How does the addition of a lateral extra-articular tenodesis alter the load-sharing within the knee after anterior cruciate ligament reconstruction?

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INTRODUCTION: There is debate about whether a lateral extra-articular tenodesis (LET) should be added during anterior cruciate ligament reconstruction (ACLR) in high-risk individuals.[1] Prior studies have shown the addition of an LET during ACLR leads to load sharing between the LET and ACL grafts,[3,4,5] which may be a key reason for reportedly high graft survival and good patient reported outcomes following ACLR with an LET.[2] However, these studies vary widely in key surgical parameters: (1) location of the femur anchor of the LET graft, and (2) knee flexion angle at time of graft tensioning. Therefore, it is critical to understand how these surgical parameters could alter the load sharing between the ACL graft, LET graft, and the menisci. Accordingly, ***our objective*** was to determine how the addition of an LET graft alters load sharing between key knee structures across a range of femoral anchor locations of the LET graft and flexion angles for graft tensioning.

METHODS: We generated a virtual cohort of 1000 models that accounted for the wide range of laxity patterns across the population. To create this cohort, we randomly sampled the linear stiffness and slack length of all ligaments of a validated 12-degree-of-freedom, musculoskeletal model of the knee[6] (***Fig. 1a***). We assumed the ACL in the model represented an ACL graft. To replicate an LET procedure, we created an additional graft strand with the same properties as the iliotibial (IT) band. This graft maintained its distal insertion point of the IT band at Gerdy's tubercle and was wrapped underneath the LCL. To account for differing surgical parameters, we tensioned the LET graft to 20 N at 30°, 45°, and 90° for each model. We also varied the femoral anchor location of the graft ±15 mm in both the anterior-posterior and superior-inferior directions from the baseline anchor location on the postero-lateral aspect of the femur. We then performed forward dynamic simulations in OpenSim-JAM of anterior (100 N) and internal rotation (10 Nm) laxity assessments at 30° flexion. We computed (1) the percent contribution of the LET and ACL graft tensions to restraining against the applied load for both laxity tests, and (2) the change in peak contact forces on the posterior lateral meniscus between the ACLR + LET and ACLR conditions. We analyzed these values using descriptive statistics (i.e., mean and standard deviation) instead of traditional statistical hypothesis tests because of the large sample size of this computational study.

RESULTS SECTION: The addition of the LET graft generally off-loaded the ACL graft tension during anterior laxity assessments (across all combinations of surgical parameters: mean ± standard deviation = -21.0 ± 10.2 %, ***Fig. 1c***). The greatest reduction in ACL graft tension occurred when the LET graft was tensioned at 90° flexion (-27.4 ± 14.4 %, ***Fig. 1c***). During the internal rotation laxity assessments, the percent contribution of the LET graft was highest when it was tensioned at 30° (49.7 ± 9.2 %, ***Fig. 1d***). The presence of the LET graft also off-loaded the posterior aspect of the lateral meniscus for both anterior and internal rotation laxity assessments (-12.79 ± 4.95 N and -17.96 ± 7.27 N respectively, ***Fig. 1e,f***). The offload of the lateral meniscus was greatest when the graft was tensioned at 90° and most consistent when the graft was placed in quadrants 2 and 3 (***Fig. 1e,f***). In general, there were limited effects of graft fixation location in terms of percent contribution of the ACL and LET during the anterior laxity assessments. However, LET contributions were sensitive to femoral anchor location during the internal rotation laxity assessments. When the LET graft was tensioned at 90° of flexion, the lowest (21.4 ± 8.9 %) and highest (46.4 ± 7.6 %) LET contributions occurred when the femoral anchor location was in quadrant 2 (superior-posterior) and quadrant 1 (superior-anterior), respectively (***Fig. 1d***).

DISCUSSION: Our key finding was that decisions about surgical parameters of an LET can greatly change the load sharing within the knee. From our data, load sharing is optimized to off-load the ACL graft when the LET graft is tensioned at 90° flexion. The posterior lateral meniscus is also most off-loaded when the LET graft is tensioned at 90° flexion, but this effect becomes variable when the graft is anchored in quadrant 1 or 4. While the LET is able to best off-load the ACL and posterior lateral meniscus when tensioned at 90° flexion, the percent contribution was lowest when placed in quadrant 2 (superior-posterior). As a result, it is necessary for surgeons to consider patient-specific characteristics when deciding at which angle to tension the LET graft and where to anchor it to the distal femur. Additionally, the effects of the LET on load sharing varies widely within our cohort which suggests that consideration for the other secondary restraints is important when personalizing an ACLR + LET for a particular patient.

SIGNIFICANCE/CLINICAL RELEVANCE: These findings highlight that load sharing within the knee is highly sensitive to modifiable surgical decisions during an ACLR + LET procedure. Thus, personalizing these decisions may further improve outcomes after ACLR+LET in high-risk patients.

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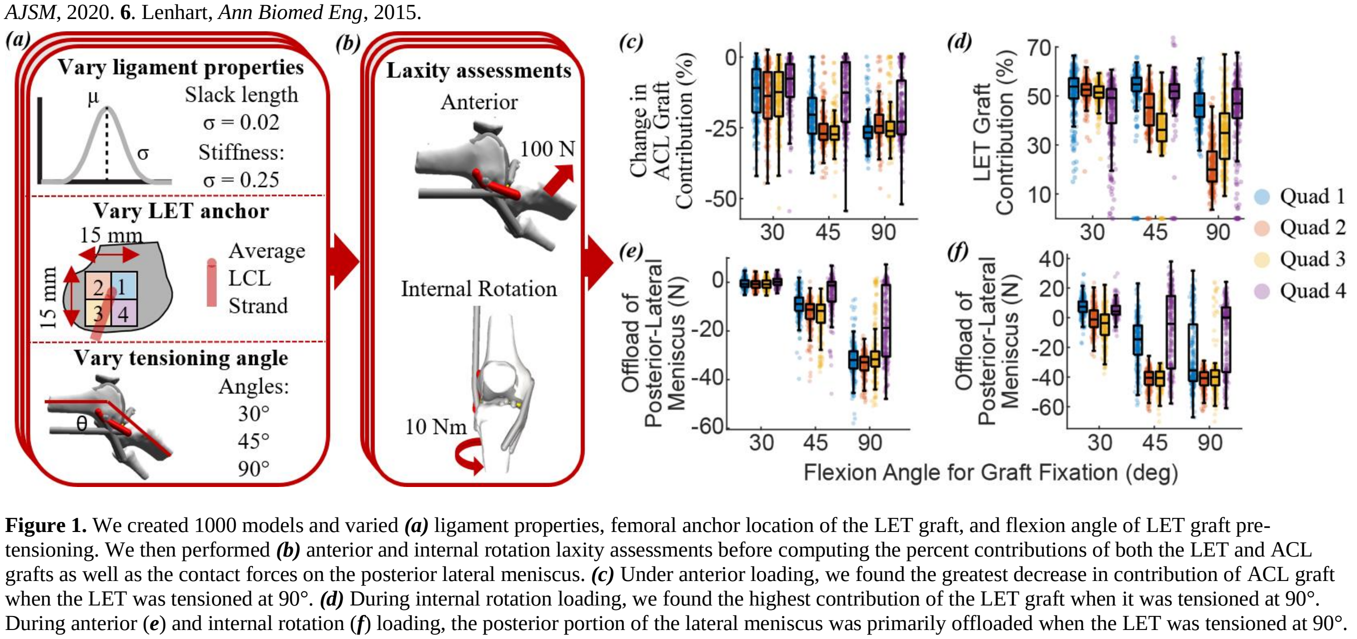

Figure 1. We created 1000 models and varied ***(a)*** ligament properties, femoral anchor location of the LET graft, and flexion angle of LET graft pre-tensioning. We then performed ***(b)*** anterior and internal rotation laxity assessments before computing the percent contributions of both the LET and ACL grafts as well as the contact forces on the posterior lateral meniscus. ***(c)*** Under anterior loading, we found the greatest decrease in contribution of ACL graft when the LET was tensioned at 90°. ***(d)*** During internal rotation loading, we found the highest contribution of the LET graft when it was tensioned at 90°. During anterior (***e***) and internal rotation (***f***) loading, the posterior portion of the lateral meniscus was primarily offloaded when the LET was tensioned at 90°.