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Evaluation and comparison of cartilage repair tissue of the patella and medial femoral condyle by using morphological MRI and biochemical zonal T2 mapping

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Abstract The objective of this study was to use advanced MR techniques to evaluate and compare cartilage repair tissue after matrix-associated autologous chondrocyte transplantation (MACT) in the patella and medial femoral condyle (MFC). Thirty-four patients treated with MACT underwent 3-T MRI of the knee. Patients were treated on either patella (n=17) or MFC (n=17) cartilage and were matched by age and postoperative interval. For morphological evaluation, the MR observation of cartilage repair tissue (MOCART) score was used, with a 3D-True-FISP sequence. For biochemical assessment, T2 mapping was prepared by using a multi-echo spin-echo approach with particular attention to the cartilage zonal structure. Statistical evaluation was done by analyses of variance. The MOCART score showed no significant differences between the patella and MFC ($p \geq 0.05$). With regard to biochemical T2 relaxation, higher T2 values were found throughout the MFC ($p < 0.05$). The zonal increase in T2 values from deep to superficial was significant for control cartilage ($p < 0.001$) and cartilage repair tissue ($p < 0.05$), with an earlier onset in the repair tissue of the patella. The assessment of cartilage repair tissue of the patella and MFC afforded comparable morphological results, whereas biochemical T2 values showed differences, possibly due to dissimilar biomechanical loading conditions.

Keywords MRI · Cartilage repair · T2 mapping · MOCART · Patella · Medial femoral condyle

Introduction

Articular cartilage lesions are common disorders of the knee joint. In a recent survey on 25,124 knee arthroscopies, cartilage lesions were found most frequently within the patella (36%) and the medial femoral condyle (MFC) (34%) [1]. However, there is a clear topographical difference in cartilage surface and cartilage thickness between these two anatomical sites [2, 3]. 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 [4–6].

Conventional magnetic resonance imaging (MRI) allows a noninvasive evaluation of articular cartilage and has been shown to be sensitive to morphological alterations at the repair site [7–10]. A validated scoring system for the morphological MR evaluation of cartilage repair sites is

the MR observation of cartilage repair tissue (MOCART) system [11]. However, this purely morphological MRI cannot define the composition of repair tissue. The ultrastructural organization of articular cartilage can be assessed by biochemical MRI noninvasively. T1 relaxation time in the presence of Gd-DTPA^{2-} (delayed gadolinium-enhanced MRI of cartilage (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 [12–14]. 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 [15]. The appearance of the cartilage layers in MRI is strongly influenced by this typical anisotropic arrangement within the different cartilage zones and by their alignment with the main magnetic field [16–18]. In histologically validated animal studies [19, 20], and a recent patient study [21], an increase in T2 values from the deep to superficial zones has been used as a marker of hyaline or hyaline-like cartilage structure. 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 [5].

With surgical cartilage repair, differences in clinical outcome have been described between cartilage transplantation in the patella and in the femoral condyle [22]. 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 [23].

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

Materials and methods

Patient population

Thirty-four patients treated with MACT were enrolled in this study. There were 17 patients whose patellar cartilage was treated and 17 patients whose MFC cartilage was treated. The patients of each group were matched from a greater cohort by age and postoperative interval to obtain better comparability. The Medical University provided ethical approval for this study, and written, informed consent was obtained from all patients before enrolment in the study.

For inclusion into the study, the patients of both groups had to have a single, symptomatic, full-thickness cartilage defect treated with MACT. MACT is a sophisticated, two-step surgical approach for the treatment of middle to large full-thickness cartilage defects by using a hyaluronan-based scaffold (Hyalograft®C, Fidia Advanced Biopolymers, Abano Terme, Italy). The defects were located on the patella (n=17), with a mean size of 3.3 cm^2 (range 1.4–5.2 cm^2), and the MFC (n=17), with a mean size of 4.2 cm^2 (range 1.3–9.82 cm^2). This difference in size, however, was not statistically significant (p=0.11). Furthermore, there was no difference between the two groups with regard to the body mass index of 24.6 kg/m^2 for the group of MACT in the patella and 25.7 kg/m^2 for the group of MACT in the MFC (p=0.30). There were eight women and nine men with MACT of the patella cartilage and five women and 12 men with MACT of the MFC.

