3D THICKNESS MAPS DERIVED FROM AUTOMATED SEGMENTATION OF KNEE ARTICULAR CARTILAGER AT 1.5T: A FEASIBILITY STUDY USING 3D FS DESS, 3D PD FS FSE AND 2D PD FS FSE

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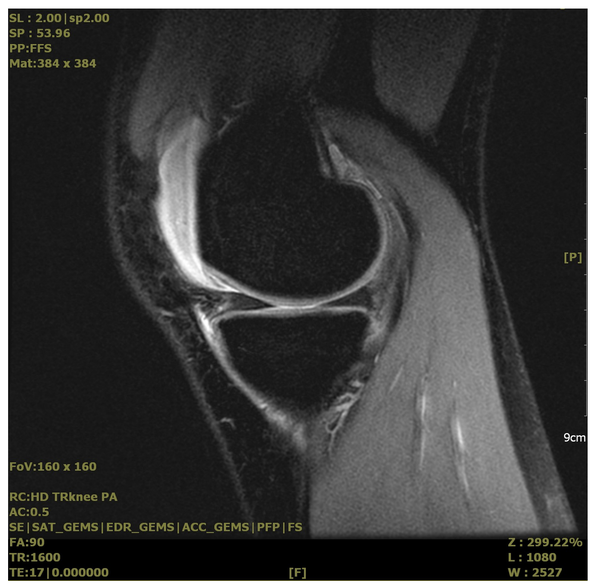
INTRODUCTION: Accurate, non-invasive visualization of post-operative knee cartilage repair can be obtained using standard clinical MRI studies, enhancing post-operative evaluation of cartilage defect repair.

PURPOSE: To evaluate the feasibility of using 3D FS DESS, 3D PD FS FSE and 2D PD FS FSE at 1.5 T to generate 3D articular cartilage (AC) thickness maps with an atlas based, voxel by voxel automated segmentation platform.

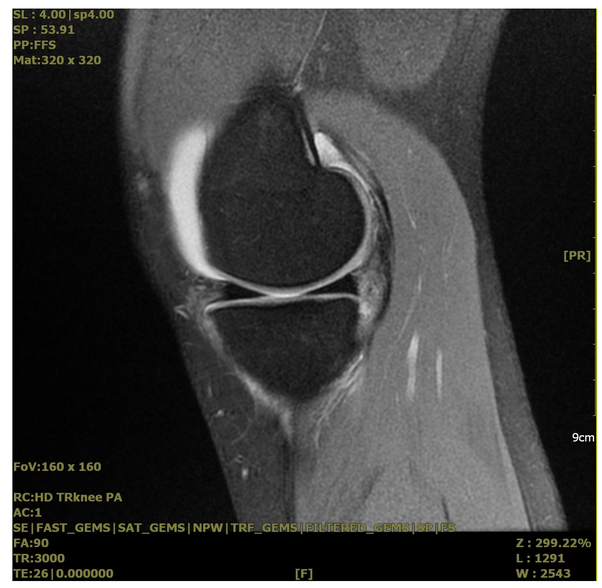
METHODS: High in-plane resolution, thin slice sequencing was performed at 1.5T and 3.0T. 3D FS DESS (WE) sequences were obtained on Siemens equipment (Verio, Germany). 3D PD FS FSE and 2D PD FS FSE sequences were obtained on GE equipment (450W, USA). The 3D PD FS FSE sequences had in-plane resolution of 384 x 384 and the 3D FS DESS has a resolution of 320x320. The 2D PD FS FSE had a matrix of 320x320. The slice thickness of the 3D FS DESS and 3D PD FS FSE sequences ranged from 0.7 to 2.0 mm. The slice thickness of the 2D PD FS FSE sequence was 2.0 mm. All sequences were optimized to enhance AC segmentation, including the selection of a TE appropriate to AC visualization, that is, a TE of 16-18. For the atlases, 3D FS DESS data from the Osteoarthritis Initiative (OAI, NIH)[2] were used. The atlases consisted of six data sets, and the segmentation platform (Qmetrics, USA) has been validated (1). For all scans, an eight channel dedicated knee coil was used. Twenty segmented data sets of each sequence were evaluated by two experienced MSK radiologists – each with over 20 years of experience – for accuracy of AC segmentation, including inclusion of defects and exclusion of non-AC tissues. For this feasibility study, subject exclusion criteria included prior surgery or a K-L score > 2. When required, editing was performed on the segmented images using the automated platform's editing tools, before the 3D thickness maps were generated.

