

Clinical and MRI evaluation of medium- to long-term results after autologous osteochondral transplantation (OCT) in the knee joint

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Abstract

Purpose Autologous osteochondral transplantation (OCT) is one of the surgical options currently used to treat cartilage defects. It is the only cartilage repair method that leads to a transfer of hyaline cartilage repair tissue. The purpose of this study was to evaluate the magnetic resonance observation of cartilage repair tissue (MOCART) score, the 3D MOCART score and various clinical scores in patients after OCT in knee joints.

Methods Two women and eight men were evaluated 6–9 years (median 7.2 years) after OCT on the femoral condyle of the knee joint. All patients were evaluated by magnetic resonance imaging (MRI) measurement, using a 3.0 T Scanner with different cartilage-specific sequences. Clinical assessment included the knee injury and osteoarthritis outcome score (KOOS), the international knee documentation committee (IKDC) subjective knee form, the Noyes sport activity rating scale and the Tegner activity score. For MRI evaluation, the MOCART score and 3D MOCART score were applied.

Results Clinical long-term results after OCT showed median values of 77 (range 35.7–71.4) for the IKDC; 50 (6.3–100), 66.7 (30.6–97.2), 65 (0–75), 57.1 (35.7–71.4) and 80.9 (30.9–100) for the KOOS subscales (quality of life, pain sports, symptoms and activity of daily living); 61.4 (22.3–86.2) for the Noyes scale; and 3 (0–6) for the Tegner activity score. The median MOCART score was 75

(30–90) after both 1 and 2 years and 57.5 (35–90) after 7 years, as assessed by different cartilage-specific sequences. The 3D MOCART score showed values of 70 (50–85) and 60 (50–80) in the two different isotropic sequences after 7 years.

Conclusion The MOCART and 3D MOCART scores are applicable tools for patient follow-up after OCT. Post-operative follow-up assessments would also benefit from the inclusion of OCT-specific parameters. Long-term results after OCT reflect an impairment in clinical scores in the first 2 years with good results during follow-up. Stable conditions were observed between 2 and 7 years after surgery. The filling of the defects and the cartilage interface appeared good at MRI evaluation after the first 2 years, but cartilage loss was observed between the medium- and long-term follow-ups. Isotropic imaging with multiplanar reconstruction is useful for daily clinical use to assess bony cylinders in cartilage repair, especially in combination with the 3D MOCART.

Level of evidence Retrospective therapeutic study, Level IV.

Keywords Cartilage repair · OCT · MRI · MOCART · 3D MOCART

Introduction

Cartilage tissue cannot self-repair [11, 12], so cartilage defects remain a challenge for treating surgeon [1, 7]. Various treatment methods, such as marrow stimulation techniques [27], cell-based cartilage repair methods [3] and osteochondral transplantation methods [6, 19], have been evaluated in the last decades. Autologous osteochondral transplantation (OCT), also known as osteochondral

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Table 1 Patient characteristics

Variables	
Demographic data	
Age (years)	38 (26–55)
Male (M)	38 (26–55)
Female (F)	42 (38–45)
Sex (M/F)	8/2
Baseline characteristics	
Knee (right/left)	6/4
Defect size in cm ²	2.8 (0.5–5.8)
Cylinders	2.4 (2–3)
Localization	
MFC	7
LFC	3

Median (range)

MFC medial femoral condyle, LFC lateral femoral condyle

autograft transfer system or mosaicplasty [7], is a cartilage repair technique in which osteochondral plugs harvested from a non-weight-bearing area of the joint are inserted into chondral or osteochondral defects with hyaline or hyaline-like cartilage [1, 24] after trauma or diagnosis of osteochondritis dissecans (OCD). OCT is performed as a one-step surgical procedure.

To evaluate not only the results of surgical cartilage repair procedures but also the pre-surgical cartilage status, magnetic resonance imaging (MRI) is the method of choice due to its non-invasiveness, multiplanar capability and high soft tissue contrast [10, 29, 31, 32].

The aim of this study was to evaluate clinical and radiological medium- to long-term results after OCT in knee joints by means of the MOCART and 3D MOCART scores as well as several clinical scores.

The study was carried out to estimate the applicability of the two MRI scores on OCT repair tissue. The hypothesis was that isotropic imaging with multiplanar reconstruction, especially in combination with 3D MOCART, is useful for assessing bony cylinders in cartilage repair.