Exclusion criteria included severe osteoarthritis and instability or deformity. These criteria and the solitary nature of the cartilage defect were preoperatively proven through conventional radiographs and MRI, and documented during initial surgery. The two groups were matched by age (patella, 36.3±7.9 years (range 23–49); MFC, 35.2±8.2 years (range 20–49)) and by length of postoperative follow-up (patella, 29.3±21.5 months; MFC, 29.3±21.5 months). For each group, the postoperative intervals (time between MACT surgery and MRI) within this cross-sectional evaluation were classified as a short-term follow-up of 6–12 months (n=6), a midterm follow-up interval of 24 months (n=6), and a long-term follow-up of 60 months (n=5).

Image acquisition

MRI was performed on a 3-T MR system (Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany) by using a dedicated eight-channel knee coil (Invivo, Gainesville, FL, USA). All patients were positioned consistently with the joint space in the middle of the coil and the knee extended in the coil. Patients were scanned after at least 0.5 h of rest.

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 multiecho spin-echo (SE) sequence using six echoes for T2 mapping. After multiplanar reconstruction of the isotropic 3D-True-FISP sequence using a 3D viewing tool, the cartilage repair site was identified to facilitate planning of appropriate anatomic coverage/localization of the subsequent 2D SE-T2 mapping acquisition. For exact localization of the T2 measurements, the morphological information from the 3D-True-FISP images was used, together with the surgical reports, and with an orthopedic surgeon present during the MR measurements. T2 relaxation times were obtained axially for the patella and sagittally for the MFC. The isotropic 3D-True-FISP was obtained in the coronal orientation for all patients [24]. T2

relaxation times were obtained from T2 maps that were reconstructed using an SE acquisition with a repetition time (TR) of 1,200 ms and six echo times (TE) of 13.8 ms, 27.6 ms, 41.4 ms, 55.2 ms, 69 ms, and 82.8 ms. The field of view (FoV) was 160×160 mm, the pixel matrix was 384×384, the voxel size was 0.4×0.4×3.0 mm, and the distance factor was 20%. The bandwidth was 228 Hz/pixel, with 12 slices; acquisition time was 4 min 9 s. The 3D-True-FISP sequence was obtained with a TR of 8.9 ms and a TE of 3.8 ms. The FoV was 160×160 mm, the pixel matrix was 384×384, and the voxel size was 0.4×0.4×0.4 mm. The data acquisition time for this sequence was 6 min 47 s.

Data analysis

In order to evaluate the morphological condition after a cartilage repair procedure for each anatomical region (patella and MFC) by using the isotropic 3D-True-FISP sequence, the MOCART scoring system was used [25]. The True-FISP sequence has very recently been shown to achieve excellent results in the evaluation of articular cartilage [24, 26, 27]. The MOCART score was designed to systematically record the constitution of the area of cartilage repair and surrounding tissues with a maximum score achievable in nine variables of 100 [10, 28]. Figures 1 and 2 illustrate morphological isotropic 3D-True-FISP data sets after MACT of the patella and the MFC.

T2 maps were obtained in-line by a pixel-wise, monoexponential, non-negative least-squares (NNLS) fit analysis using the built-in MapIt software (Siemens Medical Solutions, Erlangen, Germany). Regions of interest (ROIs) were drawn manually by an experienced senior musculoskeletal radiologist in consensus with an orthopedic surgeon with a special interest in musculoskeletal MRI. A region of morphologically normal-appearing cartilage within the same anatomical region was selected as a reference (control) cartilage. The ROIs dividing the full thickness of cartilage repair tissue as well as the control cartilage into equal-sized deep and superficial aspects were positioned on three consecutive slides covering the cartilage repair tissue. Control cartilage was defined as normal on the morphological True-FISP sequence if cartilage thickness was preserved, the surface was intact, and no intrachondral signal alterations were visible. Sample T2 maps with ROIs positioned are shown in Fig. 3. The mean number of pixels in the ROIs drawn were calculated for the patella cartilage (repair tissue, deep 427±307 and superficial 456±272; control cartilage, deep 459±217 and superficial 498±191); and for the femoral cartilage (repair tissue, deep 273±145 and superficial 287±153; control cartilage, deep 263±114 and superficial 269±104). There was no significant difference between ROIs for deep and superficial layers or between ROIs of repair tissue and control cartilage ($p \geq 0.05$); however, all ROIs within the patella were significantly larger than all ROIs within the femoral condyle ($p < 0.05$).

