Is the anterolateral ligament the smoking gun to explain rotational knee laxity or just vaporware?

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Since the publication of the 'discovery' of a new knee ligament in 2013, coined as anterolateral ligament (ALL),[1] the scientific research into this 'new' anatomical structure has grown exponentially in the past years. The *Journal of ISAKOS* (JISAKOS) publishes in this issue three studies on the anatomy of the anterolateral capsule (ALC) of the knee[2] and the biomechanics of the combined reconstruction of the anterior cruciate ligament (ACL) and the ALL.[3 4]

The history of the ALL takes us more than one century back to Segond's works,[5–7] as well as to some other reports (earlier than 2013) of this structure.[8–10] Despite much controversy and conflicting findings on the macroscopic anatomical, histological and MRI of the ALL,[11–22] a consensus paper by international knee experts has characterised the ALL as a structure within layer 3 of the ALC.[23] Nonetheless, if the ALL is really a distinct ligament structure or a thickening of the ALC remains open for debate. To better understand the phenotype of the ALC, Iseki *et al*[2] evaluated the histology, immunohistochemistry and genetic expression of the ALC from paediatric specimens to investigate if there are any ligament-like characteristics. They found no discernible histological and immunohistochemical characteristics consistent with a ligament phenotype and that the ligament genetic markers (scleraxis and tenomodulin) were largely absent and poorly expressed in the ALC. Their methodology still needs to be replicated in adult specimens, but their findings suggest that the ALC does not display ligament-like characteristics and do not support the belief that there is a distinct ligament at the ALC.

In a recent systematic review of MRI studies,[20] high variability was found in the identification of the ALL, which appeared in 51%–100% of all assessed knees (with a very high intraobserver and interobserver reliability rates), and the entire portion of the ligament was often not seen. These findings suggest that the ALL may not really exist as a distinct ligament, which goes in line with several other publications.[15–19] Being the case that the ALL was not a defined ligament, performing an anterolateral ligament reconstruction (ALLR) does not recreate the native anatomy of the knee, but should rather be considered as a lateral non-anatomical augmentation procedure.[2]

Lateral extra-articular tenodesis (LEAT) is being performed since the 1980s but has recently gained renewed interest. Lateral augmentation procedures—either LEAT or ALLR—are performed in the ACL-deficient knee in patients with high-risk profile of reinjury and aim to better control the knee internal rotation and decrease the risk of graft tear. The ALL strength varies between 49.9 N[24] and 204.8 N,[25] which is lower compared with the strength of the iliotibial band (487.9 N),[26] ALC (319.7 N)[26] or the distal iliotibial tract (769 N).[27] The strength of the iliotibial band (as compared with the ALL) suggests that this structure would be more fitted to withstand the high rotational torques. Indeed, adding a LEAT significantly decreases the forces at the ACL graft,[28 29] but an ALLR produces only a modest decrease.[30] The role of ALLR is still not well established and is currently not being broadly used in daily clinical practice, and thus, the biomechanical studies are still an important step to investigate the effect of adding an ALLR on the knee stability and contact pressures.

Two of the studies published in this JISAKOS issue explore the biomechanics of anterolateral augmentation procedures in the setting of an ACL-deficient knee.[3 4] Neri *et al*[3] performed a cadaveric biomechanical study comparing ACL reconstruction isolated and combined with five different anterolateral augmentation procedures—ALLR and modified versions of Ellison, deep Lemaire, superficial Lemaire and MacIntosh LEAT procedures. They found that in the setting of an anterolateral-deficient knee, only the ALLR and Ellison procedures restored internal rotation laxity to the native intact state over the full range of knee flexion. The deep and superficial Lemaire and MacIntosh, although better controlling internal rotation, overconstrained the knee. The same group[4] performed a pilot biomechanical study on the tibiofemoral lateral compartment contact pressures after ACL reconstruction combined with the same five anterolateral procedures described in Neri and colleagues.[3] They found that the ACL reconstruction combined with ALLR or with the Ellison procedure did not change the contact pressures, while the Lemaire (either deep or superficial) and MacIntosh procedures increased the contact pressure during tibial internal rotation. However, this study only includes four specimens which highly increases the risk of type II error,and this should be taken into account when interpreting their findings. In opposition to their findings, conflicting evidence[31] has shown no significant increase in the tibiofemoral compartment after ACL reconstruction with LEAT and, despite that the findings from Neri *et al*[4] that suggest an increased risk of knee overconstrain and subsequent risk of cartilage wear after ACL reconstruction with