Additional OCT-specific parameters, such as the congruity and interface of the cartilage and bony portion of the cylinders in the defect as well as the filling of the donor site, were also assessed.

Materials and methods

Ten patients (eight males and two females) with a median age of 38 years (range 26–55) were available for clinical and MRI evaluation for a median follow-up time of 7.2 years (range 6–9 years) after OCT. The lesion size, number of cylinders and right-to-left ratio are shown in

Table 1. A total of 15 patients were treated with this technique between 2000 and 2003, but five patients were lost to follow-up because of unavailability. Prior or additional surgeries, such as microfracture, partial meniscectomy, anterior cruciate ligament reconstruction or diagnostic arthroscopy with shaving or abrasion, were performed in all but two patients.

The inclusion criteria for surgery included symptomatic chondral or osteochondral defects with a size of 1–4 cm² [7] that either were induced by trauma (eight cases) or had occurred after OCD (two cases). Patients were between 18 and 55 years of age, and the meniscus, the ligamentous structures, and the opposing and surrounding cartilage had to be intact. The exclusion criteria included advanced osteoarthritis, axis malalignment (>5° deviation of the anatomical leg axis), generalized or rheumatoid arthritis, infections, several systemic or tumour diseases, restricted range of motion (>20°) and obesity with a body mass index >35. Preoperative radiographs (standing long-leg alignment views) and MRIs were performed to identify axis malalignment and generalized loss of cartilage in the affected compartment. An additional limiting factor for tissue harvesting was the limited availability of donor-site tissue at non-weight-bearing areas in the knee joint. The study was approved by the local ethics board.

Surgical procedure

Arthroscopic evaluation and debridement of the defect were followed by an open procedure (mini-arthrotomy). Two to three osteochondral cylinders were harvested from a non-weight-bearing area of the knee joint (notch region or distal border area of the femoral trochlea) and transferred into a prepared hole in the defect area through a press-fit technique. The osteochondral defects at the donor site were subsequently filled with the cylinders from the defect zone.

Post-operative treatment consisted of 6 weeks of non-weight-bearing, followed by a gradual increase in weight-bearing. Continuous passive motion began 2 days after surgery, and a return to sports was allowed after 6 months.

MR imaging

The MRI protocol was identical for all patients. All medium- to long-term measurements were performed on a 3.0 T MRI unit (Tim Trio, Siemens Healthcare, Erlangen, Germany) in combination with a dedicated eight-channel knee coil (In vivo, Gainesville, FL, US) (Fig. 1):

