

## Changes of Loaded T1ρ and T2 Outcomes Following Partial Meniscectomy

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**INTRODUCTION:** Approximately 50% of people who have a meniscal injury develop osteoarthritis (OA). Partial meniscectomy is a commonly performed procedure with an unpredictable risk of developing OA [1]. Magnetic resonance imaging (MRI) provides a non-invasive method of evaluating the status of articular cartilage and surrounding joint structures during OA progression. Furthermore, the advanced quantitative (qMRI) techniques of T1ρ and T2 mapping provide information related to the proteoglycan content and collagen fibril organization, respectively [2,3], of articular cartilage which are known biomarkers of OA. These qMRI outcomes have been correlated to biomechanical properties of the imaged tissue [4], and MRI compatible loading devices have been developed to apply load during image acquisition [5,6] to create a “functional” MRI exam [7]. To date, numerous studies have performed longitudinal evaluations of patients undergoing partial meniscectomy, but none have incorporated an MRI compatible loading device or qMRI when assessing post-operative outcomes. The purpose of this study was to observe changes in T1ρ and T2 values before and after a partial meniscectomy. We hypothesized that changes in tibial articular cartilage T1ρ and T2 values occur following partial meniscectomy, and that changes would occur within the medial and lateral compartments between unloaded and loaded imaging configurations.

**METHODS:** Following IRB approval with informed written consent, fourteen patients (9M/5F, 41±7 years [mean±SD]) clinically indicated for partial meniscectomy were enrolled. Of the 14 patients, 12 had partial medial meniscectomies, one had a partial lateral meniscectomy, and one had partial meniscectomies in both compartments. *MRI Acquisition:* Imaging was performed on clinical 3.0T scanner (GE Healthcare) with a flex coil [8]. Subjects were secured into an MRI compatible loading device to manually apply an axial force of 50% body weight [5,9]. A morphologic 3D SPGR with fat-saturation image series was acquired (voxel size: 0.31 x 0.31 x 1.3 mm<sup>3</sup>, TE/TR: 3.9 ms / 13.6 ms) for cartilage segmentation. A combined T1ρ-T2 acquisition [10] which assessed proteoglycan content and collagen organization, respectively (voxel size: 0.58 x 0.17 x 4 mm<sup>3</sup>; Spin Lock Times: 0, 10, 40, 80 ms; Echo times: 0, 12.9, 25.7, 51.4 ms) [8]. *Load/Unloaded MRI:* Images were acquired in unloaded (first) and loaded (second) configurations. A dwell period during loading permitted tissue stress relaxation [9]. Identical MRI acquisition parameters were used during imaging for the unloaded and loaded configurations. Imaging was performed before the partial meniscectomy procedure (PreOp) and 6-8 weeks post-operatively (PostOp). *Image Analysis:* Medial and lateral tibial articular cartilage surfaces were manually segmented from the SPGR series and resampled into the T1ρ/T2 image space for T1ρ and T2 calculations. Median T1ρ and T2 values were calculated for the medial and lateral compartments of each subject. *Statistical Analysis:* The following outcomes were calculated for T1ρ and T2 values and are reported as the median and [interquartile ranges]: **Effect of Time:** The difference between patient visits (PostOp - PreOp) for the unloaded configurations; **Effect of Loading:** The difference of Loaded - Unloaded for each individual visit; **Effect of Time and Loading:** The difference of change due to loading between study visits ((PostOp Loaded - PostOp Unloaded) - [PreOp Loaded - PreOp Unloaded]). A paired t-test was conducted separately for each outcome and compartment (n=14).

