**Measuring Hip Cartilage Deformation Under Load With 7.0T qMRI**

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**Introduction:** Measuring load distribution in the hip joint is vital to understanding the biomechanics of joint injury, disease progression and surgical intervention. Few methods are available for measuring hip contact mechanics because approaches used in other joints such as the knee (e.g. pressure sensitive film) are less suitable in the spherical geometry of the hip. Recently quantitative MRI (qMRI) has been used to measure cartilage deformation in the knee[1]. However, cartilage deformation with load has not been measured with high-field MRI in the hip. The objective of the current study was to assess the feasibility of measuring cartilage deformation at the hip under a static physiological load with MRI.

**Materials and Methods:** A human cadaveric hip (F, age 38) was removed of all tissue, leaving the capsule intact, and mounted in an MRI compatible pneumatic loading device (Fig 1). Absence of pathology was verified arthroscopically via a portal hole in the capsule. The distal femur was potted and the pelvis cut so a physiological orientation simulating single leg stance[2] was obtained when the specimen was placed in loading device. The capsule was covered with gauze soaked in phosphate buffered saline solution with protease inhibitors (PBS+) to minimize degradation and maintain joint hydration.

MR imaging of hip cartilage was performed with a fat-suppressed 3D FLASH sequence using a 15 cm inner diameter quadrature volume coil with 7T MRI (Bruker Biospin, Ettlingen Germany). Imaging parameters were: TR/TE 25/4.6 ms; flip angle 20°, slice thickness 1 mm, in-plane resolution 0.11 mm, matrix 512 x 512, FOV 5.63 cm, 16 slices per image, time: 3 min 25 s. Slices were orthogonal to the longitudinal axis of the anterior inferior iliac spine (AIIS).

We loaded the hip to approx. 1980 N (2.5xBW, nominal 80 kg) of axial compression to simulate hip loads during single leg stance[2]. Images were obtained upon initial loading and every 15 mins thereafter. For each time step, a pixel intensity subtraction technique was implemented where the intensity of each pixel in an image was subtracted from the corresponding pixel in the preceding image, producing a subtraction image. Deformation phase scanning was complete when the subtraction image showed only noise (i.e. the 2 source images were identical except for the background noise). The piston in the loading device was then retracted slightly for 8 hrs, with no cartilage thickness recovery in this time. Full retraction of the piston initiated the cartilage recovery phase and the specimen was scanned. Thereafter, the specimen was scanned approx. every hour until the recovery phase was complete, again using feedback from subtraction images. In the recovery phase, the loading device was filled with the PBS+ solution between scans, providing fluid for re-uptake. The specimen remained in the MRI scanner throughout testing.

For each time step during deformation and recovery phases, cartilage thickness was measured (Analyze 7.0, Mayo Clinic, USA) at one location on one slice. The cartilage was measured as one unit between the osseous surfaces of the femur and acetabulum.

**Results:** During loading, we observed deformation throughout the weight-bearing region of the articular cartilage (Fig 2B). Subtraction images showed the articular cartilage reached a steady-state thickness distribution after 3 hr 45 mins of loading and 16 hr 30 mins of recovery. The time-dependent cartilage thickness response to load at a single location is illustrated in Figure 3.

**Discussion:** Cartilage deformation and recovery in the hip was successfully measured using MRI. Our finding of full cartilage thickness recovery in the hip after 16.5 hrs is consistent with Song's finding of a mean thickness recovery of 90% after 14 hrs of recovery from a 1.5 x BW load in a sheep knee joint[1]. One limitation of the study is the effect of the PBS+ solution on the cartilage thickness over 16.5 hrs was not verified, however a sheep knee submerged in the same solution with gadolinium over 14 hrs showed high repeatability[1]. Our results suggest that measuring hip cartilage deformation and recovery with MRI could be a powerful tool for investigating hip joint mechanics.

**References:**

**Figure 1:** Custom-made MRI hip loading device

**Figure 2:** A. Human hip MRI image in anterosuperior region prior to load. White line shows a profile of the plane parallel to the acetabular rim used to prescribe the imaging slice. B. Closer view of image A. Hatched area shows distribution of cartilage thickness lost after 3 hr 45 mins of compressive load.

**Figure 3:** Cartilage thickness change as a function of time under continuous load (Deformation) and after release of load (Recovery). Measurements from one location on one slice in the anterosuperior region of the hip throughout deformation and recovery. Location of interest is different in deformation and recovery phases due to specimen shift with load application.