1. High-resolution proton-density turbo spin-echo (PD-TSE) sequence (TR: 2,400 ms/TE: 28 ms, Flip angle:

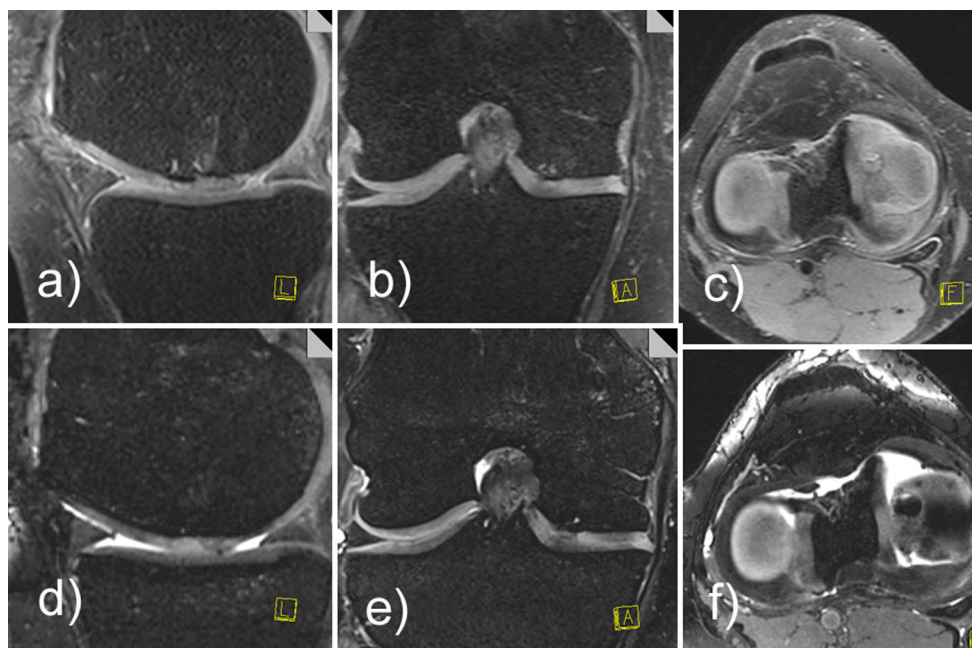


Fig. 1 Isotropic True-Fisp (a–c) and PD-SPACE sequence (d, f) in a sagittal, coronal and axial plane showing cylinders after autologous osteochondral transplantation, with good bony integration

- 160°, FOV: 120 × 120 mm, matrix: 512 × 512, slice thickness: 2 mm, Voxel size: 0.2 × 0.2 × 2 mm, bandwidth: 244 Hz/Px, number of slices: 32, scan time 6:11 min).
2. T2-weighted dual fast spin-echo (dual FSE) sequence (5,120/9.5 and 124 ms, 140°, FOV 180 × 180 mm, matrix: 448 × 448, 0.4 × 0.4 × 3 mm, 203 Hz/Px, 30 slices, 6:45 min).
3. T1-weighted turbo inversion recovery magnitude (TIRM) sequence (7,690/41, TI: 220, 150°, FOV: 150 × 150 mm, matrix: 256 × 256, 0.6 × 0.6 × 3 mm, 250 Hz/PX, 36 slices, 2:35 min).
4. Isotropic 3D True-FISP (true fast imaging with steady-state precession) sequence (8.9/3.8, 28°, FOV: 160 × 160 mm, matrix: 384 × 384, 0.4 × 0.4 × 0.4 mm, 200 Hz/Px, 320 slices, 6:45 min).
5. PD-SPACE (fat-suppressed three-dimensional proton-density sampling perfection with application optimized contrasts) sequence (1,200/30, 180°, FOV: 160 × 160 mm, matrix: 324 × 324, 0.6 × 0.6 × 0.6, 192 slices, 540 Hz/Pixel, 7:53 min).
1. Sagittal T1-SE (TR: 555 ms; TE: 13.8 ms; FOV: 150 mm; rectangular field of view: 95 %; matrix: 256 × 512; slice thickness: 3 mm; gap: 0.3 mm; number of acquisitions: 2; number of slices: 23).
2. Sagittal dual FSE (TR: 2,500 ms; TE: first, shortest, second, 120 ms; TSE factor: 12; FOV: 180 mm; rectangular field of view: 100 %; matrix: 256 × 512; scan percentage: 100; slice thickness: 3 mm; gap: 0.3 mm; number of acquisitions: 3; number of slices: 23).
3. Coronal short tau inversion recovery fast spin echo (TR: 1,200 ms; TE: 13 ms; TI: 130 ms; TSE factor: 5; FOV: 200 mm; rectangular field of view: 80 %; matrix: 256 × 256; scan percentage: 80; slice thickness: 4 mm; gap: 0.4 mm; number of acquisitions: 3; number of slices: 19).
4. Three-dimensional gradient-echo sequence with fat suppression (TR: 47 ms; TE: 4.6 ms; flip angle: 45°; FOV: 180 mm; rectangular field of view: 90 %; matrix: 256 × 256; scan percentage: 75; slices: 50; slice thickness: 2 mm; number of acquisitions: 1).

The earlier measurements at 12- and 24-month follow-ups as well as the preoperative evaluation by MRI were performed on a 1.0 T MR unit (Philips, Gyroscan Intera, Best, the Netherlands) with a standard knee protocol that incorporated the following cartilage-specific sequences:

For specific high-resolution imaging, a surface dual loop coil (TMJ coil, Philips, diameter: 8 cm) was placed over the knee compartment of interest. With this surface coil, the following sequence was applied: sagittal (femorotibial) dual FSE (TR: 2,400 ms; TE: first, shortest; second, 120 ms; TSE factor: 12; FOV: 120 mm; rectangular field of view: 75 %; matrix: 512 × 512; scan percentage: 80;

slice thickness: 2 mm; gap: 0.2 mm; number of acquisitions: 4; number of slices: 23).

