reconstruction
  - Anderson\textsuperscript{25} in a preliminary study demonstrated the efficacy of this intraarticular procedure using quadruple hamstring tendons.

- Transphyseal Reconstruction
  - Anatomic transphyseal reconstruction remains controversial because basic science studies have not determined safe drill hole size or graft tension and clinical studies have primarily involved post-menarchal adolescent female and post pubescent adolescent male patients. The potential for leg length discrepancy and angular deformity is relatively low in these cohorts.

VI. **Treatment Recommendations**

- There is a great disparity in the literature on treatment of ACL tears in the pediatric age group. Consequently, it is difficult to determine the current “best treatment”. The surgical literature is the most important factor in determining the best treatment. Unfortunately, the literature is often contradictory, leading to different treatment recommendations. Surgeons may find support for almost any
method of treatment in the literature. This may lead to a cavalier attitude that
everything works. Variation in treatment is not a problem if the outcomes of the
different treatments are the same, but if the outcomes differ, variation in treatment
may adversely affect patient care.

• Reliance on small case series in orthopaedic literature on ACL reconstruction in
the pediatric population has led to many unresolved questions. With this in mind,
the AOSSM has sponsored a multicenter research study named Pediatric ACL:
Understanding Treatment Options (PLUTO). This will be a prospective cohort
study with 10-15 centers. The inclusion criteria are patients in Tanner stages I, II
and III of sexual maturity and exclusion criteria for patients in Tanner stages IV
and V.

• The treatment arms will be nonoperative, including physical therapy, bracing, and
activity restrictions, physeal sparing reconstructions or transphyseal
reconstructions. The follow-up will include evaluation for growth disturbance,
function with the pediatric IDKC form, quality of life, activity level and skeletal
maturity. The increased scientific rigor provided by this multicenter research will
clarify the contradictions in the literature and help us determine the current best
treatment for pediatric ACL patients. Until we have this kind of information, our
recommendation is to treat patients based on their physiologic age.

• High risk prepubescent patients
  - High risk prepubescent patients in Tanner stages I or II or development,
    including males less than 12 and females less than 11, may be treated with a
    transepiphyseal ACL replacement or the modified physeal sparing procedure
    of Micheli and Kocher.7

• Intermediate risk
  - Intermediate risk pubescent patients in early Tanner stage III may also be
treated with transepiphyseal replacement or a modified physeal sparing
procedure.

• Low risk
  - More mature lower risk later Tanner stage III or stage IV patients may be
treated with a transphyseal replacement using quadruple hamstring grafts
using endobutton femoral fixation and screw and post-tibial fixation. Post
pubescent Tanner stage V patients may be treated as adults.

VII. Surgical Procedures

• Physeal sparing ACL reconstruction with the iliotibial band
  - Kocher et al7 reported the results of a physeal sparing, combined
    intraarticular and extraarticular reconstruction technique in prepubescent,
skeletally immature children (Fig. 1)
Forty-four patients in Tanner stages I or II (mean chronologic age 10.2 years) were evaluated at a mean of 5.3 years after surgery. There were two failures. The mean IKDC score was 96.7. The Lachman test was normal in 23, nearly normal in 18, and abnormal in 1. The pivot shift test was normal in 31 and nearly normal in 11. Four patients had repeat meniscal surgery. The mean growth in height from the time of surgery to follow-up was 21.5 cm. There were no growth disturbances. Although this is not an isometric ACL replacement, the functional results are very good.

- Transepiphyseal ACL Reconstruction
  - We described a method of transepiphyseal replacement. Initially there were 12 patients, mean age of 12 years, 3 were Tanner stage I, 4 Tanner stage II, and 5 were Tanner stage III. Associated procedures included repair of the lateral meniscus in 6 patients and medial meniscus in 2 patients. One patient had repair of all lateral structures and another had partial lateral meniscectomy for a very small radial tear.

C-arm visualization is used to insert guide wires in the femur and tibia (Fig. 2). An endobutton continuous loop is placed over the tendons and the tendons are pulled up through the tendon and out the femur. The graft is secured proximally with an endobutton washer and distally with a screw and post (Fig. 3).
Results

- The followup averaged 4.1 years. The mean growth from the time of the surgery to follow was 16.5 cm. The IKDC score was 96.5 out of a possible 100. The mean side to side difference was 1.5 mm with only one patient over 2.5 cm. There was no loss of extension. Five patients lost an average of 5.8 degrees of flexion, but none greater than 8 degrees. Ortho radiographs revealed no growth disturbance. The IKDC objective examination score was 7 normal, 5 nearly normal. There was one superficial infection, no DVT’s, nerve injuries, or other perioperative complications. Subsequently, we performed 55 additional cases (67 total). There have been three graft failures, one at 8 weeks, one at 9 months and another at 4 years. Two Endobutton loops broke and the washer and Endobutton had to be removed.

Transphyseal ACL Reconstruction

- Transphyseal ACL Reconstruction may be performed in lower risk Tanner stage IV patients. The efficacy of the procedure has been documented in the literature (Fig. 4).

Conclusions

- For behavioral, or other reasons, the natural history of ACL tears in children is poor. A nonoperative approach often results in recurrent instability, meniscal damage and degenerative changes. The risks of nonoperative treatment are greater than the risks of surgery. Consequently, in our opinion, the standard of care should now be surgical reconstruction in this age group. Significant leg length discrepancy or angular deformity, although rare, has been reported following ACL replacement in the skeletally immature knee. Additional research is needed to determine the drill hole size and graft tension that are safe for ACL reconstructions. The consequences of iatrogenic growth disturbances are greater.
in young children. Anatomic intraarticular ACL replacements are biomechanically superior to extraarticular and modified sparing procedures. The increased scientific rigor provided by multicenter research will clarify the contradictions in the literature and ultimately, help to determine the current “best treatment” for these patients. Until then, high risk prepubescent Tanner I, and II, and intermediate risk early pubescent Tanner stage III patients may be treated with efficacy and relative safety using a transepiphyseal ACL replacement or a modified physeal sparing procedure. Low risk pubescent Tanner stage IV patients, nearing skeletal maturity, may be treated safely with transphyseal reconstructions with small, centrally placed, perpendicular drill holes and quadruple hamstring grafts. Post pubescent Tanner stage V patients may be treated as adults.
BIBLIOGRAPHY


In New Zealand, over the past 20 years, there has been a ten-fold increase in adolescents and children presenting with injuries to the anterior cruciate ligament. This is partly due to better awareness of these injuries and improved clinical assessment. The advent of MRI scanning has also improved our ability to make this diagnosis. There is also an increased number of young athletes partaking in high risk sports with more pressure for them to perform at a high level. The sport with the highest incidence of adolescent ACL injury is motocross when we look at the number of athletes actually competing in this sport. When faced with the adolescent or a child athlete with a ruptured anterior cruciate ligament:

**My management goals are to:**

- Prevent further meniscal and chondral damage from recurrent instability
- Minimize risk of growth disturbance
- Allow functional activities

These goals can be achieved through non-operative or operative measures depending on a number of clinical factors. The first phase of management involves what I call assessment and education. This assessment involves an MRI scan, looking particularly for the presence of meniscal tears and osteochondral injuries. In the child and younger adolescent, I obtain a bone age and take a careful history of the child’s functional demands. If the patients’ menisci are intact, I will attempt to make a contract with the patient and their family that if they come out of their high risk activities and work on a non-operative program, then I will reconstruct their knee closer to skeletal maturity. In boys I try to delay until a bone age of 13 (girls bone age 11).

**Indications for Surgery**

1. Anterior cruciate ligament rupture in the presence of an MRI proven meniscus tear.
2. The patient who continues to experience significant instability symptoms after an appropriate non-operative protocol.
3. A patient who has successfully followed a non-operative protocol and has reached a bone age of 13 in boys or 11 in girls and wishes to return to high risk sports.

In choosing my surgical technique, my aim is to produce the most biomechanically sound reconstruction, remembering the primary management goal is to prevent further meniscal and chondral damage. I believe the reconstruction I perform has to be equal or better to that I would perform in an elite adult athlete. Compromising knee stability, by changing my “A” game to a compromised procedure does not seem logical.

**How safe is it to drill transphyseal?**

We are all aware of animal studies using surface area and 3-D modelling of a physis that suggest small drill holes through physis do not necessarily lead to growth arrest. The placing of soft tissue across the drilled tunnel is likely to decrease the risk of physeal bar formation but in spite of this, growth disturbance and physeal bars can occur. Our technique
can positively or negatively affect the risk of physeal bar formation. Putting screws or bone blocks across a physis is exactly what we do in paediatric orthopaedics when we want to perform an epiphysiodysis. For this reason I use a 4-string hamstring graft fixed proximally with an endotape and endobutton taking care to make sure graft is across the femoral physis not endotape. On the tibial side, I fix the graft with low profile staples away from the physis and apophysis in a fold back method. In harvesting my hamstring graft, I take care to divide the tendons at their insertion and not strip back periosteum which could lead to overgrowth or arrest of the tibial apophysis.

I alter my postoperative management in that from the end of week 1 through to week 8, I have the patient in a range of motion brace 0-90° in which they may fully weight bear. I do not do this in my adult population and believe the brace is primarily a reminder to the young person and their friends that they have had an operation. A crucial part of postoperative management of the adolescent is the long term follow-up. I clinically assess leg alignment and xray the knee at 6, 12 and 18 months postoperatively. If there is any suggestion of malalignment, clinical shortening or physeal irregularity, then I will obtain long leg standing views and/or a scanogram. If we do not look for a problem we will not find it.

With the tibial tunnel being reasonably central in the tibial physis, the main complication of physeal damage would be shortening. With this physis growing at 6mm a year this would only become a clinically relevant problem in a very young patient. The more serious potential for growth disturbance is on the femoral tunnel side with this tunnel being posterior and lateral. This has a potential to lead to a valgus deformity or less commonly a flexion deformity of the distal femur which could be confused as a progressive flexion deformity of the knee. If these problems occur and are picked up early, then simple guided growth techniques which are minimally invasive can be used to correct the deformity, as will be illustrated in my presentation. The reason I look at a bone age of 13 in boys as being a reasonable time to proceed with ligament reconstruction is that if I did create a growth disturbance, this would normally become clinically evident by 12-18 months and there would still be sufficient growth remaining for guided growth techniques to be effective.

