Three-dimensional magnetic resonance observation of cartilage repair tissue (3D MOCART) score assessed with an isotropic 3D-True-FISP sequence at 3.0 Tesla

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Introduction: Articular cartilage injuries are a common pathology of the knee joint and many patients could benefit from cartilage repair. Therefore, widespread surgical cartilage repair techniques, including marrow-stimulation techniques, osteochondral grafting, and chondrocyte implantation/transplantation, require objective and reliable follow-up examination. With its excellent soft tissue contrast and its precise morphological evaluation of articular cartilage and cartilage repair tissue, magnetic resonance imaging (MRI) is the method of choice as a non-invasive and objective outcome measure. The magnetic resonance observation of cartilage repair tissue (MOCART) scoring is claimed to allow subtle and suitable assessment of the articular cartilage repair tissue (1,2). Indeed, in many recent original articles, review articles and book chapters, the MOCART score is used and discussed in the follow-up after different cartilage repair procedures (3-5).

This MR assessment of the MOCART score is based on standard MR sequences. Depending on the locality of the area of cartilage repair, the MR evaluation of the cartilage repair tissue is performed on sagittal, axial or coronal two-dimensional (2D) planes using high spatial resolution together with a slice thickness of 2-4 mm. In contrast, new isovoxel sequences have the potential for high-resolution isotropic imaging with a voxel size down to 0.4mm^3, and can thus be reformatted in arbitrary planes without any loss of spatial resolution. Building on these capabilities of multi-planar reconstruction (MPR), the cartilage repair tissue could be visualized three-dimensionally (3D, and its classification and grading by an MR-based scoring system might benefit. Concerning the accuracy of cartilage imaging and the pre-operative diagnostic performance for the detection of cartilage defects, the 3D true fast imaging with steady-state precession (True-FISP) has shown promising results (7).

The purpose of this study is to introduce an improved MOCART score using the possibilities of 3D MPR in the evaluation of cartilage repair tissue after matrix-associated autologous chondrocyte transplantation (MACT). Its further aim is to compare this 3D-MOCART scoring system using the 3D True-FISP sequence with the conventional MOCART scoring system using standard sequences and a 2D evaluation.

Material and Methods: One hundred consecutive MR scans were prospectively included in this study between February 2007 and September 2008. MRI was performed during clinical routine at standard follow-up intervals of 1, 3, 6, 12, 24, and 60 months after MACT of the knee joint. The frequency of the follow-up intervals in this cross-sectional evaluation was as given: 1 month (n=10); 3 months (n=13); 6 months (n=14); 12 months (n=16); 24 months (n=28); and 60 months (n=19). The mean follow-up interval was 21.4 ± 20.6 months. The 100 MRI scans were performed on 60 patients with a mean age of 35.8 ± 9.4 years. The clinical routine MRI was performed on a 3T MR unit (Tim Trio, Siemens Healthcare, Erlangen, Germany) using a dedicated eight-channel knee coil (In vivo, Gainesville, FL, USA). The MR protocol was identical for all 60 patients and consisted of a set of localizers, a high-resolution proton-density turbo spin-echo (PD-TSE) sequence (0.2x0.2x2mm, TA: 6:11 min), a T2-weighted dual fast spin-echo (dual-FSE) sequence (0.4x0.4x3mm, TA: 6:46 min), and a T1-weighted turbo inversion recovery magnitude (TIRM) sequence (0.6x0.6x3mm; TA: 2:35 min) for standard 2D MOCART evaluation. Additionally an high-resolution isotropic 3D-True-FISP sequence (0.4x0.4x0.4mm; TA: 6:47 min) was added for 3D assessment of the MOCART score.