**RESULTS:** **Effect of Time:** Median T1ρ and T2 values were prolonged at PostOp as compared to PreOp. T1ρ prolongation was found in the medial compartment and T2 prolongation was found in both compartments. The changes of T1ρ and T2 between PreOp and PostOp were not statistically significant, p>0.05: **Medial Compartment:** T1ρ: 0.2 [-1.4, 1.9] ms and T2: 0.6 [-2.0, 3.3] ms; **Lateral Compartment:** T1ρ: -0.8 [-1.6, 0.0] ms and T2: 0.2 [-1.8, 2.2] ms. **Effect of Loading:** T1ρ and T2 values were reduced following the application of load for PreOp and PostOp but was only significant in the medial compartment for PreOp (p=0.002, Fig. 1). **Effects of Time and Loading:** Median differences were negative for T2 in the medial and lateral compartments, and T1ρ in the medial compartment, but these differences were minimal (<1ms) and statistically insignificant, p>0.05 (Fig. 2): **Medial Compartment:** T1ρ: -0.3 [-4.4, 3.7] ms and T2: -0.9 [-3.0, 1.3] ms; **Lateral Compartment:** T1ρ: 0.4 [-1.8, 2.6] ms and T2: -0.9 [-3.6, 1.9] ms (Fig. 2).

**DISCUSSION:** This longitudinal study utilized a novel MRI compatible loading device to evaluate MRI changes in patients undergoing partial meniscectomy. Between the pre-operative to post-operative time points, unloaded T1ρ values were prolonged in the medial compartment, but shortened in the lateral compartment. However, unloaded T2 values became prolonged in both compartments. These findings may indicate that early degeneration in the tissue may be starting to manifest in the medial compartment just 6-8 weeks after surgery, consistent with most patients (93%) having undergone a medial compartment partial meniscectomy. When combining the effects of time and loading, median differences were negative for all except the T1ρ values of the lateral compartment. As OA is associated with T1ρ and T2 prolongation [2] as well as larger changes of T1ρ and T2 due to loading [8,11], we may anticipate that a negative change of median value may indicate a reduced load bearing capability of the articular cartilage. Continued evaluation of these patients at later time points, ≥ 1 year post-op, will permit observing when significant changes in T1ρ and T2 values occur after surgery. This functional MRI approach could enable earlier detection of patients at risk for OA development and could guide rehabilitation strategies or inform decisions about further interventions.

**CLINICAL RELEVANCE:** No studies have explicitly performed a longitudinal qMRI evaluation of patients undergoing partial meniscectomy with an MRI compatible loading device. While the current results of this study did not find significant worsening of the articular cartilage in the short term (6-8 weeks post-op) there is evidence of the initiation change starting. Results from this longitudinal study may give clinicians insight into potential methods for tracking patient health after meniscal injury.

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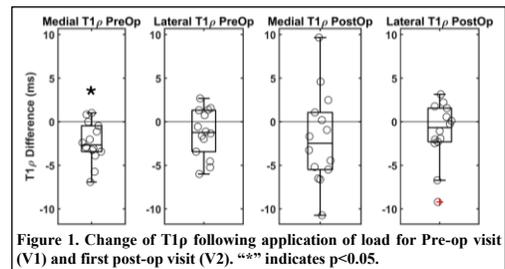


Figure 1. Change of T1ρ following application of load for Pre-op visit (V1) and first post-op visit (V2). “\*” indicates p<0.05.

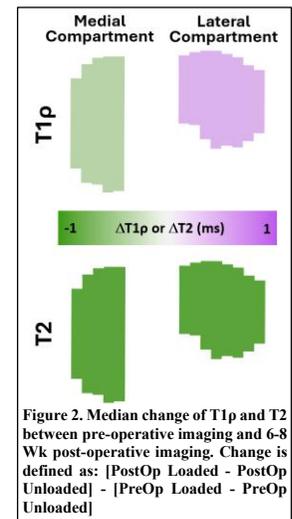


Figure 2. Median change of T1ρ and T2 between pre-operative imaging and 6-8 Wk post-operative imaging. Change is defined as: [PostOp Loaded - PostOp Unloaded] - [PreOp Loaded - PreOp Unloaded]