In a consecutive series of 103 patients with 105 knees operated on for anterior cruciate ligament rupture at or younger than 16 years of age, we found 79% of patients had a meniscal tear at the time of surgery. The longer the interval between injury and surgery, the more common medial meniscal tears became. These findings are very similar to other reported series and this certainly influences our approach to managing these patients. We were able to repair 94 menisci with only 13% requiring further treatment for failure to heal or re-tear.

Historically, there has been anxiety around the risk of causing growth disturbance, which has possibly led to non-operative treatment, which in some patients will have led on to further meniscal and chondral damage through instability episodes. At present we have no reliable options for young patients with meniscal and chondral loss in their knees. We do, however, have reliable methods of treating growth disturbance. I believe the fear of growth disturbance should not be a contraindication to knee preservation surgery.

It would be wrong to suggest that all adolescents treated with anterior cruciate ligament reconstruction do well. All recent literature suggests that the adolescent has a higher re-rupture rate and certainly our series would support this with a re-rupture rate of (9%). I believe the higher re-rupture in adolescents compared to adults is not related to anatomic or technical reasons but due to the impact the adolescent brain has on the patient's ability to follow a postoperative regime and understand the consequences of deviating from the recommended path.

A KOOS questionnaire was completed by 80% of our patients and as you will see from the accompanying graph, a large number of patients certainly feel their knees are not normal.


Session II

Revision ACL
Can Failure of ACL Reconstruction be Prevented?

Ryosuke Kuroda, Takehiko Matsushita, Tomoyuki Matsumoto, Yuichi Hoshino, Masahiro Kurosaka
Department of Orthopedic Surgery, Kobe University Graduate School of Medicine, Kobe, JAPAN

Anterior cruciate ligament (ACL) reconstruction has become one of the more common procedures performed by orthopaedic surgeons over the past 10 years. Successful long-term results are achieved in 75% to 95% of these patients, but 8% have unsatisfactory results due to recurrent instability and graft failure\(^1\)\(^2\)\(^3\). To prevent failure of ACL reconstruction, surgeons should understand ACL anatomy, surgical technique of anatomic ACL reconstruction. Also surgeons should understand that successful ACL reconstruction does not depend not only on surgery itself, but also other factors, such as post-operative rehabilitation/training for returning to sports and risk factors of re-injury and failure of graft incorporation.

**ACL Anatomy**

ACL consists of two primal functional bundles, anteromedial (AM) bundle and posterolateral (PL) bundles. Those two bundles play different functional roles and contribute differently to knee stability throughout the range of motion. It is essential to understand the anatomy of the native ACL to perform anatomic reconstruction. ACL attaches to the medial side of the lateral femoral condyle and to the medial inter notch region of the tibia. Several studies revealed that the ACL is functionally composed of two functional bundles, the AM and PL bundle. In 1938, Palmer first described the ACL as composed of AM and PL bundle\(^4\). Then, Girgis et al. also reported the presence of the two bundles later\(^5\). They are named after the position of their insertion sites of tibia and the functional roles of the two bundles were investigated by more researchers\(^6\)\(^7\). On the femoral side, two bundles are horizontally aligned and the AM bundle insertion site is located at a deeper position than the PL bundle insertion site with the knee in a 90° flexion (operating position). At the full extension of the knee, both bundles align vertically. Some anatomic and biomechanical studies have also shown that ACL can be divided into three functional bundles, AM, intermediate, and PL bundle, although the importance of the functional roles of the intermediate bundles has not been well understood\(^6\).
Bony landmark
The origin of AM bundle is located at the transition of the intercondylar line to the border of the articular cartilage. The ACL fibers attach to the concaved area between the lateral intercondylar ridge (resident’s ridge) and the articular cartilage margin. An osseous landmark “lateral bifurcate ridge” exists between the femoral attachment site of AM and PL bundle to identify the femoral attachment site of each bundle. Those studies have shown the importance of the anatomic bony landmarks as a reference for tunnel positions in anatomic ACL reconstruction.

Portal technique
The usefulness of the three portal techniques was reported in several studies, which provide a proper view of the ACL remnants and bony landmarks such as the lateral intercondylar ridge (resident’s ridge) and the lateral bifurcate ridge, facilitating an anatomical positioning of the graft. The location of the accessory medial portal is usually just above the medial meniscus and slightly anterior to the medial condyle, not to interfere with the articular cartilage of the medial condyle during femoral tunnel drilling. Lubowitz et al. recommended that the medial portal is to be created as inferior as possible and also as medial as possible for a more perpendicular reaming, which is essentially the same location to the accessory medial portal mentioned above.

Remnant preservation
Biological integration of the grafted tendon is a crucial prerequisite for successful ACL reconstruction. Theoretically, preservation of the biological and mechanical properties of the ACL remnant tissue may be able to restore proprioceptive function of the graft after ACL reconstruction. ACL remnant has been demonstrated in experimental studies to have a role in improving revascularization, ligamentization and reinnervation of the graft. Histological studies showed that the human ACL remnants contain a cellular capacity for healing potential. However, these findings are still not supported enough by clinical findings.

Rehabilitation
Rehabilitation after ACL reconstruction is necessary for a successful surgical outcome. There was strong evidence of no added benefit of bracing following ACL reconstruction. Several new modalities for rehabilitation after ACL reconstruction have been reported, however, range-of-motion, strengthening, and functional exercises should be included at least. Accelerated rehabilitation does not appear to be risky, but
further investigation is needed\(^\text{17}\).


13 Lubowitz, J. H. Anteromedial portal technique for the anterior cruciate ligament femoral socket: pitfalls and solutions. *Arthroscopy* 25, 95-101,


Management of Failed ACL Surgery

Christopher Hamor, MD
Blue Cross of Western Pennsylvania Professor
University of Pittsburgh
Medical Director, UPMC Center for Sports Medicine

Overview

- The problem
- Classification of failures
- My revision ACL practice – evolution of my technique
- Case examples

ACL Graft Failure in U.S.

This is a big problem!

- ~175,000 primary ACL/yr
- 6th most common ortho procedure
- 10-15% failure in the literature ("experts")
- 85% of 1st ACL surgery is done by surgeons doing less than 10 per year... >15% failure?

Etiology of Failure

The most common causes of ACL failure in my experience are:

1. Graft placement
2. Traumatic graft failure
3. Failure to address secondary restraints. This includes the meniscus!
4. Early aggressive rehab

Pre-Operative Planning

- History and physical – the most important!
- Prior surgical notes can be helpful
- Well done X-rays are key!
- MRI – overrated!!!
- CT scan – occasionally

Etiology of Failure

University of Pittsburgh

Mechanisms of Failure

Classification

1. Surgical technique
2. Biological (graft healing)
3. Trauma

Early vs. late
- If < 6 months probably technical!
Dr. Harner’s ACL Revision Experience

- Years in practice: 24
- Number of primary ACL’s/yr: 120-150
- Number of revision ACL’s/yr: 25-30
  - Single stage (one surgery) ~ 30%
  - Two staged (two surgeries) ~ 70%
- Technique (anatomic)
  - Single bundle
  - Medial portal (femoral)
- Graft Selection
  - Allo (BTB) 33%
  - Auto (BTB) 66%

CDH Revision Experience

- Additional procedures ~ 70%
  - Meniscal surgery ~ 60%
  - Meniscal transplant 5-8/yr (~20%)
  - Collateral surgery ~ 20% (med > lat)
  - Osteotomy 1-2/yr

Case Examples

1) Rev ACL single staged (1 surgery)
2) Rev ACL with lat. men root repair (2 surgeries)
3) Rev ACL medial meniscal transplant
4) Rev ACL with ITB tenodesis
5) Other case examples
  - revision ACL with MCL Surgery
  - revision ACL with lateral meniscus transplant
  - rev ACL with HTO (closing wedge)

Single Stage ACL Revision

- 30 y/o male
- Oct 2007 ACL Hamstrings auto (menisci ok)
- Oct 2010 Injury playing football
- Diagnosis: Acute traumatic ACL graft failure
- X-ray: Tunnels position ok / no expansion
- Plan: Single stage revision with BTB allograft (did not want autograft)

Single Stage ACL Revision

Pre-operative X-rays (tunnels in good position)

Pre-operative MRI
Single Stage ACL Revision

- No tourniquet
- No leg holder
- Intra-op mini fluor

Femoral tunnel (medial portal) 11mm

Case I

Tibial tunnel
(Graft removal, dilate to 11mm)

Case I

BTB Allograft (11 mm)

Case I

Endobutton

Endobutton

Case I

Post-operative X-rays
Look like pre op

Case II: Single Stage ACL Revision

Vertical femoral tunnel

- Twenty-five year old expert skier
- 2006: BTB auto (with bioscrews)
- March 2010: Traumatic injury to ACL graft
- Diagnosis
  - Acute traumatic failure of ACL graft and lateral meniscus root tear
- Plan
  - Single stage revision
  - BTB allograft (patient preference)
  - Lateral meniscus root repair
**Single Stage ACL Revision**

*Case II*

*Vertical femoral tunnel*
*Tibial tunnel OK*

*New Femoral tunnel (medial portal)*
*11 mm*

*Femoral Tunnel*

*Medial portal*

*Femoral Tunnel*

*Femoral new tunnel*
*Fluoro check*

*Femoral Tunnel*

*Tibial Tunnel*
Case Examples

- 28 y/o male
- 2 yr s/p ST/med mx
- Instability (early)
  Medial pain
  3+ Lach / AMRI
- Etiology: Surgical tech.
  (2nd restraints, ACL graft)
- Rx: Single bundle Rev
  MM transplant

Pre op x-rays
Case Examples

- 18 y/o male
- Rev double-bundle ACL + MCL sx
- 9 month post op instability
- Etiol: biological/trauma
- Rx: 2 stage revision
  1). ICBG auto to both tunnels
  2). Rev. BTB auto + JTB (6 mo later)
Conclusions

1. You must define the etiology of failure and pathophysiology.
2. Address all deficiencies: "not just a new cruciate"
3. Use intra op fluoroscopy to help determine correct tunnel position before drilling.

