

# Morphological and biochemical (T2) MR evaluation and comparison of cartilage repair tissue of the patella and the medial femoral condyle

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**Introduction:** In a recent survey on 25,124 knee arthroscopies, cartilage lesions were found most frequently within the patella (36%) and the medial femoral condyle (34%). However, there is a clear topographical difference in cartilage surface and cartilage thickness between these two anatomical sites. Furthermore, when looking at biochemical and biomechanical properties, this regional variation is also obvious, most likely due to different loading conditions that influence the compressive and tensile behavior of articular cartilage (1,2).

Conventional magnetic resonance imaging (MRI) allows a non-invasive evaluation of articular cartilage and has been shown to be sensitive to morphologic alterations at the repair site. A validated scoring system for the morphological MR evaluation of cartilage repair sites is the magnetic resonance observation of cartilage repair tissue (MOCART) system (3). However, this purely morphological MR imaging cannot define the composition of repair tissue. The ultrastructural organization of articular cartilage can be assessed by biochemical MRI non-invasively. T1 relaxation time in the presence of Gd-DTPA<sup>2-</sup> (dGEMRIC) reflects the proteoglycan content of articular cartilage, whereas T2 relaxation time is sensitive to the integrity and orientation of the collagen network and hydration. For T2 mapping, the zonal assessment of deep and superficial cartilage layers has been shown to provide additional information based on the anisotropy of collagen fibers. An increase in T2 values from the deep to superficial zones has been reported as a marker of hyaline or hyaline-like cartilage structure (4). Together with the proteoglycan content, the collagen content and the network architecture are the major determinants of the biomechanical properties of articular cartilage, where a topographical difference has been reported between patella and femoral cartilage.

With surgical cartilage repair, differences in clinical outcome have been described between cartilage transplantation in the patella and in the femoral condyle (5). Furthermore, the difference in the quality of articular cartilage repair between the patella and the femoral condyle is known to be strongly influenced by the mechanical environment (6).

The objective of the present cross-sectional study was to compare cartilage repair tissue in the patella and cartilage repair tissue in the medial femoral condyle in patients after matrix-associated autologous chondrocyte transplantation (MACT) using morphological scoring and biochemical *in vivo* zonal T2 mapping.

**Material and Methods:** Thirty-four patients treated with MACT underwent 3T-MRI of the knee. Patients were treated on either patella (n=17) or MFC (n=17) cartilage and were matched by age (patella:  $36.3 \pm 7.9$  years, range 23 – 49 years; MFC:  $35.2 \pm 8.2$  years, range 20 – 49) and post-operative interval (patella:  $29.3 \pm 21.5$  months; MFC:  $29.3 \pm 21.5$  months). MR imaging was performed on a 3 Tesla MR scanner (Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany), with a gradient strength of 40mT/m, using a dedicated eight-channel knee coil (In vivo, Gainesville, FL, USA). The protocol for both groups was identical and consisted of a morphological 3D true – fast imaging with steady-state precession (True-FISP) sequence for the morphological assessment and a multi-echo spin-echo (SE) sequence using six echoes for T2 mapping. In order to evaluate the morphological condition after a cartilage repair procedure for each anatomical region (patella and MFC) using the isotropic 3D- True-FISP sequence, the MOCART scoring system was used. T2 maps were obtained in-line by a pixel-wise, mono-exponential, non-negative least squares (NNLS) fit analysis using the built-in MapIt software (Siemens Medical Solutions, Erlangen, Germany). Regions of interest (ROI) dividing the full thickness of cartilage repair tissue as well as the control cartilage into equal-sized deep and superficial aspects. For additional evaluation, the evaluation was performed concerning different post-operative follow up periods (short-term (6-12months), mid-term (24 months) and long-term (60 months)). Quantitative evaluation was accomplished by analyses of variance using a three-way ANOVA with random factors, considering the different measurements within each patient.

