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Angaben zur Veröffentlichung / Publication details:

Blanke, Fabian, Nicola Oehler, Maximilian Haenle, Robert Lenz, Stephan Vogt, and Thomas Tischer. 2021. "All-arthroscopic hydrogel-based autologous chondrocyte transplantation in the knee joint: good clinical and magnetic resonance imaging outcome after 24 months." *Arthroscopy: The Journal of Arthroscopic & Related Surgery* 37 (6): 1892–1899.e1. <https://doi.org/10.1016/j.arthro.2021.01.038>.

All-Arthroscopic Hydrogel-Based Autologous Chondrocyte Transplantation in the Knee Joint: Good Clinical and Magnetic Resonance Imaging Outcome After 24 Months

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Purpose: To evaluate subjective and objective clinical and magnetic resonance imaging–based radiologic outcomes after short-term follow-up in patients with focal full-size cartilage lesions of the knee joint treated with all-arthroscopic hydrogel-based autologous chondrocyte transplantation. **Methods:** A retrospective study on patients with isolated focal cartilage defects of the knee joint who were treated with arthroscopically conducted matrix-induced autologous chondrocyte transplantation was performed. Clinical scores were assessed at baseline and final follow-up using the Tegner Score, visual analog scale, the International Knee Documentation Committee, and the 5 subscales of the Knee Injury and Osteoarthritis Outcome Score. Magnetic resonance imaging scans of the treated knee joints were evaluated with the updated MOCART (Magnetic Resonance Observation of Cartilage Repair Tissue) 2.0 scoring system at follow-up. **Results:** Twenty-nine consecutive patients were included in the study. Mean time to follow-up was 24.9 ± 1.1 months. Average visual analog scale decreased significantly from 6.5 ± 3.1 preoperatively to 2.3 ± 1.6 at follow-up ($P < .0001$). Tegner score increased from 3.1 ± 1.3 to 4.3 ± 1.2 ($P < .0001$) and the International Knee Documentation Committee from 43.8 ± 21.9 to 64.9 ± 18.9 ($P < .0001$). Also, all Knee Injury and Osteoarthritis Outcome Score subscales displayed significant improvements. Patients showed similar improvements of nearly all clinical scores independent of the defect size. Average MOCART2.0 score was 70.0 ± 13.6 and 20 patients scored ≥ 70 points. All 8 patients with large defects (>5 cm²) scored ≥ 75 points. **Conclusions:** In this small study, injectable matrix-induced autologous chondrocyte transplantation therapy in the knee joint led to favourable clinical and radiologic short-term results with significant improvements in all clinical scores and MOCART2.0 scores, confirming morphologic integrity of the transplanted chondrocytes. Therefore, this minimally invasive procedure represents a promising operative technique for cartilage regeneration, even for large-diameter lesions. **Level of Evidence:** IV, therapeutic case series.

Cartilage is a bradytrophic tissue containing relatively few cells with restricted mitotic capabilities and is thus known to have limited intrinsic regenerative potential. Due to this fact, therapy of symptomatic focal chondral lesions remains challenging.¹ The currently available cartilage repair procedures can be divided into

bone marrow–stimulation techniques, e.g., microfracture, bone marrow–stimulation combined with scaffolds, and autologous transplant procedures like osteochondral transplantation and autologous chondrocyte implantation (ACI).¹ Microfracture is known to induce the formation of fibrous cartilaginous repair

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The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

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tissue biomechanically inferior to normal hyaline cartilage and to tend to intralesional ossification in long-term follow-up.¹ Also, both microfracture and osteochondral transplantation have been shown to be limited in terms of size.²