To evaluate the postoperative clinical outcome, each patient subjectively evaluated the knee function at follow-up, using the patient-based Brittberg score, dividing clinical outcome into five groups: excellent (1), good (2), fair (3), poor (4), and failure (5) [29].

Statistical tests were used to perform the data analyses. Quantitative evaluation was accomplished by analyses of variance by using a three-way ANOVA with random factors, considering the different measurements within each patient. For the trend in between the cartilage layers (deep–superficial), a three-way analysis of variance with random effects with two repeated measures factors was performed. SPSS version 16.0 (SPSS Institute, Chicago, IL, USA) for Mac

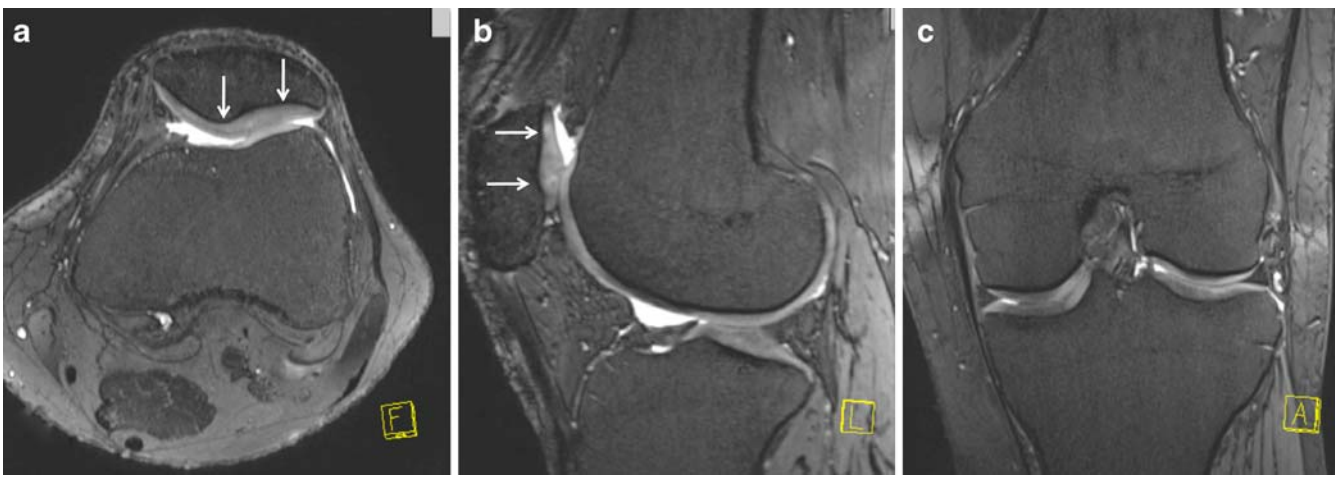

Fig. 1 Morphological 3D isotropic true fast imaging with steady-state precession (True-FISP) sequence of one patient 24 months after matrix-associated autologous chondrocyte transplantation (MACT) of the patella (*arrows*). The isotropic data set is reconstructed in transversal (**a**), sagittal (**b**), and coronal (**c**) direction. Slight effusion is still visible; the cartilage repair tissue is integrated nicely; the signal intensity is identical to the adjacent cartilage