Caution: ITB tenodesis is contraindicated in the setting of a lateral meniscectomy. Consider revision with lateral meniscus transplant.

Conclusions

4. When in doubt, stage your revisions
5. Use autograft over allograft when possible
   - Use BTB over soft tissue

Thank You
Based on an unusual practice of 70% elite athletes a strong insight into ‘fine-tuning’ of athletes’ ACL surgical technique has been allowed and are discussed in this presentation.

Many surgeons have a single favoured method of ACL reconstruction, but experience often leads a surgeon to tailor the operation to the athlete concerned.

Patellar tendon autograft remains the ‘best graft’ but at a cost- albeit a cost that has reduced considerably over the past 5 years or so with improved harvest techniques. The graft is strong, has the lowest re-rupture rates and is best for most elite soccer players, those with MCL laxity, and generally lax individuals.

Hamstring autograft is good for jumping sports, rugby, and judo and has low rates of anterior knee pain- but a higher re-rupture rate than patellar tendon autograft, and does weaken flexion which can be problematic in the elite climber. It allows for double-bundle techniques- not that elite level sports people like any technique that is not ‘tried and tested’!

The only indication for allograft that is unquestioned is for the elite power athlete eg high-level track athlete or rower, where power is all-important and little rotational stress on a graft occurs. The problem is the high re-rupture rates.

The role of synthetic graft for ACL reconstruction is very limited but the issue has risen again after renewed interest in some countries.

Increasingly lateral tenodesis-type procedures are being useful and this is based on good basic science at last. Refined understanding of the lateral soft tissue envelope has identified meaningful structures that may benefit from replication / reinforcement with dramatic additive biomechanical advantage for the intra-articular part of the reconstruction. They are usually used in revision cases but are employed in higher than average risk cases eg hyperlaxity of significant malalignment – the most common being the varus soccer-players knee, which will lead, with impaired proprioception, to heavy stress on the intra-articular graft. The extra-articular procedure protects the intra-articular graft during healing and maturation, and then adds a powerful resistance to the coupled anterior tibial translation and internal rotation of the ‘pivot-shift’ phenomenon. Since all ACL ruptures have a lateral injury it represents a significant contributor to ‘anatomical ACL reconstruction’. The technique has been greatly refined since the crude and variable practises of a few decades ago.

Rehabilitation times to return to play need to vary for specific sports as do the nature of the rehabilitation programmes.
Session III

ACL & Osteoarthritis
Osteoarthritis After ACL Injury & Reconstruction: Can We Prevent It?
Constance Chu, MD USA
Treatment of ACL Pathologic Laxity, Malalignment and Unicompartmental Osteoarthritis

Mark Clatworthy

Overview

1. Indications for combined ACL / Osteotomy

2. Overview of
   i) Relationship of tibial slope and the cruciate deficient/reconstructed knee
   ii) ACL / posteromedial opening wedge osteotomy for varus knee
   iii) ACL / posterolateral opening wedge osteotomy for mild valgus knee
   iv) ACL / medial closing wedge distal femoral varus osteotomy for valgus knee

3. Detailed Surgical Technique for Combined Hamstring ACL & posteromedial opening wedge osteotomy  Critical factors
   i) ACL reconstruction first
   ii) Anteromedial Portal Technique which enables central vertical tibial tunnel which doesn’t encroach on plate
   iii) Mark tibial tunnel position and proposed osteotomy position
   iv) Place distractor very posterior to decrease tibial slope and enable posterior plate placement
   v) Place knee in full extension when securing plate to further decrease slope
   vi) Fix the ACL graft in the tibial tunnel after plate fixation

4. Literature review
ACL Reconstruction with Unicompartmental Knee Replacement
Christopher Dodd, FRCS UNITED KINGDOM
Session IV

Patellofemoral Instability
Biomechanics of Patellofemoral Instability
Andrew Amis, PhD, DSc UNITED KINGDOM
Imaging of the Patellofemoral Joint and Assessment of Instability
Myles Coolican, FRACS AUSTRALIA
Lateral Patella Dislocations
Risk Factors for Injury
Elizabeth A. Arendt, M.D.
University of Minnesota
Professor and Vice Chair
Dept of Orthopedics, U of Minnesota
USA
I have no conflict of interest to declare

Minnesota Study
MAYO and University of Minnesota

- Number of patients: 564
- Number of knees: 565
- Sex distribution (n=565): 275 F, 289 M
- Average age (n=238): 19.84 ± 8.65 years
- Average female age (n=126): 19.70 ± 9.05 years
- Average male age (n=112): 20.01 ± 8.21 years

Anatomic Factors

H. Brattström, a pediatric orthopaedist
Osteriden, Sweden

First to publish a study on trochlear dysplasia
Used axial knee x-rays at 30° of flexion

“The trochlea is a flattening of the trochlear groove”

Sex and Age

Age Distribution of Dislocations

Minnesota Study
MAYO and University of Minnesota

- Surgery * (n=565 knees): 77 yes (14%)
  *osteochondral fragment

- Contact vs. non-contact (n=239 knees): 54 contact injuries, 174 non-contact injuries, 11 not mentioned

- Prior contralateral dislocation? (n=238): 21 yes, 216 no, 1 unknown

Brattström H. Shape of the intercondylar groove
normally in recurrent dislocation of patella.
Acta Orthop Scand. 1964 (69(Suppl)):1-147.
**Patella Alta**

Patella alta:
- its relationship
to lateral patella
dislocation was
first reported

Blumensaat C (1938) Die lageabweichungen und verringenker der

---

**Patella Alta**

The association of patella alta with patella instability was subsequently
discussed by numerous authors internationally.


Lancourt JE, Cristin JA (1975) Patella alta and patella infera: Their


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**Classification of Patellar Instability**

<table>
<thead>
<tr>
<th>Instability Grade</th>
<th>Joint Laxity</th>
<th>Iliax</th>
<th>Percent of Total Group (Fraction)</th>
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<tr>
<td>Total/average</td>
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<td></td>
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Runow A. The dislocating patella: etiology and prognosis in relation to
generalized joint laxity and anatomy of the patellar articular cartilage.

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**“Lyon School” of PF Instability**

- Addresses “objective” patella instability using anatomical principles based on the
teachings of H. Dejour and G. Walch
- Hallmark is
  - Consistent documentation using standardized imaging
    techniques (true lateral / CT image)
  - Surgical principles founded on
    anatomical pathology

---

**Trochlear dysplasia**

Shallow, flat or convex groove
96% of OPI patients

---

**Patella Alta**

30% Dislocation population

Caton - Deschamps Index
> 1.2

Control = 0 %, P = 0.001

---

**Tibial Tubercle - Trochlear Groove**

56% > 20 mm Dislocation population

Control 12 mm P = 0.003
**Patellar Tilt**

> 20°
83 %
Dislocation population

**Anatomic Factors in PF Stability**

**Non-bony factors**

- Dynamic Forces
  - Muscle attachments
- Soft Tissue Restraints
  - Patellofemoral ligaments

**MPFL**

*the Queen of the PF joint*

MPFL is the “essential” stabilizer against lateral patella displacement

**PF Alignment**

**Limb Alignment**

- Limb Alignment
  - Genu Valgum: no
  - Femoral anteverision: no
  - Tibial external rotation: (maybe)

- PF Alignment
  - Tilt: yes
  - Q vector: (maybe)
  - Alfa: YES
  - Trochlear Dysplasia: YES

**Risk Factors**

- Primary lateral patella dislocation
- Recurrent lateral patella dislocation
- Predictors of poor outcomes
  - Injury variable
  - Anatomic variables
  - ? Neuromuscular variables?

**Literature “Agreement”**

Formal indications for surgical treatment:

- Dislocation w/ treatable large osteochondral fragment

- Debate continues on what to do with soft tissue (repair/reconstruction/leave alone)

**Can we predict who will re-dislocate, and if yes…?**

**Should we offer surgical solution after primary dislocation?**

**Recurrent PF Dislocation**

- Females > males
- Younger > older at time of 1st event
- Neuromuscular factors (aka) ACL issues
- Bony morphology
  - trochlear dysplasia (↑ in females ?)
  - Patella alta
Literature “Agreement”
Factors associated with recurrence
- Younger age
- (+) family history
- Bilaterality
- Minimal (low energy) trauma
- Previous history of a patella dislocation

Role of dysplastic anatomy as a risk factor is recognized.
Its role in recurrence not well characterized.

Do multiple risk factors have accumulative effect?

Primary vs. Recurrence
Lateral Patella Dislocation
- Incidence of primary dislocator having a recurrent patella dislocation:
  - 17% over a 2-5 yr. period
- Incidence of recurrent dislocator having a recurrent patella dislocation:
  - 49% over a 2-5 yr. period

Fithian, AJSM 2004

Primary Patella Dislocations
How do we manage these injuries non-operatively?

MPFL - Injury Correlation
Where does it tear?
- Off patella: 54% (13-76%)
- Mid-substance: 12% (0-30%)
- Off femur: 34% (12-66%)
- Multiple sites

Sillanpaa, et al., SMARS 2012

Primary Patella Dislocations
Managing the acute injury
- Cast vs. Taping (1 RCT)
- Cast vs. none (1 RCT)
- Articles including PT variables: (0)
  - Different physical therapy regimens
- Articles including injury variables: (0)
  - Contact vs. non-contact, (+) fx.
- Articles including anatomic variables: (0)
  - Alta, trochlea dysplasia

Smith et al., KSST 2011

Meta-analysis
Operative vs. Non-op LPD
- 11 articles
- Initial rehab
  - No detail: 2
  - Fixed immobilization 2-4 wks.: 6
  - Allowed some limited motion: 3

Smith et al., KSST 2011

MCL / MPFL
The MPFL is an extra-articular structure that shares anatomic similarities to the MCL
MCL / MPFL

Surgical Stabilization for Lateral Patellar Instability

Medial restraint: does it heal?