Since Brittberg et al. introduced ACI as the only chondrocyte-based technique to treat cartilage defects, this procedure has proven beneficial, even for large-diameter chondral defects, by producing functionally and mechanically stable cartilage.³⁻⁶ The methods of ACI have evolved from first generation with a periosteal flap covering the implanted fluid chondrocyte suspension, to second generation where the periosteal cover has been replaced by a biodegradable collagen I/III membrane. In the third generation of ACI, chondrocytes are seeded into a 3-dimensional scaffold as a structural template, which is implanted into the defect, referred to as matrix-induced autologous chondrocyte transplantation (MACT).⁷ Yet, all these methods need an arthrotomy of the knee for implantation and need further, mostly suture-based fixation of the template. Recently, promising techniques using for example either 3-dimensional autologous chondrocyte spheroids (chondrosphere; co.don AG, Teltow/Berlin, Germany) or an injectable, in situ polymerizing hyaluronic acid hydrogel-containing chondrocytes (Novocart inject; TETEC Tissue Engineering Technologies AG, Reutlingen, Germany) have been developed.^{8,9} These new methods allow for an all-arthroscopic application of the autologous chondrocytes, and there is no need for further fixation. Another substantial advantage is the anatomical fit of the latter hydrogel-based procedure. Recent studies have shown promising results after injectable hydrogel-based MACT (Novocart inject) therapy in the hip joint.¹⁰⁻¹² Yet, to our knowledge, there are only very few studies on the outcome of all-arthroscopic implantation of spheroids in the knee joint.¹³⁻¹⁵ Thus, the aim of this study was to evaluate subjective and objective clinical and magnetic resonance imaging (MRI)-based radiologic outcomes after short-term follow-up in patients with focal full-size cartilage lesions of the knee joint treated with all-arthroscopic hydrogel-based autologous chondrocyte transplantation. We hypothesized that this treatment method would lead to both clinically and radiologically convincing results in the present study cohort.

Methods

Study Design and Study Group

This study was conducted in accordance with the principles of the Declaration of Helsinki and meets the ethical standards of this journal. Institutional review board approval for the study was obtained from the review board of the hospital (ID: HS-181/19) and verbal informed consent was obtained before commencement.

Between January 2017 and May 2020, 29 consecutive patients who were referred to our hospital were examined in this retrospective study. Inclusion criteria were the following: closed epiphyseal plate, focal cartilage defects of the knee joint grade 3 or greater according to International Cartilage Repair Society classification with intact subchondral bone and surrounding cartilage and defect size of $\geq 2 \text{ cm}^2$ and $\leq 10 \text{ cm}^2$. Patients with radiologically apparent degenerative joint disease, additional simultaneous cartilage lesions, opposing defects, malalignment in the knee ($>3^\circ$ varus or valgus), instability of the collateral/cruciate ligaments, total/subtotal resected meniscus, vascular disorders (peripheral arterial disease), or inflammatory arthritis were excluded from the study. The following concomitant surgeries were performed: plica resection $n = 14$, removal of free joint bodies $n = 6$. In all patients, MACT was the first-line treatment. Preoperative diagnostics included clinical examination and MRI of the affected knee. Clinical assessments were performed by 2 experienced orthopaedic surgeons, F.B. and N.O. According to lesion size, subgroups of patients were formed for further analysis (cross-sectional area $\leq 5 \text{ cm}^2$ and $>5 \text{ cm}^2$).

Surgical Technique and Rehabilitation

Surgical interventions were performed by 4 experienced surgeons. A 2-stage approach was conducted for each patient. During the initial arthroscopic surgery of the affected knee joint, the cartilage defect was investigated and measured, and indication for MACT was reconfirmed with minimum lesion size of 2 cm^2 . A cartilage biopsy specimen was harvested with a punch (4-mm diameter) from the non-weight-bearing femoral trochlear/intercondylar notch of the knee. The specimen was then sent together with an autologous blood sample of 9 mL to the manufacturer (TETEC Tissue Engineering Technologies AG). The second all-arthroscopic procedure was performed after a mean time period of 28 ± 4.8 days (range 22-42). Knee position of the patient varied depending on the location of the chondral defect. Lesions of the trochlea were transplanted with an extended knee, whereas femoral lesions were treated in 90 to 120° flexion. For lesions of the lateral tibia knees were placed in the figure of 4 position. The lesion was debrided to produce stable perpendicular margins without affecting the subchondral bone. After stopping the fluid irrigation to keep the defect dry, the chondral defect was carefully filled with Novocart inject, a combination of 2 components, A and B. Component A consisted of the autologous cartilage cells suspended in a solution containing modified human albumin (maleimido-albumin, human serum albumin [MAHSA]), isotonic sodium hyaluronate, human serum, and cell culture media. Component B contained a cross-linking component consisting

