

Normal T2 map profile of the entire femoral cartilage using a novel angle/layer dependent approach

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Purpose: T2 mapping is a widely utilized MR technique for quantitative assessment of cartilage degeneration. Previous studies have compared T2 values between subregions in the knee joint (1), or between weight-bearing and non weight-bearing region (2). However, there has been no study that assessed angular and layer dependent variations of T2 value in entire femoral cartilage. The purpose of this study was to create normalized T2 map profiles from the entire femoral cartilage of normal volunteers to assess regional variations using a novel angle/layer dependent approach.

Methods: Twenty healthy knees with equal number of left/right knees (mean 28.9 years; range: 19-38) were investigated in this study. T2 images were acquired at a 3T MR scanner (Achieva, Philips Healthcare, Netherlands) utilizing an 8-channel knee coil. The imaging protocol included a 2D, turbo spin-echo T2-weighted sequence (TR/TE= 2700/26ms, FA= 90, imaging plane= true sagittal to B₀, FOV/slice thickness/gap= 140/3/0mm, matrix size= 512×512). Manual segmentation of entire femoral cartilage was performed by two raters independently slice by slice using Matlab (Mathworks, Natick, MA, Fig. 1). The center of the medial condyle (MC), lateral condyle (LC), and trochlea (T) were defined by referring to reformatted coronal images. Then we converted a total of 31 slices into 23 normalized slices in each subject, based on three anatomical landmarks by every 3-mm slice thickness (e.g. MC+3, MC+6, T-3). We calculated the average T2 values for two layers (deep and superficial) and 4-degree step angles over segmented cartilage at each normalized slice. We created 3D-graph of T2 profiles shown as approximate curved surfaces using custom Matlab program. Inter- and intra-rater reliabilities were assessed using intraclass correlation coefficient (ICC). T2 value between the deep and superficial layer at the center of each femoral compartment were compared using unpaired *t*-test/Mann-Whitney test for normal/non-normal distributed data, respectively. T2 values between magic angle and other representative angles were compared using Kruskal-Wallis test and Steel-Dwass post hoc test. Statistical analyses were performed using R version3.0.2 for Windows software (R Development Core Team, Vienna, Austria). *P* values less than 0.05 were considered to be statistically significant.

Results: The inter- and intra-rater ICCs of average T2 values in entire femoral cartilage were either “good” or “excellent” in each layer (Fig.2). The ICCs with respect to each normalized slice showed that the inter- and intra-rater ICCs around the trochlea, and both edges of the condyles were lower than those around the center of the medial and lateral condyle (Fig.2). Average T2 value was significantly higher in the superficial layer than in the deep layer at the center of each femoral compartment (Table 1). T2 profiles on 3D graph exhibited magic angle effect clearly in each layer at the entire femoral cartilage, the medial and lateral condyle (Fig.3). Scatter plots of T2 values at the magic angle and other representative angles showed that magic angle effect at the medial condyle was observed more clearly, especially in whole and deep layer, while in superficial layer the peaks shifted to $\pm 30^\circ$ (Fig.4a-c). T2 value at the lateral condyle showed wide and dull peaks from -70° to -54° , and a large variety of T2 value was observed especially at 0° in the superficial layer (Fig.4d-f).

Conclusion: The normal T2 map profile of entire femoral cartilage showed variations in ICCs by location and in T2 values by angles and layers. The results indicate the importance of evaluating cartilage in consideration of these variations for diagnosis of cartilage degeneration in specific location of the knee.

References:

- (1) Surowiec RK, et al. Knee Surg Sports Traumatol Arthrosc. 2013;22(6):1385-95
- (2) Shimoi T et al. Skeletal Radiol. 2013;42:363-70

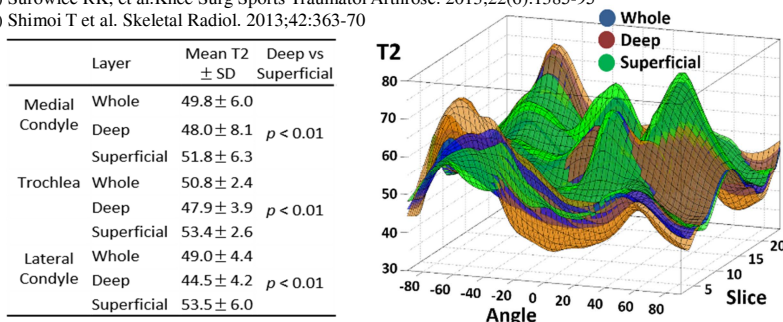


Table 1 T2 values in each layer at the center of femoral compartment. Fig. 3 3D graph of the entire femoral cartilage

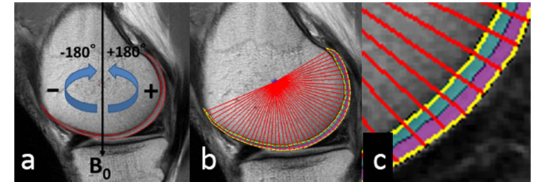


Fig.1 Articular segmentation with angle/layer dependent approach (a) Static magnetic field (B₀) was defined as 0 degrees, with negative/positive angles were located anterior/posterior to the central point. (b) Radial lines from a central point divided cartilage into 4-degree segments. (c) Segmentation of cartilage into deep (0-50%) and superficial layers (51-100%) of relative thickness.

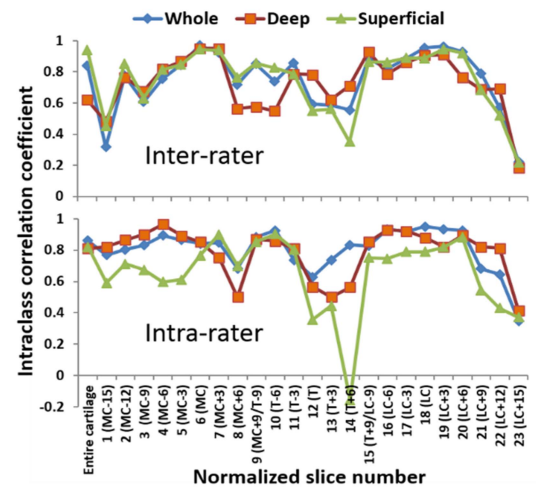


Fig. 2 Inter- and intra-rater reliability of T2 values

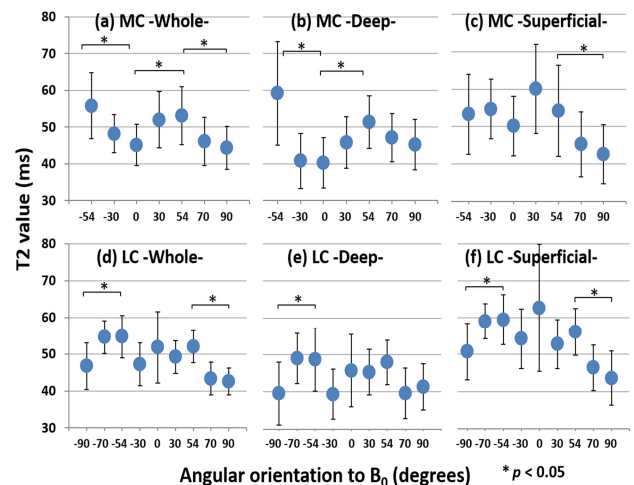


Fig. 4 Comparison of T2 values between magic angle and others