- How to achieve healing? (natural history study, injury correlation, potential for healing)

Acute Patella Dislocation
Rate of Recurrence

- 74 pts. w/ acute 1st time dislocation
- Pts. seen within 4 wks. of injury by qualified personal, + documentation
- Standardized rehab protocol

Atkin, Fithian, et al., AJSM, 2000

Primary Patella Dislocations
Managing the acute injury

- Role of immobilization
  - in what degree of knee motion
- Use of McConnell taping
- Reduce swelling / Restore Muscle Activation

Acute Patella Dislocation
Review of the Literature

- Studies are variable
  - surgical technique
  - bony risk factors (alta, troch. dysplasia)
  - variable non-op management
- Bracing in extension for a short period of time may reduce the redislocation rate

Treatment

- Tape [McConnel]
  - Medial glide
  - Medial tilt
  - A/P tilt
  - Rotation
  - Fat pad unloading

Patella Dislocation
Acute Phase Management

- Primary patellar dislocation
- Randomized controlled trial
- Tape vs. cast
  - 6 weeks Rx.
  - Intense PT
- N= 12

Akkie Rood et al., Arch Orthop Trauma Surg (2012)

Patella Dislocation
Acute Phase Management

Results:
- Tape > cast
- No recurrences

Akkie Rood et al., Arch Orthop Trauma Surg (2012)
Literature “Agreement”
Concerning op vs non-op management:
- Clinical scores & subjective results are similar
- ↑ rate of dislocation in operated patients
- ↑ late complications in operated patients (flexion contracture/PF OA)

Clinical Agreement !
- Physiotherapy is essential for optimal recovery of function
- Phased approach to sport / activity preferred
- Rehab should include review of body movement patterns

Physical Therapy Progression
- CORE exercises
- Double stance exercises
- Single leg exercises
- Dynamic activities

Rehabilitation of PF Injury
- Examine abnormal motion patterns.
  - Review double limb and single limb bent knee patterns

Examining Single Leg Mechanics
- “Functional valgus” Femoral IR
  - Hip substitution Pelvic drop
- Hips level Knee over toes with flexion
  - Control into full extension pelvis level

Examining Double Leg Mechanics
- Excessive anterior knee excursion
- Normal (note hamstring firing)

Existing Validated Measures of Functional Limb Performance
- Single Leg Hop for Distance
- 6M Timed Hop
- Triple Hop for Distance
- Triple Cross-over Hop for Distance

Bolgla LA, JOSPT 1997
Greenberger HB, JOSPT 1995

Single-Limb Single Hop Test for Distance
Description: distance a travels w/ single hop on 1 limb
Nature of variable: Continuous
Units of measurement: Centimeters
Measurement properties: Test-retest reliability
- Healthy individuals: ICC = 0.92, SEM = 4.61 cm,
- Mean distance: 208.08-208.24 cm
LSI reliability in patients with ACL reconstruction
- ICC = 0.92
- Range of mean LSI 16 wks post-ACL= 81.0%-82.9%
- Mean LSI at 22 weeks post-ACL reconstruction = 88.2%
Single-Leg Hop

*Qualitative* assessment of form and controlled motion
*Quantitative* measurement of distance

Single Leg Squat

Demonstrates leg strength and pelvic symmetry
*Quantitative* measurement of knee flexion
*Qualitative* assessment of body motion

Retro Step-up

Targets quad & hip extensor strength
*Qualitative* assessment of hip/knee alignment, pelvic symmetry
*Quantitative* measurement of step height.

Balance

Single Leg Reach Test

Demonstrates balance & strength with sagittal plane motions
*Quantitative* Measure distance reached
*Qualitative* assessment of body motion

Balance: SEBT

• Star Excursion Balance Test
  - Anterior Reach
  - Posterolateral Reach
  - Postermenedial Reach

Core Stability Testing

Flexor Timed Repetition Test
Side Bridge Endurance Test
Trunk Curl Timed Repetition
Pelvic Bridge Endurance Test

Pelvic Bridge Endurance Test
Squat Endurance Test

References


Algorithm for management of recurrent patellar instability

Julian A Feller FRACS
Melbourne, Australia

Treatment options

- Non-operative
- MPFL reconstruction
- Distal tibial tuberosity transfer
- Medial tibial tuberosity transfer
- Trochleoplasty
- Lateral retinacular release
- Supracondylar femoral osteotomy
- Derotation femoral osteotomy (+ corresponding tibial osteotomy)

Principles for decision-making

The following questions should be answered:

- Does the patient have recurrent patellar instability?
- Is surgery warranted?
  - Recurrent, not controlled with non-operative measures
- Is the overall limb alignment (femoral torsion, knee valgus) within normal limits?
  - Usually is. Needs to be significantly abnormal to consider correction, particularly in primary situation
- Is the MPFL deficient?
  - Usually is. MPFL reconstruction has become the mainstay of surgery for recurrent patellar instability.
- Is J-tracking present?
  - If yes, implies a bony procedure will probably be required. NB MPFL reconstruction acts a check-rein to control lateral displacement of the patella, rather than by pulling the patella medially.
- Does the patellar sit high?
  - Consider distalization, particularly if J-tracking is present.
• Is there trochlear dysplasia?
  
  o This is common, but it is not yet clear what degree of dysplasia warrants correction and when trochleoplasty should be considered. Although most frequently used as a salvage procedure, it is increasingly used as a primary procedure.

• Is there normal medial patellar glide?
  
  o If no, consideration may be given to a lateral retinacular release. This is however controversial as the lateral retinaculum is in fact a stabilizer of the patella. Lateral release more likely to have a role in the treatment of patellofemoral osteoarthritis.

Once these questions have been addressed, most patients will generally fall into one of the four following categories, the first and second being the most common:

• Normal patellar height, normal TT-TG distance: medial patellofemoral ligament reconstruction.

• Patella alta, normal TT-TG distance: medial patellofemoral ligament reconstruction and distal tibial tuberosity transfer. It is in this group that trochleoplasty may have a role as a primary procedure, particularly if there is marked J-tracking of the patella.

• Patella alta, increased TT-TG distance: medial and distal tibial tuberosity transfer +/- MPFL reconstruction.

• Normal patellar height, increased TT-TG distance: medial tibial tuberosity transfer. It is in this group that a lateral release is may occasionally be considered. An additional medial patellofemoral ligament reconstruction is usually avoided for fear of excessively increasing the load on the medial half of the patellofemoral compartment if the reconstruction is inadvertently over-tensioned.
Tibial Tubercle Osteotomy: Techniques Used in Instability
Elvire Servien, MD, PhD, Prof FRANCE
The M.P.F.L.
A philosophy and technique for reconstruction

P. J. Erasmus, M. Thaunat
Knee Clinic,
Stellenbosch.
University of Stellenbosch

Philosophy:

Our philosophy is to restore the patella to its original position and stability as it was before the dislocation and rupture of the medial patello femoral ligament (MPFL). This philosophy is based on the established principle that “form follows function”

The patella is a sesamoid bone in a soft tissue sleeve that originates on the anterior iliac spine and proximal femur and inserts distally on the tibial tubercle. The patella aligns itself in the soft tissue sleeve and not with the femur as such (1). Till the end of gestation the form of the patella and trochlea probably has a genetic basis. After birth the knee goes into full extension, a bipedal stance develops which results in a femoral obliquity and secondary valgus of the extensor mechanism soft tissue sleeve. These epigenetic factors now determine the position of the patella in relation to the trochlea and probably play the major role in the eventual shape of the patella and trochlea which develop congruent articulating surfaces (2) (3). There is a difference between the bony and cartilage morphology of the patello femoral joint (4) (5). This means that congruent cartilaginous articulation may co-exist with an underlying bony incongruence.

In the last 30° of extension the patella lies outside the bony constraints of the trochlea and is now dependant on soft tissue constraints (6). The MPFL has been shown to be the primary stabilizer against lateral dislocation (7). The lateral retinaculum also has a restraining effect against lateral dislocation of the patella (8). In more than 30° of flexion the patella stability is provided by the trochlea and the soft tissues becomes less important.

The exact origin of the MPFL on the medial epicondyle is still undecided, Steensen (9) suggests that it attaches anterior to the epicondyle while Smirk (10) suggests a posterior implantation although in some of his specimens the origin was anterior. Schottle (11) and Wijdicks (12) both suggested a radiological point on the medial femur as the origin of the MPFL, there is a difference between the two points

In reconstructions we prefer an anterior position on the epicondyle as this prevents a windscreen wiper effect as well as an abnormal and sensitive prominence over the epicondyle

In a study presented in 1997 we were able to demonstrate that the MPFL is non isometric and becomes tight in extension and lax in flexion (13). (Illustrations 1 and 2)
This has subsequently been confirmed by others (9) (10). In recent, unpublished, cadaver studies we could demonstrate that patella alta increases the non isometry of the MPFL. Placing the reconstruction more proximal, on the medial epicondyle, will result in a reconstructed MPFL that is lax in extension and tight in flexion; this might cause loss of knee flexion and might cause excessive pressure on the medial patellar facet (14). (Figure 1) Conversely placing the reconstruction too distally, on the medial epicondyle, will result in an over tight MPFL in extension and a lax ligament in flexion. An over tight reconstruction in extension might result in an extensor lag as the tension in the reconstructed ligament might be more than in the patellar tendon when the quadriceps muscles are maximally contracted (Figure 2). In reconstructing the MPFL the aim should be to create a “favourable anisometry” in the reconstructed ligament (15) In cases of severe patella alta it might be impossible to achieve a “favourable anisometry” as non isometry progressively increases with the height of the patella. In these cases a distalization of the patella might be necessary to improve the isometry. In contrast to the MPFL the lateral retinaculum is lax in extension and tightens in flexion (16) (17).
In nearly all patella dislocations there is damage to the MPFL. In our own series 70% had damage at the patellar insertion while the remaining was damaged at the femoral origin, in all however, there were some interstitial damage to the whole ligament. These findings correspond with that of Garth (19) but differ from the MRI findings of Sallay (18).

**Management:**

In the majority of patients that present with patellar dislocation there is underlying pathology such as ligamentous hyper laxity, trochlear dysplasia and patella alta (20). This underlying pathology predisposes to an acute overload of the soft tissue stabilizers and rupture of the MPFL with patella dislocation.