The evaluations of the 2D MOCART and the 3D MOCART were performed on a Leonardo Workstation (Siemens Healthcare, Erlangen, Germany) by two observers in consensus, both of whom were experienced in musculo-skeletal and cartilage imaging.

The standard 2D MOCART score [16, 17] was analysed with PD-TSE, dual FSE and the TIRM sequence for the specific assessment of fluid in the bone (bone marrow oedema).

Furthermore, the evaluation of the 3D MOCART [33] was performed by means of the isotropic True-FISP and PD-SPACE sequences, where an angulated view in three planes (sagittal, coronal and axial) was achievable based on the MPR of the isotropic dataset.

In addition to the original MOCART parameters, we also assessed the congruity of cartilage, the congruity of bone, the cartilage and bone interfaces of the cylinders in the defect and the filling of the donor site (Fig. 2).

Clinical evaluation

For the clinical evaluation, the CARRERA (Cartilage Repair Registry Austria) questionnaire [17] was used, including subjective knee-specific scores. The embedded subjective knee scores included the patient portion of the

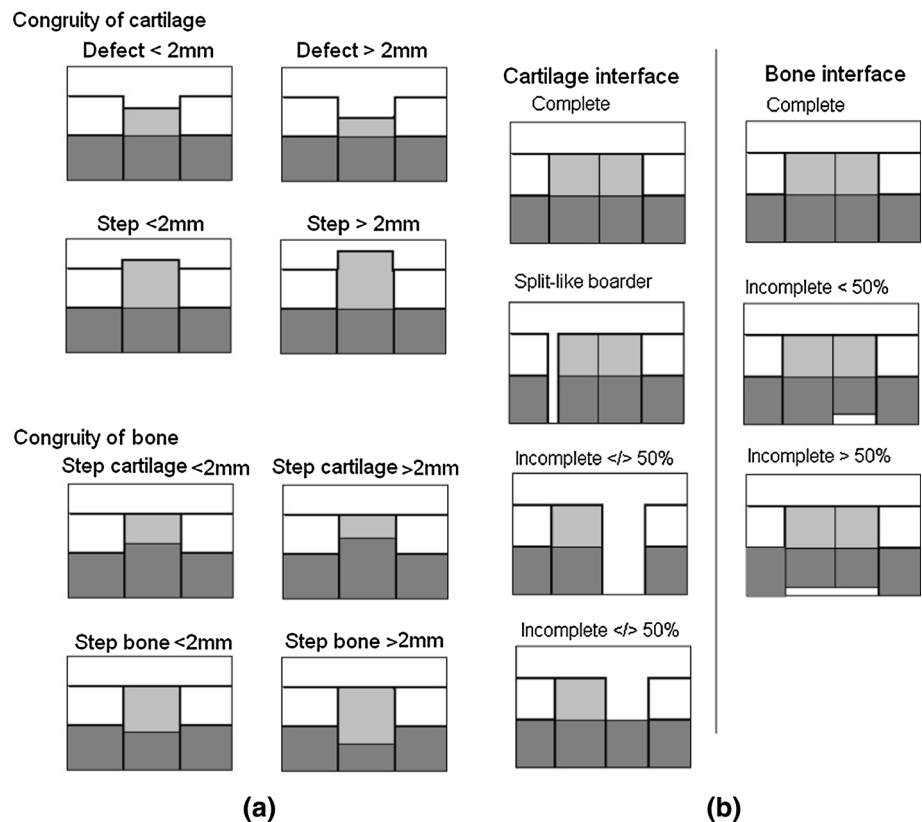
international knee documentation committee (IKDC), the knee osteoarthritis outcome score (KOOS), the Tegner activity score and the Noyes sports activity rating scale. The IKDC score [13] represents the patient’s symptomatic status during the past 4 weeks, the function of the knee, and the level of sports activity and is divided into ‘Patient’ and ‘Surgeon’ portions, both of which included in the ICRS Cartilage Injury Evaluation package. The KOOS [2, 23] consists of five subscales (quality of life, pain, symptoms, sports and recreation, and activity of daily living); the Noyes score [21] grades the level and intensity of sports activity; and the Tegner activity score [28] rates activities ranging from sick leave or disability up to contact and high-impact competitive sports such as soccer.

The study was approved by the local ethics board (Medical University of Vienna, Austria, approval number 049/2000). The study was performed at the Medical University of Vienna, Department for Trauma Surgery.

