

Biomechanical MR Imaging of the Human Knee Cartilage after Cartilage Transplantation

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Target audience: Radiologists who specialize in biomechanical MR imaging of human knee articular cartilage transplants

Purpose: MR imaging of the knee joint under loading enables obtaining biomechanical information about cartilage properties¹. T2 mapping of the articular cartilage is the technique of choice for joint MR imaging because it shows degeneration associated with changes in water content and damage to the collagen fiber network^{2,3}. Use of dedicated MR-compatible compression device on the patient lying in magnet in the supine position allows simulating physiological load. The purpose of this study was, therefore, to characterize the time-dependence of cartilage stiffness in the repair tissue of the femoral condyle under static loading using T2 mapping of the femoral condyle, in patients who underwent cartilage transplantation.

Methods: Ten patients (mean, 41 years \pm 8; six male and four female, three right and seven left knees) after cartilage transplantation were measured using a multi-slice multi-echo (MSME) T2 mapping technique on a 3 Tesla MR imaging system (Siemens Healthcare, Erlangen, Germany). Load corresponding to 120N was applied to the knee, using an MR-compatible, custom-made, pneumatically controlled compression device. Four T2 measurements were performed. First, a load-free measurement was obtained, followed by two consecutive loading measurements and one additional load-free T2 measurement at the end of the series. ROIs were drawn manually by an experienced radiologist in the deep and superficial zones of the weight-bearing area on the femoral cartilage where the cartilage transplant was located, and were compared with T2 relaxation time values in the weight-bearing zone of healthy volunteers under the same loading conditions. One selected slice was evaluated in each subject. Mean values, standard deviations, and pixel counts were recorded and statistically analyzed by Pearson's correlation test.

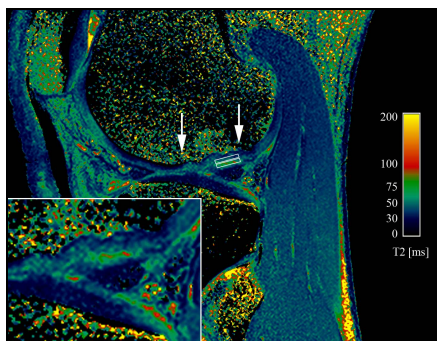


Fig.1: T2 map of a human knee with a cartilage transplant in the load-bearing zone

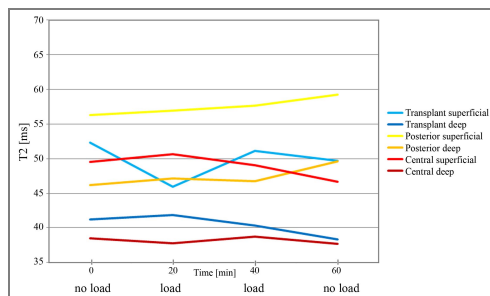


Fig.2: T2 development during loading procedure in case of patients after cartilage transplantation

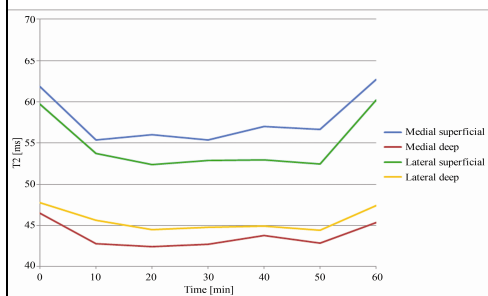


Fig.3: T2 development during loading procedure in case of asymptomatic volunteers

Results: Figure 1 shows the pseudo-colored T2 relaxation time value variations inside the cartilage transplant (zoomed area), corresponding to the internal structure of collagen fibers and water content. Figure 2 shows mean T2 values in the superficial and deep regions of cartilage transplants, as well as posterior and central native cartilage. Graph reveals non-significant changes in T2 values during „no load–load–load–no load“ sequence (Fig.2), which is in contrast to the results from asymptomatic volunteers (Fig.3). Mean cartilage transplant values for the „no load–load–load–no load“ sequence at the superficial ROIs were in the range of 46.0 to 52.4ms and in the deep ROIs were in the range of 38.3 to 41.8 ms. In native, normal-appearing cartilage of patients after cartilage transplantation, mean superficial ROIs values for the „no load–load–load–no load“ sequence were in the range of 56.3 to 59.3ms and 46.3 to 49.7ms in deep layer. Normal-appearing cartilage (posterior and central) and cartilage transplant were always evaluated in the same slice. The Pearson's correlation coefficient for the T2 values in the superficial transplant layer between non-loading and loading was 0.74, and for the deep transplant layer between non-loading and loading it was 0.65.

Discussion: In this study, cartilage transplant did not exhibit a decrease of T2 values, as expected from the results in healthy volunteers. This may imply that the collagen fiber organization within the repair tissue had not yet developed after this cell-based cartilage transplantation technique, and therefore, the matrix within the repair tissue had reacted differently to the static load applied during these experiments. This implies that the proposed method could be used for the further evaluation of cartilage transplant maturation over time, in the post-surgery period, and may give insight into the biomechanical properties of repair tissue after surgery.

Conclusions: In our previous study¹ on asymptomatic volunteers without cartilage transplants, we showed that loading of the knee joint during MRI can demonstrate the biomechanical characteristics of human knee cartilage. Our current study shows that, in patients after cartilage transplantation, T2 mapping patterns, under loading, behave differently compared to the characteristic T2 mapping behavior in volunteers with healthy intact cartilage under loading conditions. This could possibly be attributable to the different ultra-structural composition of the collagen fiber network in repair tissue compared to normal healthy cartilage, and thus, could explain the different biomechanical properties.

References: 1. Toshiyuki S, Szomolanyi P, Juras V, Zbyn S., Nishii T, Trattnig S. Biomechanical MR Imaging of the Human Knee Cartilage *in vivo*. *Proc. Inter. Soc. Mag. Reson. Med.* 2012, 20: 2727. (2012). 2. Burstein D, Bashir A, Gray ML. MRI techniques in early stages of cartilage disease. *Investigative Radiology*. Oct 2000;35(10):622-638 3. Mamisch TC, Trattnig S, Quirbach S, Marlovits S, White LM, Welsch GH. Quantitative T2 mapping of knee cartilage: differentiation of healthy control cartilage and cartilage repair tissue in the knee with unloading—initial results. *Radiology*. Mar 2010;254(3):818-826.