Primary repair has a high failure rate, in our own series there was 31% redislocations in a four year follow-up period. This corresponds with the results published by Nikku (21). Most cases of primary dislocations are now treated non surgically with a brace that allows full flexion but restricts the last 30° of extension. By restricting full extension the MPFL is relaxed and might heal in a more favourable length. In exceptional cases a primary reconstruction or direct repair of the MPFL and medial retinaculum would be considered.

The principle of our repair philosophy is to reconstruct the MPFL with stronger tissue than before, to compensate for the underlying predisposing pathology, without changing the original position of the patella and its original conformity with its underlying trochlea. In marked patella alta we would consider lowering the patella through a distal transfer of the tibial tubercle as the non isometry of the MPFL in these cases make an effective reconstruction of the MPFL very difficult. The normal MPFL fails at 208N with an elasticity of 8N/mm (22). A double gracilis fails at 1550N with an elasticity of 336N/mm (23). We prefer a double gracilis graft which although stronger than the MPFL is less strong and stiff than a double semitendinosus tendon.

Preoperative evaluation consists of a proper clinical examination with specific attention to dynamic patella tracking, patella height and possible P-F chondral damage. The contra lateral patella is also properly evaluated as the principle is to restore the injured knee to the pre dislocation situation. Standard X-rays of the knee is done including a true lateral with the quads maximally contracted. This lateral X-ray is used to evaluate patellar height according to the Bernageau technique (24). On MRI images the ratio described by Biedert (25) can be used.

**Surgical Technique of MPFL reconstruction:**
Three, 3 cm long incisions are made over the gracilis tendon, over the medial edge of the patella and over the medial femoral epicondyle (figure 3).

![Figure 3](image)

*Figure 3*

*Skin incisions over the gracilis, the medial patella and the medial epicondyle*

The gracilis tendon is harvested with a routine technique. At the incision over the medial edge of the patella a cut is made through the 2nd fascial layer. From here a dissecting scissors is used to tunnel between the 2nd and 3rd fascial layers towards the medial epicondyle. At the medial epicondyle the 2nd fascial layer is again incised over the tip of the scissors. *(Figure 4)*

![Figure 4](image)

*Figure 4*

*Dissecting with scissors between the 2nd and 3rd layer from the patella to the medial epicondyle*

Intra operative screening, as suggested by Schottle\(^{(11)}\), can be useful to find the area on the medial side of the femur where the MPFL originates; we would caution in using the x rays to find a definite point. In our technique routine x-rays are not used. A guide wire is inserted on the anterior slope of the epicondyle, slightly proximal. In the proximal third of the medial edge of the patella two 3 mm drill hole are made approximately 10-12 mm apart. These drill holes should be on the edge of the patella. Larger drill holes and holes that go into the centre of the patella might act as stress raisers which can lead to
stress fracture of the patella and should be avoided. A tape is now placed around the guide wire at the medial epicondyle then between the 2\textsuperscript{nd} and 3\textsuperscript{rd} fascial layers and through the drill holes at the medial edge of the patella. With the knee in full extension, a bone hook is inserted at the distal pole of the patella. While pulling proximally on the bone hook, in the direction of the femoral shaft, the tape is temporary fixed at the drill holes on the patella with needle holders. (figure.5)

![Figure 5](image-url)

**Figure 5**

*Pull proximally with a bone hook on the patella and the knee in full extension*

*Tension in the patella tendon should be more than in the reconstructed MPFL*

The stability of the patella, comparing to the opposite knee, as well as the lengthening pattern of the tape is observed. If the femoral fixation point is correct the patella will be stable in full extension. The tape would be maximally tight at full extension and become progressively more lax with flexion. If this tension pattern is not seen the position of the guide pin on the femur needs to be changed. Moving the guide pin more proximally will decrease the tension in extension and increase the tension in flexion (figure 1). Conversely moving the guide pin more distally will increase the tension in extension and decrease tension in flexion (figure 2). The ideal position is where the tape is at its tightest in extension and becomes lax with flexion while stability of the patella is maintained. Care should be taken to ensure that there is more tension in the patellar tendon than in the reconstructed MPFL. This is best achieved by pulling the patella proximally with the bone hook when tying the temporary tape. When a satisfactory tension pattern, in both the tape and patellar tendon is achieved the guide wire, in the epicondyle, is over drilled with a 4.5 mm cannulated drill.
A 5 mm bone anchor is placed in the depth of the drill hole on the femur. The loop of the double gracilis tendon is tied into the femoral bone tunnel with the anchor. The two free ends of the looped tendon are now brought between the 2\textsuperscript{nd} and 3\textsuperscript{rd} fascial layers to the exposed medial edge of the patella and through the two 3 mm drill holes on the medial edge. The free ends of the gracilis tendon are then folded back on themselves. (Figure 6)

![Bone anchor just anterior from the medial epicondyle. Two 3 mm drill holes through the medial patella rim.](image)

The reconstructed ligament is tensioned in the same manner as described above with the testing tape. Tensioning is done with the knee in full extension while simultaneously pulling with a bone hook on the patella, in the direction of the femoral shaft. This manoeuvre prevents over tensioning of the reconstructed MPFL. Excessive tension in the reconstructed ligament can lead to an extensor lag. This happens when the tension in this reconstructed ligament is more than in the patellar tendon with the knee locked in full extension by maximum quadriceps contraction.

After tensioning, the medial and lateral movement, of the operated patella, should be similar to that of the contra lateral patella, the idea being to restore stability to the pre-dislocation situation. It is suggested that both knees be draped allowing intra-operative comparison of the patellar movement. Once the tensioning is satisfactory the free end of the folded back tendon is sutured to itself and the surrounding soft tissue with non-absorbable material. (Figure 7)
Post-operative immediate full passive motion is encouraged. Active flexion and light isometric quadriceps exercises are done. For the first 4 weeks, post operative, the patient is mobilized partial weight bearing, using two crutches.

After 4 weeks, the crutches are discarded and intensive quadriceps rehabilitation started. Quadriceps rehabilitation is often prolonged and can take up to 6 months or even longer. Normal sporting activities are allowed as soon as full quadriceps rehabilitation is achieved.

**Results:**

Between 1994 and 2006, we did 148 MPFL reconstructions using this technique. In 4 cases the MPFL reconstruction was combined with a distal tibial tubercle transfer osteotomy. No medial transfer of the tibial tubercle or lateral retinaculum releases were done on any of the patients. There were three redislocations in this group all associated with a definitive injury and in all the cases there were an avulsion of the medial edge of the patella, they were all successfully treated by a reimplantation of the avulsed fracture (26). One patient had an extensor lag secondary to an over tight reconstructed MPFL, she was successfully treated with a percutaneous tenotomy.

In a 7 year follow-up study on 29 patients done from 1996 to 1999 there were no redislocations, the average scores were the follows; Tegner 5.8, Lysholm 88.5 and IKDC 81. Primary chondral damage to the patella and trochlea had a negative effect on the Lysholm but not on the Tegner and the IKDC scores. There were no signs of progressive P-F degeneration.
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MPFL tight in extension
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Trochleoplasty: Indications & Technique
David Dejour, MD FRANCE
Session V

Meniscus
As the purpose of this book boils down to motivated and documented investigation as to why meniscal tissue, as it has been created, is indeed to be saved as much as possible, meniscectomy needs to be kept to a minimum in view of correct indications and appropriate techniques.

Menisci are vestigial tissue, but an integral part of the “self maintaining transmission system” as the knee joint can be considered.

Minimal tissue resection, which very often can be described as “adequate” e.g. leaving the meniscal rim should be the rule.

Indeed, care can be taken to resect what has been torn and removing meniscus tissue to only avoid any further “impingement” that may remain sensitive to rotational “painful” stress and thus clinical symptoms.

Arthroscopic techniques allow for repeat surgery. It may be required in case of persistent mechanical derangement. The fulcrum to proceed to repeat arthroscopy surgery, however needs to remain clinical. All to often, this repeat surgery does not alter clinical findings if it is based on – needles - imaging alone.

Potential meniscal repair therefore is warranted in all cases when meniscal resection has been considered. Full options remain when in excess of partial resection suture of the meniscal remnant to the meniscal wall appears to be required.

Biomechanical investigation and testing on meniscal repair devices has been extensive.
Tensile forces have been investigated but remain of lesser importance in clinical practice.

Shearing forces “resistance” in meniscal investigation is of paramount clinical importance but cannot be performed valuably in vitro.

Experience learns that a red on red clear heals spontaneously in 4 to 6 weeks. When appropriate rest is taken into account.

The purpose of meniscal stabilization is to bridge this period safely in order for the scar tissue to settle and stabilize the lesion.

In that respect, no in vivo testing has been able to be initiated. Thus, clinicians appreciate implant material investigation essentially focussed on material properties, safety guidelines and ease of insertion with convincing evidence based on physiological meniscal healing.

The implants developed over the recent years allow arthroscopic meniscal suturing all around the meniscal rim. Good stabilization is obtained in the majority of cases. Average results show up to 80% clinical healing at long term follow-up. Failures result mostly because of poor indication or unstable knee joint as defective findings.

Less documented reasons also could be poor meniscal tissue, low cellularity and thus poor healing response. The documentation of this finding is obviously hard to retain. The interested knee surgeon recognizes these clinical findings when at surgery the meniscal core presents with – yellow – degeneration and precarious healing response often related to age and overload.

One of these “degenerative” findings, indeed, is the meniscal cyst. Prone to increased shearing forces in it’s – achillis heel – fixation around the Musculus popliteus tendon, the lateral meniscus may induce it’s horizontal tear and accordingly it’s cyst formation.

Depending on it’s intra-articular “opening” the symptomatic cyst needs to be resected and the
torn meniscus repaired. Repair is mandatory at all costs in order to avoid underlying cartilage
degeneration, if at all possible.