Statistical analysis

For the statistical analysis, SPSS software (SPSS Inc., version 16.0) was used to perform the descriptive and inductive statistical analyses. The results are presented as descriptive data in the text, tables and graphs. The boxplot graphical display of the data shows an arbitrary,

Fig. 2 Schematic presentation of the evaluated variables for repair tissue, including congruity of cartilage, congruity of bone (a), cartilage interface and bone interface (b)



abnormally distributed dataset; therefore, we used non-parametric tests for our statistical evaluation. The changes in the clinical scores over time were measured by the Wilcoxon ranks test for dependent variables, in which a p value of <0.05 was considered statistically significant. Correlation of the variables of the 3D MOCART score for the two different MRI sequences was achieved using a bivariate correlation with the Spearman correlation coefficient.

Results

The subjective clinical results showed increasing values in all scores compared to the preoperative baseline data up to 1 and 2 years post-operatively and plateaued at 6–9 years after surgery (as shown in Table 2). The changes, compared to the preoperative data, were statistically significant ($p < 0.05$) for the IKDC after 1 and 7 years, for all three follow-ups of the KOOS QoL subscale and the KOOS sports and recreation subscale, for the KOOS pain subscale after 1 and 2 years, for the KOOS symptoms subscale after 7 years and for the KOOS ADL subscale after 1 and 7 years.

Radiological results

In the 2D evaluation of MOCART, the filling of the defect (the congruity of cartilage of at least one cylinder) was persistent, whereas the cartilage interface showed impairment over time, similar to the irregularity of the surface, which increased (Table 3). The bony part of the cylinder showed increasing ossification and integration to the adjacent bone (100 % bony integration, but in 70 % granulation tissue, 10 % cyst, 20 % granulation tissue and cyst), whereas a high amount (in 90 %) of bone marrow

oedema (BME) (10 % BME missing, 20 % diameter <1 cm, 70 % between 1 and 5 cm) remained stable over time. The MOCART score was 75 (median, range 55–85) after 1 year and 75 (30–90) after 2 years. After 7 years, the score resulted in a median value of 57.5 (35–90), as assessed by the cartilage-specific sequences measured by the 3.0 T MRI scanner.

Other OCT-specific parameters such as the congruity of cartilage decreased (according to the loss of volume of cartilage tissue: good congruity after 1 year and increased bony steps in the cartilage after approximately 7 years), whereas the congruity of bone remained stable over time (good congruity or small bony steps in the cartilage).

The cartilage portion of the cylinder appeared homogeneous and, in most cases, iso-intense in comparison with the surrounding cartilage. Effusion in the joint decreased over time.

There was no incomplete ‘cylinder interface’ or ‘bony interface’ in this series, and there was no loosening of cylinders.

The defects in the donor site were completely filled and congruent in five cases (50 %) by all measurement techniques, whereas the border between cartilage and bone seemed congruent to the surrounding tissue in three cases (30 %) as a result of increasing ossification and osteophyte generations (Fig. 3).

The results of the 3D MOCART variables of the two isotropic sequences correlated significantly ($p < 0.05$) with the filling of the defect, the structure or homogeneity, the signal intensity and the appearance of osteophytes; BME and effusion exhibited good correlation coefficients (0.8–1.0). Medium coefficients (0.5–0.57) were computed for the remaining variables. The 3D MOCART results are presented in Table 4 with scores of 70 (median, range 50–85) in the 3D True-Fisp sequence and 60 (50–80) in the PD-SPACE sequence.

Table 2 Clinical results after 1, 2 and 7 years (median + range)

	Preoperative	1-year FU	2-year FU	7-year FU
IKDC Pat	52.9 (20.7–57.5)	70.7 (2.3–86.2)*	82.8 (10.3–89.7)	77 (18.4–90.8)*
KOOS QL	31.3 (0–75)	50 (6.3–87.5)*	62.5 (6.3–100)*	50 (6.3–100)*
KOOS pain	69.4 (27.8–91.7)	88.9 (13.9–97.2)*	93.1 (16.7–97.2)*	66.7 (30.6–97.2)
KOOS sport	40 (0–50)	60 (0–85)*	70 (0–85)*	65 (0–75)*
KOOS symptoms	50 (32.1–57.1)	53.6 (25.0–67.9)	50 (21.4–67.9)	57.1 (35.7–71.4)*
KOOS ADL	73.5 (30.9–88.2)	94.1 (22.1–100)*	95.6 (10.3–100)	80.9 (30.9–100)*
Noyes	85 (0–90)	90 (0–95)	90.0 (0–90)	61.4 (22.3–86.2)
Tegner	3 (1–7)	3 (1–6)	4.5 (1–6)	3.0 (0–6)

