Introduction

- Modern, intra-articular ACL reconstruction techniques achieve good results for the majority of patients, but they fail to restore normal knee biomechanics, particularly with regards to tibial rotation\(^1\)
- A residual pivot shift, a clinical manifestation of anterolateral rotational laxity, is associated with poor outcomes and reduced patient satisfaction\(^2\), and as such altered kinematics may further contribute to the development of osteoarthritis\(^3\)
- Primary ACL graft failure is a significant issue, particularly in young patients returning to high demand pivoting and contact sports
- The aim of the addition of a lateral extra-articular tenodesis (LET) at the time of revision ACL reconstruction is to attempt to better restore knee stability and prevent further injury to the already compromised joint
- Recently, there has been significant interest in the anatomy of the anterolateral structures of the knee and their role in the control of tibial internal rotation
- This talk will outline the rationale for performing LET procedures, with particular focus on the revision ACL scenario

Historical Rationale for Extra-Articular Reconstruction

- Lateral extra-articular procedures were designed to control anterolateral rotatory instability
- They were considered to have a clear biomechanical advantage over intra-articular reconstructions in controlling rotation, due to the longer lever arm of a peripherally based reconstruction to resist torque
- Ellison described the ACL as "the hub of the wheel", and noted, "it is easier to control rotation of a wheel at its rim than at its hub"\(^4\)
- Initially performed as isolated procedures, they were subsequently combined with intra-articular reconstructive techniques
- Over time, they were largely abandoned due to concerns regarding their biomechanics and perceived non-anatomical nature, equivocal results, and the large scale uptake of arthroscopic techniques

Extra-Articular Procedures

- The first lateral extra-articular procedure was described by Strickler in 1937\(^5\)
In 1975, Lemaire published the first description of his own extra-articular technique. A 15 cm by 12 mm strip of the posterior ITB was harvested, again left attached distally at Gerdy's tubercle (Figure 1.). Just distal and deep to the origin of the LCL, an osseous tunnel was drilled, exiting on the posterior surface of the condyle very close to the capsular attachment. The ITB was passed through this tunnel, and then back under the proximal LCL and sutured onto itself. The graft was secured with the knee held in full external rotation (over constraining the knee).

In 1976, MacIntosh presented the results of 90 cases operated using his technique. Termed the “lateral substitution reconstruction for the anterior cruciate ligament”, this procedure utilized a 20 cm strip of ITB, left attached at Gerdy’s tubercle, which was routed under the LCL, through a sub-periosteal tunnel and around the insertion of the lateral intermuscular septum, and finally back under the LCL.

Other notable techniques include the Ellison and the Losee procedures amongst others.

Does the Anterolateral Ligament Exist? **Yes**

- In 2013, Claes and colleagues published their description of the anterolateral ligament (ALL).
- Identified in 40 of 41 specimens, this extra-capsular structure was found to originate just anterior to the LCL, posterior and proximal to the popliteus tendon insertion, and to insert onto the proximal tibia roughly midway between Gerdy’s tubercle and the fibula head.
- Subsequently, a number of authors have contributed to our understanding of this structure with further anatomical and histological studies and descriptions of radiological landmarks.
- However, the term "anterolateral ligament" was probably first used by Kaplan in his 1962 study of the iliotibial tract.
- The term was also used by Terry to describe the function of the capsulo-osseous layer of the iliotibial tract, and again by Vincent to describe a structure running from the lateral femoral condyle to the lateral meniscus and anterolateral tibia, demonstrated by dissection from the intra-articular aspect of the joint capsule during total knee arthroplasty.

Does the ALL have a role in controlling Al. Rotatory Laxity? **Yes**

- Dodds determined the ALL to be isometric from 0-60° of flexion, and to lengthen with internal tibial rotation, strongly suggesting a role in rotational control.
- Monaco examined the effect of cutting the ACL and lateral capsular ligament using a navigation system and manually applied forces. His description of division of the lateral capsular ligament would have involved division of the ALL. He found an increase in internal rotation in all knee flexion angles in the ACL deficient knee following division of the lateral capsular ligament, which was significant at 30° with an increase in internal rotation of 5.5°.
- Spencer investigated both sectioning and reconstruction of the ALL using navigation and manually applied forces. He measured an increase in internal rotation in extension of 2° after division of the ALL in the ACL deficient knee while performing a simulated pivot shift.
- Parsons, using a six degree of freedom robot, found the ALL to be the primary restraint to internal rotation at knee flexion angles greater than 35°, with the ACL providing the greatest restraint closer to extension.
- Nitri demonstrated that the ALL helped control rotation in greater flexion angles, but also that reconstruction of the ALL caused over constraint at all flexion angles.
However…

- Kittl found the ALL played no significant role in internal rotational control. In a similar robotic experiment, he determined the superficial and deep components of the ITB to be the primary restraints to internal rotation from 30-90°, with the ACL having a significant contribution at 0° only.
- Musahl demonstrated that lateral meniscectomy resulted in an increase in anterolateral tibial translation in a cadaveric model.
- Shybut also showed that lateral meniscus posterior root tear resulted in an increase in anterolateral rotation.

