

# Quantitative Assessment of Graft Maturation After Anterior Cruciate Ligament Reconstruction Using Quadriceps Tendon: Insights from Ultra Short Echo Time T2\* Mapping

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## INTRODUCTION:

Graft tendon ligamentization after anterior cruciate ligament (ACL) reconstruction is believed to mature through three phases: early healing, remodeling, and maturation phases. Although methods such as the signal-to-noise quotient (SNQ) on magnetic resonance imaging (MRI) have been used to assess ligamentization, their accuracy and quantification are debated. Conversely, MRI ultrashort echo time (UTE) T2\* mapping is a highly accurate technique for quantifying the status of tendon and ligament tissues. It has been reported as useful for evaluating ligamentization, as a higher collagen content and organized tissue correspond to lower T2\* values. Recently, the quadriceps tendon (QT) has gained attention as a graft material for ACL reconstruction. The clinical outcomes were comparable to those of hamstring and patellar tendon grafts with an increasing number of cases. However, no study has evaluated the ligamentization process of the reconstructed ACL using a QT graft. This study aimed to prospectively observe the trends in UTE T2\* values for the intra-articular and intraosseous regions of the reconstructed ACL from 6 to 12 months after ACL reconstruction using MRI-UTE T2\* mapping and to assess the ligamentization process of the reconstructed ACL with a QT graft.

## METHODS:

We identified 10 patients (6 males, 4 females; mean age  $18.8 \pm 11.6$  years) who underwent primary ACL reconstruction using QT between June 2022 and May 2023. These patients were examined for up to at least 12 months postoperatively and underwent MRI examinations at 6, 9, and 12 months after surgery. The ACL reconstruction was performed by a single orthopedic surgeon. The QT was harvested without bone at a thickness of 6 mm, width of 10mm and length of 50–55 mm, and a single-bundle graft tendon was created. All patients underwent postoperative rehabilitation using a standardized program. UTE T2\* mapping images were obtained using a 1.5-T MRI scanner. A 5–10 mm<sup>2</sup> region of interest, free from artifacts was selected (Figure 1). Measurements were taken three times at three sites in the intra-articular region of the reconstructed ACL based on the method reported by Okuda et al. (proximal, middle, and distal), and one site each was measured in the intraosseous region of the tibia and femur. The average value was defined as the UTE T2\* value for each region. A repeated measures two-way analysis of variance was performed, with postoperative time (6, 9, and 12 months) as the within-subject factor and measurement location (intra-articular and intra-osseous regions) as the between-subject factor. Main effects and interaction effects were tested for significance, with a significance level set at  $p < 0.05$ . If a significant main effect was found, post-hoc tests with Bonferroni correction were performed for pairwise comparisons.

## RESULTS:

At 6 months postoperatively, the UTE T2\* values (ms) were  $12.8 \pm 1.2$  in the intra-articular region,  $8.1 \pm 0.7$  in the tibial intraosseous region, and  $7.4 \pm 0.8$  in the femoral intraosseous region. At 9 months, the values were  $10.8 \pm 0.8$ ,  $7.9 \pm 0.8$ , and  $7.2 \pm 0.9$ , respectively. By 12 months, they had decreased to  $10.2 \pm 1.1$ ,  $7.0 \pm 0.6$ , and  $7.0 \pm 0.8$ , respectively.

UTE T2\* values showed significant changes over time and across measurement sites (Figure 2). A significant main effect of time was observed, with values decreasing progressively from 6 to 12 months ( $p < 0.01$ ). Regionally, intra-articular values were significantly higher than those in the intraosseous regions of the tibia and femur ( $p < 0.01$ ), with no significant difference between the tibial and femoral sites. A significant interaction effect between time and region was also observed. Intra-articular UTE T2\* values peaked at 6 months and declined significantly thereafter, whereas the values in the intraosseous regions remained relatively stable over time. Compared to the native ACL, the graft showed significantly higher UTE T2\* values at 6 months ( $12.8 \pm 1.2$  vs.  $11.9 \pm 2.4$ ,  $p = 0.04$ ) and significantly lower values at 9 months ( $10.8 \pm 0.8$  vs.  $11.9 \pm 2.4$ ,  $p < 0.05$ ).

## DISCUSSION AND CONCLUSION:

MRI-UTE T2\* mapping proved effective in assessing the ligamentization process of ACL grafts reconstructed with the quadriceps tendon. Intra-articular UTE T2\* values decreased significantly from 6 to 12 months postoperatively, reflecting progressive graft maturation. At 6 months, the graft was still undergoing maturation; however, by 9 months, the values had reached levels comparable to the native ACL, indicating substantial ligamentization of the graft.

Figure 1: Measurement of UTE T2\* values

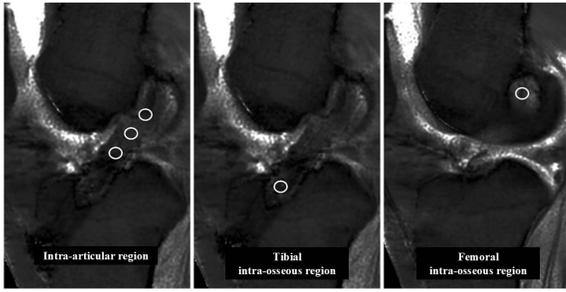


Figure 2: Boxplot of changes in UTE T2\* values for the intraarticular and intraosseous regions of reconstructed ACLs between 6 to 12 months

