

Reconstruction of osteochondral defects by combined bone grafting and a bilayer collagen membrane as a sandwich technique

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Abstract

Treatment of osteochondral lesions of the knee remains a major challenge in orthopedic surgery. Recently established procedures like autologous chondrocyte implantation or matrix-associated chondrocyte implantation yield good results, but include the disadvantage of two-step procedures. The purpose of this study was to evaluate the clinical and magnetic resonance imaging outcome of repairs of osteochondral defects of the knee by a combined procedure of bone grafting and covering with a bilayer collagen membrane in a sandwich technique. Seven male patients with a mean age of 42 (range 30-55) years and symptomatic focal osteochondral lesions of the knee grade IV according to the International Cartilage Repair Society classification were included. The mean diameter of defects was 28.6 (range 15-40) mm. Results were evaluated at a minimum of 24 months after surgery by International Knee Documentation Committee score, Lysholm-score, visual analogue scale, and magnetic resonance imaging with specific cartilage sequences, evaluating the ICRS score and the Magnetic Observation of Cartilage Repair Tissue (MOCART) score. All patients judged the operation as successful. Among the patients available for the long-term follow-up, mean visual analogue scale value was 1.3 (range 0-3) out of 10 points. Mean International Knee Documentation Committee score was 80.8 (range 63.2-88.5) out of 100 points. Mean Lysholm score was 85 (range 55-95) out of 100 points. None of the patients had to be reoperated until today. Evaluation of magnetic resonance imaging using the MOCART score revealed a good correlation to the clinical outcome. This is the first study reporting results after reconstruction of osteochondral defects of the knee joint by bone grafting and a bilayer collagen membrane. This new method offers the advantage of a one-step-procedure and yields both good clinical and magnetic resonance findings. We conclude that this procedure can be a valuable tool to improve joint

function after osteochondral defects, trauma, and in joints with local arthritic lesions.

Introduction

Treatment of full-thickness cartilage defects remains a challenging purpose in joint surgery. Early diagnosis and appropriate treatment of such defects is important to prevent early osteoarthritis and the need for arthroplasty. A therapeutic state of the art has not been established yet. The incidence of chondral lesions in the knee joint is estimated around 10-12% of all individuals.¹ Retrospective analyses of large collectives with thousands of patients who underwent knee arthroscopy in the United States and Europe indicate an incidence of chondral lesions of 63%,² and incidences between 4 and 11% of full-thickness cartilage defects that would have been appropriate for biological cartilage repair.³⁻⁵ Treatment options include osteochondral transfer,⁶ also known as osteochondral autologous transplant system (OATS). This method consists of harvesting of bone-cartilage cylinders from less weight bearing areas of the joint and transplantation into the defect. For larger defects, a combination of several bone-cartilage cylinders can be used (mosaicoplasty).

Microfracturing the subchondral bone is widely accepted as therapy for smaller focal defects,^{7,8} with good results in an eleven-year follow-up.⁹

Tissue engineering techniques like autologous chondrocyte implantation (ACI) have opened a possibility of regenerating hyaline articular cartilage.⁷ ACI was introduced in 1987 by Peterson,¹⁰ and has shown good results at ten years of follow-up.¹¹ A comparison of ACI and microfracturing two years after repair of knee cartilage defects revealed similar results.¹² As a further development of ACI, matrix-associated chondrocyte implantation (MACI) appears to generate even better results than ACI.¹³⁻¹⁶ However, both ACI and MACI include the disadvantage of two-step procedures like time loss, increased costs, extended work incapacity, and donor site morbidity from the chondrocyte harvesting procedure which include more complex regulatory issues in Europe.¹⁷

This explains an increasing interest in cell-free repair approaches, like the collagen type I gel CaReS®-1S (Arthro Kinetics, Krems/Donau, Austria),¹⁷ and the Chondroguide® membrane (Geistlich, Wolhusen, Switzerland).¹⁸ Chondroguide® is a resorbable membrane used in autologous matrix-induced chondrogenesis (AMIC), consisting of porcine collagen type I and III in a double layer with a compact and a porous side.