Obviously appropriate rehabilitation protocol may be needed to finalize optimal results.
Scientific consensus is not available. All intrinsic factors need to be taken into account for
adequate rehabilitation. Individually sized protocols signed potentially better clinical end
results.
Meniscal Transplantation: The University of Pittsburg Experience

Christopher Harner, MD USA
Cincinnati Sportsmedicine Meniscus Transplant Studies 1988 - 2013
- All prospective
- Cincinnati Knee Rating System and IKDC Objective:
  Preop, Postop yrs 1, 2, 5, 10
- MRI: 2 yr p.o. or when required
- FU surgery: when required

Meniscus Transplant History
- Fresh-frozen, irradiated 2.5 MRad (9/88-3/92): N = 96
- Cryopreserved
  N = 40 reported JBJS 2004 (11/95-3/00)
  N = 37 performed after JBJS study grp (3/00-11/05)
- AlloSource (9/05-1/10): N = 32
- Regeneration Technologies, Inc. (RTI) (1/09-7/12): N = 19
- Musculoskeletal Transplant Foundation (MTF) (3/10- present): N = 9

Strict Patient Selection Criteria for Meniscus Transplantation
- Prior meniscectomy
- Age < 50 years
- Pain in meniscectomized compartment
- ≥ 2 mm TF space 45° weight bearing PA views
- No advanced joint deterioration MRI, confirmed at arthroscopy prior to transplant
- No or only minimal bone exposure on TF surfaces
- Normal axial alignment, or willing to undergo osteotomy first
- No ligament instability or willing to undergo ACL recon, usually staged
- BMI within normal range
- No full-thickness femoral condylar defect or willing to undergo concurrent osteochondral autograft or ACI

Exclusionary Criteria
- Advanced joint arthritis, flattening femoral condyle, concavity of tibial plateau, osteophytes prevent anatomic seating of transplant
- Uncorrected lower limb malalignment
- Uncorrected knee ligament deficiency
- Pre-existing knee arthrofibrosis
- Significant muscle atrophy
- Prior joint infection
- Symptomatic, advanced PF deterioration
- Obesity (BMI > 30)
- Patient with no symptoms or articular cartilage deterioration
Clinical Study #1: FF, Irradiated (ICL 1998)

N = 96 transplants, 82 pts  
ACL recon: 81%  
Clinical FU mean 3.6 yrs (2-9.2 yrs)  
Grafts evaluated f.u. scope or MRI: characteristics classified according to peripheral healing, position, size, tears  
Results:  
- Overall 9% normal, 20%, altered, 70% failed, 1% unknown  
- Correlation MRI arthrosis rating and transplant failure rate:  
  - No/mild: 6%  
  - Moderate: 45%  
  - Advanced: 80%

Clinical Study #2: Cryopreserved (JBJS 2004)

N = 40 transplants, 38 pts  
100% FU mean 3.3 yrs (2-7 yrs)  
Osteochondral autograft transfer: 40%, Cruciate recon: 22%  
MRI 12-67 mos p.o.  
Rating graft characteristics:  

<table>
<thead>
<tr>
<th>Final Rating</th>
<th>MRI</th>
<th>TF Pain, Clin Eval</th>
<th>FU Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Displace: 0-25%</td>
<td>No pain, exam NL</td>
<td>No tears</td>
</tr>
<tr>
<td></td>
<td>Signal: 1, 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altered</td>
<td>Displace: 26-50%</td>
<td>Mild pain, improved</td>
<td>&lt; 1/3 menis removed</td>
</tr>
<tr>
<td></td>
<td>Signal: 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failed</td>
<td>Displace: &gt; 50%</td>
<td>Pain not improved</td>
<td>&gt; 1/3 menis removed</td>
</tr>
</tbody>
</table>

Results:  
- TF compartment pain, marked improvement 100% preop, 29% p.o. (mild)  
- Recreational activities: no problems 0% preop, 76% p.o.  
- Patient perception: 89% improved  
- 42% normal, 30% altered, 28% failed

Clinical Study #2 Long-term Update

29 grafts survived study #1: followed mean 7 yrs p.o. (3-15.6 yrs)  
- 16 converted to failure mean 9 yrs p.o. (6-14.5 yrs)  

Final failure rate all 40 transplants: 67% (27)  
Medial: 14/20 (70%)  
Lateral: 13/20 (65%)  

Time to failure: mean 6.4 yrs  

<table>
<thead>
<tr>
<th>Year</th>
<th># Transplants</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 2</td>
<td>3 (7.5%)</td>
</tr>
<tr>
<td>&gt; 2 - 5</td>
<td>8 (20%)</td>
</tr>
<tr>
<td>&gt; 5 - 10</td>
<td>11 (27.5%)</td>
</tr>
<tr>
<td>&gt; 10</td>
<td>5 (12.5%)</td>
</tr>
</tbody>
</table>
| No failure | 13 (32.5%)   | 45%
Clinical Study #3: Meniscus Transplantation Techniques (AJSM 2006)

Lateral, Medial Meniscus
- Bone-meniscus-bone keyhole technique
  - Measure graft and host plateau for fit, extrusion
  - Careful preparation bone trough & graft
  - Inside-out repair
  - ROM for fit

Medial Meniscus: bone-meniscus-bone slot technique
- Caution, prevent meniscus overhang/extrusion

MRI weight bearing study: measure transplant motion, position, size compared to opposite normal meniscus

Full WB, standing N = 8
- 0, 30, 60, 90°
- 0.5 T vertical open magnet
- T1 weighted, T2 fat sat, fast SE

Partial WB, N = 29
- 0, 30°
- 0.7 T open magnet, T1 weighted
Results: techniques successful preventing displacement, excursion ant & post horns

Illustrations in the axial plane of the native and transplanted menisci, approximating the pattern of meniscal displacement from full extension to 90° of flexion. Noyes' Knee Disorders, Saunders, 2009.

Clinical Studies #4-6 (Ongoing): Comparison Different Graft Processing, Procurement Techniques

AlloSource (9/05-1/10)
   N = 32, followed mean 29 mos. p.o. (19-62 mos)
   Concurrent osteochondral autograft transfer, ACI: 3
   ACL recon: 1
   Short-term failure rate: 31% (7 failed ≤ 2 yrs p.o., 3 failed 3-5 yrs p.o.)

RTI (1/09-7/12)
   N = 19, followed mean 23 mos. p.o. (12-37 mos)
   Concurrent osteochondral autograft transfer, ACI: 2
   ACL recon: 0
   Short-term failure rate: 26% (4 failed ≤ 2 yrs p.o., 1 failed 2.5 yrs p.o.)

MTF (3/10- present)
   N = 9
   Concurrent osteochondral autograft transfer: 1
   ACL recon: 0
   Short-term failure rate: 0%

Conclusions, Clinical Recommendations

Goals Meniscus Transplantation: Short vs. Long-Term Results
   - Decrease TF pain: yes, only short-term
   - Increase activity level: yes, only short-term
   - Chondroprotective effects: possible, short-term, before remodeling
   - Improve joint stability: possible, short-term

Concurrent or Staged ACL?
   - Too small numbers for conclusions
   - Expands indications
Concurrent osteochondral autograft transfer, ACI
- Expands indications

Recommendations:
- Indicated younger patients TF pain, no other options, definite short-term benefit
- Patient education key, probably all will fail in long-term
- Future tissue engineering, cell-based therapy improve success rates
- Be aggressive: repair all meniscus tears possible, including complex & avascular

References
Session VI

Live Surgical Demonstrations: Patellofemoral Instability
AIM and PRINCIPLE:

The surgical aim is to restore the patella back to its original position. The reconstructed MPFL should be stronger than the original torn MPFL to compensate for:

- Patella alta
- Trochlea dysplasia

The reconstructed MPFL should be non isometric:

- Tight in extension
- Lax in flexion

SURGICAL TECHNIQUE:

A gracillis autograft from the same leg is used. The gracillis is long enough and also strong enough to compensate for underlying abnormalities such as trochlea dysplasia, patella alta and an increased TT-TG.

In a patient with normal patella height the MPFL reconstruction is done as an isolated procedure. In cases of severe or moderate patella alta it is combined with a distal transfer of the tibial tubercle. In these cases the tibial tubercle osteotomy and distal transfer is done first as it has an effect on the isometry of the MPFL.

In more series of more than 200 cases we did the following:

- No lateral release
- No medial tubercle transfer
• No trochleaplasty
• No vastus medialis advancement
• No rotational osteotomies
• Distal tibial tubercle transfer – 20%

Using the technique described by Schoettle an X-Ray can be of value to locate the area but not the point of the femoral position of the graft. The X-Ray is only about 60% accurate in defining an exact point of origin on the femur.

The principle of the surgery is to reconstruct the MPFL to behave as the original MPFL which is tight in extension and lax in flexion. We want to create a ligament with a “favourable non-isometry”

The isometry is dependent on the position of the graft at the femoral condyle.
• The more proximal the position the more lax the ligament will be in extension and more tight in flexion; this can create a situation of an unstable patella in extension with loss of flexion and overload on the P-F joint is.
• A more distal position will result in a graft that is tight in extension and lax in flexion; if the graft position is too distal the graft will be too tight in extension resulting in an extensor lag.

The origin of the MPFL is on the anterior slope of the medial epicondyle; the proximal distal position must be determined intra operatively using a tape to test the tension in
• Extension
• Flexion
• Patella pulled proximally with a bone hook – fig 2

![Fig 2](image)

The insertion is on the middle proximal medial patella. Two insertion points are used
• One in the middle of the patella
• The other 1 to 1.5 cm proximal to the middle of the patella

Three small 2cm long incisions are made
• One over the gracillis which is harvested in a routine way
• One over the medial epicondyle of the femur
• One over the medial edge of the patella
  o Dissect with a scissors between the 2nd and 3rd facial layers to the medial epicondyle
- Cut onto the scissors at the medial epicondyle – fig 3

Figure 3

Use a double folded tape

- Free end through the drill hole in the medial patella rim
- Place it between the 2nd and 3rd facial layer and bring the loop out at the femoral epicondyle
- Place a guide wire through the loop and into the predetermined point on the femoral epicondyle
- Test the isometry in flexion, extension and with the patella pulled proximally
  - Should be tight in extension but with less tension than in the patella tendon with the patella pulled proximally and lax in flexion
    - If unsatisfactory move the guide wire either proximally or distally on the femoral condyle according to the explanation above
    - Once satisfactory over drill with a cannulated drill and place a bone anchor in the depth of the femoral drill hole
    - Double the gracillis graft, the loop is fixed with a sliding knot in the femur and the free ends pulled through the drill holes in the patella

Repeat the isometry testing in flexion and extension and if satisfactory fix the gracillis graft on the patella by folding it onto itself and suturing it together. The suturing should be done while the patella is pulled proximally with a bone hook; this will prevent an over tight graft

REHABILITATION

Immediate intensive isometric quadriceps strengthening
Immediate full weight bearing mobilization; crutches only for support as long as the patient find it necessary
Back to full activity when quadriceps is fully rehabilitated; usually 3-6 months
Trochlear dysplasia classification

Only for dislocation !!!!