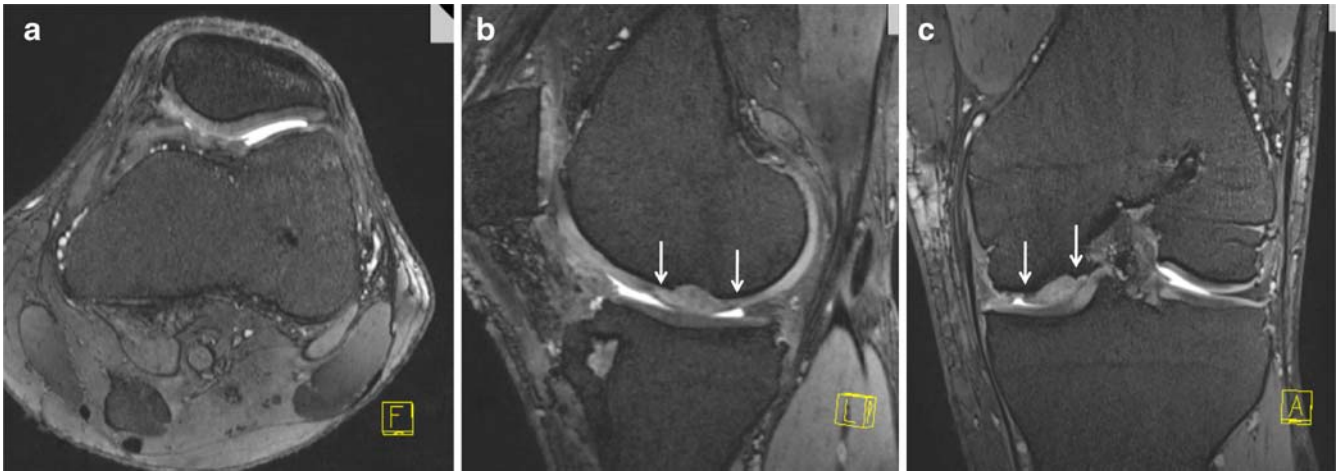

Fig. 2 Morphological 3D isotropic True-FISP sequence of one patient 12 months after MACT of the medial femoral condyle (MFC) (*arrows*). The isotropic data set is reconstructed in transversal (**a**), sagittal (**b**), and coronal (**c**) direction. Slight effusion is still visible; the cartilage transplant is integrated nicely, albeit with hypertrophy of the repair tissue. The signal intensity of the repair tissue is nearly normal with slight areas of signal alteration

(Apple, Cupertino, CA, USA) was used, and a p value less than 0.05 was considered statistically significant.

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±12.7 (ranging from 50 to 90) for the patella and 71.5±12.5 (ranging from 50 to 90) for the MFC (p=0.685). The results for the different variables of the score are given in Table 1. When looking at these variables, there are differences between the patella and the MFC; however, none of them was statistically significant. The most pronounced differences were found for filling of the defect by the repair tissue (p=0.091), the surface characteristics (p=0.172), and the signal intensity (p=0.201). Several of the variables, including structure (p=0.304), possible adhesions (p=0.325), and the constitution of the subchondral bone (p=0.488), were more alike between the patella and the femoral condyle, whereas no difference could be observed between the integration of the cartilage repair tissue to the border zone (p=1.000), the constitution of the subchondral lamina (p=1.000), and possible effusions (p=1.000).