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As migration of articular chondrocytes has been previously reported by Morales *et al.*¹⁹ *in vitro* and *ex vivo*, the cell-free approach seems to be promising. Both CaReS®²⁰ and Chondroguide®¹⁸ have previously been used as a chondrocyte carrier in matrix associated autologous chondrocyte implantation (MACI). Our study group has recently reported slightly better results for the CaReS® technique compared to microfracturing in patients with patellofemoral cartilage defects.²¹

Magnetic resonance imaging (MRI) is well established for non-invasive follow-up of cartilage repair procedures.²² The purpose of this study was to evaluate the clinical and MRI-outcome of repairs of osteochondral defects of the knee by a combined procedure of bone grafting and covering with the Chondroguide® membrane.

Materials and Methods

The study was performed in accordance with the Helsinki Declaration. The local Ethical Committee approved the study and informed consent was obtained from all patients. Seven male patients with a mean age of 42 (range 30-55) years and symptomatic focal osteochondral lesions of grade IV according to the International Cartilage Repair Society (ICRS) classification of the knee were included into the study.²³ One patient suffered from similar

osteochondral defects in both knees and was operated bilaterally within a three months period. Defects were located at the medial femoral condyle (MFC) in seven knee joints and at the lateral femoral condyle (LFC) in one knee joint. The mean diameter of defects was 28.6 (range 15-40) mm. Accompanying knee joint malalignment of more than 5° was addressed simultaneously by high tibial osteotomy in 4 out of 7 patients. Exclusion criteria included chronic inflammatory diseases, kissing lesions or further cartilage degeneration in other compartments, and ligamental joint instability.¹⁷

Surgery was performed by debridement of cartilage, followed by bone grafting with either cancellous chips or monocortical cancellous cylinders from the iliac crest. After precise cutting of the membrane according to the size of the template, the graft site was covered by the Chondrogide® membrane fixed by fibrin glue and sutures, the porous side facing the bone. Durability of the fixation was tested by fully moving the joint intraoperatively for at least ten times. Partial weight bearing on crutches was performed for six weeks postoperatively.

Clinical outcome was assessed preoperatively and 24 months after surgery, using the International Knee Documentation Committee (IKDC) score,^{24,25} Lysholm score,^{26,27} and visual analogue scale.⁶

The MR examinations were acquired on a 3T scanner (Magnetom Verio, Siemens, Erlangen, Germany) using a dedicated transmit/receiver 15-channel knee coil (Siemens, Erlangen, Germany). The scan protocol included transversal, coronal and sagittal high-resolution PD-TSE sequences (TR: 3000 ms, TE: 36 ms, ETL: 10, slice thickness: 2 mm, FOV: 160 mm, matrix: 358×512 px) supplemented by an isotropic single-slab 3D PD-TSE sequence (SPACE, TR: 1000 ms, TE: 43 ms, ETL: 127, slice thickness: 0.6 mm, FOV: 172×180 mm, matrix: 320×269 px). Evaluation of MRI was performed preoperatively and 24 months after surgery using the Magnetic Observation of Cartilage Repair Tissue (MOCART) score as introduced by Marlovits *et al.*^{28,29}

Results

Four patients got lost in the follow-up, leaving three patients with four concerned knee joints for clinical and radiological follow-up after at least 24 months. Among the four patients with incomplete follow-up, two were highly satisfied with their results at follow-up after four respectively six months. They performed full weight bearing and reported to be free of pain. One patient was not within reach for any follow-up. Finally, one patient had a traumatic cartilage defect of the medial

femoral condyle due to a III° open fracture of the distal femur. After several prior debridements and plate osteosynthesis, the cartilage defect was treated by a monocortical cancellous bone graft from the iliac crest and the Chondrogide® membrane. In the following weeks, he suffered from wound infection, followed by osteoarthritis, and finally underwent total knee arthroplasty 18 months after the procedure. Among the three patients with four knee joints available for the long-term follow-up, mean VAS value was 1.3 (range 0-3) out of 10 points. All patients considered their current status to be at least equal or better than before surgery. Mean IKDC score was 80.8 (range

63.2-88.5) out of 100 points. Mean Lysholm score was 85 (range 55-95) out of 100 points. None of the patients had to be reoperated until today. Results of MRI evaluation, according to MOCART score,²⁸ are shown in Table 1. The patient with the lowest Lysholm- and IKDC-scores correspondingly showed the least good MRI-patterns of cartilage repair (Figures 1-4).

Discussion

The most important finding of our study was that reconstruction of osteochondral defects of

Table 1. MRI evaluation by MOCART score, by absolute number and percentage.

