Dynamic imaging produces different 3D knee kinematic information than static imaging

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INTRODUCTION Osteoarthritis is generally believed to be initiated by, and its progression facilitated by, abnormal joint mechanics (Wilson 2008). In many in vivo studies, knee kinematics have been assessed using images acquired at a series of static positions over the range of motion (ROM). The limitation of these methods is that there may be differences between the kinematics estimated from sequential static poses of the joint and the kinematics of the joint moving at physiological rates.

The purpose of this study was to compare kinematic results from a validated 3D static MR kinematics technique (Fellows 2005) to a novel 3D dynamic MR kinematics technique (d’Entremont ISMRM 2010) to determine whether imaging during continuous movement produces different kinematic information than imaging a joint at sequential static positions.

METHODS Ten normal subjects (mean age 31, 8 male, 7 right knees) were imaged on a 3T Philips Achieva scanner using a novel stretchable 8-channel knee coil array which permits knee flexion while maximizing the SNR independently of the knee size and shape (Nordmeyer-Massner ISMRM 2008). A MR-compatible loading rig was created to allow free leg motion with a force of 15% body weight applied in the ankle-hilum direction.

One high-resolution scan was taken (multi-slice T1-weighted FSE, 8:52 min), which provided detailed subject-specific bone models. Then three types of low-resolution loaded scans were taken: static standard (16 slices, 2D TSE, 23 seconds), static fast (8 slices, ultrafast gradient echo, 1.9 seconds) and dynamic (30 sets, 8 slices each, ultrafast gradient echo, 56 seconds) (Fig. 1). The two static scans were performed together at each of six flexion angles. During the dynamic scan, performed after the static scans, the subject was asked to move very slowly, but no specific rate of motion was required. Angles for the static scans were chosen to cover the same flexion range as the dynamic scan.

RESULTS Differences were on the order of the knee, 7 right knees) were imaged on a 3T Philip's Achieva scanner using a novel stretchable 8-channel knee coil array which permits knee flexion while maximizing the SNR independently of the knee size and shape (Nordmeyer-Massner ISMRM 2008). A MR-compatible loading rig was created to allow free leg motion with a force of 15% body weight applied in the ankle-hilum direction. Limitations of this method include the restricted ROM of the dynamic scans and a difference in patellar kinematics of 2.25 mm between normal and pathological subjects (Bonferroni-adjusted α = 0.016; bold values p < 0.0001). In conclusion, dynamic-based 3D kinematics measures provide different information from static 3D measures, and may represent kinematic results closer to those in activities of daily living.

DISCUSSION We observed differences between static versus dynamic 3D results in a majority of knee kinematic parameters. These differences are consistent with results from 2D measures of patellar tracking in both CT and MR (Muhle 1995, Dupuy 1997, Brossmann 1993). Although the motion was slow, there is likely a different muscle activation pattern when moving into a position actively than being passively positioned and subsequently loaded. Differences measured are on a clinically relevant scale; average differences in patellar kinematics of 2.25 mm between normal and pathological subjects have been reported (MacIntyre 2006).

Table 1: Comparison between summary measures (Bonferroni adjusted α = 0.016; bold values p < α).

Figure 1: Sample images

Figur 2: High-res segmentation

Figure 3: Representative results for kinematic parameters