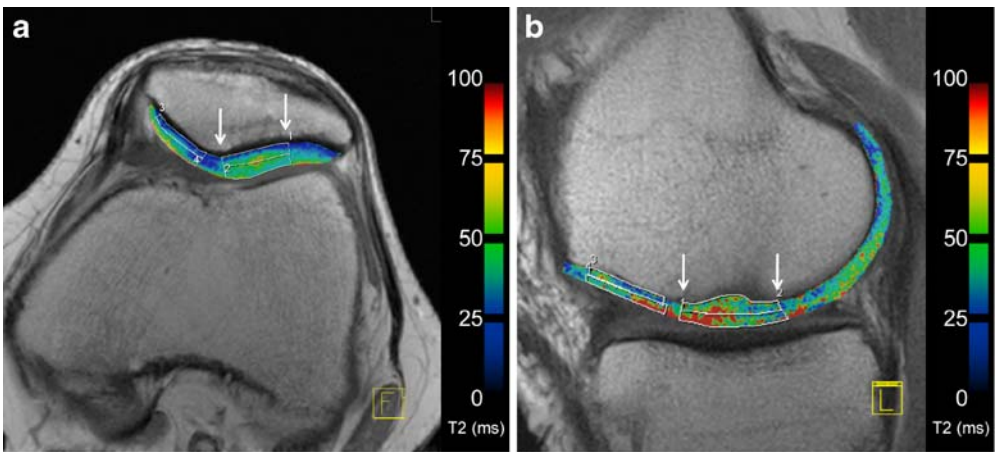

Fig. 3 Biochemical quantitative T2 maps of the patient visualized in Fig. 1 after MACT of the patella (**a**) and the patient displayed in Fig. 2 after MACT of the MFC (**b**). *Arrows* mark areas of cartilage repair; zonal (deep and superficial) region of interest analysis was prepared for the cartilage repair tissue (*arrows*) and healthy control cartilage. Whereas for the cartilage repair tissue within the MFC 12 months after surgery (**b**) higher T2 values are clearly visible which adjusts the cartilage repair tissue within the patella 24 months after surgery (**a**) more to the adjacent cartilage

Table 1 MRI evaluation of cartilage repair tissue in the patella (n=17) and medial femoral condyle (n=17) by using the magnetic resonance observation of cartilage repair tissue (MOCART) score

Variables (points for scoring)	Patella	MFC
Degree of defect repair and filling of the defect		
Complete (20)	9 (52.9)	6 (35.3)
Hypertrophy (15)	5 (29.4)	4 (23.5)
Incomplete		
>50% of the adjacent cartilage (10)	3 (17.7)	4 (23.5)
<50% of the adjacent cartilage (5)	0 (0)	3 (17.7)
Subchondral bone exposed (0)	0 (0)	0 (0)
Integration of border zone		
Complete (15)	13 (76.5)	12 (70.6)
Incomplete		
Demarcating border visible (slit-like) (10)	3 (17.6)	4 (23.5)
Defect visible <50% of the length (5)	1 (5.9)	1 (5.9)
Defect visible >50% of the length (0)	0 (0)	0 (0)
Surface of the repair tissue		
Surface intact (10)	12 (70.6)	9 (52.9)
Surface damaged <50% of depth (5)	4 (23.5)	5 (29.4)
Surface damaged >50% of depth (0)	1 (5.9)	3 (17.6)
Structure of the repair tissue		
Homogeneous (5)	12 (70.6)	9 (52.9)
Inhomogeneous (0)	5 (29.4)	8 (47.1)
Signal intensity of the repair tissue		
Normal (identical to adjacent cartilage) (30)	6 (35.3)	8 (47.1)
Nearly normal (slight areas of signal alteration) (15)	8 (47.1)	9 (52.9)
Abnormal (large areas of signal alteration) (0)	3 (17.6)	0 (0)
Subchondral lamina		
Intact (5)	9 (52.9)	9 (52.9)
Not intact (0)	8 (47.1)	8 (47.1)
Subchondral bone		
Intact (5)	12 (70.6)	10 (58.9)
Not intact (0)	5 (29.4)	7 (41.1)
Adhesions		
No (5)	16 (94.1)	17 (100)
Yes (0)	1 (5.9)	0 (0)
Effusion		
No (5)	9 (52.9)	9 (52.9)
Yes (0)	8 (47.1)	8 (47.1)

Values by number of patients and percentage within the group

The subdivision based on the different follow-up intervals after surgery showed stable values for the MOCART score within the patella (75.8 at 6–12 months, 70.0 at 24 months, 74.0 at 60 months) and the MFC (70.8 at 6–12 months, 72.5 at 24 months, 71.0 at 60 months), and also no significant differences for the single variables of the score (p>0.05).

Biochemical results

A comparison of T2 relaxation times (milliseconds) 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±4.6 and superior 55.9±6.6 (mean 48.7±5.2); cartilage repair tissue, deep

Table 2 Mean T2 values (milliseconds) for cartilage repair tissue and control cartilage of all patients, subdivided into groups according to postoperative follow-up interval

