INTRODUCTION:
Objective of this work was to develop a procedure for detecting longitudinal local and local cartilage thickness changes due to osteoarthritis (OA) using three dimensional MRI data.
Method for measuring precision of such changes is essential.
Our method enables the observation of natural characteristics (shape and thickness variation) within a set of normal and mild OA cartilage thickness maps.
Enables the cross-sectional and longitudinal analysis of disease progression.

MATERIALS AND METHODS:
10 subjects, five male and five female, 44.8 years on average (5 with no OA history and 5 with mild OA) were scanned 5 times using a Phillips Gyroscan Intra 1.5T MRI imaging system (Phillips, Netherlands).
All subjects consented to the study protocol.
Two imaging sequences were used. The parameters for the first sequence were: TE 2.6ms, TR 46ms, 1NEX, and a 45° flip angle. While the parameters for the second sequence were TE 2.6ms, TR 53ms, 1NEX, 45° flip angle, and MTC on.
A 512 X 512 matrix with a FOV of 18.00cm was used to reconstruct the images. The slice thickness was 1.5mm.
Both sequences were registered and fused to form a 3D multiparametric data set.
A single radiologist obtained the cartilage volume and thickness using the process illustrated in Figure 1. Validation tests on the segmentation process produced good repeatability and reproducibility results.
The cartilage thickness was obtained using a process similar to the one proposed by Tamez-Pena et al. for computing the distance map between the femur and the subchondral bone surface.

RESULTS:
For all the subjects, all the scans were segmented and analyzed using the methodology described in Figure 1.

Inter-Subject Registration:
Some effort has been dedicated to registering the cartilage longitudinally. Recently, Cohen et al. have constructed a patellofemoral template based on a user defined anatomical coordinate system. However, to the best of our knowledge, no such atlas exists for the tibia medial cartilage.

Intra-Subject Registration:
Assuming that the differences in the thickness points coordinates are most likely due to global changes, a good origin approximation of the common coordinate system may be derived from the centroids corresponding to the two thickness maps.
The translation vector of the global change is the difference between the two thickness map centroids.
The rotation matrix is comprised of the principal axes of the two thickness maps. Each principal axis is defined as the axis going through the established centroid with its orientation in such a way that the sum of the square distance between the centroid and the individual points corresponding to a thickness is minimal.

For all the subjects, all the scans were segmented and analyzed using the methodology described in Figure 1.

DISCUSSION AND CONCLUSIONS:
The developed methodology can determine the shape and thickness variations within the tibia medial cartilage among a set population.
The precision of measuring the focal and local cartilage defects within the tibia medial cartilage was determined.
Plans for applying this method to a large population set are in the works. Such results will reveal the actual shape and analysis of prevalence data in the case of clinical studies of OA.

Fig. 1: Cartilage extraction process.

Fig. 2: Tibia medial cartilage probability map based on the study population.

Fig. 3: Tibia medial cartilage mean thickness map (a) and tibia medial cartilage standard deviation map (b) generated using the study population.

Fig. 4: Tibia medial cartilage mean thickness map (a) and tibia medial cartilage standard deviation map (b) generated using the five scan collected from a knee with no OA history.

Fig. 5: Tibia medial cartilage mean thickness map (a) and tibia medial cartilage standard deviation map (b) generated using the five scan collected from a knee with mild OA.

Fig. 6: Cartilage Mean Thickness Map (a) and Cartilage Standard Deviation Map (b) generated using the five scan collected from a knee with mild OA.

Fig. 7: a) Difference map of the simulated defect in the anterior-posterior region of the tibia medial cartilage. b) Z-score map illustrating area of significant change in the simulated and original cartilage.

Table 1: Summary of the average mean thickness and the RMS of the standard deviation.

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<th>Subjects</th>
<th>OA Knee</th>
<th>Average ATE</th>
<th>RMS of the ATE</th>
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<td>0.55</td>
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<td>2</td>
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References: