Loading and knee-alignment have significant influence on cartilage T2 in porcine knee joints

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Introduction

Knee imaging using quantitative magnetic resonance imaging (MRI) techniques such as delayed gadolinium-enhanced MRI of cartilage (dGEMRIC), T2 relaxation time (T2 mapping) and T1rho showed great advancements in non-invasive assessment of the articular cartilage, particularly with regard to matrix composition and degenerative changes. [1] MRI in most of these investigations was performed without externally loading the knee with patients or volunteers lying supine on the imaging table. Physiological magnetic resonance imaging (MRI) under loading or knee malalignment conditions has not been thoroughly investigated. We developed a non-metallic pressure device to be used during MRI under variable loading or knee alignment conditions in excised porcine knee joints, and assessed the influence of loading and knee alignment on T2 mapping of the knee femoral cartilage.

Materials and Methods

Ten porcine knee joints were harvested *en bloc* with intact capsules and surrounding muscles and imaged using a custom-made pressure device and 3.0-T MRI system. Sagittal T2 maps were obtained at knee neutral alignment without external loading (no loading), under mechanical compression of 140 N corresponding to approximately one-third of the body weight (neutral loading), under after 30 min of the same compression (neutral loading-2), and under the same loading conditions as in neutral loading with the knee at 10° varus alignment (varus loading). T2 maps were generated using a monoexponential fit from 2D multi-spin echo sequences (TR, 1500 ms; 8 echoes between 10.0 ms and 80.0 ms; field of view, 10 cm; matrix, 384 × 256; slice thickness, 3 mm; signal averaging, 1; acquiring time, 6 min and 51 s). T2 values of deep, intermediate, and superficial zones of the medial and lateral femoral cartilages at the weight-bearing area were compared among these conditions using custom-made software. After imaging, cartilage contact pressure between the femoral and tibial cartilages was measured by placing a pressure-sensitive film; this value was then correlated with cartilage T2 measurements.

Results

In the medial cartilage, the mean T2 values of the deep, intermediate, and superficial zones decreased by 1.4%, 13.0%, and 6.0% under neutral loading. They further decreased by 4.3%, 19.3%, and 17.2% under varus loading compared to those without loading.(Figs 1 and 2) In the lateral cartilage, these mean T2 values decreased by 3.9%, 7.7%, and 4.2% under neutral loading, but increased by 1.6%, 9.6%, and 7.2% under varus loading. (Figs 1 and 3) There was a significant decrease in T2 values in the intermediate zone of the medial cartilage under both neutral and varus loading, and in the superficial zone of the medial cartilage under varus loading ($p < 0.05$). In all three zones, changes in T2 time between neutral loading and neutral loading-2 ranged from 0.8% to 3.7%, but the difference was not significant. Total contact pressure values at the medial and lateral cartilages were 47 ± 8.4 N and 46 ± 5.1 N under neutral loading and 94 ± 21 N and 35 ± 7.8 N under varus loading. These values significantly correlated with T2 values in the superficial and intermediate zones of the medial and lateral cartilages for each condition.

Conclusion

In the present study, the influence of loading on T2 mapping of the cartilage was investigated using whole animal knee joints retaining all intraarticular structures, capsules, and surrounding muscles. These realistic joint models allowed for loading under near-physiological conditions unlike excised cartilage specimens, and permitted examining simulated disease conditions (e.g., varus knee alignment). As expected from experimental studies [2], a decrease in cartilage T2 occurred in response to compressive loading in neutral alignment, with remarkable side- and depth-dependent variation in T2 changes. These T2 changes were significantly related to the contact pressure measurements recorded by the pressure-sensitive film. Our results indicate that T2 mapping under loading allows non-invasive, biomechanical assessment of site-specific stress distribution in the cartilage.

References

[1] Burstein D, et al. Invest Radiol 35:622-38,2000. [2] Gründer W, et al. Magn Reson Med 43:884-91,2000.

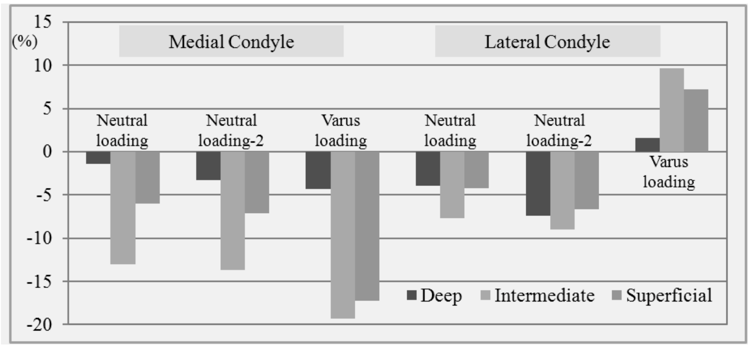

Fig 1: Change in T2 values at each loading condition. Changes were calculated as (values at each loading condition – values at no loading) /values at no loading × 100.

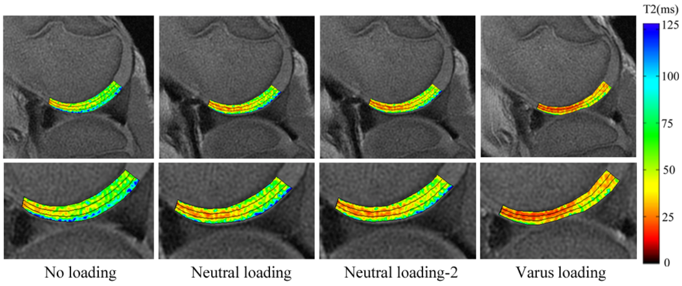

Fig 2: Representative sagittal MRI of the medial femoral cartilage in the porcine knee at each condition. The femoral cartilage was subdivided into three zones using custom-made software.

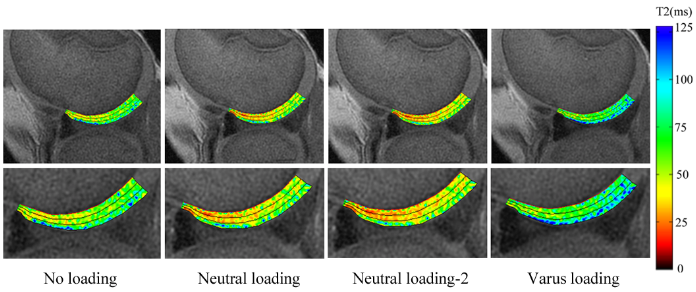

Fig 3: Representative sagittal MRI of the lateral femoral cartilage in the porcine knee at each condition. The femoral cartilage was subdivided into three zones using custom-made software.