**The Anterolateral Complex**

- The anterior cruciate ligament is the primary restraint to anterior tibial translation.
- A number of structures contribute to the control of internal tibial rotation at the knee, including the ACL, the anterolateral ligament, the iliotibial band, and the lateral meniscus (the Anterolateral Complex).
- These recent studies have helped to clarify the complex anatomy and function of the anterolateral knee, and would suggest that lateral extra-articular procedures may be more anatomical than previously believed.

**Current Rationale for Lateral Extra-articular Procedures**

- Contemporary ACL reconstruction techniques fail to fully restore normal knee kinematics with failure rates as high as 24% having been reported.
- Recent large-scale cohort studies, systematic reviews and registry reports would suggest a rate between 3.5-7%.
- Draganich studied the effect of both an isolated extra-articular reconstruction and a combined approach in a cadaveric model. The isolated lateral procedure was found to over-constrain tibial internal rotation; however, when the lateral procedure was performed after an intra-articular reconstruction and care was taken not to tension the tenodesis with the knee in external rotation, both anterior translation and rotation were restored to that of the intact knee.
- In an in-vivo study using intra-operative navigation, Monaco demonstrated reduced internal rotation after the augmentation of an intra-articular graft with a lateral extra-articular reconstruction.
- Spencer examined the effect of an anatomical ALL reconstruction and a modified Lemaire extra-articular procedure in the ACL deficient knee. The anatomical ALL reconstruction, based on the landmarks of Claes, was ineffective in controlling internal rotation or anterior translation in an early phase pivot shift test, supporting the isometry findings of Kittl. With the modified Lemaire reconstruction, however, there was a trend towards reduced internal rotation and a significant reduction in anterior translation.
- Engebretsen found that an iliotibial tenodesis reduced the forces seen in an ACL graft by 43%.

**Does an anterolateral reconstruction work clinically?**

- The first comparative study of intra-and extra-articular reconstruction versus intra-articular reconstruction alone was published by Jensen in 1983. In this retrospective study, he found the combined procedure group showed the most marked reduction in anterolateral laxity.
Subsequent studies, however, challenged the superiority of combined procedures. Strum reported no benefit of combined procedures over isolated intra-articular reconstructions, stressing the importance of a well-performed intra-articular procedure\textsuperscript{31}

O’Brien found no difference in clinical stability for those treated with a central third patella tendon intra-articular graft with or without the addition of a lateral extra-articular sling procedure; however 40% of the extra-articular group had chronic pain or swelling associated with the additional procedure\textsuperscript{32}

In a randomized, prospective study, Anderson compared patella tendon, hamstring and hamstring combined with lateral extra-articular procedures, and found no benefit to the addition of the extra-articular reconstruction\textsuperscript{33}

Lerat reported the results for 138 patients at a mean follow-up of 11.7 years\textsuperscript{34}. IKDC functional results were good or excellent in 60%. The pivot shift was negative in 66%, grade 1+ in 30% and grade 2+ in 4%. There were 12 graft failures

Pernin and Neyret reported the long-term outcomes of 100 patients treated by Henri Dejour with a patella tendon intra-articular reconstruction and a modified Lemaire procedure, at a mean follow-up of 24.5 years and with particular respect to the risk factors for the development of osteoarthritis\textsuperscript{35}. 74% reported their outcome to be good or excellent, with IKDC assessment normal or near normal in 46%. The pivot shift was negative in 77%, with 17% having a moderate pivot (2+) and 6% a gross pivot (3+). Radiographically, the percentage of knees without degenerative changes was stable from 11.5 years (41%) to 24.5 years (39%), however, amongst those with degenerative changes the proportion with severe osteoarthritis increased from 10% to 27%. Both medial meniscectomy and medial articular cartilage lesions at the time of surgery were predictive of the development of osteoarthritis, as were increased age at operation and increased delay between injury and surgery. Residual laxity was not found to correlate with the radiological outcome, however, only anterior translation and not rotatory laxity was assessed

Marcacci reported results of his technique at 11 years follow-up in 54 knees in high level sports participants, 90.7% achieved good or excellent IKDC scores, with three knees showing a slight residual pivot shift\textsuperscript{36}. No increase in osteoarthritis was noted for this combined procedure compared to historical controls.

A recent systematic review and meta-analysis by Hewison found a significant reduction in the pivot shift for combined procedures compared to intra-articular reconstruction alone, although this did not translate into improved IKDC scores\textsuperscript{37}. The quality of included studies, however, was poor, with an unclear to high risk of bias for most articles

Currently, a large, multi-centre, prospective randomized trial is underway, comparing intra-articular versus combined intra-and extra-articular reconstruction in a young, high risk population (Getgood et al, ISAKOS Multicentre Grant Award 2013).