of α,ω -bisthio-polyethylene glycol in solution.⁸ Using a special injection system with a dual-chamber syringe provided by the manufacturer (TETEC Tissue Engineering Technologies AG), these 2 components were mixed during the application, resulting in a cross-linked hydrogel at the site of administration. The application was performed until the cartilage defect was completely filled and the hydrogel fitted flush with the margins of the cartilage margins (2.5 mm approximate application height). Polymerization was completed after 30 to 60 seconds, and the bioresorbable hydrogel bonded immediately to the bottom of the defect and kept the cells at the defect location without the need of further fixation (Fig 1). Polymerized hydrogel contains 0.4 to 1.6 million chondrocytes per cm².

All patients adhered to a standardized postoperative rehabilitation protocol. For patients with cartilage defects located on the femoral condyle or the tibial plateau, this consisted of the non-weight-bearing of the operated extremity for 6 weeks. After maintaining a stretched position for 48 hours, range of motion was restricted from 0° up to a flexion of 60° for 2 weeks postoperatively using a hinged brace (Collamed; Medi GmbH & Co, Bayreuth, Germany). For patients with chondral defects of the trochlea, rehabilitation consisted of a restricted range of motion of 0 to 30° flexion within the first 3 weeks and 0 to 60° flexion for another 3 weeks after surgery using the same hinged brace. Full weight-bearing was allowed after 6 weeks. Return to sports was allowed 6 months after surgery.

Clinical Outcome Scores

All patients were evaluated preoperatively and at follow-up, including physical examination and completion of a questionnaire. The subjective and functional scores applied to evaluate the clinical outcome included the Tegner Score,¹⁶ visual analog scale (VAS), and the subjective and objective evaluation form of the International Knee Documentation Committee (IKDC).¹⁷ Also, the Knee Injury and

Osteoarthritis Outcome Score (KOOS) assessing knee pain, symptoms, activities of daily living (ADL), sports and recreation, and knee-related quality of life (QoL) was assessed.¹⁸ Clinical relevance was assessed applying minimal clinically important difference (MCID), minimal detectable change, and minimal important change according to recent literature.¹⁹

Radiologic Outcome Scores/MRI Evaluation

MRI of the respective knee joint was conducted before surgery and at final follow-up. Since MRI scans were part of the routine clinical follow-up and not conducted for a prospective study, sequence parameters varied slightly. Yet, the majority of the patients underwent MRI examination on the same 3.0-Tesla scanner (Avanto; Siemens Medical Systems, Erlangen, Germany) using an 8-channel phased-array extremity coil. The following sequences were performed: (1) sagittal fat-saturated (fs) proton-density-weighted turbo spin-echo (PDw TSE) sequence, (2) a sagittal T1-weighted TSE, (3) a coronal fs PDw TSE sequence and for patients with trochlear chondral defects, and (4) an axial fs PDw TSE sequence, respectively.

The MRI scans were evaluated using the Infinitt PACS viewer (Infinitt Europe GmbH, Frankfurt, Germany). Size of the lesions were determined with the PACS measuring tool. MRI scans were analyzed using the MOCART (Magnetic Resonance Observation of Cartilage Repair Tissue) 2.0 Knee Score, a recently published update on the original MOCART score.²⁰⁻²² This revised version integrates 7 variables (volume fill of cartilage defect, integration into adjacent cartilage, surface of the repair tissue, structure of the repair tissue, signal intensity of the repair tissue, bony defect or bony overgrowth, subchondral changes). Overall, a score ranging from 0 to a maximum of 100 points may be reached.²² MRI evaluations were performed by 2 independent experienced clinicians with musculoskeletal subspecialty. After an initial blinded assessment, all images were reviewed in consensus.

