Differences between X-ray and MRI-determined knee cartilage thickness in weight-bearing and non-weight-bearing conditions

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Target audience
People conducting longitudinal osteoarthritis research using MRI and/or radiograph will find this information useful.

Purpose
Although MRI directly visualizes cartilage, cartilage thickness has not shown longitudinal differences compared to radiographic joint space narrowing [1]. Loading may cause cartilage compression, resulting in a narrower joint space width in x-rays compared to MR. This study investigates the impact of loading on minimum joint space width (mJSW) in radiographs and on medial femorotibial cartilage thickness (MFT_th) in MRI images, as well as the relationship between T1ρ and T2 values and loaded vs. unloaded mJSW.

Methods
Subjects: Women age 55 (+/- 6) years (n=25) and BMI 28 (+/- 2.4) had x-rays and MRI taken of their knees in weight-bearing and non-weight-bearing conditions. Of the 31 subjects, 11 had no OA (KL[2] = 0), and the rest had mild or moderate (KL= 2 or 3) radiographic OA.

X-ray acquisition: Radiographic images were acquired from all subjects in a modified Lyon-Schuss weight-bearing position using a Synaflexer positioning frame. The "loaded" x-ray was acquired with the subject standing, and the "unloaded" x-ray was acquired with the subject lying prone. Minimum joint space width (mJSW) was determined after delineating the medial joint space edges using an in-house spline-based analysis tool.

MRI acquisition: MR images, including spoiled gradient-echo (SPGR), T1ρ, and T2 images, were acquired on a 3T scanner, using an 8-channel knee coil and a loading device [3] without and with loading equal to 50% body weight. The medial cartilage was manually segmented using the SPGR images. Mean cartilage thickness of the medial femorotibial compartment (MFT_th) was calculated by summing the mean thickness values of the femoral and tibial cartilages for the narrowest slice. T1ρ and T2 maps were generated, and were analyzed using segmentation of the contact area of the femur and tibia.

Statistics and Analysis: The percent change from unloaded to loaded conditions was calculated and used to determine the standardized response mean (SRM) for x-ray and MRI. The loading conditions were compared using Student's T-tests. Pearson's correlation coefficient was calculated between x-ray and MRI.

XRAY (mJSW)	unloaded (mm)	loaded (mm)	
KL = 0	3.32	3.34	p= 0.920
KL = 2	3.46	3.19	p= 0.030 *
KL = 3	3.08	2.95	p= 0.041 *
MRI (MFT_th)	unloaded (mm)	loaded (mm)	
KL = 0	2.64	2.52	p= 0.027 *
KL = 2	2.71	2.58	p= 0.035 *
KL = 3	2.74	2.55	p= 0.047 *

Table 1: loaded and unloaded mJSW (top) and MFT_th (bottom) values grouped by KL score. (*) represents a significant difference (p<0.05) between loaded and unloaded conditions

Results
The mJSW for the loaded X-rays (mean = 3.16 mm) was significantly less ($p < 0.05$) than the unloaded X-rays (mean = 3.29 mm). The MRI MFT_th also decreased ($p < 0.001$) from unloaded (mean = 2.70 mm) to loaded (mean = 2.55 mm). When grouped by KL score, the mean mJSW and MFT_th values for each group were all significantly different from loaded to unloaded except for the mJSW at KL = 0 (see Table 1). The SRM for MRI was -0.84% and for X-ray was -0.44% indicating greater sensitivity in MRI. Pearson's correlation coefficient was r = 0.760 between the loaded X-ray and unloaded MRI values and r = 0.808 between both loaded conditions. When separated evenly into high and low mJSW % difference from unloaded, mean T1ρ and T2 values were higher when there was a greater decrease from unloaded for both MFC and MT and under both loading conditions, although this difference did not reach significance.

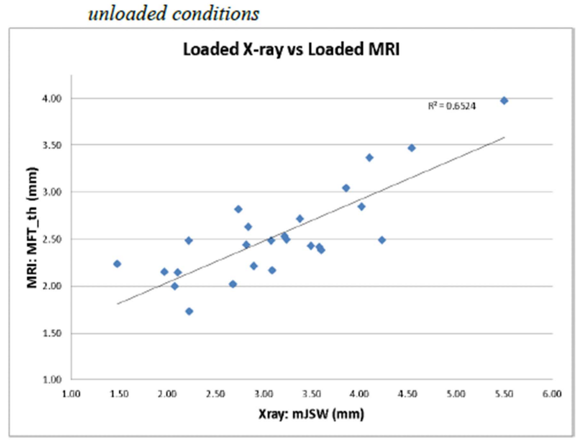

Figure 1: mJSW and MFT_th values plotted against one another. There was strong correlation between x-ray and MRI measures of joint space when both were loaded. This correlation was not as strong when the x-ray was loaded but the MRI was unloaded

Discussion
Both MRI and X-ray detected significant decreases in measured joint space width from the unloaded to loaded conditions. The SRM for MRI was higher than that for X-ray, which contradicts past studies [1]. The higher correlation coefficient between the two loaded conditions indicates slightly better correlation when both modalities use loading. It logically follows that the loading difference does account for some of the differences in sensitivity to OA progression. Additionally, a greater % difference from unloaded seems to correspond to a higher median T1ρ and T2 value—this is expected, as higher T1ρ and T2 values correlate to greater damage to the cartilage.

Conclusion
Loading has a significant effect on cartilage deformation, regardless of OA status. MRI may be at least as adept at detecting progression of OA as X-ray, given proper patient set-up.

References
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