A Two-Year Longitudinal Study of the Interrelationship between Trabecular Bone and Articular Cartilage of the Osteoarthritic Knee

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Introduction:

Measurement of bone or cartilage structural parameters, individually, may be insufficient to determine the pathogenesis of osteoarthritis (OA) because morphological changes that occur in bone and cartilage are interdependent. In a previous cross-sectional study of bone and cartilage interaction, Lindsey et al. (1) used MRI to determine that cartilage degeneration in the knee joint is associated with changes in bone structure. As a further investigation, it would be important to study how such a relationship changes over time. Therefore, the purpose of this study is to examine the relationship between structural changes of bone and cartilage in patients with varying degrees of OA (of the knee) over the course of two years, using *in vivo* MR imaging.

Methods:

A total of thirty-eight subjects were scanned at baseline and twelve months, but only eighteen were scanned at twenty-four months (drop-outs due to death, knee replacement and unwillingness to continue). The severity of each subject's OA was evaluated using the x-ray based Kellgren-Lawrence (KL) scale: KL scores of 1 and 2 were considered mild OA and classified as OA1 (n = 13); KL scores of 3 and 4 were considered severe OA and classified as OA2 (n = 17). Additionally, a group of control subjects with no radiographical evidence of OA (n = 8) were included in the study. A GE SIGNA 1.5 Tesla echo-speed system (GE Medical Systems, Waukesha, WI) and bilateral dual-phased array coil (USA Instruments, Cleveland, OH) were used to acquire images. High resolution axial images were acquired for bone analysis using a 3D fast gradient-echo sequence (TE = 4.5 ms, TR = 30 ms, Flip angle = 40°, resolution = 195 x 195 x 1000 μm^3), and high resolution, fat suppressed, 3D SPGR sagittal images (TE = 3.3 ms, TR = 30 ms, Flip angle = 30°, resolution = 234 x 234 x 2000 μm^3) were acquired for cartilage analysis. Based on the axial images, regions of interest (ROI) consisting of trabecular bone were segmented in the femoral shaft, medial and lateral condyles, and medial and lateral tibia. These regions were analyzed to measure the following parameters: apparent trabecular number (App. Tb.N), apparent trabecular thickness (App. Tb.Th), apparent bone volume fraction (App. BV/TV), and apparent trabecular separation (App. Tb.Sp). Additionally, based on the sagittal images, the articular cartilage was segmented using a spline-based, semi-automatic technique and was defined in four distinct regions: medial and lateral tibia, and medial and lateral femur. Total cartilage volume and average thickness were calculated for each region. Cartilage volume was normalized by the epicondylar distance in order to eliminate variation due to joint size.

Results and Discussion:

The results of this study indicate that in the femur, bone and cartilage structural parameters decrease over time in patients with OA. For example, figure 1 illustrates a decreasing trend in App. BV/TV of the femur in individual OA1 patients. Moreover, figure 2 depicts a decline in the mean values of the App. BV/TV in the medial condyle for both OA1 and OA2 patients over a two-year period. Similarly, nine out of ten OA1 patients showed a significant (p =0.068) reduction in medial femoral cartilage thickness (mean = -19.04%, range = (-0.63 to -39.78%)) and all ten OA1 patients showed a significant (p=0.083) reduction in lateral femoral cartilage thickness ((mean = -19.94%, range = (-6.22 to -35.52%)), as illustrated in figure 3. The average rate of change of cartilage thickness and volume (table 1) was calculated as the least squared means. Representative data from the femur shows a decreasing trend, however, the standard error (in parenthesis) shows a large variation in individual patient data (fig. 3). This variation could be due to a short follow-up time of two years, an insufficient sample size, or to the heterogeneity of the cohort and OA progression in general. Furthermore, significant correlations were established between lateral cartilage thickness and medial femoral bone parameters, based on the entire longitudinal data (table 2). These correlations reveal that as lateral cartilage thickness decreases, App. BV/TV and App. Tb.N of the medial condyle decrease while App. Tb.Sp increases.

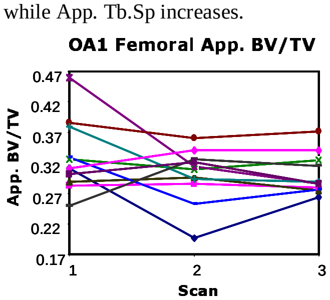

Figure 1

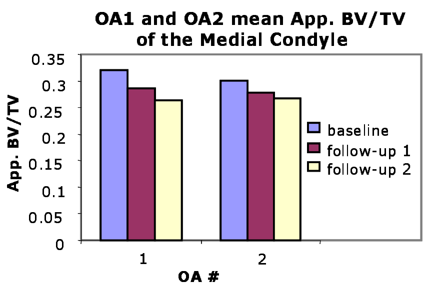

Figure 2

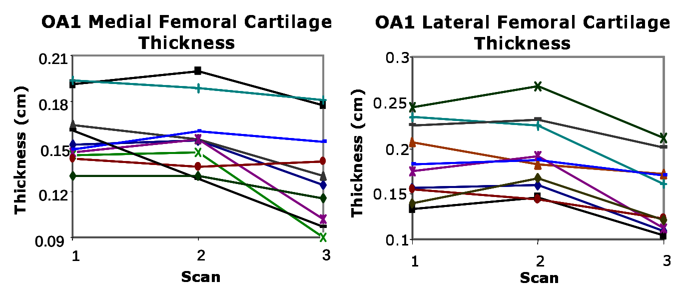

Figure 3

		Cartilage Th.	Cartilage Vol.
Lat Cond	OA1	-10.5 (11.0)	-7.0 (5.8)
	OA2	-9.4 (11.2)	-5.3 (7.3)
Med Cond	OA1	-7.7 (10.3)	-10.2 (14.2)
	OA2	-2.5 (10.4)	-5.4 (14.5)

Table 1 (above): The average rate of change of cartilage thickness and volume. Standard error is in parenthesis.

Table 2 (right): Correlations between lateral cartilage thickness and medial femoral bone parameters, based on the entire longitudinal data.

OA	Cartilage	Bone	Correlation
OA1+OA2	Lateral Femoral Th.	App. Tb.N Medial Condyle	0.46(p=0.006)
OA2	Lateral Femoral Th.	App. Tb.N Medial Condyle	0.60(p=0.04)
OA1+OA2	Lateral Tibial Th.	App. BV/TV Medial Condyle	0.42(p = 0.01)
OA2	Lateral Tibial Th.	App. BV/TV Medial Condyle	0.60(p = 0.04)
OA1+OA2	Lateral Tibial Th.	App. Tb.N Medial Condyle	0.53(p=0.001)
OA2	Lateral Tibial Th.	App. Tb.N Medial Condyle	0.74(p=0.004)
OA1+OA2	Lateral Tibial Th.	App. Tb.Sp Medial Condyle	-0.41(p=0.02)
OA2	Lateral Tibial Th.	App. Tb.Sp Medial Condyle	-0.61(p=0.03)

Conclusion:

This study demonstrates a longitudinal relationship between the morphological changes in bone and cartilage structure in patients with varying degrees of OA. Although a large variation of bone and cartilage changes is evident between patients, significant trends are seen in a relatively small sample size with a short follow-up duration. This study emphasizes the potential of quantitative MRI as a tool for the monitoring of OA and the status of the joint.

References:

[1] Lindsey, C, et al. ISMRM Proc. 97; 2002

Acknowledgements:

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