Human ACL reconstruction

current state of the art

Rudolph Geesink MD PhD
Maastricht
The Netherlands
Human or canine ACL repair ...!?
ACL anatomy ...

right knees
ACL double bundles ...
ACL double or triple bundles ...?
ACL double bundle footprints ...
ACL double bundle functionality ...
ACL imaging on MRI ...

Normal ACL and PCL ligaments on MRI
Knee kinematics ...
Knee kinematics ...
Knee epicondylar axis ...
Knee rollback and medial pivot...
Forces in the ACL ...

McLean’s setup to measure knee forces ...
Forces in the ACL ...
Females have somewhat larger rotation potential in the knee and are therefore more prone to ACL injuries (Park).
# Epidemiology of ACL injuries ...

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACL injuries USA</strong></td>
<td>&gt; 900.00 per year</td>
</tr>
<tr>
<td><strong>ACL reconstructions USA</strong></td>
<td>- 385.000 per year ↑</td>
</tr>
<tr>
<td><strong>ACL injuries Europe</strong></td>
<td>&gt; 500.000 per year ↑</td>
</tr>
<tr>
<td><strong>ACL reconstructions Europe</strong></td>
<td>&gt; 170.000 per year ↑</td>
</tr>
</tbody>
</table>
Injury mechanisms of the ACL ...
Injury mechanisms of the ACL ...

ACL injuries occur when bones of the leg twist in opposite directions under full body weight.
Damage and overstretch of the ACL ...
Diagnosis of ACL injuries ...

- trauma history
- symptoms
- physical examination
- imaging studies
- arthroscopy
Clinical diagnosis of ACL injuries ...

Anterior drawer sign for ACL injury
Clinical diagnosis of ACL injuries ...
Clinical diagnosis of ACL injuries ...

Pivot shift test
Quantification of ACL laxity ...

MEDmetric® arthrometer KT1000
MRI diagnosis of ACL injuries ...
MRI diagnosis of complex injuries ...

**Unhappy triad:**
- ACL rupture
- MCL rupture
- meniscal rupture
- cartilage damage
Arthroscopic diagnosis of ACL injuries ...
Arthroscopic diagnosis of ACL injuries ...
A typical ACL tear does not heal ...
Conservative treatment of ACL injuries...

physical therapy - exercises
Conservative treatment of ACL injuries ...

*Braces in use for treatment of ACL injuries or after ACL reconstruction*
Surgical procedures for ACL injuries ...

persistent instability with giving way symptoms ...
Treatment rationale for ACL injuries ...
Restore stability and prevent osteoarthritis ...
Surgical procedures for ACL injuries ...

Jones procedure...
ACL arthroscopic surgery ...
Relevant factors for good surgical outcome ...
Graft choice ...

Patellar tendon or hamstring tendon as used for graft in ACL repair
Doubling (or 4 - 8x) of hamstring grafts ...

Semitendinosus tendon used for ACL reconstruction, difference in size and geometry between patellar tendon and hamstring tendon grafts.
Graft fixation ...
Graft slippage (**fixation problem**) versus graft elongation (**graft problem**) resulting in late instability (Kahn)
Synthetic ligaments ...?
## Synthetic ligaments ...?