a) 3D FS DESS

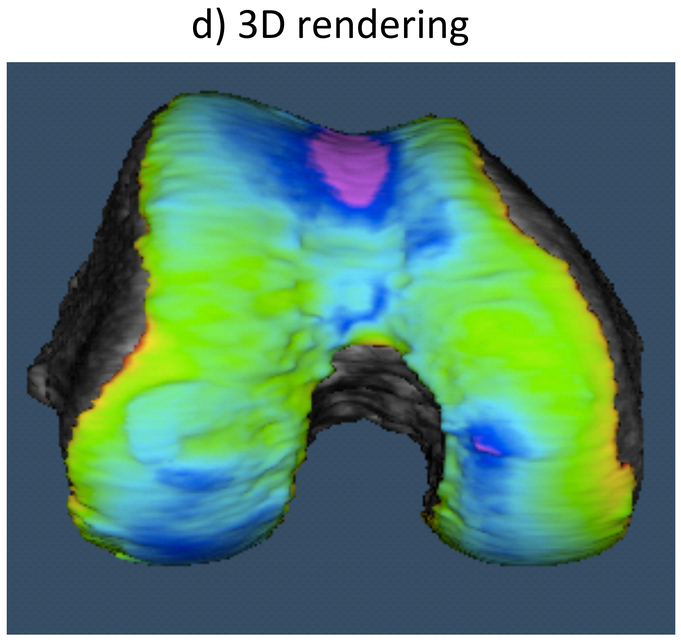
b) 3D PD FS FSE



c) 2D PD FS FSE



d) 3D rendering



e) 3D rendering

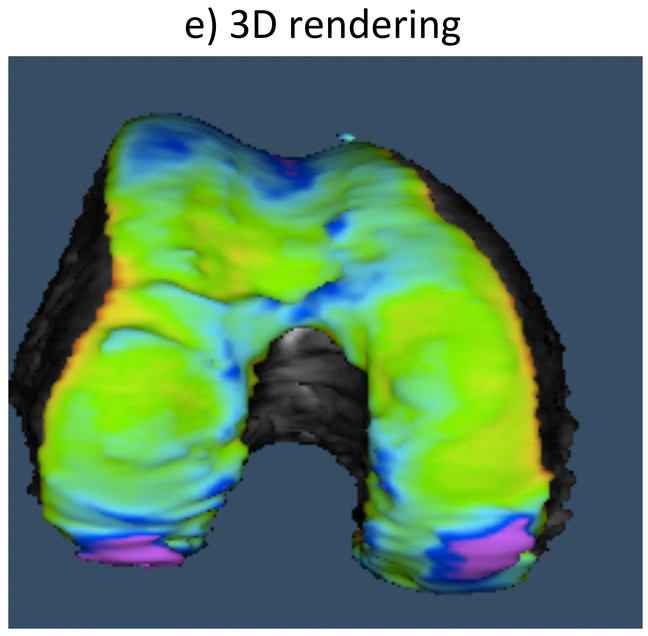


Figure 1: Sagittal images (a, b and c) of the knee with – from left to right – 3D FS DESS, 3D PD FS FSE and 2D PD FS FSE. All sets were amenable to automated segmentation. Image (d) is a 3D surface rendering of femur and articular cartilage of knee imaged in (a); Image (e) is a rendering of femur and articular cartilage of knee imaged in (b) and (c).

RESULTS: The three sequences tested at 1.5 T all segmented; with some data sets, minor editing was required for proper segmentation before generating the 3D thickness maps. When required, the editing process was performed by the experienced MSK radiologist, and the editing took 10-15 minutes or less. Unexpectedly, although the atlases were created from Osteoarthritis Initiative (OAI) 3D FS DESS data sets, PD based sequences, 3D and 2D, segmented robustly (Fig 1). 3D thickness maps were created from each sequence acquisition seamlessly by the automated platform.

CONCLUSIONS: With proper sequencing and supervision, atlas based, voxel by voxel segmentation and the subsequent generation of 3D thickness maps is feasible at 1.5T with a variety of sequences. This result creates the possibility of AC segmentation with sundry sequences, giving radiologists flexibility in sequence selection. The creation of sequence specific atlases presumably will improve segmentation results, and result in concomitant less editing. Further work will address this presumption, with surgical correlation.

References:

[1] Unsupervised Segmentation and Quantification of Anatomical Knee Features: Data From the Osteoarthritis Initiative. Tamez-Pena, J, et al. IEEE Transactions on Biomedical Engineering; April 2012; Vol 59; No 4; pp 1177-1186.

[2] The OAI is a public-private partnership comprised of five contracts funded by the National Institutes of Health. Private funding partners include Merck Research Laboratories; Novartis Pharmaceuticals Corporation, GlaxoSmithKline; and Pfizer, Inc.