Degree of defect repair and filling of the defect	
Complete	1 (25%)
Hypertrophy	1 (25%)
Incomplete: >50% of the adjacent cartilage	0 (0%)
Incomplete: <50% of the adjacent cartilage	2 (50%)
Subchondral bone exposed	0 (0%)
Integration to border zone	
Complete	1 (25%)
Incomplete: demarcating border visible (split-like)	2 (50%)
Incomplete: defect visible <50% of the length of the repair tissue	0 (0%)
Incomplete: defect visible >50% of the length of the repair tissue	1 (25%)
Surface of the repair tissue	
Surface intact	1 (25%)
Surface damaged: <50% of repair tissue depth	2 (50%)
Surface damaged: >50% of repair tissue depth or total degeneration	1 (25%)
Structure of the repair tissue	
Homogenous	1 (25%)
Inhomogenous or cleft formation	3 (75%)
Signal intensity of the repair tissue	
Isointense	2 (50%)
Moderately hyperintense	1 (25%)
Markedly hyperintense	1 (25%)
Subchondral lamina	
Intact	0 (0%)
Not intact	4 (100%)
Subchondral bone	
Intact	0 (0%)
Not intact	4 (100%)
Adhesions	
No	4 (100%)
Yes	0 (0%)
Effusion	
No	2 (50%)
Yes	2 (50%)

the knee joint by bone grafting and a bilayer collagen membrane in a one-step-procedure yields both good clinical and magnetic resonance results.

In spite of all scientific progress in regenerative joint surgery, clinical application is still lagging behind. In Germany, 159.137 patients underwent total knee arthroplasty (TKA) in 2009, compared to less than 3.000 who underwent cartilage repair procedures in the same time. According to the estimated incidence of 4-11%, only about one out of ten patients obtains the appropriate treatment by biological cartilage repair. From 2005 until today, the annual count of TKA has almost tripled in Germany. Economical studies revealed that successful ACI or MACI are usually reducing costs in healthcare. Even in case of failure of ACI or MACI, all options of arthroplasty are still available.

Several studies have investigated a combined approach of autologous bone grafting with either cancellous bone chips or monocortical cancellous cylinders and additional MACI. All of these trials included a two-step approach with chondrocyte transplantation and the prior need of chondrocyte harvesting. To our knowledge, this is the first trial to report results of combined autologous bone grafting and autologous matrix-induced chondrogenesis (AMIC) for osteochondral defects in a one-step approach.

Maus *et al.* reported three-year results of 13 patients (mean age 34.9 years) with osteochondral defects of the knee (ICRS grade IV or IV B, mean defect size 8.1 cm²) after autologous bone grafting combined with matrix-associated autologous chondrocyte transplantation (MACT) with the CaReS® system (ArthroKinetics, Krems/Donau, Austria). They found significantly improved IKDC- and ICRS-function scores compared to preoperatively.³⁰ However, they did not perform MR imaging in the follow-up.

Ochs *et al.* reported the results of a one-step-procedure of bone grafting and MACT for osteochondrosis dissecans of the knee (ICRS grade III and IV). They used monocortical cancellous bone cylinders with the Novocart 3D®-system to reshape the surface. After a mean follow-up of 16 months, they found significantly improved IKDC- and Lysholm-scores compared to the preoperative status.³¹ They did not perform MR imaging in the follow-up. In addition, it did not become clear how they could perform chondrocyte transplantation in a one-step-procedure.

Basad *et al.* presented clinical and MRI findings one and two years after iliac bone grafting and MACI in patients with OD grade III and IV. They performed a two-step-procedure with debridement and cancellous bone grafting in the first operation, and a double-layer MACI fixed with fibrin glue in the second operation.