FU follow-up, QL quality of life, ADL activities of daily living

* p value < 0.05 indicating an statistical significant difference between baseline data and follow-up in the Wilcoxon signed ranks test for dependent variables

Table 3 MOCART score after 1, 2 and ~ 7 years

	Points [30]	FU_years					
		1		2		7	
		N	%	N	%	N	%
M1 defect fill							
Complete fill	20	6	60	5	50	6	60
Hypertrophy	15	3	30	3	30	1	10
Incomplete fill >50 %	10	1	10	1	10	2	20
Incomplete fill <50 %	5	0		1	10	1	10
Subchondral bone exposed	0						
M2 cartilage interface							
Complete	15	7	70	7	70	3	30
Demarcation	10	2	20	1	10	2	20
Defect <50 % of the length	5	1	10	1	10	4	40
Defect >50 % of the length	0	0		1	10	1	10
M3 surface							
Intact	10	7	70	5	50	1	10
Damage <50 % depth	5	0		4	40	4	40
Damage >50 % depth	0	3	30	1	10	5	50
M4 structure							
Homogenous	5	10	100	10	100	9	90
Inhomogeneous	0	0		0		1	10
M5 signal 1							
Normal	15	7	70	7	70	7	70
Nearly normal	5	3	30	3	30	3	30
Abnormal	0	0		0		0	
M5 signal 2							
Normal	15	7	70	7	70	7	70
Nearly normal	5	3	30	3	30	3	30
Abnormal	0	0		0		0	
M6 subchondral lamina							
Intact	5	4	40	6	60	1	10
Not intact	0	6	60	4	40	9	90
M7 subchondral bone							
Intact	5	2	20	3	30	0	
Not intact	0	8	80	7	70	10	100
M8 adhesion							
No	5	4	40	3	30	5	50
Yes	0	6	60	7	70	5	50
M9 effusion							
No	5	6	60	7	70	8	80
Yes	0	4	40	3	30	2	20

100

Discussion

The most important finding of the present study was the development of cartilage loss in long-term follow-up with consistently good clinical results. This development was optimally evaluated on cartilage-specific sequences on 3.0 T MRI using the MOCART score. Isotropic imaging is

advantageous for the multiplanar evaluation of cylinders, and the 3D MOCART score makes results comparable.

The OCT and its related osteochondral grafting techniques represent a possibility to treat focal, small- to medium-sized chondral or osteochondral defects [8, 9, 22]. Diverse studies have reported good-to-excellent results in up to 93 % of cases in different areas of the knee and ankle

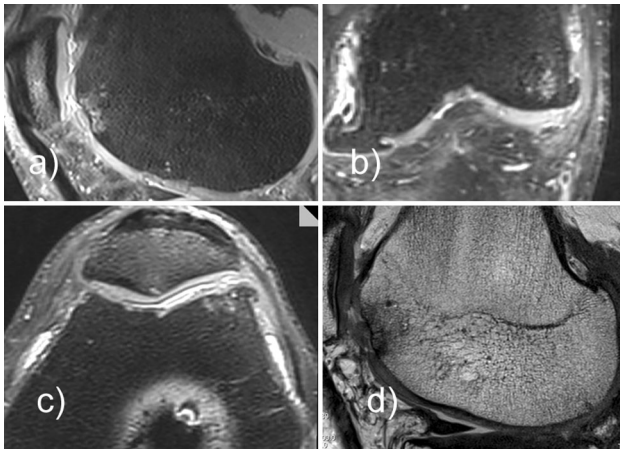


Fig. 3 PD-SPACE (a–c) and PD-TSE (d) sequence—donor site

joints, as well as in a range of active patient populations [8, 18]. The results depend on age, gender and the size of the lesion [26]. Consistently good-to-excellent results were also observed in the present study, as demonstrated by the subjective and objective MR data. The values increased from preoperatively up to 2 years post-operatively and remained at least stable in the longer evaluation, as reported in similar studies [5, 15, 29]. However, in one study, deterioration was found between 12-month follow-up and the long-term follow-up [25].