<table>
<thead>
<tr>
<th>Prosthesis</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Carbon              | Reduction and even distribution of stress between graft and soft tissue attachment.  
                      | Polylactic acid coat protects graft during implantation.  
                      | Encourages ingrowth of collagen into implant.                                                             | Migration of carbon wear particles.  
                      | Unacceptable incidence of implant stretching and rupture led to poor long-term functional outcomes.     |
| Gore-Tex            | Tensile strength 3X native human ACL.                                     | Progressive long-term loosening.                                                                        |
| Dacron              | Polyester coating serves to protect implant from abrasion.                 | Poor long-term stability.                                                                               |
| Leeds-Keio Artificial Ligament | Acts as a scaffold for soft tissue ingrowth  
                      | Excellent max. tensile strength which exceeds that of native ACL.                                      | Acts as more of a load-bearing prosthesis, allowing for fibrous tissue ingrowth.  
                      | Large number of long-term graft ruptures.                                                                |
| Kennedy Ligament Augmentation Device | Protects autogenous graft from excessive stresses | Weak implant-graft interface.  
                      | Propensity to cause intra-articular inflam. response and resulting synovitis and effusions.              |
| LARS Ligament       | Mimics natural ACL structure and orientation.  
                      | Reduces shearing forces on the implant.  
                      | Porosity encourages tissue ingrowth.                                                                   | Residual post-operative laxity still present.  
                      | No long-term follow-up studies yet.                                                                     |
| Tissue-engineered Scaffolds | Duplicate mechanical & structural properties of native ACL  
                      | Restoration of normal knee joint kinematics.  
                      | Implant can resemble normal ACL over time.                                                              | Loses strength over time.  
                      | Allogenicity of collagen scaffolds can lead to rejection.  
                      | Consistent reproducible batch-to-batch variability.  
                      | Collagen not as modifiable as biodegradable polymers.                                                    |

(Mascarenas)
Gore-Tex ligament and micro-structure after 6 years in vivo.

Leeds-Keio ligament and micro-structure after 6 years in vivo.
LARS ligament augmentation ...
Back to autografts ...!

new opportunities with new materials ..?
New opportunities ..?
ACL arthroscopic surgery ...
Do we really need 2 ACL bundles ..?
Advantages of double bundle ACL repair ...

- Total contact area between tendon and bone is larger by about 40%.
- Usually sufficient to harvest one tendon (semitendinosus).
- Less surgical injury is done.
- Allows for anatomica restoration of the oval shape of the ACL insertions.
- Tension is shared between two bundles.
- Four points of fixation provide better graft stabilisation.
- Thinner grafts decrease risk on impingement with PCL.
- Small tunnel diameter provides better anatomical conditions in case of later revision.
- Possible to reconstruct a single bundle of a partially torn ACL.
Graft preparation for single femoral tunnel - double bundle ACL repair
Double bundle ACL surgical technique ...

Orientation of future drill holes.
Double bundle ACL surgical technique ...

Preparation of femoral AM graft tunnel
- thicker drill tibia
- thinner canal in femur
Double bundle ACL surgical technique ...

second PL tunnel is drilled,
again tibial thicker than femur

a pull-through wire is brought
through the PL tunnel
Double bundle ACL surgical technique ...

...by which the graft is pulled through the tunnel

similar procedure for AM tunnel. Graft fixation at femoral end.
Double bundle ACL surgical technique ...

tensioning and fixation of both grafts at tibial side.
Arthroscopic techniques ...

Arthroscopic placement of interference screw
Final result of DB-ACL repair with skin incisions.
Aiming devices ...

Drill guides to improve the accuracy of bone tunnel drilling & pull-through wires for DB-ACL graft.
Aiming devices ...

Drill guide and hamstring grafts for DB-ACL repair
Graft tensioner and laxity tester during surgery
ACL computer navigation ...
ACL computer navigation ... 

Optimization:
- isometric stability
- range of motion

femoral & tibial tunnel navigation ...
- tunnel osteophyte removal
- widen tunnel in PCL dominant knee > 1-mm of graft diameter
- avoid PCL impingement
- avoid overstuffing narrow space with graft
- avoid too wide drill canals
- experience ... experience ...
Relevant factors for good surgical outcome ...

- **Reconstructing the ACL anatomy**
- **Restoring the native insertion site anatomy of the ACL**
- **Restoring the tension pattern of each bundle**
- **Individualising the surgery for each patient**
- **Bone morphology dictates the motion of the knee**
Problems and complications ...
Complications ...

- Infection
- Neurovascular Injury
- Extensor Mechanism Dysfunction
- Loss of Motion
- Cyclops Lesion
- Arthrofibrosis
- ACLR Poor Outcome
Problems ...
Relevant factors for good surgical outcome ...

- Graft Choice
- Tunnel Placement
- Graft Tension
- Graft Fixation
- Tunnel Motion
- Graft Healing

Woo, 2004

Closer to the Normal ACL
Thank you

rgeesink@mac.com