**Indications for LET**

**Revision ACLR:** The results for revision ACL reconstruction are generally inferior to those for primary procedures this may also be an indication for extra-articular augmentation

- Trojani reported a multi-centre series of 189 revision procedures, of which 26 included a lateral extra-articular reconstruction\textsuperscript{38}. While the pivot shift was better controlled and there was a trend towards a lower failure rate in the extra-articular group, there was no difference in IKDC scores
Primary ACLR: The results of intra-articular reconstruction are satisfactory for the majority of patients, and as such extra-articular reconstruction should be reserved for those most likely to benefit from the additional intervention
  - This may include those at higher risk of failure, such as younger patients and those returning to pivoting sports
  - A high degree of clinical laxity (grade 2/3 pivot), generalized ligamentous laxity or hyperextension recurvatum
  - Another associated injury that may be an appropriate indication is medial meniscal lesions requiring meniscectomy. Loss of the medial meniscus increases graft forces by up to 50%\textsuperscript{39}, and is associated with reduced IKDC scores and inferior pivot shift control after ACL reconstruction\textsuperscript{40}

Concerns over LET: Is it safe?

- Over constraint
  - One concern regarding extra-articular procedures is that this improved internal rotational control comes at the expense of over-constraint of the lateral compartment. While early studies of isolated procedures would support this, these techniques often called for graft fixation with the knee in maximal external rotation, and this finding was not borne out by Draganich for combined reconstructions\textsuperscript{27}
  - Kittl's recent study demonstrated that graft courses passing deep to the LCL and attaching proximal to the lateral femoral condyle demonstrated near isometric behavior\textsuperscript{41}. Both the MacIntosh and modified Lemaire demonstrated favorable length change behavior

- Osteoarthritis
  - There is no published evidence that lateral extra-articular procedures cause increased lateral compartment osteoarthritis. Zaffagnini, in a randomized trial comparing patella tendon, four strand hamstring and Marcacci's combined technique, noted no differences in radiological outcomes at five years\textsuperscript{42}

Preferred Technique: The Modified Lemaire LET (Figures A-E)

- Following the final tensioning of the ACLR, a modified Lemaire procedure is performed
- A 6 cm curvilinear incision is placed just posterior to the lateral femoral epicondyle
- The posterior border of the ITB is identified and freed of any fascial attachments to the level of Gerdy's tubercle
- An 8 cm long x 1 cm wide strip of ITB is harvested from the posterior half of the ITB, ensuring that the most posterior fibres of the capsuloosseous layer remain intact
- It is left attached distally at Gerdy's tubercle, freed of any deep attachments to vastus lateralis, released proximally and a #1 vicryl whip stitch is placed in the free end of the graft
- The FCL is then identified. Small capsular incisions are made anterior and posterior to the proximal portion of the ligament and Metzenbaum scissors are placed deep to the FCL to bluntly dissect out a tract for graft passage. An attempt is made to remain extracapsular, while ensuring there is no iatrogenic damage to popliteus
- The ITB graft is then passed beneath the FCL from distal to proximal
- The lateral femoral supracondylar area is then cleared of the small fat pad found proximal to the lateral head of gastrocnemius using electrocautery. The attachment site should be identified just anterior and proximal to the lateral gastrocnemius tendon
• The periosteum is cleared using a cob on the metaphyseal flare of the lateral femoral condyle
• Care is taken not to damage ACL femoral fixation as the suspensory loop button is often found close to this location
• The graft is then held taught but not over tensioned, with the knee at 60 degrees flexion and the foot in neutral rotation to avoid lateral compartment over-constraint
• The graft is secured using a small Richards staple and then folded back distally and sutured to itself using the #1 vicryl whip stitch
• The wound is irrigated, hemostasis is confirmed and closure is performed in layers. We do not close the posterior aspect of the ITB at the level of the transverse ligament to avoid over tightening the lateral patellofemoral joint
• Post-operative rehabilitation is the same as for any ACLR and weight bearing and range of motion is performed as tolerated so long as there is no significant meniscal repair
Conclusion

- High grade anterolateral rotatory laxity is NOT an isolated ACL injury
- The Anterolateral Complex Includes the ALL, the ITB and the lateral meniscus
- Lateral extra-articular procedures are effective in controlling internal rotation at the knee, with recent anatomical and biomechanical studies supporting the rationale for their use in specific cases
- In combination with intra-articular reconstruction, these procedures may have a role in specific high risk and revision scenarios; however, further research is needed to better clarify these indications
- Augmentation of a revision ACLR is an appropriate indication for LET where no other residual laxities need to be addressed.

References


