QUANTIFYING MENISCAL VOLUME AND ARTICULAR CARTILAGE THICKNESS IN PATIENTS TREATED WITH PARTIAL MENISCECTOMY

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INTRODUCTION

Meniscal injuries may place the knee at risk of osteoarthritis (OA) by disrupting its load-bearing capabilities. Partial resection is routinely performed to alleviate symptomatic meniscal tears. While the volume of meniscal tissue removed likely contributes to functional loss, it is unknown whether there is a critical amount of meniscal tissue that can be removed without diminishing the structure's chondroprotective function. The use of quantitative MRI to measure meniscal volume and articular cartilage thickness has been validated *ex vivo* (Bowers et al., 2007; 2008). The purpose of this study was to evaluate the reliability of these techniques to quantify meniscal volume and articular cartilage thickness *in vivo*, before and after surgery, in patients treated with partial meniscectomy. We expected significant reductions in the volume of the resected menisci following surgery (Fig 1), but did not expect any volume change in the uninjured menisci, or in cartilage thickness, over the 1-month study interval.

METHODS

MR Imaging: After IRB approval and informed consent were obtained, 4 human subjects' injured knees (2 right, 2 left) were imaged on a 3T scanner (Siemens Trio, Erlangen, Germany), using a surface coil, prior to partial meniscectomy (2 medial, 2 lateral) and 1 month after surgery. The T2*-weighted 3D-CISS (constructive interference in the steady state) sequence (1mm slices) was used to image the menisci (Bowers et al., 2007), and the T1-weighted WE-3D FLASH sequence (1.5mm slices) was used to image articular cartilage (Eckstein et al., 2004; Bowers et al., 2008).

Segmentation Technique: The femoral and tibial articular cartilage structures of each knee were manually segmented in the sagittal plane and reconstructed using commercial software (Mimics 9.11; Materialise, Ann Arbor, MI). Similarly, the menisci were manually segmented in both the sagittal and coronal planes. 3D voxel models were generated and wrapped with a triangular mesh to create a virtual solid model of each structure (Fig 1).

Meniscal Volume: The volume of each 3D meniscal model was calculated by surface integration. The uninjured menisci served as repeated normals.

Articular Cartilage Thickness: Cartilage thickness measurements were performed on load-bearing regions of interest (ROIs). 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 6 femoral ROIs (3 medial, 3 lateral) (Fig. 2a). 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 with MATLAB (The Mathworks, Inc., Natick MA, USA). The calculated inertial axes were projected onto the centroid of each tibial compartment to determine ROI orientation (Fig. 2b). The mean thickness of each cartilage patch was calculated with a closest point algorithm using MATLAB (Bowers et al., 2008).

__Statistical Analysis__: Two-way repeated measures analyses of variance were performed to compare meniscal volume in response to surgical time point (pre-operative vs. post-operative) and meniscus (injured vs. uninjured). Pair-wise comparisons were made with the Holm-Sidak test. One-way repeated measures analyses of variance were performed in each cartilage ROI to compare pre-operative and post-operative cartilage thickness values.

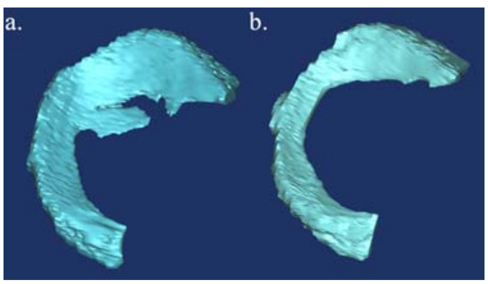

Figure 1: MR-based 3D models of a medial meniscus with a flap tear, (a) before and (b) after partial meniscectomy.

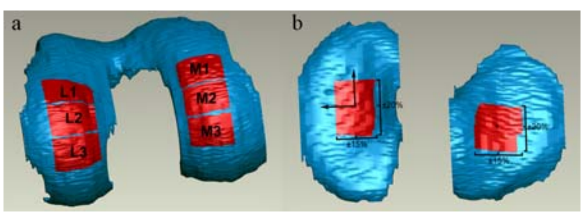

Figure 2: (a) Femoral ROIs. "L" and "M" denote lateral and medial. Regions 1-3 denote the areas divided from the notch toward the posterior femur. (b) Tibial ROIs were centered about the centroid of each condyle.

RESULTS

The pre-operative mean volume of the injured menisci was significantly greater than the post-operative volume ($p=0.003$), and there was no significant difference between the pre-operative and post-operative mean volumes of the uninjured menisci ($p>0.88$; Figure 3). There was no significant difference between the pre-operative and post-operative mean thickness of any cartilage ROI ($p>0.33$).

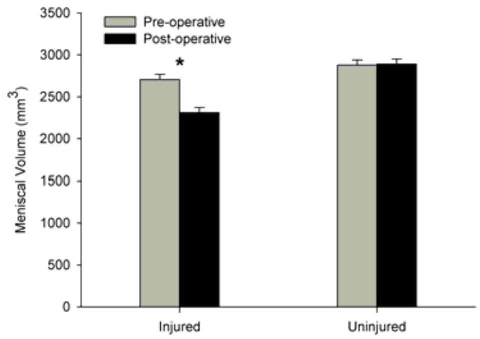

Figure 3: Mean volumes (mm^3) of the injured and uninjured menisci, before and after partial meniscectomy. * denotes a statistically significant difference in volume.

DISCUSSION

Our data demonstrate that the described segmentation techniques are able to quantify meniscal volume and articular cartilage thickness *in vivo* in patients treated with partial meniscectomy. Although a relatively small sample size was studied ($n=4$), statistically significant differences were seen between pre-operative and post-operative volumes of the resected menisci ($p=0.003$); no significant differences were seen in the uninjured menisci, or in any cartilage ROI, before and after partial meniscectomy. This approach may offer a novel means of studying the relationship between the volume of meniscal tissue removed during partial meniscectomy and subsequent changes in articular cartilage thickness.

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