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Lemaire and MacIntosh procedures, long-term clinical studies have shown no increase in the rate of knee osteoarthritis when a LEAT is added to the ACL reconstruction.[32] Other biomechanical studies have reported opposite results when comparing traditional LEAT techniques and ALLR.[33 34] Inderhaug *et al*[33] showed that while deep Lemaire and MacIntosh procedures restored native rotational kinematics, the ALLR failed to restore normal internal rotation and underconstrained the knee. Trentacosta *et al*[34] also showed that the LEAT technique using the iliotibial band better restored the intact kinematics as compared with ALLR. Other studies[35–37] have found comparable biomechanical outcomes between the two techniques and with no advantage of one over the other. Among other confounders, the results may vary between studies due to techniques employed and fixation angle and fixation site, as it has been shown that these can highly influence residual laxity after ALLR.[38 39] Results from the pool of biomechanical studies discussed earlier suggest that anterolateral procedures using the LEAT seem to be superior in controlling rotational laxity due to ACL insufficiency,[33 34] but no definitive conclusion still cannot be achieved due to some conflicting findings.[35–37]

The addition of lateral augmentation procedures—either LEAT or ALLR—to ACL reconstruction remains one of the most controversial topics in ACL research, but their role in controlling high rotational laxity and protecting the graft in patients with high-risk profile has gained increasing support. Indeed, the Stability study[40] has shown that adding a LEAT to an anatomical ACL reconstruction reduces the risk of clinical failure by 38% and graft rupture by 67% as compared with ACL reconstruction alone. In line with the renewed interest in LEAT, clinical studies[41–44] have reported the results of combined ACL and ALLR, suggesting superior outcomes when compared with ACL reconstruction alone. In patients displaying high-grade pivot-shift, the addition of LEAT[45 46] or ALLR[47 48] seem to result in significant improvement in controlling rotational laxity. However, in patients where concomitant high-grade ALL injury is present, Ahn *et al*[49] have showed that there may be an increased risk of residual rotational laxity, even when an ALLR is performed; however, these results should be viewed with caution as there are some limitations associated with unbalanced groups in the sample size and the poor capability of MRI to discriminate the grade of ALL injuries.[20 50] In a similar fashion, when the LEAT or ALLR augmentation procedures are performed during ACL reconstruction revision cases, the addition of these augmentation procedures shows similar clinical and functional outcomes when comparing to isolated ACL revision, but displays a better control of rotational laxity.[47 51–53] Although both procedures seem to play a meaningful clinical role as an augmentation in primary and revision ACL reconstructions, the role of the ALL in restoring the knee native kinematics is still controversial, with some studies demonstrating no significant contribution of the ALL in controlling tibial internal rotation.[54–56] More importantly, we still do not know which technique will yield better clinical outcomes and a greater reduction of the risk of graft tear. Future research should focus on high-powered and high-quality randomised controlled trials comparing ACL reconstruction combined with either LEAT or ALLR with systematic approaches (surgical indications, graft selection, surgical technique, graft positioning and fixation) to investigate if there is any superiority of any of these techniques in clinical improvement, laxity restoration and risk of graft tear. Future clinical trials comparing both techniques and with long-term follow-up should shed light on the effect of the potential risk of overconstraining the knee in the incidence of knee osteoarthritis.

Only time will tell if the ALL will be the smoking gun to explain rotational knee laxity or if it will be just another vaporware.

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