Localization	Follow-up			T2 deep	T2 superior	T2 mean
MFC	6–12 months	Cartilage repair tissue	Mean	58.7	61.1	59.9
			StDv	7.8	10.6	8.7
		Control cartilage	Mean	44.1	53.4	48.8
			StDv	4.2	8.7	6.1
		Differences	*p*	0.001	0.064	0.001
	24 months	Cartilage repair tissue	Mean	46.6	50.1	48.3
			StDv	7.7	8.6	8.0
		Control cartilage	Mean	43.0	51.1	47.1
			StDv	5.7	5.7	5.4
		Differences	*p*	0.217	0.736	0.655
	60 months	Cartilage repair tissue	Mean	45.2	51.8	48.5
			StDv	6.3	11.0	7.8
		Control cartilage	Mean	46.4	54.5	50.5
			StDv	2.7	4.3	3.3
		Differences	*p*	0.579	0.476	0.471
Patella	6–12 months	Cartilage repair tissue	Mean	42.9	49.5	46.2
			StDv	7.8	10.6	8.7
		Control cartilage	Mean	44.1	53.4	48.8
			StDv	4.2	8.7	6.1
		Differences	*p*	0.001	0.064	0.001
	24 months	Cartilage repair tissue	Mean	46.6	50.1	48.3
			StDv	7.7	8.6	8.0
		Control cartilage	Mean	43.0	51.1	47.1
			StDv	5.7	5.7	5.4
		Differences	*p*	0.217	0.736	0.655
	60 months	Cartilage repair tissue	Mean	45.2	51.8	48.5
			StDv	6.3	11.0	7.8
		Control cartilage	Mean	46.4	54.5	50.5
			StDv	2.7	4.3	3.3
		Differences	*p*	0.579	0.476	0.471

The statistical significances are given for the differentiation of cartilage repair tissue and control cartilage

50.4±9.5 and superior 54.5±10.9 (mean 52.5±9.7)) compared with the patella (control cartilage, deep 35.0±6.7 and superior 44.3±7.9 (mean 39.7±7.0); cartilage repair tissue, deep 39.1±7.6 and superior 45.2±8.2 (mean 42.2±7.5)) ($p<0.001$). Differences between the control cartilage and the cartilage repair tissue were most obvious within the deep cartilage layer for both the patella (deep $p=0.023$, superior $p=0.646$, mean $p=0.166$) and the MFC (deep $p=0.001$, superior $p=0.479$, mean $p=0.048$). The increase from deep to superficial cartilage layers was significant for the control cartilage ($p<0.001$) and the cartilage repair tissue ($p<0.05$); however, highly significant results were more pronounced within the control cartilage (patella $p=0.008$, MFC $p=0.002$).

Further evaluation of the different postoperative follow-up intervals (i.e., short-term 6–12 months, midterm 24 months, long-term 60 months) was performed only for deep and superficial cartilage layers, and the resulting T2 values are given in Table 2. A highly significant increase from deep to superficial cartilage layers was found for all control cartilage sites ($p<0.001$). The cartilage repair tissue showed differences between the patella and the MFC in the zonal assessment. When looking at the patella, a significant zonal increase could be observed within all follow-up

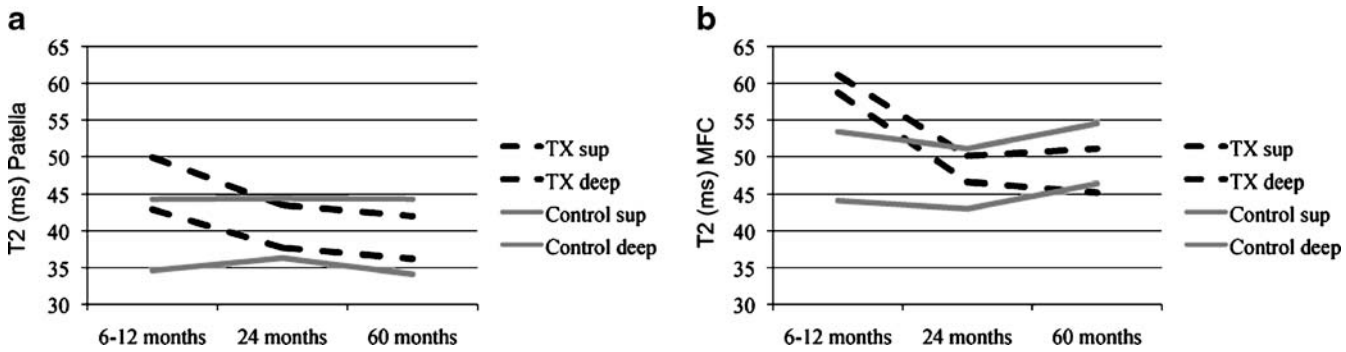

Fig. 4 Zonal T2 evaluation of the patient group after MACT of the patella (**a**) and the patient group after MACT of the MFC (**b**). Results are displayed over time concerning the short-term (6–12 months), midterm (24 months), and long-term (60 months) follow-up. For both anatomical sites stable T2 values with a clear zonal stratification are visible for the healthy control cartilage (*gray*). For the cartilage repair tissue (*black*) higher T2 values in the short-term follow-up adapt over time for both sites; the zonal stratification of the T2 values shows an earlier onset within the patella, compared with the MFC

