Lateral Extra-Articular Tenodesis is Associated with Improved Anterior Cruciate Ligament Graft Signal on MRI Two Years following ACL Reconstruction with Quadriceps Tendon Autograft in Skeletally Immature Athletes

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INTRODUCTION: The addition of lateral extra-articular tenodesis (LET) to an ACL reconstruction (ACLR) has been found to reduce the risk of ACL retear in high-risk patients. The primary aim of this study was to evaluate ACL graft maturity using signal intensity ratios (SIR) on magnetic resonance imaging (MRI) at six months, one year, and two years postoperatively in skeletally immature patients undergoing ACLR with quadriceps tendon autograft (QTA) either with or without concomitant LET. The secondary aim was to evaluate the safety of LET by calculating the physeal disturbance-related reoperation rate in the ACLR+LET group. We hypothesized that the addition of LET to an ACLR would be associated with improved graft maturity (lower average SIR values) across all timepoints compared to patients without LET. In addition, we hypothesized that there would not be any instances of physeal disturbance-related reoperations in patients who underwent ACLR+LET.

METHODS: Records of all patients ≤18 years old who underwent an ACLR with QTA between 2015 and 2021 were retrospectively reviewed. Patients undergoing primary ACLR with open distal femoral and proximal tibial physes were included if they had MRI ordered for physeal monitoring at minimum two years postoperatively. Patients were excluded if they had evidence of a posterior cruciate ligament (PCL) injury on MRI, were undergoing revision ACLR, or if the knee MRI was obtained for a new injury. To measure SIR, the single sagittal slice, which demonstrated the majority of the intra-articular ACL graft and the insertion of the PCL onto the tibia, was chosen, and three circular regions of interest (ROI) were chosen on the intra-articular graft (proximal, middle, and distal). An additional ROI was chosen at the PCL insertion as the PCL signal intensity (SI). The average value of the three ROIs from the intra-articular graft was recorded as the ACL graft SI. The SIR was then calculated from the following previously described formula: SIR=(ACL Graft SI)/(PCL SI). Physeal disturbance-related reoperation information was obtained via chart review. Statistical analysis was performed to evaluate differences in SIR values at each timepoint. Statistical significance was evaluated at the $\alpha < 0.05$ level.

RESULTS: Seventy-three patients were identified, and following application of exclusion criteria, 29 patients (39.7%) who underwent ACLR with QTA with or without concomitant LET remained for analysis. Sixteen patients (55.2%) underwent ACLR with LET, and 13 patients (44.8%) underwent ACLR only (no LET). For the entire cohort, the average age was 13.57 years, 41.4% were female, and 58.6% underwent transphyseal ACLR. The average follow up was 3.3 ± 1.0 years. Six months postoperatively, there was no statistically significant difference in SIR values between the two groups ($p = 0.57$). Similarly, at one-year postoperative, there were no differences in SIR values between the two groups ($p = 0.47$), although SIR values tended to be higher in the ACLR-only group (mean SIR = 2.19 ± 0.51) compared to the ACLR+LET group (mean SIR = 2.03 ± 0.45). Two years postoperatively, the median SIR was lower in the ACLR+LET group (median SIR = 1.33, interquartile range: 1.14 – 1.56) compared to the ACLR-only group (median SIR = 1.86, interquartile range: 1.68 – 2.09, $p = 0.0012$). Following multivariate regression analysis, presence of LET was associated with lower SIR values (β coefficient: -0.49, 95% confidence interval: -0.91, -0.05, $p = 0.029$) after controlling for surgical technique (β coefficient: -0.28, 95% confidence interval: -0.70, 0.15, $p = 0.19$) and sex (β coefficient: -0.10, 95% confidence interval: -0.51, 0.32, $p = 0.63$). All patients returned to sports at most recent follow up. Eleven patients (37.9%) underwent reoperation, and the average time to reoperation was 2.47 ± 0.85 years for the entire cohort. One patient in the ACLR-only group sustained an ACL retear and underwent revision ACLR+LET at 5.2 years postoperative. Four patients in the entire cohort sustained a contralateral ACL tear for which they underwent ACLR+LET. There were no differences with regard to reoperation rate and time to reoperation between the two groups ($p = 0.47$, $p = 0.40$, respectively). No patients in the ACLR+LET group underwent distal femoral epiphysiodesis or hemi-epiphysiodesis. One patient in the ACLR-only group developed a physeal bar in the posterolateral femoral physis for which they underwent a distal femur varus/extension osteotomy at 2.5 years postoperatively.