The new 3D MOCART score was based on the standard 2D MOCART score adding variables and subcategories to use the advances of isotropic 3D MR imaging. The new 3D MOCART was assessed using the isotropic 3D-True-FISP sequence and its MPR. The 3D MOCART score was based on the 2D MOCART score; changes and additives were based on the new possibilities of isotropic MR imaging, on the authors' experience during studies and clinical routine, on published manuscripts and abstracts by other groups, on presentations and discussions during international conferences, and on the needs of daily patient care. Variables were 1) defect fill, 2) cartilage interface, 3) bone interface, 4) surface, 5) structure, 6) signal intensity, 7) subchondral lamina, 8) chondral osteophyte, 9) bone marrow edema, 10) subchondral bone, and 11) effusion. Additionally for all variables the exact localization of a possible pathology or alteration, referring to the whole cartilage transplant and to the weight-bearing zone, can be depicted.Statistical analysis was performed to correlate results of the standard 2D MOCART score (analyzed with the PD-TSE, dual FSE and TIRM sequences) and the new 3D MOCART score (analyzed with the 3D True-FISP sequence) to assess the capabilities of the new scoring system. Furthermore image quality and possible artifacts were evaluated.

Results: The correlation between the standard 2D MOCART score and the new 3D MOCART showed for the eight variables "defect fill", "cartilage interface", "surface", "adhesions", "structure", "signal intensity", "subchondral lamina", and "effusion" – a highly significant (p<0.001) correlation with a Pearson coefficient between 0.566 and 0.932. The variable "bone marrow edema" correlated significantly (p<0.05; Pearson coefficient: 0.257). Two variables of the new 3D MOCART score could not be correlated, as they where not part of the standard 2D MOCART score. The subjective quality of the three standard MR sequences was comparable to the isotropic 3D-TrueFISP sequence. Artifacts were more frequently visible within the 3D-TrueFISP sequence.

Discussion: In the clinical routine follow-up after cartilage repair, the 3D MOCART score, assessed by only one high-resolution isotropic MR sequence, provides comparable information than the standard 2D MOCART score. Hence the new 3D MOCART score has the potential to combine the information of the standard 2D MOCART score with the possible advantages of isotropic 3D MRI at highfield. A clear limitation of the 3D-TrueFISP sequence was the high number of artifacts. Future studies have to prove the clinical benefits of a 3D MOCART score.

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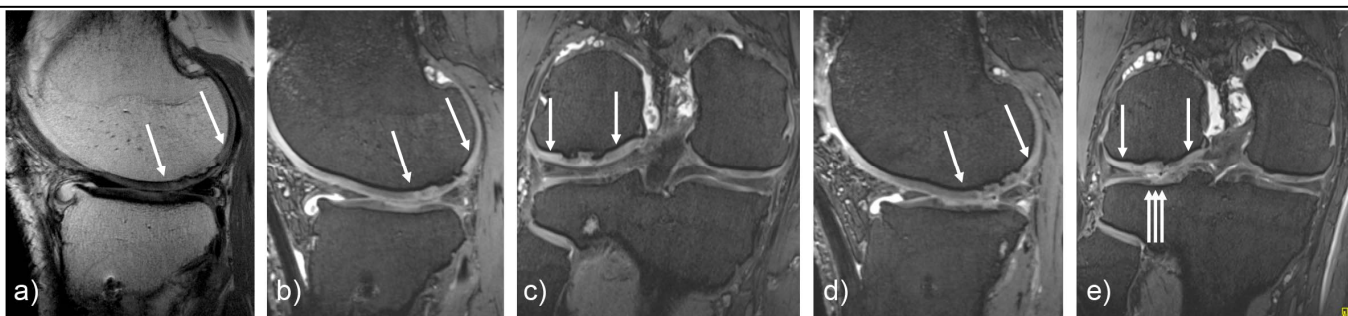
Figure 1) shows a patient after MACT (arrows) of the LFC visualized using the PD-TSE sequence (a) and the MPR of the 3D-True-FISP sequence (b-e) where chondral osteophytes can be visualized in every plane, depicting a corresponding tibial cartilage defect (3 arrows).