intervals ($p<0.05$). When looking at the MFC, cartilage repair tissue showed no zonal variation for the shortest postoperative interval ($p=0.235$), but for the mid- and the long-term follow-up a significant zonal stratification could be observed ($p<0.05$). The zonal T2 evaluation over time is shown in Fig. 4 for the patella and the MFC.

When comparing results for the patella and the MFC, significant differences in T2 values could be found for all control cartilage sites, with higher values for cartilage sites within the MFC. When looking at the cartilage repair tissue sites again, nearly all measured T2 values were significantly higher within the MFC compared with the patella. These results are displayed in Fig. 5.

Clinical results

Regarding the postoperative outcome a symptomatic relief could be achieved and none of the patients reported a failure of the therapy. Overall the Brittberg score showed good results for both groups with 2.27 after MACT of the MFC and 2.33 after MACT of the patella and no significant difference between both sites ($p=0.825$).

Discussion

In this study, cartilage repair tissue after MACT and healthy control cartilage were compared between two anatomical sites within the knee joint with a different requirement profile due to differences in loading conditions [30–32]. Within the patellofemoral joint, patellar cartilage compresses and slides against the femoral groove during knee motion, and significant shear stress is applied. The femorotibial joint is mainly exposed to compressive stresses and the presence of menisci affects the load distribution. This topographical variation is reflected in differences in structure, composition, and mechanical

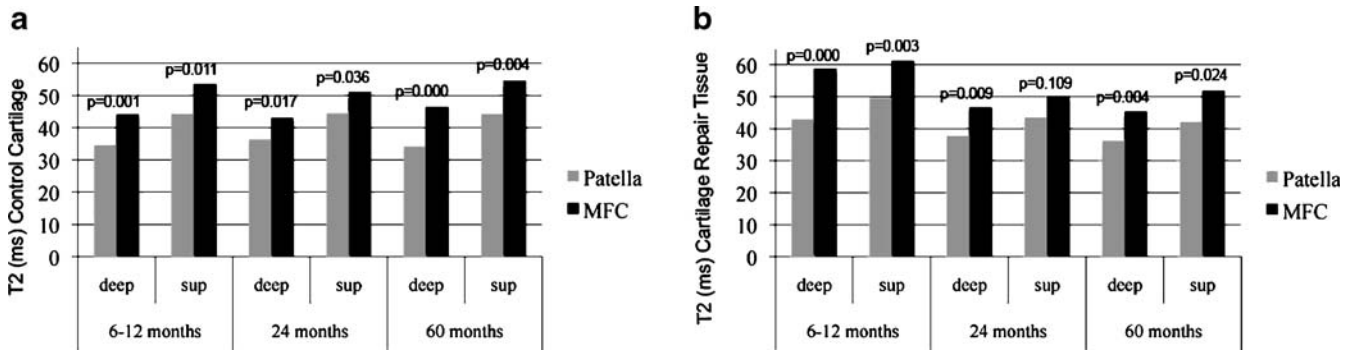

Fig. 5 T2 values of control cartilage (**a**) and cartilage repair tissue (**b**) as a comparison between the patella (*gray*) and the MFC (*black*) with given significances. Nearly all measurements show significant higher T2 values within the MFC compared with the patella. The *p* values, however, are always lower for the deep cartilage layer, compared with the superficial cartilage layer

properties [33]. The morphological results of the obtained MOCART score as well as the clinical results in our patients after MACT, however, did not show significant differences between the two anatomical sites. A recent study by Behrens et al. [34], based on a comparable cartilage repair procedure, also reports no differences between these anatomical sites. The only available in vitro study about histological results between the patella and the femoral condyle, however, revealed differences in the mechanical properties of osteochondral repair tissue [23].