Trochlear Dysplasia Type B and D

Create a new groove – remove the prominence +++

Technique for Deepening TROCHLEOPLASTY

Open periosteum - Peri trochlear cortex removal
Sus trochlear dysplasia - Supra trochlear spur removal

Six Step for...

1. Mid Vastus approach → MPFL, Patellar cartilage
2. Sus-trochlea exposure
Trochlear Analysis - New trochlear design

According to TT-TG

Native groove
Condylo-trochlear line
New groove
Lateralized (TT-TG)
Condylo-trochlear line

David DEJOUR
LYONORTHOCLINIC
FRANCE
The supra trocheal spur
+++ Patellar tilt
Missed engagement

Technique for
Deepening TROCHLEOPLASTY

4 Cancellous bone removal
5 mm Thickness
Cartilage & sub-chondral bone

Technique for
Deepening TROCHLEOPLASTY

5 Cutting in the new trocheal groove
+/- medial and lateral facet
Fixation with absorbable sutures or staples

Native groove
Absorbable sutures

Technique for
Deepening TROCHLEOPLASTY

Patellar medio-lateral tracking

A Amis, C Oguz, A M J Bull, W Senavongse, D Dejour

Biomechanical effect on patellar tracking

A Amis: Imperial College London (UK)

Trochleoplasty effect
Decrease the TT-TG value
“Trochlear Groove Lateralisation”
Proximal re-alignment

Original Groove
Lateralization of the Groove
Reduce the TT TG

TT-TG: 19 mm
TT-TG: 14 mm

Isolated Trochleoplasty
Correct 2mm

Proximal Re-Alignment

Sulcus angle 172°
Sulcus angle 155°
MPFL has to be repaired!!!

VMO plasty shouldn’t be done!!!

As a combined procedure

Who are address for...

Series 1993 – 2006

- 55 knees in 46 patients
- 30 Female
- 22 Right - 9 bilateral (20%)
- 23 years old (14 – 47) Mean age
- Family history 22 (40%)

BUT ...

Previous surgery 24 (43%)

- 12 Medialisation
- 2 Distalisation
- 6 Vastus Medialis
- 6 Patellar tendon medialisation (open physis) +++
- 2 Isolated Lateral release
- 1 Arthroscopic bone fragment removal

Indication for Trochleoplasty

100% Recurrent Instability

Instability and pain
62 % Abnormal Tracking ++++

No surgery for Isolated pain or Arthritis

Clinical Results

Subjective Evaluation
- 22 % Very Satisfied
- 74 % Satisfied
- 0 % Disappointed
- 4 % Unhappy

IKDC Subjective
- 78 points (40 – 100) Global :
  - 29% > 90 Very good results
  - 71 % < 90
### PF Score

**Global**: 88 points (61-100)

- **Stability**: 87% normal - No recurrence
- **Pain**: 39% no pain - 50% Weather
- **Stairs**: 82% No problem
- **Kneeling**: 42% normal - 6% impossible
- **Walking**: 79% normal - 21% Limited
- **Swelling**: 71% No - 29% activities - 0% constant

*No influence of previous surgery*

---

### Deepening Trochleoplasty

Salvage procedure +++

- **Difficult population**
- **Low influence**
- **Of previous surgery**
- **Cartilage damage**
- **Very efficient on stability +++**
- **Good correction of patellar tilt & MPFL +++**

Good and difficult indication dedicated to very special patients

---

### Stability = Balancing

- **Bony structures**
- **Soft tissues balancing**

**Surgical Algorithm**

"le menu à la carte" de LYON

*Henri Dejour 1987*

**Correct One by One anatomical abnormalities**

---

**Thank You!**
Session VII

Live Surgical Demonstrations: ACL
Anatomic ACL Reconstruction
Freddie H. Fu, MD, DSc (Hon), DPSc (Hon);
University of Pittsburgh, Department of Orthopaedic Surgery
Correspondence: ffu@upmc.edu

I. Rationale for Anatomic Double-Bundle ACL Reconstruction
   § Anatomy is the basis of orthopedic surgery. The goals of anatomic ACL reconstruction are to restore 60-80% of the native ACL anatomy, and to maintain a long term knee health.
   § Traditional ACL-R has been successful in returning patients to sports activities. However, radiographic evidence of degenerative changes has been observed in up to 90% of patients at mid-term follow-up study after traditional single-bundle ACL reconstruction.1-2
   § Critical review of the literature from the last ten years reveals that between 10% and 30% of patients complain of pain and residual instability following traditional single-bundle ACL reconstruction.3 Meta-analysis showed that no more than 60% of the patients will make a full recovery after their ACL reconstruction.4
   § The PL bundle, which is not traditionally reconstructed, plays a significant role in rotatory stability in the knee. Numerous clinical and basic science studies have demonstrated that: 1) traditional single-bundle ACL reconstruction does not adequately restore normal knee kinematics, particularly tibial rotation5, and 2) anatomic double-bundle reconstruction more closely restores normal knee kinematics when compared to single-bundle reconstruction.6

II. The principle of anatomic ACL double bundle reconstruction
   § Reproducing the two bundle anatomy of ACL
     - The ACL is composed of two functional bundles, the anteromedial (AM) bundle and the posterolateral (PL) bundle.7 Cadaveric studies have demonstrated that the AM bundle is approximately twice as long as the PL bundle, and that the two bundles have a similar cross-sectional diameter.

   § Reproducing the insertion sites of ACL
     - The insertion sites of the AM and PL bundle should be identified and marked for anatomic tunnel placement. The femoral insertion sites of the AM and PL bundle are oriented vertically with the knee in extension and become horizontal in 90° of knee flexion (surgical position for ACL reconstruction surgery). In extension the two bundles are parallel and in flexion they become crossed.7

   § Reproducing the tension pattern of ACL
     - The AM bundle has its highest tension at 45 degrees of knee flexion, and is taut throughout the range of motion. The PL bundle has its highest tension at full extension,
and becomes lax as the knee flexes. The AM and PL graft should be fixed at these angles of knee flexion to closely reproduce the native tension pattern.\textsuperscript{8}

- **Individualized surgery**
  - The insertion sites of each bundle should be identified and marked, and the size of the insertion sites should be measured to tailor the surgery for each individual. The concept of double bundle ACL reconstruction can be applied to all ACL reconstructive techniques (single bundle, double bundle, revision, one-bundle augmentation). The decision of whether to utilize either a single or a double bundle technique should be dictated by the unique anatomy of the patient.\textsuperscript{9}

### III. Pitfalls in Traditional ACL reconstruction

- Femoral insertion sites orientation changes with knee flexion: The femoral AM and PL insertion sites are horizontally oriented when the knee is close to 90 degrees of flexion, while they are vertically oriented in knee extension. This important concept is often neglected in ACL reconstruction.

- The use of clock face reference: The knee is a 3 dimensional structure. The clock concept is easy to use, but a 2 dimensional description and inaccurate in describing the location of femoral tunnel placement, which may lead to non-anatomic tunnel position.

- Inability to observe the femoral insertion site: traditional 2portal techniques do not provide a clear view of the femoral insertion site. By using a 3portal technique with a high lateral portal (LP) a central portal (CP) and a medial portal (MP) this problem is overcome. The CP provides a clear view of the notch and femoral insertion site, while the MP can be used as a working portal. The LP provides a good view of the tibial insertion site.
Graft impingement: is caused by non-anatomic graft placement. The native ACL does NOT impinge with notch and PCL. Adequate restoration of the size, shape and orientation of the native ACL anatomy prevents from impingement.

Mismatch tunnels: With fear of impingement, we traditionally mismatch our tunnel placement by placing the tibial tunnel more posteriorly (close to the PL insertion site), and placing the femoral tunnel at the native AM or high AM position.\textsuperscript{10-11} This non-anatomic ACL reconstruction leads to inferior biomechanical properties and inferior biological healing due to non-physiological biomechanical stress to the graft.

Double bundle ACL-R does not necessarily mean anatomic reconstruction, if the native anatomy was not followed as a guideline for double tunnel placement.

IV. Anatomic Double Bundle ACL Reconstruction

Pre-operatively, the ACL insertion site and ACL length can be measured on the sagittal MRI. The ACL inclination angle can also be measured, as can be seen below.\textsuperscript{12}

![MRI images showing ACL inclination angles and graft sizes.](image)

The MRI can also be used to measure the size of the certain autografts. Both the patellar tendon and the quadriceps tendon size can be measured on the sagittal MRI cut. As can be appreciated below, the quadriceps tendon is often much larger than the patellar tendon and provides a vigorous autograft.\textsuperscript{13}
Anatomic double-bundle ACL reconstruction is an “Insertion Site Surgery”. We utilize three portals: LP, CP and MP.

- We routinely place the arthroscope in the CP and work through the MP. Doing so, visualization of the femoral insertion of the ACL is greatly enhanced and the need for notchplasty is virtually eliminated.\(^\text{14}\)

- The anatomic insertion sites of each native ACL bundle are marked on the femur and tibia with a thermal device, with care taken to preserve the border of the bundles for later reference. This is a critical step in identifying the correct placement of the tunnels, and is performed prior to resection of any residual ACL tissue. In addition, the length and width of the AM and PL bundle insertion site are measured as references to decide tunnel diameters. The surgery is individualized for each patient.

- There is a large area on the medial wall of lateral femoral condyle for potential non-anatomic tunnel placement. Our preliminary data suggested that it may occupy more than 65% of the area on the wall.

- A “lateral bifurcate ridge” is often seen on the femoral insertion between the AM and PL bundles, whereas a “lateral intercondylar ridge” is often seen on the upper limit of both the AM and PL bundles. These are useful surgical landmarks in addition to the native insertion fibers.\(^\text{15,16}\)
Notchplasty destroys the femoral anatomy of the ACL insertion site and is not necessary if CP and MP are used.