In MRI evaluation, different morphological and biochemical cartilage-specific sequences are available to assess the repair tissue in comparison with surrounding healthy cartilage [14, 32]. A helpful tool is the semiquantitative evaluation of scores with variables, which make the results comparable between patients and during the course of follow-up. These scores may also prove helpful in predicting clinical properties in future [4].

One of the most often used, adapted and enhanced scores is the MOCART score [16, 17]. It was primarily developed for assessing repair tissue after matrix-associated autologous chondrocyte transplantation (MACT) and also after OCT, in which different additional parameters can be helpful in evaluating the cartilage and bony integration of the cylinders; it can also be used to assess the location and filling of the donor site.

Such scores and evaluation parameters provide the opportunity to compare patients and studies even in multi-centre trials, and to demonstrate the maturation of repair tissue in follow-up, with statistically significant correlations between different parameters and different clinical scores [15, 29]. Furthermore, a new score, the 3D MOCART score, has been introduced and adapted to the requirements of isotropic sequences, thus providing the possibility of observing the repair tissue in the axial, coronal and sagittal plane [33].

Table 4 3D MOCART score after ~7 years assessed in 2 isotropic MRI sequences

	Points	3D True-Fisp		PD-SPACE	
		Count	%	Count	%
M01 defect fill					
0 %, 0–25 %	0	0		0	
25–50 %	5	1	10	0	
50–75 %	10	1	10	2	20
75–100 %	10	0		1	10
100 %	15	7	70	7	70
100–125 %	15	1	10	0	
125–150 %	5	0		0	
150–200 %, >200 %	0				
M02 cartilage interface					
Complete	15	4	40	4	40
Demarcation	10	2	20	5	50
Defect <50 % of the length	5	4	40	1	10
Defect >50 % of the length	0	0		0	
M03 bone interface					
Complete	5	9	90	8	80
Partial delamination	0	1	10	2	20
Complete delamination	0	0		0	
Delamination of periosteal flap	0	0		0	
M04 surface					
Intact	10	2	20	1	10
Damage <50 % depth	5	6	60	6	60
Damage >50 % depth	0	2	20	2	20
Adhesions	0	0		1	10
M05 structure					
Homogenous	5	3	30	2	20
Inhomogeneous, cleft formation	0	7	70	8	80
M06 signal					
Normal	15	6	60	6	60
Nearly normal	10	4	40	4	40
Abnormal	0	0		0	
M07 subchondral lamina					
Intact	5	4	40	1	10
Not intact	0	6	60	9	90
M08 osteophyte					
Absent	5	1	10	3	30
<50 % thickness	5	4	40	2	20
>50 % thickness	0	4	40	5	50
M09 bone oedema					
Absent	5	4	40	1	10
Small (<1 cm)	0	4	40	4	40
Medium (<2 cm)	0	2	20	5	50
Large (<4 cm)	0	0		0	
Diffuse (>4 cm)	0	0		0	

Table 4 continued

	Points	3D True-Fisp		PD-SPACE	
		Count	%	Count	%
M10 subchondral bone					
Intact	5	4	40	5	50
Not intact	0	6	60	5	50
Granulation tissue		2	20	0	
Cyst		4	40	5	50
Sclerosis		0		0	
M11 effusion					
Absent	15	4	40	3	30
Small	10	4	40	5	50
Medium	10	2	20	2	20
Large	0	0		0	
	100				

3D True-Fisp true fast imaging with steady-state precession, TruPD-SPACE proton-density sampling perfection with application optimized contrasts

These two scores are designed not only to assess cartilage repair tissue after MACT but also to evaluate the radiological outcome after OCT procedures. In the previous studies, the MOCART score was used for such applications [15, 20, 29]. To our knowledge, no other specific evaluation score or defined evaluation parameter relating to this specific subject has been published to date. The pointing scale showed high scores after 1 and 2 years, but the scores decreased thereafter. The 2D and 3D evaluation scores were comparable after 7 years. Marcacci reported complete defect filling in 62.5 % of cases [15], which is comparable to the results of the present study (60 %). We observed complete filling in most cases, often combined with delamination or damage to the cartilage surface, which was completely intact in just 10 % of cases. In comparison, complete filling in the 3D evaluation was found in 70 % of the cases, and the same amount of surface damage was observed. Regarding the integration of the grafted cartilage in this series, the ‘cartilage interface’ was complete in only 30 % (MOCART) or 40 % (isotropic sequences) of cases compared to 75 % of cases in Marcacci’s study [15].