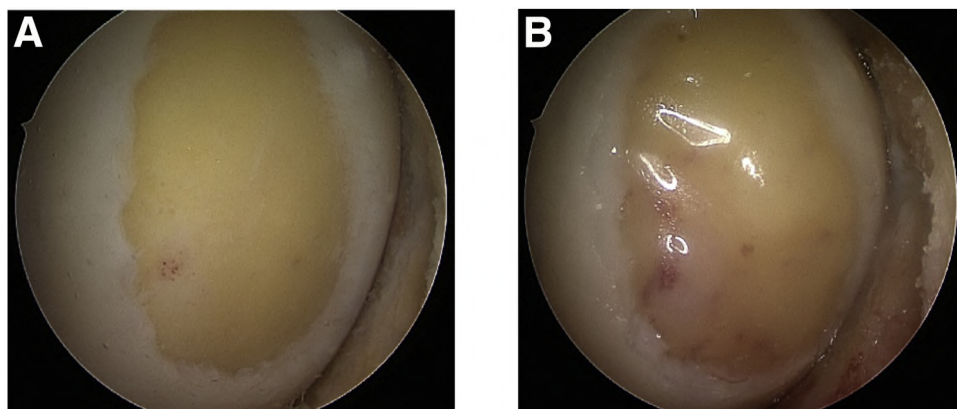


Fig 1. Cartilage defect IV° of the right medial femur condyle (A) before and (B) after application of Novocart inject.

Statistical Analysis

Statistical analysis was performed using GraphPad Prism 7 software (GraphPad software, San Diego, CA). Continuous and categorical variables were expressed as mean $\pm$ standard deviation (range) and n, respectively. Preoperative and follow-up clinical scores were compared using paired Student *t* test. Correlations between defect size, defect localization, MOCART scores, and clinical scores were analysed using Spearman coefficient ρ . *P* values $<.05$ were considered statistically significant.

Results

Demographic Data and Baseline Characteristics

Two patients were excluded from the study due to a varus deformity $>3^\circ$ of the knee joint and additional simultaneous cartilage lesions within the same joint, respectively. Of the remaining examined cohort of 29 patients, 25 were male and 4 were female. Mean age was 39.8 ± 7.4 (range 25-53) years, and the average time to follow-up was 24.9 ± 1.1 (range 24-27) months. Of all chondral lesions treated, mean defect size was 4.5 ± 1.6 (range 2.3-8.0) cm^2 and 15 were located on the trochlea, 8 on the medial femur condyle, 4 on the lateral tibial plateau, and 2 on the lateral femur condyle (Table 1).

Clinical Outcome

Overall, patients showed statistically significant improvement from baseline to follow-up evaluation in all clinical scores (Tegner, IKDC, KOOS, Table 2).¹⁹ Also, average VAS decreased significantly from 6.5 ± 3.1 (range 1.0-10.0) preoperatively to 2.3 ± 1.6 (range 0.0-5.0) at follow-up ($P < .0001$, Table 2). With regard to parameters of clinical importance, for Tegner score minimal detectable change of 1 was reached by 16 of 29 patients (55.2%, Table 2). MCID of 16.7 for IKDC was reached by 18 of 29 patients (62.1%, Table 2). MCID values for subscales of KOOS are shown in Table 2.

With regard to the IKDC objective knee examination form at follow-up, 24 patients (82.8%) showed full range of motion (limitation: extension $<3^\circ$ /flexion $<5^\circ$) and the remaining 5 patients (17.2%) showed only a slight limitation of extension $3-5^\circ$ and flexion $6-15^\circ$. In total, 23 patients (79.3%) displayed no effusion of the affected knee joint at follow-up and the remaining 6 patients (20.7%) showed mild effusions. Moderate crepitus of the affected knee joint was detectable in 14 patients (48.3%). Patients with larger chondral lesions ($>5 \text{ cm}^2$) showed similar improvements compared with patients with smaller defects ($\leq 5 \text{ cm}^2$) in all scores.

