Three-Dimensional MRI of Ankle Cartilage with Noninvasive Distraction at 3 Tesla

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Introduction

Despite sustaining comparable functional loadings, and despite having nominally thinner cartilage, the ankle joint is much less susceptible to primary osteoarthrosis than are the hip or the knee. Accurate assessment of the tibial and talar surface cartilage thickness distributions is important both for clinically staging individual patients, and for advanced biomechanical studies of tibiotalar load transmission. Distinguishing these respective thicknesses is especially valuable in the context of determining local cartilage strain (and hence stress) as the articulating bony members move through the duty cycle, thus affording assessment of site-specific cumulative mechanical demand.

Three-dimensional (3D) MRI is capable of exquisitely depicting articular cartilage [1,2]. However, most studies have considered the knee joint with its relatively thick cartilage and easily distinguishable opposing surfaces. Articular cartilage in the ankle joint has been rarely studied with MRI [3,4] and is difficult to image with any modality due to the relative thinness of the cartilage and the anatomy of the ankle, where there is a close fit between the talar dome and the mortice. The cartilage on the tibial surface and talar dome thus cannot be distinguished on imaging without distracting the two surfaces. Noninvasive distraction of the joint could potentially open up the joint space to sufficiently separate and visualize the cartilage surfaces with high-resolution MRI at 3T. The purpose of this work was to investigate the feasibility and utility of noninvasive ankle joint distraction during 3D MRI to improve the visualization and contrast between tibial and talar cartilage surfaces.

Methods

Five healthy volunteers with no history of ankle pain were fit into a novel noninvasive MR-compatible ankle distraction device (Fig. 1). The device generates an adjustable distraction force on the joint via a strap looped over the heel and top of the foot and attached to an extended leg brace. The distraction force applied was adjusted qualitiatively such that the subject reported a significant pull on the joint but no pain.

MR images of the distracted joint were obtained on a Siemens Trio 3T scanner (Siemens, Erlangen, Germany) using a transmit/receive extremity coil. The acquisition utilized a 3D FLASH sequence with water excitation to suppress signal from fat and isotropic resolution of 0.5 x 0.5 x 0.5 mm^3 over a 12 x 12 x 10 cm^3 field of view. Imaging parameters were TR/TE = 12.3/5.2 ms with a flip angle of 12 degrees, yielding a total imaging time of about 10 minutes. Subsequently, the tension in the distractor was released, and an identical 3D volume was acquired with the same pulse sequence and parameters to acquire a comparison volume of the undistracted joint.

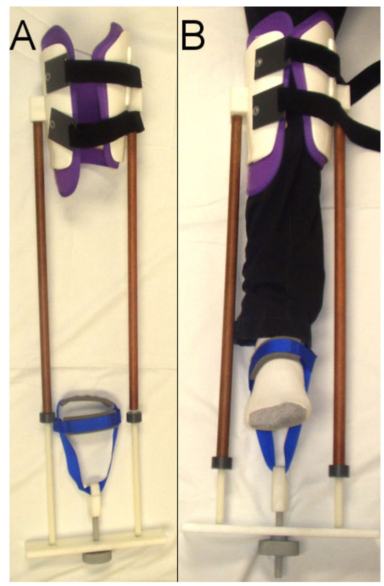

Figure 1: MR compatible ankle distraction device. (A) Construction. (B) In use.

Results

Visualization of the tibial and talar cartilage surfaces was markedly improved with distraction in four of the five subjects based on consensus evaluation of two expert observers. The remaining subject reported a loss of tension in the distraction device during imaging. Figure 2 shows coronal and sagittal views comparing results from distracted and corresponding undistracted acquisitions and demonstrates the dramatic improvement in delineation of the tibial and talar cartilage surfaces due to distraction applied during imaging.

Discussion

Three-dimensional MR imaging coupled with noninvasive distraction of the ankle joint is capable of generating excellent separation and visualization of tibial and talar cartilage surfaces. This combination opens the way to quantitative assessments of tibial and talar cartilage surface thickness for clinical and biomechanical evaluation.

References

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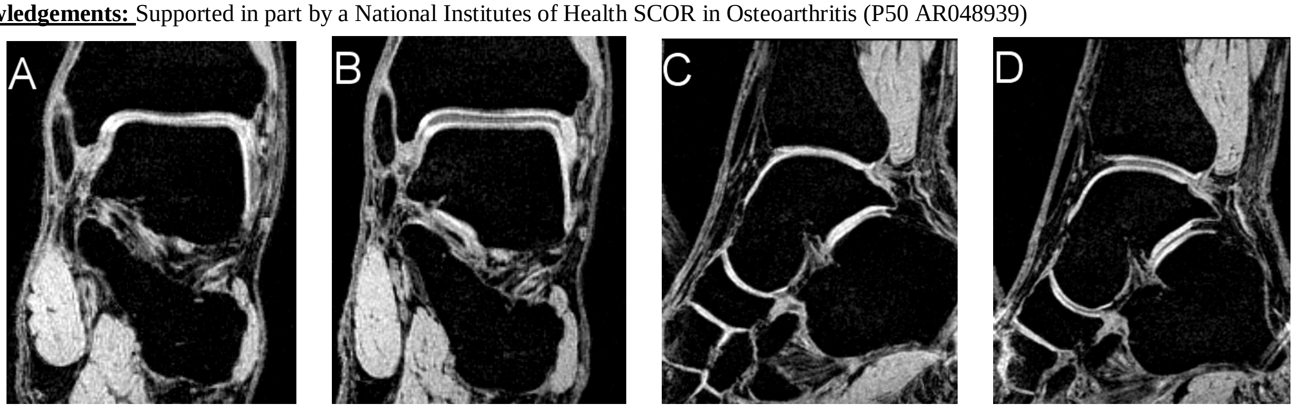

Figure 2: Sample slices from 3D volume data sets of ankle cartilage. (A) Coronal view of undistracted ankle. (B) Corresponding coronal view from acquisition with distraction. (C) Sagittal view of undistracted ankle. (D) Corresponding sagittal view from acquisition with distraction. Each volume was acquired with isotropic 0.5 x 0.5 x 0.5 mm^3 resolution in approximately 10 minutes. The improved separation and visualization of the surfaces is readily apparent.