3D LASER SCAN BASED ACCURACY TEST OF IN-VIVO CARTILAGE THICKNESS MEASUREMENT FROM MRI

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INTRODUCTION

Osteoarthritis (OA) is a highly prevalent joint disease and a leading cause of disability. Diagnosis and monitoring of OA progression is usually determined using radiographs, computer tomography and magnetic resonance (MR) imaging. Among these modalities, MRI has shown excellent capability in imaging soft tissues and has been used to quantify cartilage morphology [1]. Three-dimensional (3D) cartilage models reconstructed from plain MR images can provide important quantitative information on articular cartilage surface area, thickness and volume. However, there remains a need to evaluate the factors influencing the *in vivo* accuracy of MRI derived geometry. The purpose of this study was to test the accuracy of articular cartilage thickness measurement from MR images by using a 3D laser scanner.

METHODS

Data was obtained from two total knee replacement (TKR) patients (age 79 and 82, both male) after IRB approval and informed consent were obtained. Prior to TKR surgery, MR images of the knee were acquired using a 1.5T GE Signa Scanner (GE Healthcare, Milwaukee, WI). We used a 3D spoiled gradient echo sequence in the sagittal plane with fat-saturation, TR=60ms, TE=5ms, flip angle=40°, matrix 256x256, rectangular field of view 140x140mm, slice thickness 1.5mm, 60 slices. Tibial articular cartilage in the MR images was segmented and reconstructed into 3D surface models using custom software [2].

After TKR surgery, the entire resected tibial plateau was immediately taken into the laboratory to measure the actual shape of the cartilage using a 3D laser scanner (Model-15, Cyberware, Monterey, CA). This scanner has an average accuracy of 50-200 µm [3]. The cartilage surface was properly coated using a powder spray of negligible thickness to prevent laser scan error due to optical properties of the cartilage before acquiring the 3D surface shape of the cartilage [4]. After laser scanning, the articular cartilage on the tibial plateau was removed using a 6.0% sodium hypochlorite solution. A second laser scan was then performed to obtain the 3D surface of the subchondral bone. Data from the laser scans obtained before and after articular cartilage removal were then aligned and combined to estimate the true articular cartilage thickness.

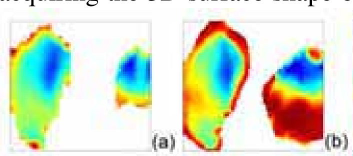

Figure 1: Tibial cartilage thickness maps of the first subject calculated using (a) MRI and (b) 3D laser scan.

Thickness maps were calculated for both 3D cartilage models, one from MR images and the other from 3D laser scans, by calculating the Euclidean distance between cartilage surface and bone-cartilage interface surface, and encoded on the surfaces of the models. The two models were aligned and projected onto a plane as shown in Fig. 1 to compare thickness measurements across the entire surface.

RESULTS AND DISCUSSION

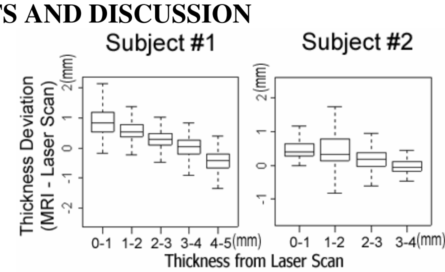

Figure 2: Comparison of thickness measurements for the tibial cartilage between 3D models from MR images and laser scan data. The graphs in the lower rows show the deviation of the MR-based cartilage thickness measurement from the laser scan-based measurement.

The correlation coefficients (R^2) between the thickness measurements from the MR images and the 3D laser scan were 0.7463 ($p<0.001$) and 0.7068 ($p<0.001$) for the first subject and the second subject, respectively. The deviation graphs show that MR will overestimate the true thickness of articular cartilage for thin cartilage (<3mm).

This result is consistent with other studies [4]. The high voxel anisotropy caused by a through plane resolution of 1.5mm vs. in-plane resolution of 0.6 mm has the effect of over-estimating cartilage thickness in regions of thin cartilage.

CONCLUSIONS

Cartilage thickness measurements from MR images have a good correlation with the measurements from laser scan data that best estimate the actual thickness. Thin cartilage less than 3mm has an inclination to be overestimated in MR images with high voxel anisotropy. This result has important implications for protocol design in longitudinal studies that follow cartilage volume and thickness with MRI.

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