When patients of the subgroup with large chondral defects ($>5 \text{ cm}^2$) were evaluated individually, all 8 patients showed reduction of VAS, improvement of

Table 1. Demographic Data and Baseline Characteristics of the Study Population

Demographic Data/Baseline Characteristics	
Patients, n	29
Sex, n, male/female	25/4
Age, y, mean $\pm$ SD (range)	39.8 ± 7.4 (25-53)
Follow-up, mo, mean $\pm$ SD (range)	24.9 ± 1.1 (24-27)
Side affected, n, left/right	12/17
Defect size, cm^2 , n (range)	4.5 ± 1.6 (2.3-8.0)
<3	4
3-5	17
>5	8
Defect localization, n	
Medial femur condyle	8
Lateral femur condyle	2
Medial tibial plateau	0
Lateral tibial plateau	4
Trochlea	15

SD, standard deviation.

Tegner Score and KOOS (subgroups pain, ADL, sports and recreation). Also, IKDC was rated higher at follow-up compared with baseline examination by the majority of these 8 patients ($n = 6$, 75%).

Apart from the symptoms subgroup of KOOS, defect localization (lesions of the femorotibial joint vs trochlear lesions) did not significantly influence subjective clinical outcome, as the patients of these subgroups displayed similar scores (Appendix Table 1, available at www.arthroscopyjournal.org).

Radiologic Outcome

Current MRIs of all 29 patients were available at mean follow-up of 24.9 ± 1.1 (range 24-27) months at the time point of follow-up examination. Average MOCART2.0 score was 70.0 ± 13.6 (range 40.0-85.0). Twenty patients (69.0%) scored 70 points or greater and only 1 patient (3.4%) displayed a score less than 50. Score distribution according to the distinct subdomains is displayed in Table 3. Altogether, 10 patients (34.5%) showed complete filling of the defect. Graft hypertrophy was detected in 6 patients (20.7%). Complete integration into adjacent cartilage was achieved in 24 patients (82.8%). Overall, 18 patients (62.1%) showed no subchondral changes ($n = 14$, 48.3%) or only minor edema-like marrow signal alterations ($n = 4$, 13.8%). Bony defects or overgrowth were observed in 15 patients (51.7%), yet alterations were of minor extent.

Interestingly, all 8 patients with large chondral defects ($>5 \text{ cm}^2$) scored 75 points or greater. There was no correlation between clinical outcome scores and MOCART2.0 scores. Fig 2 shows an example of a patient's MRI of the affected knee joint before (A, coronal and B, sagittal view) and after (C, coronal and D, sagittal view) MACT.

Table 2. Evaluation of Clinical Outcome According to the Distinct Scores (VAS, Tegner, IKDC, KOOS) Before Surgery and at Follow-Up Examination

Score	Baseline		Follow-up		P Value	MCID (MDC, MIC)	
	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range		Threshold Levels*	Patients $\geq$ MCID (%)
VAS	6.5 $\pm$ 3.1	1.0-10.0	2.3 $\pm$ 1.6	0.0-5.0	<.0001	—	—
Tegner	3.1 $\pm$ 1.3	1.0-5.0	4.3 $\pm$ 1.2	2.0-6.0	<.0001	MDC 1	55.2
IKDC	43.8 $\pm$ 21.9	9.2-78.2	64.9 $\pm$ 18.9	27.6-89.7	<.0001	MCID 16.7 (12 mo)	62.1
KOOS							
Pain	50.4 $\pm$ 25.1	8.3-91.8	73.8 $\pm$ 19.3	36.0-100.0	<.0001	MIC 16.7	69.0
Symptoms	46.6 $\pm$ 13.6	10.8-60.8	56.5 $\pm$ 15.4	28.5-85.8	.0005	MIC 10.7	48.3
ADL	59.6 $\pm$ 27.3	0.0-95.5	80.4 $\pm$ 15.8	44.3-100.0	.0002	MIC 18.4	48.3
Sports and recreation	27.1 $\pm$ 21.1	0.0-75.0	68.2 $\pm$ 20.3	25.0-93.8	<.0001	MIC 12.5	86.2
QoL	39.7 $\pm$ 32.1	0.0-100.0	55.2 $\pm$ 23.5	12.5-100.0	.0350	MIC 15.6	58.6

NOTE. Values are given as mean $\pm$ SD and range, respectively.

ADL, activities of daily living; IKDC, International Knee Documentation Committee; KOOS, knee injury and osteoarthritis outcome score; MCID, minimal clinically important difference; MDC, minimal detectable change; MIC, minimal important change; QoL, quality of life; SD, standard deviation; VAS, visual analog scale.