DISCUSSION AND CONCLUSION: We found that LET is associated with improved graft maturity two years following ACLR with QTA in skeletally immature patients after controlling for both surgical technique and sex. Although there was no statistically significant difference between groups at 6 months and 1 year postoperatively, SIR values tended to be lower in the ACLR+LET group compared to the ACLR-only group at both timepoints. We speculate that improved graft maturity on MRI with the addition of LET to an ACLR may be due to the protective effect of the LET on the ACL graft. It is important for surgeons to understand the timing and processes underlying ACL graft maturation so that patients can progress through the postoperative rehabilitation process and return to sports at the appropriate time without placing undue risk on the healing graft and potentially compromising graft integrity.

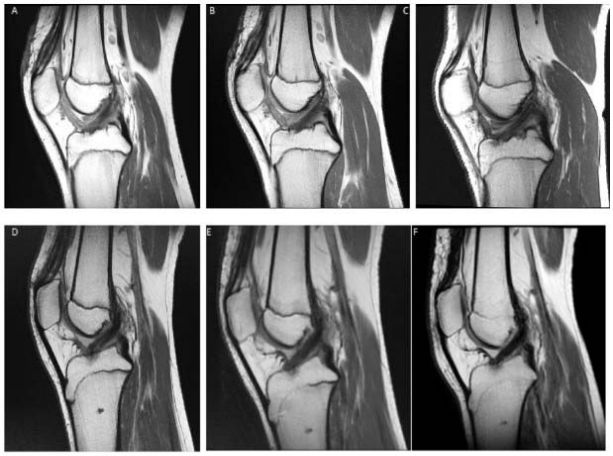

Figure 1. Example of sagittal MRI images at 6-months, 1-year, and 2-years postoperatively in a patient who underwent ACLR-only (A through C) and ACLR+LET (D through F).

	All Patients (n = 29)	ACLR+LET (n = 16)	ACLR-Only (n = 13)	P-value
Age at Surgery (years)	13.57 ± 1.12	13.82 ± 1.11	13.27 ± 1.10	0.19
Sex				
Female	12 (41.4%)	10 (62.5%)	2 (15.4%)	**0.022***
Male	17 (58.6%)	6 (37.5%)	11 (84.6%)	
BMI (kg/m²)	21.0 ± 3.2	20.2 ± 3.4	22.1 ± 2.7	0.11
Race				
White	20 (69)	13 (81)	7 (54)	0.12
Asian	1 (4)	0 (0)	1 (8)	
Unknown/Declined	3 (10)	0 (0)	3 (23)	
Other	5 (17)	3 (19)	2 (15)	
Ethnicity				
Hispanic/Latino	5 (17)	2 (12.5)	3 (23)	0.72
Not Hispanic/Latino	21 (73)	12 (75)	9 (69)	
Unknown/Declined	3 (10)	2 (12.5)	1 (8)	
Laterality				
Left	18 (62.1%)	9 (56.2%)	9 (69.2%)	0.70
Right	11 (37.9%)	7 (43.8%)	4 (30.8%)	
Technique				
All-epiphyseal	12 (41.4%)	3 (18.7%)	9 (69.2%)	**0.010***
Transphyseal	17 (58.6%)	13 (81.3%)	4 (30.8%)	
Concomitant Procedures				
Medial Meniscus Repair	10 (34.5%)	6 (37.5%)	4 (30.8%)	1.0
Lateral Meniscus Repair	14 (48.3%)	10 (62.5%)	4 (30.8%)	0.14
Partial Lateral Meniscectomy	2 (6.9)	1 (6.3%)	1 (7.7%)	1.0
Follow Up (years)	3.3 ± 1.0	3.0 ± 1.1	3.6 ± 0.8	0.12

Table 1. Demographic information for patients included in the study. ACLR: anterior cruciate ligament reconstruction, LET: lateral extra-articular tenodesis, BMI: body mass index. *Statistical significance at $p < 0.05$ level.