The anterolateral ligament: a closed chapter?

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The work by Thein *et al.* (1) assessed the biomechanical behavior of the anterolateral ligament (ALL). The interest in the extra-articular structure relies on the anterolateral rotatory instability of the knee, i.e., the complex rotational and translational instability of the tibiofemoral joint, that is caused by combined sagittal plane linear laxity (anterior translation) with an axial rotatory abnormality (internal rotation) after rupture of the anterior cruciate ligament (ACL) (2). The instability that the patient perceives after ACL rupture is clinically elicited by the pivot-shift test. It has been estimated that up to 25% of the ACL reconstructed patients have residual pivot shift (3) revealing the inability of current ACL reconstructive techniques to restore normal knee kinematics. To improve the results of current intra-articular ACL reconstruction and obtain better kinematic restoration of function it has been proposed that extra-articular structures that contribute to the pivot-shift phenomenon must be addressed (4).

Overall, the methods of the study were performed well. Twelve cadaveric knees were used in the study and three different stability tests were performed: a simulated pivot-shift examination, simulated Lachman test and simulated anterior drawer examination. The sequence of stability tests was performed under three different knee states in the following order: ACL intact knee, ACL-sectioned and ACL + ALL sectioned. The *in situ* loads borne by the ACL and the ALL in the ACL-intact knee and borne by the ALL in the ACL-sectioned knee were determined by the principle of superposition. Prior to determination of the intact knee state, a medial arthrotomy was performed to evaluate the joint for degeneration, ligament damage and previous surgery. A point of critique is that when evaluating *in situ* forces, the knee in its intact state should be determined first. An arthroscopic evaluation and sectioning of the ACL using a small portal would have significantly reduced anatomic changes to the knee joint and preserved the integrity of the knee joint. In addition, no clear description was provided in Thein's work on the precise location of the ALL in their knees.

It was found that sectioning the ALL in the ACL-sectioned knee led to significantly increased anterior translation in both anterior stability and pivot-shift tests, and significantly increased internal tibial rotation during the simulated pivot-shift test. The load born by the ALL in the ACL-intact knee was minimal in response to the simulated pivot-shift and the anterior loads. In the ACL-sectioned knee the load borne by the ALL increased with nearly 5 to 6 folds in response to isolated anterior loads and more than 3 folds in response to the simulated pivot-shift. This finding might cause some to conclude that the ALL is indeed the crucial stabilizing ligament of the knee as it was postulated to be in earlier studies (5). Interestingly though, the increased loads carried by the ALL in the ACL-sectioned knee were only seen at the extremes of tibial translations. The ALL failed to contribute until the tibia has displaced beyond normal boundaries that are present with an intact ACL. The authors concluded that the ALL is a secondary stabilizer of the knee with minimal function in the ACL intact knee. The ALL resisted both anterior tibial translation and axial tibial rotation but only beyond physiologic ranges of the ACL-intact knee, therefore they suggest that in a well-functioning ACL-reconstructed knee, ALL reconstruction appears to be limited.

The last several years, a vast amount of research has been dedicated to the small structure at the anterolateral aspect of the knee. Where the ALL was first (re-)introduced as a key component of knee stability in which an ALL reconstruction might solve many—if not all—issues seen in contemporary ACL reconstruction, enthusiasm has steadily diminished with each subsequent study. The present study by Thein *et al*. further sustains this trend.

Since the publication by Claes *et al*. in 2013 (5), several dissection studies have repeated the measurements of the ALL anatomy. With hundreds of cadavers now dissected, researchers continue to disagree on the exact attachment sites of the ALL, its histology, and its relationship with the surrounding layers. Some question whether the ALL exists at all. The presence of the ALL in dissection studies has ranged from 0% to 100% (6,7). Where Claes *et al*. (5,7) was able to easily identify the macroscopic ALL, describing a 'well-defined ligamentous structure, clearly distinguishable from the anterolateral joint capsule', others (6) could not find the well-defined lateral capsular structure in any of the specimen. Some studies have found supporting evidence that the ALL constitutes histological ligamenteous properties (8-10), whereas a more combined constitution of capsular and ligamenteous properties was found in the study by Dombrowski *et al*. (6). The femoral attachment site of the ALL has shown high variability, anatomic descriptions vary from anterior-distal (10), anterior-proximal (8), to the center of (5) and posterior-proximal (11,12) to the femoral fibular collateral ligament (FCL).

It comes to no surprise that since the anatomy of the ALL is still at debate, the biomechanical role of the ALL in knee stability remains similarly unclear. Most recent *in vitro* and *in vivo* reports agree that the ALL is likely a non-isometric structure that increases in length with increasing flexion angles (13-16). Length increases of the ALL between full-extension to 90° of knee flexion have ranged from approximately 12% to 50% depending on the study set-up.

Conflicting results have been reported on the contribution of the ALL as a secondary restraint for internal rotation. Some authors concluded that the ALL is an important structure in providing rotational stability (17,18). However, Thein *et al*. (1) here described a much less profound role of the ALL (1), which is in line with the study by Saiegh *et al*. (19) in which no increased laxity of the knee after cutting the ALL in an ACL-sectioned knee state was seen (19).

In the study by Nitri *et al*. (20) it was found that in the face of a combined ACL and ALL sectioned knee state, concurrent ACL and ALL reconstruction significantly improved the rotatory stability of the knee compared with solely reconstructing the ACL. In a subsequent study from the same research group however, Schon *et al*. (21) tried to find the optimal knee flexion angle for fixation of the anatomic ALL reconstruction that would most accurately restore native knee kinematics without overconstraining the knee. In agreement with the observations of the ALL length changes, showing non-isometric behavior with increased length at increased knee flexion angles; their data demonstrated that anatomic ALL reconstruction overconstrained the knee joint at each tested ALL graft fixation angle and through all tested knee flexion angles beyond 15° of flexion (21). This suggests that the combined ACL and anatomic ALL reconstruction may be inappropriate and unsafe to restore knee kinematics. In our recent *in vivo* analysis of the ALL, we found that of all the possible lateral extra-articular reconstructions, the anatomic ALL reconstruction as described by Claes *et al*. on the industry website following their cadaveric study might be the least biomechanically favorable option.

Probably one of the positive aspects of the renewed interest in the ALL is that the traditional non-anatomic extra-articular reconstructions are seeing a revival in biomechanics studies as well. These extra-articular reconstructions had fallen out of favor with the rise of intra-articular ACL reconstruction. Since researchers started measuring the biomechanics of the ALL and its reconstruction, it was not more than logical to include these traditional non-anatomic reconstructions in the same study design. In brief, whenever the anatomic ALL reconstruction was judged against any of the traditional non-anatomic reconstructions, the later resulted in with more favorable biomechanics (16,22,23).

In summary, the ALL remains a subject of controversy in its presence, anatomy and function. The current study is a further corroboration of the growing trend in the literature which suggests that the ALL is unable to address the pivot-shift phenomenon and therefore is unsuitable for reconstructive purposes. Improved understanding of the complex anatomy of the extra-articular structures of the knee and its biomechanics may help the development of a reconstructive technique that is able to augment the intra-articular ACL reconstruction. This may be a next step in improving the restoration of knee kinematics.

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Footnote

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