*According to recent literature.¹⁹

Failure/Complications

One patient, aged 39 years, with a cartilage lesion of 4 cm² at the trochlea reported persisting pain and movement restriction in the affected knee joint at follow-up examination. MOCART2.0 scoring was the lowest of all patients with 40 points. In this case, the MACT procedure was considered as failure and revision surgery with removal of the tissue graft and focal articular prosthetic resurfacing was performed subsequently after follow-up examination.

Discussion

This small case series could demonstrate promising short-term clinical and radiologic outcomes after all-arthroscopic hydrogel-based MACT in patients with focal cartilage lesions in the knee joint. This was expressed by significant improvements in clinical scores from baseline to follow-up and convincing MOCART2.0 scoring, reflecting high morphologic integrity of the transplanted chondrocytes.

In the present study, at an average follow-up of 24.9 months the patient cohort scored 4.3 in Tegner activity

level, 64.9 points in the IKDC and VAS was rated 2.3 on average. Subscales of KOOS were assessed with 73.8 (pain), 56.5 (symptoms), 80.4 (ADL), 68.2 (sports and recreation) and 55.2 points (QoL), respectively. Former studies after arthrotomy-based MACT of the knee joint (one of which conducted with the Novocart 3D scaffold), showed comparably good clinical results, with Tegner scores ranging from 3.6 to 4.4 and IKDC from 61.1 to 74.3 points at similar time points of follow-up (24 months).^{23,24} KOOS subscales of pain (range from 81 to 86 points) and ADL (range from 85 to 91 points) were rated slightly greater, whereas the subgroups of symptoms (range from 54 to 65 points), sports and recreation (range from 38 to 54 points), and QoL (range from 43 to 60 points) were rated similar or slightly lower compared with the present results.^{23,25} Yet, comparability of baseline scores varied among the distinct outcome scores.¹³

Siebold et al.^{13,14} assessed clinical outcomes after all-arthroscopically conducted MACT of the knee joint with spheroids and found greater scores for the KOOS subscales pain, symptoms and ADL, whereas the subcategories of sports and recreation, QoL, and the Tegner and IKDC score showed varying, partially comparable results, depending on the distinct study. Yet, in these studies, examination was conducted at an average follow-up of 34 months compared with almost 25 months in the present study. It has been proposed that clinical outcome scores improve throughout the post-operative timeline, short follow-up time as a limitation of the study might account for this discrepancy and clinical scores of the present patients might even improve over the time.^{14,26} Despite the significant improvement of all clinical scores from baseline to follow-up in the present study and the comparable values in line with previous studies, absolute values of VAS, Tegner score and IKDC reflect moderate

Table 3. MOCART2.0 Score: Overall and Distribution According to Subdomains

MOCART2.0 Score Subdomains (Points)	Follow-up	
	Mean $\pm$ SD	Range
Volume fill of cartilage defect (0-20)	14.8 $\pm$ 5.9	0.0-20.0
Integration into adjacent cartilage (0-15)	14.1 $\pm$ 1.9	10.0-15.0
Surface of the repair tissue (0-10)	6.4 $\pm$ 3.0	0.0-10.0
Structure of the repair tissue (0-10)	3.4 $\pm$ 4.6	0.0-10.0
Signal intensity of the repair tissue (0-15)	9.1 $\pm$ 4.2	0.0-15.0
Bony defect or bony overgrowth (0-10)	7.1 $\pm$ 2.6	5.0-10.0
Subchondral changes (0-20)	13.8 $\pm$ 7.5	0.0-20.0
Total (0-100)	70.0 $\pm$ 13.6	40.0-85.0

MOCART, Magnetic Resonance Observation of Cartilage Repair Tissue; SD, standard deviation.

