MRI Based Distance Maps of the Joint Space Width in the Knee Joint

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Introduction:

This work evaluates the reproducibility of a new method for measuring the joint space width (JSW) on statically loaded knees from three-dimensional (3-D) MRI data. The system consists of a loading jig (Fig. 1) and JSW analysis software that allows the reconstruction of the two-dimensional (2-D) distance maps between the femur and the tibia bone surfaces.

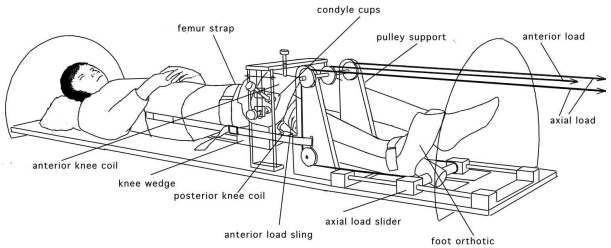

Fig. 1 Loading device used to apply axial loads during MR imaging[1]

Methods:

- 10 healthy volunteers, (4 males and 6 females; age 26.8±6.1 years; height 168±6.1cm; weight 619±105N) with no history of knee joint injury or pathology, participated in the study after providing consent with approval from our Research Subjects Review Board.
- Two different operators repeatedly positioned each subject in the knee loading device. The loading device imposes an axial load on the target knee that simulates a standing weight approximately equal to half the subject's body weight. For each positioning, the knee was imaged first in the unloaded, then in the loaded state using a fast gradient recalled echo sequence (TE: 1.9, TR: 7, 1 Nex, Flip angle 40°, time of scan 2:05 min, 64 1.5 mm slices, FOV: 17 cm, 256 x 256 matrix).
- The acquired images were analyzed by an automated 3-D segmentation algorithm that detects spatially independent structures such as the femur and the tibia. Errors presented in the segmentations were corrected by a trained analyst. The resulting segmentations were used by an unsupervised JSW algorithm that identifies the medial and lateral compartments of the knee joint.
- Both unloaded and loaded medial and lateral compartments of the tibia-femur joint space were analyzed by 2-D distance maps, where qualitative and quantitative information was extracted. (Fig. 2)
- The minimum JSW, the overall average, and a localized average within a 5mm radius of the most inferior femur point were evaluated.
- Intra and inter-operator reliability were evaluated by comparing results from repeated image processing and subject repositioning. The intraclass correlation coefficient and standard error of the measurement were calculated for each comparison.

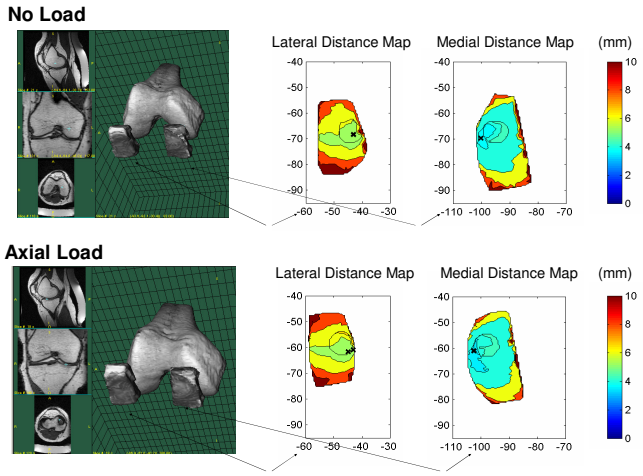

Fig. 2 Left, 3-D reconstruction of the distance map over the femur for the unloaded case (top image) and axially loaded case (bottom image). Right, lateral and medial distance maps (mm) within the pre-determined weight bearing region of the tibia and the femur. The **x** represents the minimum JSW, while overlapping enclosed region represents the region within 5mm radius of the most inferior femur point.

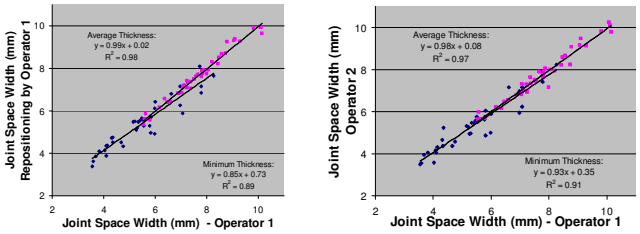

Fig. 3 Intra and inter-operator correlation of the overall average thickness (pink/square) and minimum thickness (blue/diamond) JSW.

Results:

- Lowest variability in JSW was found in the overall average of the weight bearing region. (Fig. 3, Table 1)
- The location of the minimum thickness changed significantly between the unloaded and loaded sequences for some of the subjects, making it less reliable for analyzing the JSW.
- The localized average thickness proved reliable and less prone to artifact in measurements near the boundaries of the weight bearing regions.
- The intra-operator correlation of the minimum JSW was 0.89, while inter-operator correlation for the same measurement was 0.91. A higher correlation was found between the overall average thickness for both intra and inter-operator, 0.98 and 0.97. (Fig. 3)

		Intra Operator Reproducibility			Inter Operator Reproducibility		
		Overall Average	Minimum	Localized Average	Overall Average	Minimum	Localized Average
No Load	Mean Thickness (mm)	7.80	5.54	6.75	7.76	5.56	6.79
	SEM (mm)	0.122	0.31	0.166	0.197	0.23	0.228
	ICC(2,1)	0.99	0.936	0.977	0.97	0.964	0.976
Loaded	Mean Thickness (mm)	7.64	5.45	6.76	7.66	5.46	6.75
	SEM (mm)	0.13	0.29	0.215	0.11	0.32	0.161
	ICC(2,1)	0.989	0.943	0.976	0.992	0.947	0.985

Table 1. Intra and inter-operator reproducibility in JSW under unloaded and axially loaded conditions.

Discussion/Conclusions:

- The average JSW decreased more in the medial than the lateral compartment when an axial load was applied, however the decrease was not significantly different from zero.
- The variability in joint space width measurements is mainly associated with the positioning of the subject and not the image processing aspect of the procedure.[1] Repeatability of the JSW measurements is particularly remarkable given the resolution of the MR images acquired, where the in plane resolution is 0.66mm per voxel.
- The loading device provides consistent positioning of the knee joint which has been shown critical in radiographic imaging studies.[2,3]
- The intra-operator variability is somewhat greater than the inter-operator variability for the average thickness, which suggests that the initial loading helps to settle the knee joint in a steady position. Repeated loading may lead to slight compression that may increase variability.
- As shown previously[1], a relaxation period prior to image acquisition may be important in reducing variability between measurements.
- Further analysis is required to test the loading device along with the image processing procedures on subjects with osteoarthiritic knee joints.

References:

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