INTRODUCTION:

Osteoarthritis (OA) of the tibiofemoral (TF) joint is marked by distinct changes in articular cartilage (AC) volume and thickness [1-4]. In vivo methods that accurately track these initial changes are crucial for documenting the onset and progression of OA. Quantitative magnetic resonance imaging (qMRI) has shown promise for assessing changes in cartilage morphometry, and may prove to be a valuable measure for OA progression. Our group recently validated a qMRI approach for evaluating articular cartilage thickness *ex vivo* using phantom and cadaver models [5-6]. However, in order for this method to be applied in long-term clinical studies, it must first be validated *in vivo*.

The purpose of this study was to assess the validity of qMRI for determining AC thickness *in vivo*. Subjects undergoing arthroscopic partial meniscectomy were chosen because they offered the opportunity for repeated imaging. Ten subjects participated; their injured and uninjured knees were imaged before and after surgery. Our specific aim was to determine the reliability of our segmentation method for quantifying TF AC thickness *in vivo* in specific load-bearing regions. We expected qMRI to be reliable for determining AC thickness *in vivo*.

METHODS:

**Subjects:** Study approval was granted by the Institutional Review Boards of Brown University and Rhode Island Hospital prior to subject recruitment. Ten subjects (9 males, 1 female) with a mean age of 36.2 years (range 22-48 years) were included after informed consent was obtained. MRI data from these subjects were also used for a separate study of meniscal volume [7].

**MR Imaging:** MR imaging was performed on both knees of each subject, an average of 11.5 days before and 27.2 days after surgery; the time between pre- and post-operative MRI averaged 39.7 days. Each knee was imaged on a 3T MRI (Siemens Trio, Erlangen, Germany). The AC was imaged using the T1-WE-3D-FLASH sequence (0.3x0.3x1.5mm).

**Manual Segmentation:** The AC of each scan was manually segmented in the sagittal plane by an experienced examiner (MEB) using commercial software (Mimics 9.11, Materialise, MI). Once segmented, the AC was reconstructed, and a 3D voxel model of each structure was created. Each voxel model was wrapped with a triangular mesh to create a virtual solid model.

**AC Thickness:** Cartilage thickness measurements were performed on load-bearing regions of interest (ROIs) [5-7]. A cylinder was fit to the bone-cartilage interface of the 3D femoral cartilage model. A line was drawn from a distinctive notch on the lateral condyle to the center of the cylinder. Each femoral condyle was divided from the notch point toward the posterior aspect of the femur to create 3D femoral ROIs (3 medial, 3 lateral). Two ROIs (1 medial, 1 lateral) were defined on the cartilage regions of the tibial 3D model. The inertial axes of the medial compartment and the centroid of each compartment were calculated using MATLAB (The Mathworks, Inc., MA). The calculated inertial axes were projected onto the centroid of each tibial compartment to determine ROI orientation. The mean thickness of each cartilage patch was calculated with a closest point algorithm using MATLAB [5-7]. Each ROI was labeled M (medial) or L (lateral), and was further denoted (1 anterior), 2 (middle), 3 (posterior), or T (tibia) (Fig. 1).

**Statistical Analyses:** Statistical analyses were carried out using mixed linear modeling (SAS version 9.1.3, SAS Institute, NC). The correlations of measures taken within the same subject, knee, and ROI were accounted for by including random effects for intercept and the interaction of these factors. The measurements taken for the same region were assumed to be independent from the other structures, and have correlated errors (repeated effects). Orthogonal contrast statements were used to test the difference between pre- and post-surgery for each region. Type I error was maintained at 0.05 across all comparisons by the Holm test (sequential Bonferroni). A post-hoc power analysis was conducted to estimate the smallest changes detectable with 10 subjects at 95% power in the uninjured compartments.

RESULTS:

There was no statistically significant difference between the mean pre- and post-operative thickness of any ROI (adjusted p=1.00; Fig. 2). The AC regions showed a mean error of 0.86% between pre- and post-operative thickness values.

DISCUSSION:

Although knee injury has been correlated with early OA, to date, a cause-effect relationship between these has not been established. An accurate, reliable method that can quantify *in vivo* changes in AC thickness would allow knee-injured patients to be tracked over time, thereby helping to elucidate the mechanisms involved in early OA development.

The present study demonstrates that qMRI can reliably determine TF AC thickness *in vivo*. There was no significant difference in AC thickness between time points, despite 95% power to detect changes in thickness of 0.23mm. These results suggest that our qMRI method is a repeatable tool for determining TF AC thickness *in vivo*. This quantitative method may be useful in future long-term studies designed to evaluate the outcome of knee injuries and their surgical treatments.

REFERENCES:


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