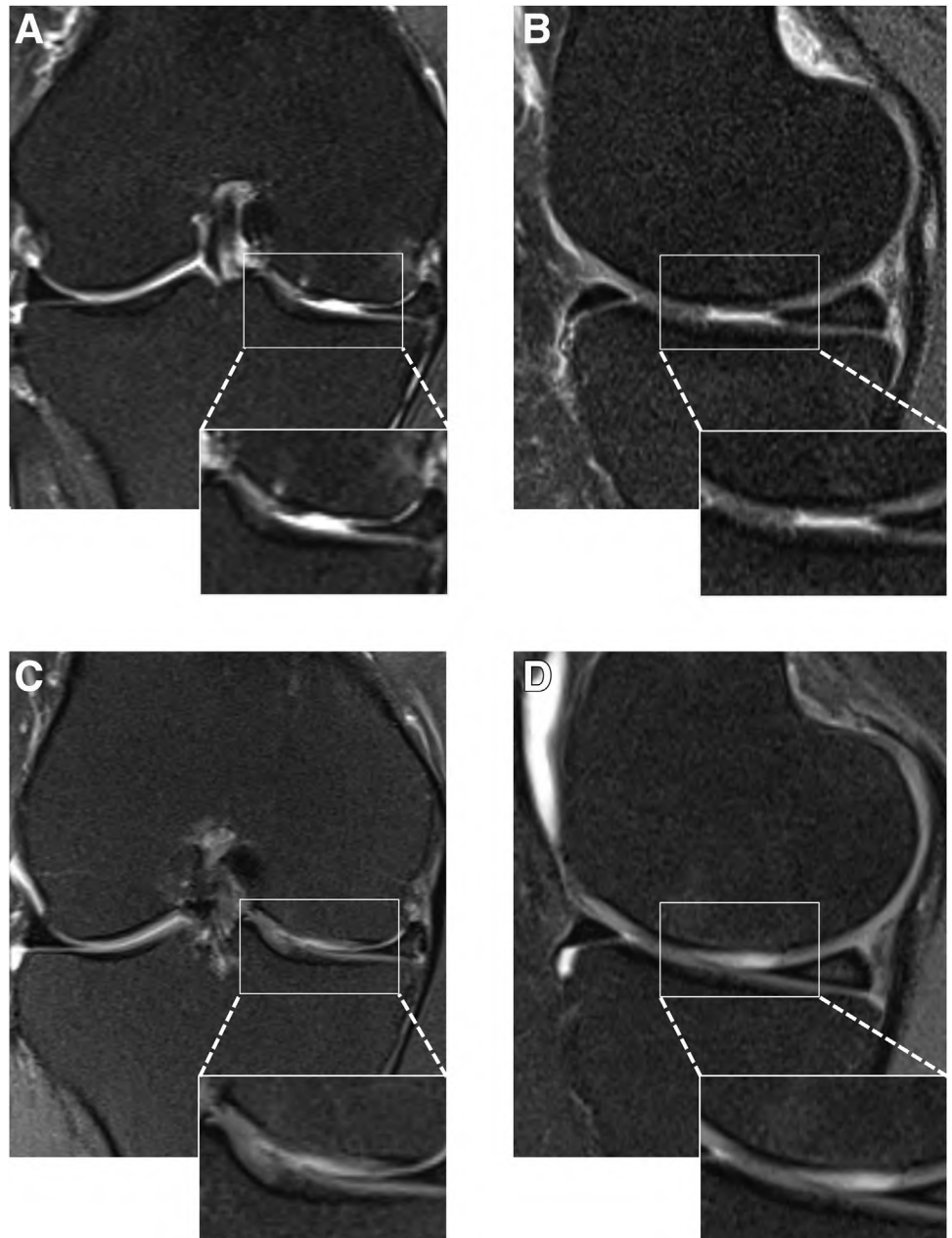


Fig 2. Proton-density weighted magnetic resonance images (coronal and sagittal view) of a patient with a cartilage defect of the right medial femur condyle (A) and (B) before and (C) and (D) 24 months after therapy with Novocart inject.

subjective levels and MCID values were only reached in 48% to 69%, so that these results could hopefully even improve in the further course.