In the present study, a clear difference in T2 values was observed between the patella and the MFC. As T2 is known to reflect the collagen content and orientation, as well as the hydration of cartilage, this can be seen as a sign of a topographical variation in its ultrastructural composition. Existing studies concerning T2 measurements of the patella and weight-bearing femoral cartilage have also observed higher T2 relaxation times for the femoral condyle; however, no statistically significant difference could be observed [15, 35, 36]. The higher T2 values for weight-bearing femoral cartilage in this study could be due to topographical differences in biomechanical and structural composition, as there are studies indicating that collagen fiber organization differs between weight-bearing (such as the MFC) and more non-weight-bearing (such as the patella) regions of the joint [37, 38]. Nevertheless, specific factors, such as the acquisition of the data in the axial or sagittal orientation, as well as the angular dependence of T2 relaxation time in cartilage as a result of the static magnetic field, may also alter the T2 values [14, 39]. However, in the supine position, both assessed cartilage sites are far away from the possible magic angle.

Furthermore, papers concerning biomechanics have reported clear differences between the femoral condyles and the patella cartilage [5, 6]. Whereas the MFC is seen as one of the stiffest cartilage sites, the patella is reported to be one of the softest [6]. Kurkijärvi et al. [5] point out that these topographical differences in the mechanical properties should be considered when conducting quantitative MRI. For T2 mapping as performed within this study, zonal evaluation of T2 values seems to be an adequate tool by which to characterize the functional properties of cartilage [5]. The zonal increase in T2 relaxation between deep and superficial cartilage layers is reported to be comparable between patellar and femoral cartilage [15]. These results are in-line with the findings of the present study with a comparable zonal pattern for healthy control cartilage.

In the evaluation of cartilage repair tissue provided by MACT with maturation over time, a different pattern in the zonal structure could be observed, possibly because of different biomechanical loading conditions applied during its maturation. This is best visualized in Fig. 4, where, in the patella, a constant difference between the deep and the superficial cartilage layers of the repair tissue was found, whereas within the MFC, this difference increased over time. In an animal study by Watrin-Pinzano et al. [19], a significant increase from deep to superficial cartilage aspects over time was regarded as a favorable sign of cartilage repair tissue maturation. Another animal study by White and co-workers [20] related a significant zonal increase in T2 values to a hyaline or hyaline-like cartilage structure. A recent article by Welsch at al. [21], looking at different cartilage repair tissues in a cross-sectional follow-up, reported a slight significant increase in T2 values after MACT of the femoral condyle. The results of the present study, in light of those results, might be because the more distinct and earlier zonal increase in T2 values of cartilage repair tissue in the patella is really due to a faster maturation or possibly due to the thicker cartilage. In addition to the clear differences in cartilage thickness between the patella and the MFC [3], a difference in the thickness of the different anatomical cartilage zones has also been described, with an extended deep zone in the patella compared with the femur [4]. This may account for the clearer difference within the deep cartilage layer than within the superficial cartilage layer (Fig. 5). Furthermore the different postoperative care and rehabilitation approaches may alter the early results [40]. After MACT on the patella, joint movement, as measured by range of motion (ROM), is limited to about 30°, whereas weight-bearing begins earlier with steadily increasing weight-bearing of the knee joint and full weight-bearing after 6–8 weeks. After MACT on the MFC, it is the opposite, with earlier onset of ROM up to 90°, but subsequent later full weight-bearing after 8–10 weeks [40]. This may explain the earlier zonal organization in MACT of the patella.

The limitations of the present study are the lack of histological proof and the relatively low patient number. Another limitation is the cross-sectional character of this study and the small number of early (6–12 months) follow-up intervals and the lack of very early (< 6 months) follow-up intervals. Furthermore, it remains a challenge for future biochemical evaluations of cartilage repair tissue to include not only two (deep and superficial) but three zones, which would adapt much more to the anatomical constitution of articular cartilage. With the currently available resolution, this would be possible only in the patella. Nevertheless, to our knowledge, the present study is the first to compare cartilage repair tissue within the patella and the MFC by using morphological and biochemical MRI parameters.

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 and clinical evaluation showed no clear difference between these anatomical sites. The zonal T2 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 with the MFC. 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 is still challenging.

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