The tibial and femoral tunnels are placed at their native insertion site, which are marked with a thermal device.

The PL femoral tunnel is always drilled through the anteromedial portal. A potential advantage of drilling the femoral AM tunnel transtibially is the creation of a longer tunnel which diverges from the PL femoral tunnel, and we routinely attempt this approach first before using the MP. However, oftentimes it cannot reach the anatomic insertion site. In that case, the tunnel will be drill through the anteromedial portal.

Finally, the grafts are passed. First the PL graft is passed, followed by the AM graft. Femoral fixation is typically performed with an EndoButton.

Post-operatively, MRI can be used to compare the pre- and post-op insertion site size to measure how much of the insertion site is restored. In addition, the pre- and post-operative inclination angle can be compared. After anatomic ACL reconstruction, the ACL inclination angle should be similar to the native ACL inclination angle.
- 3D CT scan can be used to evaluate tunnel position.

V. **Anatomic Single Bundle ACL Reconstruction**
- Except for one bundle augmentation (performed when only one of the two native bundles are torn), there are a few other scenarios where we prefer to perform single bundle surgery (30%): 17
  - Small native ACL insertion site (< 14mm)
  - Open growth plates
  - Severe arthritic changes
  - Multiple knee ligament injuries
  - Severe bone bruises
  - Narrow intercondylar notch

- Our single bundle surgery is performed with careful attention to soft tissue and bony landmarks. We carefully investigate the rupture pattern of the ACL and we identify the native ACL insertion sites - just as we do for double bundle ACL surgery. Then, the tibial tunnel is placed at between the native insertion sites of the AM bundle and PL bundles, or at the center of the entire tibial insertion site.
- The distance from anterior margin of ACL footprint to center of tibial tunnel should be measured, and the femoral tunnel should be placed at the same distance from the posterior margin (knee in 90° flexion) of the femoral ACL footprint.

VI. One Bundle Augmentation
- In cases only the AM or the PL bundle was torn, we save the intact bundle and “augment” this bundle with a single bundle graft.

VII. Revision ACL Reconstruction
- The same double bundle concept and its principles for primary anatomic ACL reconstruction can be applied to revision ACL surgery.
- Pre-operative imaging can inform the surgeon about placement of the previous tunnels. Below is an example of a bilateral MRI. This shows that the inclination angle of the primary ACL reconstruction is higher than that of the contralateral native ACL, suggesting non-anatomic tunnel placement. This can then be confirmed by the 3D CT scan.
- If the old tunnels are anatomic, they can be reused. If the old tunnels are non-anatomic, new tunnels need to be created. If there is enough room, new tunnels can be created in one stage. Alternatively, the graft can be placed “over the top” on the femoral side, or a two-staged procedure, with bone-grafting, can be considered.

- After the revision surgery, the native inclination angle should be restored.
VIII. Biological Enhancement

- Typically the graft heals to the bone through bleeding created by drilling the tunnels.
- We have begun using a “fibrin clot” to try to enhance the healing of the two bundles together and to the bone.
- A fibrin clot is created from the patient’s own blood by gently stirring it in a glass beaker for 5–10 minutes and contains many of the same growth factors advertised as being present in commercially available blood preparation products, such as platelet rich plasma (PRP).

IX. Clinical Outcome of Anatomic ACL Reconstruction

- Clinical improvements have been demonstrated in recent prospective and randomized level I and level II studies. These studies have shown superior outcomes for double bundle reconstruction than single bundle reconstruction.\(^{18-20}\)
- While the first results are encouraging, additional work is needed to critically evaluate the outcomes of anatomic ACL reconstruction in terms of joint kinematics, degenerative joint changes, and patient-reported outcomes. Better methods for rotational laxity measurement, medium- and long-term outcomes are needed in the future.
- In an excellent meta-analysis by Lubowitz et al. the results of pivot shift consistent with the convention of IKDC were summarized. The normal and nearly abnormal data were pooled together for pivot shift and therefore, SB and DB achieved 94.6% and 97.5% of good pivot shift results respectively with no difference between the two groups. This is how we reported clinical outcome for many years. However, if we want to review the data more critically by only comparing the “normal” category, DB provided significantly better results (83.1% DB vs. 67.9% SB).\(^{21-22}\)
- To fully assess the outcome of ACL reconstruction, we need to improve our outcome measures. New outcome measures should be accurate, precise and reliable. Some examples are: in-vivo kinematics with dynamic stereo x-ray, high resolution/ 3D MRI and 3D CT scan.
- Only when we have good outcome measurements, can we improve our surgical technique and protect the long-term knee health of our patients.

X. Conclusion

- The goals of anatomic ACL reconstruction are to restore 60-80% of the native ACL anatomy, and to maintain a long term knee health.
The double bundle anatomy, insertion sites, and tension pattern need to be reproduced to restore native ACL anatomy and knee kinematics.

Anatomic Double-Bundle ACL Reconstruction is a concept that can and should be applied to single bundle, one-bundle augmentation and revision ACL surgeries.

We need better, more objective outcomes measures, including biology, kinematics and imaging.

References:


Isakos 2013
Extra-articular R combined to ACL R.
Rationale and long term follow-up
Ph Neyret
E Servien
S Lasog
P Verdonk
V Duthon
Lyon University

Disclosure: I have no conflict of interest with this presentation

UNIVERSITY TEACHING CENTER

1992
Extraarticular Reconstruction in the Anterior Cruciate Ligament Deficient Knee

In rare circumstances, a medial and/or lateral extra-articular procedure may be indicated for severe laxity of the medial/lateral and other secondary restraints. Associated with a chronic ACL deficient knee treated with an intra-articular reconstruction Unanimously approved.

Combined intra-articular and extra-articular reconstruction.
- it may protect the intra-articular graft during the graft-healing phase.
- once the patient returned to activity it provided a secondary restraint to the pivot shift.
- decreased the forces going through an intra-articular reconstruction by 43% in-vitro (Engbrethsen)


Background
1. Different types of lesions occur on lateral compartment when the ACL ruptures
2. We have to deal with various types of ACL injuries that may lead to various ACL insufficiencies
3. Is a single bundle ACL R. enough to treat these various types of ACL insufficiencies
1. Different types of lesions occur on lateral compartment when the ACL ruptures

2. We have to deal with various types of ACL injuries that may lead to various ACL insufficiencies

3. Is a single bundle ACL R. enough to treat these various types of ACL insufficiencies

- Yagi AJSM 2002: biomechanical advantages to the double bundle

- Japan: Kurosaka, Muncia, Takeuchi, Yasuda, Ochi
- Italy: Perdizzini, Maracci, Aglietti
- US: Fu AAOS 2006
- Christel, Colombet,….
How to control Rotatory instability in ACL deficient knee?

- In Two Bundle ACL, R. forces passing through the second bundle aiming to control rotation are high.
- In KJT, R. forces passing through the anterolateral tetothesis aiming to control rotation are low.

Lyon Technique KJT

Preparation of ACL graft with gracilis autograft attached.
Creation of bone tunnel under Gerdy’s tubercle with awl.

Gerdy’s tubercle

Drill femoral tunnel for ACL graft posterior to LCL.

Insert ACL graft together with gracilis tendon in femoral tunnel.

The graft is passed and crossed underneath the LCL.

The two bundles are passed through the tunnel, in an opposite way.

Fixation of the two bundles by suturing at the exit of the Gerdy’s tunnel.

During fixation of extra articular tenodesis, the knee is in NEUTRAL ROTATION!

Removal of excessive bundles and closure of fascia.
Ultra long-term results after ACL reconstruction

Jerome Permin, Peter Verdonk, Tarik Ait Si Selmi, Philippe Massin and Philippe Neyret


Aim of the study

✓ To evaluate the functional and radiological outcome of an intra-articular bone-patellar tendon-bone ACL reconstruction with an extra-articular augmentation more than 24 years after surgery.

Surgical Technique

✓ Originally described by H. Dejour
  ➡ Intra-articular Bone-Patellar Tendon-Bone
  ➡ Extra-articular Lemaire ITB Plasty

➡ Evaluation of medial meniscus and cartilage through medial arthroscopy

Radiographic Findings

Results
Combined intra-articular and extra-articular reconstruction.

- Marcacci’s technique
  hamstrings graft as an intra-articular reconstruction combined with an extra-articular augmentation.
  This technique avoided some of the problems associated with using an ITB graft, such as donor site morbidity and cosmesis.

Combined intra-articular and extra-articular reconstruction.

- Their 10 year results
- No significant degenerative change of the lateral compartment.
- Average return to sports at 4 months.
  .... is a valid surgical option.


ACL R with versus without extra articular tenodesis

Roth compared isolated intra with combined intra- and extra-articular reconstruction.

- No benefit in using additional extra-articular repair in combination.
- However there was no indication as to why some patients had isolated intra-articular reconstruction and some had a combined procedure.

ACL R with versus without extra articular tenodesis

Other studies have also not shown a benefit of an additional extra-articular reconstruction.


60 Isolated Graft « KJ »

60 Combined ACL Graft « KJT »

Subjective IKDC Score

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<td>75.2</td>
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Mobility

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Dif. Stress X-Rays

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Lateral compartment

Final Evaluation IKDC

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Indications

- Evolved laxity
- Revision surgery
- Sports @ risk

Conclusion 1
Intra-articular ACL reconstruction is a popular and effective procedure. However, attempts to improve its results and perform a more kinematic restoration of the knee joint must address the extra-articular structures that contribute to the pivot shift phenomenon and not just variations of the intra-articular procedure.

Conclusion 2
Further anatomical, biomechanical, radiological, and other studies may help inform the development of extra-articular augmentation of ACL reconstruction. This may be a key factor in providing a more biomechanically faithful restoration of the knee.
A superior view of the tibial plateau of a left knee showing an intra-operative view of a left knee demonstrating the anterolateral ligament (ALIL) inserting onto the lateral meniscus (LM), which has been elevated, and the lateral tibial plateau (LTP). The lateral femoral condyle (LFC) is labeled.
Session VIII

Meniscal Root Tear
Medial Meniscal Root Tear
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