Nemec et al. [20] reported approximately 60 % BME, whereas we observed 90 % in the TIRM sequence as well as in the PD-SPACE, where we saw a more detailed presentation than in the True-Fisp (60 %): a gradient-echo sequence with less fluid sensitivity. Thus, both sequences have advantages, but in different situations. Other differences between the True-Fisp and the PD-SPACE are reported as correlation coefficients in Table 4.

The status of the ‘subchondral lamina’ is strongly related to the parameter ‘congruity of bone’, which reveals the

appearance of bony steps or ossification of the cartilage portion of the cylinder. The subchondral lamina is a more ‘MACT-specific’ parameter; other such parameters include ‘Structure’ and ‘Signal intensity’, which are less specific and applicable to OCT. However, the appearance of a non-intact subchondral lamina or the appearance of osteophytes are not method-specific problems but rather technique-specific problems.

Regarding additional MRI evaluation parameters, the cartilage portion of the different osteochondral cylinders in one defect appeared divergent; this finding led us to consider ‘congruity of cartilage’ to be an OCT-specific parameter (Fig. 2), and this parameter was checked in all cylinders.

The integration of the cylinders to the adjacent bone was complete in all patients (vs. 95.9 % [15]), with remaining subchondral bone changes such as granulation tissue, sclerosis or cysts occurring after approximately 7 years in all cases. No incomplete ‘cylinder interface’ or ‘bony interface’ was observed.

The evaluation of surrounding tissue and the donor site is important not only for radiological follow-up but also for clinical considerations. Both isotropic and conventional MRI measurements present advantages for this type of evaluation. The MPR technique allows a broad presentation of the donor site, independent of any slice plane, but the presentation is less detailed than in the 2D MRI.

The appearance of the donor site in MRI was clinically less relevant because none of the patients had any donor-site morbidity; however, symptoms can still occur in this region. The occurred holes should therefore be filled with the cylinders of the damaged region.

The small transplant size can be attributed to the fact that larger cartilage lesions had led to the indication for treatment with matrix-associated autologous chondrocyte transplantation. The use of OCT for cartilage repair is less expensive and much less demanding of the patient compared with reconstructive techniques, but it is limited by the defect size and is dependent on the availability of harvestable regions. Other limitations of the present study are its retrospective nature, the small number of patients and the fact that we used different MRI scanners. Since the 9-year period covered by this study, MRI techniques have changed. Nevertheless, we believe that the variables used in the two 2D measurements are relevant and that their comparison is appropriate. However, a more detailed presentation of cartilage loss, defects on the surface or small gaps in the surrounding cartilage can be assessed using 3T MRI, thus leading to a worsening of the MOCART score (as seen in later follow-up in the present study).

To our knowledge, there are no other studies that have used isotropic sequences to evaluate post-operative OCT

results. MPR allows for a very detailed morphological MRI evaluation and is therefore advantageous compared with 2D evaluation not only in medium- to long-term follow-up measurements after OCT but also in the assessment of surrounding structures, including cartilage, menisci and the cruciate ligaments. Isotropic imaging is useful in the clinical setting to obtain appropriate imaging not only for cartilage-specific evaluation but also for pre- and post-operative imaging in trauma and orthopaedic surgery.

Conclusion

To conclude, osteochondral transplantation showed good clinical results in medium- to long-term follow-up and is therefore a good treatment option for small- to medium-sized chondral and osteochondral lesions. The MOCART and 3D MOCART scores are applicable tools for patient follow-up after OCT and are therefore recommended for use on cartilage-specific and isotropic sequences. MRI evaluation showed that the filling of the defects and the cartilage interface appeared to be good at the 1- and 2-year follow-ups. However, cartilage loss was observed in medium- to long-term follow-up. For the evaluation of this surgical method, it would also be useful to include additional OCT-specific parameters to make comparisons between patients during the post-operative follow-up period.

Conflict of interest The authors declare no conflicts of interest.

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