Quantification of Meniscal Extrusion Using Knee MRI Radial Multiplanar Reconstructions (rMPRs)

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DISCLOSURES: Ike R. Vayansky (N), Faysal Altahawi (N), Ahmet Hakan Ok (N), Richard Lartey (N), Nancy Obuchowski (3B-RSNA's QIBA; 5-Siemens, QURE, Takeda), Will Holden (N), Anish Ghodadra (N). Xiaojuan Li (3C-Siemens; 7B-Osteoarthritis and Cartilage, Magnetic Resonance in Medicine), Carl S. Winalski (4-Pfizer, Viatris; 8-Editorial Board - Osteoarthritis and Cartilage).

INTRODUCTION: Meniscal tear(s) or degeneration may lead to loss of meniscal function. A defunctionalized meniscus may "extrude" beyond the tibial margin to where it can no longer convert axial loads to hoop stress. Because of the abnormal contact stresses, knees with over 3 mm of meniscal extrusion on magnetic resonance imaging (MRI) are at risk for rapid progression of osteoarthritis (OA) and subchondral stress fractures. MRI is commonly used to determine meniscal position; however, since only sagittal and coronal images are typically obtained, extrusion measurement is limited to the mid-coronal (medial/lateral) or mid-sagittal (anterior/posterior) images leaving most of the meniscal circumference unmeasured. 3D MRI acquisitions allow for image reconstruction in any plane. Radially oriented multiplanar reconstructions (rMPRs) "rotated" about the meniscal center of curvature allow for a more complete measurement of the meniscus. Our objective was to create a tool for quantifying meniscal position/extrusion from rMPRs around the entire circumference and show its reproducibility. Our goal is to explore meniscal extrusion as a biomarker for OA and post-traumatic osteoarthritis (PTOA).

METHODS: This study was approved by the local IRB and informed consent was provided by all patients. A custom MATLAB GUI was created to generate rMPRs for each meniscus from 3D-FSE (fast spin echo) knee MRI acquisitions (3T, 0.43x0.43x0.7mm voxels). The center point for the radius of curvature of each meniscus was chosen as the center of rotation for creating rMPRs. The GUI generates rMPR images on-the-fly for any rotation angle around the meniscal circumference (90° chosen to be anterior). Using the MATLAB GUI, readers (two trained researchers and one experienced musculoskeletal radiologist) independently measured the distance between the tibial margin and inferior-most peripheral aspect of the meniscus on rMPRs every three degrees over a 120-degree interval from 120° - 240° (90°=anterior, 270°=posterior) for knees from the Multicenter Orthopaedic Outcome Network (MOON) nested cohort at 10+ years after unilateral ACL reconstruction. The inter-reader agreement and reproducibility of radial measurements was evaluated from the pooled data (all knees, medial and lateral menisci, all angles) by generating reproducibility coefficient (RDC), intraclass correlation coefficients (ICC), coverage probability plot, and within-subject within-angle standard deviation value. RDC value includes the difference between 95% of repeat measurements. ICC was calculated for absolute agreement using two-way, random reader, average measurement approach. The probability coverage plot displays the absolute value of the difference between readers measurements against the proportion of measurements within that absolute difference value (Fig.1) and the within-subject within-angle standard deviation quantifies the average deviation across all reader pairs for each subject and each angle.

RESULTS: Our sample size was five knees (10 menisci, five medial, five lateral). The mean radial resolution (mean x-dimension voxel size) of the rMPRs was 0.64mm and overall RDC was 1.05 mm. Overall ICC was 0.92 (±0.01). Coverage probability plot showed 79.5% of all reader measurements fall within 0.64 mm (~1 voxel). Overall within-subject within-angle standard deviation was 0.25 mm. Fig. 2 shows measured meniscal position for medial and lateral menisci on a polar coordinate plot with the interquartile ranges for the measurements with the zero line represents the tibial bone margin.

DISCUSSION: Results show meniscal position measurements taken from MRI rMPRs produced by this software method are reproducible across different readers, clinical cases, and for both the medial and lateral menisci. Given the coverage probability plot and the calculated RDC, rater measurements can be expected to differ by less than 1.0 mm. The low within-subject within-angle standard deviation indicates that readers made similar measurements under the same conditions (subject and angle), further demonstrating the reproducibility. Finally, the ICC value was calculated to be over 0.9 indicating excellent agreement between measurements for all readers. This preliminary study is limited by a small sample size with relatively uniform patient characteristics. Future work will expand the size and diversity of the patient cohort as well as measure intrareader reproducibility.

SIGNIFICANCE/CLINICAL RELEVANCE: Meniscal pathology is known to be associated with OA and PTOA; however, MRI meniscal extrusion measurements have been limited to a small portion of the mid-body of the meniscus. Radially oriented MPR images allow for extrusion measurements of the entire meniscus, and such measurements may prove useful as a predictive biomarker for OA and/or meniscal surgical outcomes.

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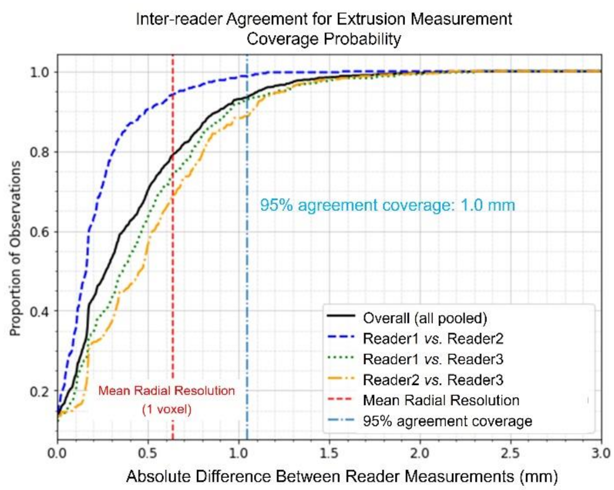

Fig. 1. Overall Coverage Probability Plot shows proportion of paired reader measurements with less than the absolute difference (mm) shown on x-axis pooled for all menisci & all readers (overall) & each reader pair.

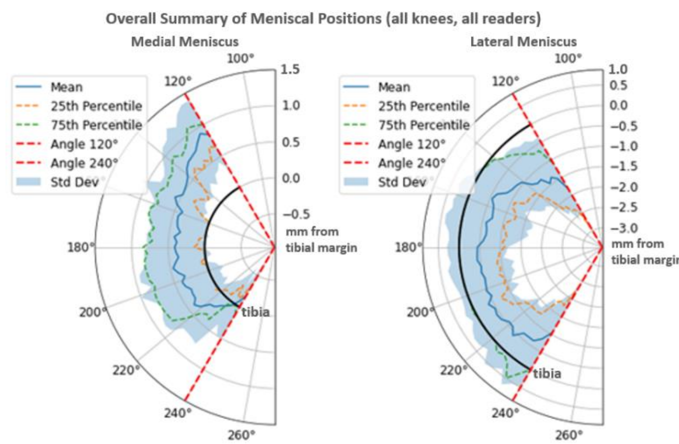

Fig. 2. Overall summary statistics of meniscal position measurements (mm) relative to the tibial margin (all knees & readers) plotted in polar coordinates mm. Tibial margin = 0 (black line). Average measurement - solid blue line. Interquartile ranges – dashed lines.