Besides enhanced subjective outcome scores arthroscopically conducted chondrocyte transplantation presumably prevents typical arthrotomy-based adverse events like adhesions, arthrofibrosis and decreased range of motion.²⁷⁻²⁹ In our study, as one of the most important advantages of this minimally invasive procedure, we could emphasize this advantage, since the vast majority of 82.8% showed full range of motion of their knee joint and only 6 patients demonstrated mild effusions. The only complication observed was graft

failure in 1 patient, which represents an incidence that is in keeping with the literature.²⁹

This progression in surgical techniques of ACI is also reflected by the development of an updated version of the original MOCART score, the recently introduced MOCART2.0 score, in which omission of the former variables “adhesion” and “effusion” renders the scoring system more sensitive to the assessment of cartilage tissue morphology itself.²² Earlier studies indicated a maturation process of the chondrocytes reflected by an improvement of the MOCART score postoperatively within the first 2 years.^{30,31} In the present study, at 24 months follow-up, integrity of the transplanted

chondrocytes was rated high with an average MOCART2.0 score of 70.0 points. Previous work showed results of 68.9 to 73.2 points with former MOCART score.²³⁻²⁵ Yet, since in this study the updated MOCART2.0 score was applied, comparability needs to be assessed with future studies. Graft hypertrophy is described to represent a major complication of ACT. In our study 20.5% of the patients showed hypertrophy of the transplant on MRI scans, which is in line with recent studies by Niethammer et al.,^{30,31} who found graft hypertrophy to occur in 22% to 25% after MACT with Novocart 3D.

According to a recent guideline on the treatment of focal cartilage defects and based on the proven effectiveness in several studies, the different established techniques of autologous chondrocyte transplantation were recommended as the preferable therapy for large diameter chondral lesions ($>3\text{-}4\text{ cm}^2$).^{1,2} Isolated analysis of the subgroup of patients with cartilage lesions $>5\text{ cm}^2$ in the present study did also show both favourable clinical and radiologic scoring and correlation analysis of defect size with subjective outcome scores did not show a significant statistical dependency. Thus, with the present results we could demonstrate that all-arthroscopic application techniques using a hydrogel with autologous cartilage cells mixed with a cross-linking component seem to be a probable procedure to also address large-diameter cartilage lesions.

Limitations

The present study certainly has several limitations. First, the small study group renders it difficult to securely evaluate clinical effectiveness of the technique. Second, the lack of a control group restricts the ability to draw any conclusions on the superiority to other chondrocyte transplant procedures.

Conclusions

In this small study, injectable MACT therapy in the knee joint led to favorable clinical and radiologic short-term results with significant improvements in all clinical scores and MOCART 2.0 scores confirming morphologic integrity of the transplanted chondrocytes. Therefore, this minimally invasive procedure represents a promising operative technique for cartilage regeneration, even for large-diameter lesions.

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Appendix

Appendix Table 1. Comparison of Clinical Outcome Scores (VAS, Tegner, IKDC, KOOS) According to Location of Cartilage Lesion (Femorotibial vs Trochlea)

Score at Follow-Up	Femorotibial		Trochlea		P Value
	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range	
VAS	2.8 $\pm$ 2.5	0.0-7.0	4.0 $\pm$ 2.5	1.0-8.0	ns
Tegner	3.8 $\pm$ 1.1	2.0-5.0	4.1 $\pm$ 1.2	2.0-6.0	ns
IKDC	66.3 $\pm$ 20.1	33.3-89.7	56.7 $\pm$ 19.1	27.6-85.1	ns
KOOS					
Pain	74.1 $\pm$ 22.1	36.0-94.5	70.6 $\pm$ 19.3	30.5-100.0	ns
Symptoms	63.3 $\pm$ 14.5	35.8-85.8	47.7 $\pm$ 11.7	28.5-67.8	.004
ADL	79.8 $\pm$ 22.4	33.8-98.5	77.7 $\pm$ 15.0	44.3-100.0	ns
Sports and recreation	65.0 $\pm$ 23.5	25.0-90.0	56.2 $\pm$ 33.7	5.0-93.8	ns
QoL	58.4 $\pm$ 25.4	18.8-100.0	45.8 $\pm$ 27.2	12.5-87.5	ns

ADL, activities of daily living; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; ns, not significant; QoL, quality of life; SD, standard deviation; VAS, visual analog scale.