**Results:** Morphological Results: For the morphological evaluation, the MOCART scoring system for all postoperative intervals together showed no significant difference between the two cartilage repair sites, with a MOCART score of  $73.2 \pm 12.7$  (ranging from 50 to 90) for the patella and  $71.5 \pm 12.5$  (ranging from 50 to 90) for the MFC ( $p=0.685$ ). Biochemical T2 results: A comparison of T2 relaxation times (ms) for all patients after MACT of the patella and for all patients after MACT of the MFC showed significantly higher T2 values for the MFC (control cartilage: deep= $44.4 \pm 4.6$ , superior= $55.9 \pm 6.6$ , mean= $48.7 \pm 5.2$ ; cartilage repair tissue: deep= $50.4 \pm 9.5$ , superior= $54.5 \pm 10.9$ , mean= $52.5 \pm 9.7$ ) compared to the patella (control cartilage: deep= $35.0 \pm 6.7$ , superior= $44.3 \pm 7.9$ , mean= $39.7 \pm 7.0$ ; cartilage repair tissue: deep= $39.1 \pm 7.6$ , superior= $45.2 \pm 8.2$ , mean= $42.2 \pm 7.5$ ) ( $p<0.001$ ).

**Discussion:** In conclusion, the preliminary results of this initial study demonstrate that differences in T2 values could be found for healthy control cartilage, as well as cartilage repair tissue, between the patella and the MFC. The morphological evaluation showed no clear difference between these anatomical sites. The zonal pattern of healthy cartilage was comparable for the patella and the MFC. The cartilage repair tissue in the patella showed an earlier onset of this significant zonal increase from deep to superficial cartilage layers compared to the MFC. However, in all measurements, this zonal stratification was more clearly visible and more distinct for healthy control cartilage compared to cartilage repair tissue. Although this study demonstrates the feasibility of describing differences in T2 relaxation times and zonal T2 patterns between cartilage sites with known different biomechanical properties, the *in vivo* assessment of these properties of articular cartilage still remains challenging.

**References:** 1. Kurkijarvi et al. Magn Reson Med 2004 ; 52:41-46. 2. Lyra et al. J Biomed Mater Res 1999 ; 48 :482-487. 3. Marlovits et al. Eur J Radiol 2004 ;52-3 :310-9. 4. White et al. Radiology 2006 ;241 :407-414. 5. Hangody et al. Injury 2008 ;39 Suppl 1 :S32-39. 6. Buckwalter et al. Iowa Orthop J 2003 ;23 :66-74.

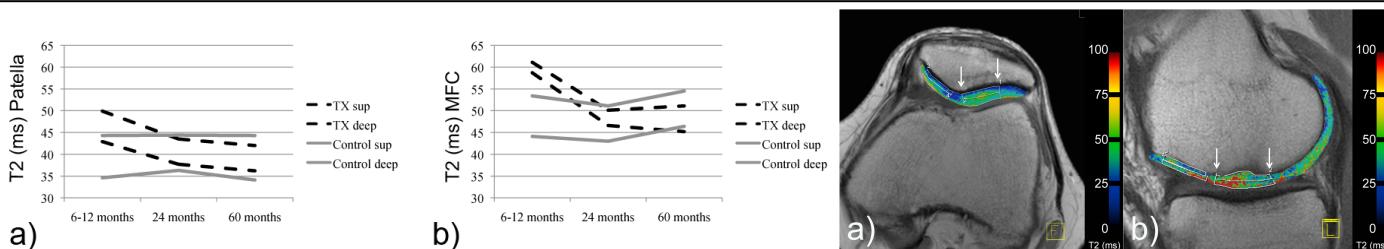


Figure 1 visualizes the zonal pattern of T2 relaxation within the patella (a) and the MFC (b) according to the different follow-up periods. Higher T2 values of the cartilage transplant (dotted black line) in the short-term follow-up adapt over time to the values of the control cartilage (continuous grey line) as a possible sign of cartilage repair tissue maturation. Figure 2 shows exemplary T2 maps of patients after MACT (arrows) of the patella (a) and the MFC (b).