Quantifying Patellar Tendon Microstructure Using Diffusion Tensor Imaging (DTI) After Bone-Patellar Tendon-Bone (BPTB) Autograft Harvest for Anterior Cruciate Ligament Reconstruction (ACLR)

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INTRODUCTION: The bone-patellar tendon-bone (BPTB) autograft is commonly used for anterior cruciate ligament reconstruction (ACLR). This graft, however, is associated with graft site morbidities such as patellar tendon pain and persistent knee extensor weakness impacting recovery [1]. Healing of the graft site tendon's macrostructure has been documented [2] and is related with knee extensor strength [3], reflecting the importance of structural recovery for better clinical outcomes. Macrostructural adaptations in tendons, however, are slow, and hence, acute response to intervention targeting the graft site tendon may not be accurately captured. Studying the underlying tendon microstructure may better detect acute response to interventions, but traditional methods to quantify tendon microstructure requires invasive procedures such as biopsies. Diffusion tensor imaging (DTI) is a non-invasive, magnetic resonance imaging (MRI)-based method for quantifying tissue microstructure in-vivo with the potential to advance our knowledge on patellar tendon recovery after autograft harvest [4]. The purpose of this study was to quantify patellar tendon microstructure using DTI after BPTB autograft harvest for ACLR.

METHODS: We descriptively analyzed patellar tendon DTI scalar metrics in four participants after unilateral ACLR using BPTB autograft. Demographics, International Knee Documentation Committee scores, and maximum voluntary isometric knee extension strength are reported in **Table 1**. Images were obtained on a 3T SIGNA Premier MRI (GE HealthCare) with an 18 channel T / R knee coil. 3D CUBE proton density weighted images were acquired for anatomical reference ($0.5 \times 0.5 \times 0.66$ mm^3 resolution, TR / TE = 1000 / 33.1 ms, ETL = 41). Diffusion weighted imaging, a technique which sensitizes MR signal to random Brownian motion of water in tissue, was acquired to assess tendon microstructure (Axial oblique orientation, aligned with the tendon, $1.5 \times 1.5 \times 3$ mm^3 resolution, b = 800 s/mm^2, 30 directions, 2 NEX). Scans were repeated with reversed phase encoding and processed with FSL TOPUP and EDDY (FMRIB Software Library) to correct for susceptibility and eddy-current induced image distortions. Diffusion tensor fitting was performed with FSL's diffusion toolbox, and scalar maps were generated for FA (fractional anisotropy), MD (mean diffusivity), $\lambda 1$ (axial diffusivity), $\lambda 2$, and $\lambda 3$ (**Figure 1**).

RESULTS: In all four participants after ACLR using BPTB autograft, diffusivity in all principal axes ($\lambda 1$, $\lambda 2$, $\lambda 3$, and MD) were higher in the involved compared to the uninvolved limb (**Figure 2**). In contrast, FA was lower in the involved versus uninvolved patellar tendon. Participant D, who was furthest out from surgery and had the most symmetrical knee extensor strength, had the most symmetrical measure for all DTI scalar metrics assessed (**Table 1**).

DISCUSSION: DTI scalar metrics captured the expected tendon microstructural characteristic (poor tissue organization as reflected by low FA) in the graft site tendon where tendon healing secondary to graft harvest takes place. The overall higher diffusivity may be due to loosely packed collagen fibers and greater spacing within the extracellular matrix of the healing tendon, allowing for better flow of water molecules compared to healthy tendons which have tightly packed collagen fibers with minimal extracellular matrix spacing. Further segmenting the BPTB graft site tendon in reference to the region of graft harvest [2] will be performed in the future to continue expanding our knowledge on graft site tendon healing at the microstructural level using DTI.

SIGNIFICANCE/CLINICAL RELEVANCE: DTI should be further explored as a non-invasive tool to quantify tendon microstructure in patients after ACLR using BPTB autograft to characterize graft site tendon recovery. Relevance of DTI metrics in relation to clinical outcomes will also be established.

REFERENCES: [1] Smith et al., 2020, *JOSPT*; [2] Ito et al., 2024, *JOR;* [3] Ito et al., 2023, *KSSTA;* [4] Wengler et al., 2020, *JMRI*

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IMAGES AND TABLES:

Table 1

Participant	Sex	Age (years)	Height (m)	Weight (kg)	Time since surgery (months)	International Knee Documentation Committee (IKDC)	Maximum Voluntary Isometric Knee Extension Test at 60°		
							Involved (Nm)	Uninvolved (Nm)	Quadriceps Strength Index (%)
A	Male	20	1.90	94.0	7.6	83	206	399	51.6
B	Female	24	1.64	67.9	13.8	70	149	228	65.4
C	Female	25	1.59	62.4	14.9	93	210	235	89.4
D	Male	23	1.78	61.1	23.4	84	241	233	103.4

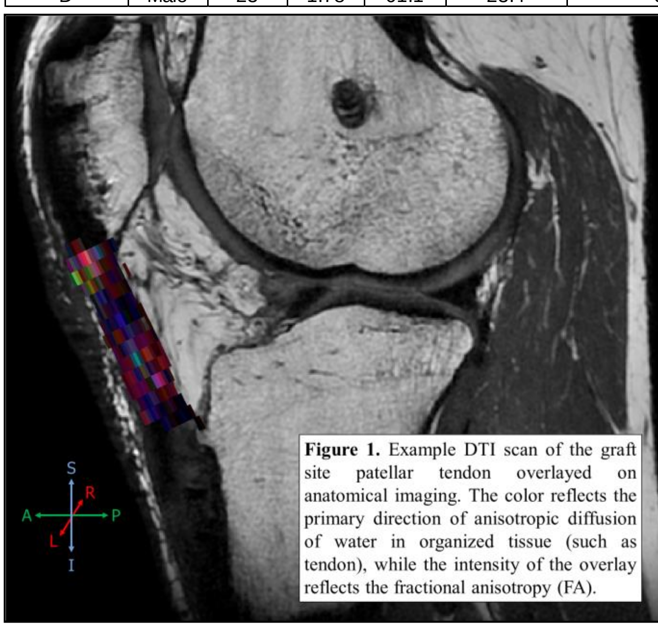

Figure 1. Example DTI scan of the graft site patellar tendon overlayed on anatomical imaging. The color reflects the primary direction of anisotropic diffusion of water in organized tissue (such as tendon), while the intensity of the overlay reflects the fractional anisotropy (FA).