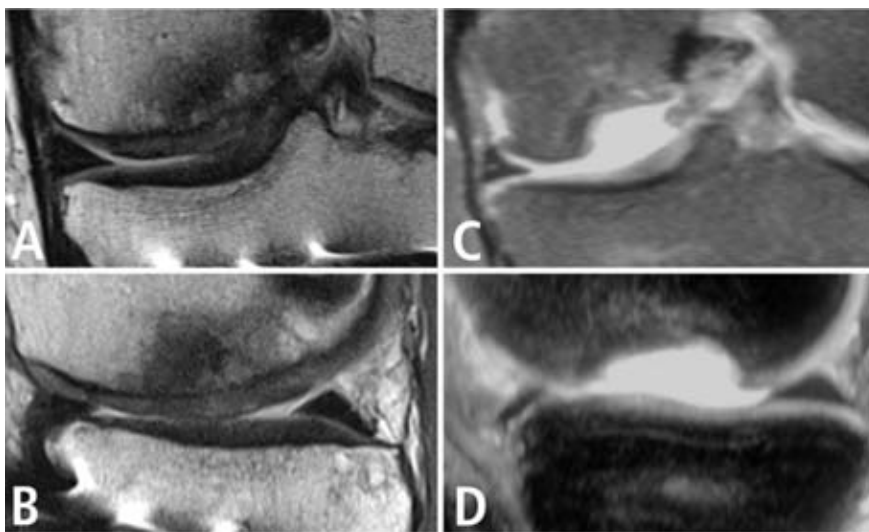


Figure 1. Post- and preoperative magnetic resonance imaging of left knee joint of patient 1. A) Coronal view 2 years after surgery, B) sagittal view 2 years after surgery, C) coronary view before surgery, D) sagittal view before surgery.

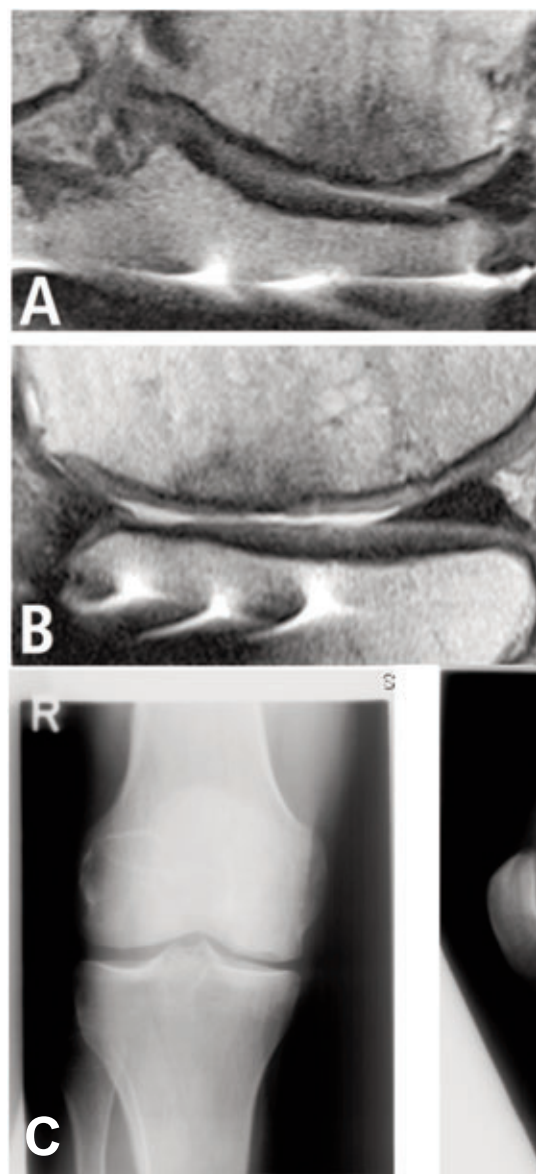


Figure 2. Postoperative magnetic resonance imaging and preoperative X-ray of right knee joint of patient 1. A) Coronal view 2 years after surgery, B) sagittal view 2 years after surgery, C) below preoperative X-rays.

They found significantly improved clinical scores postoperatively. Additionally, the MRIs in the follow-up showed regredient subchondral edema and an almost normal signal intensity of the cartilage repair tissue.³²

Several limitations apply to this study: first, a larger sample size and a lower drop-out rate in the follow-up would have been desirable. Second, operative techniques were not uniform due to the different sizes of defects, using either cancellous chips or monocortical cancellous cylinders from the iliac crest for bone grafting. Third, the high tibial osteotomy simultaneously performed in seven out of eight knees may have caused a higher morbidity for these patients. However, the results of

this study may be of relevance for the treatment of osteochondral defects of the knee joint in the future.

Conclusions

This is the first study reporting results after reconstruction of osteochondral defects of the knee joint by bone grafting and a bilayer collagen membrane. This new method offers the advantage of a one-step-procedure and yields both good clinical and magnetic resonance findings. We conclude that this procedure can be a valuable tool to improve joint function

after OD, trauma, and in joints with local arthritic lesions.

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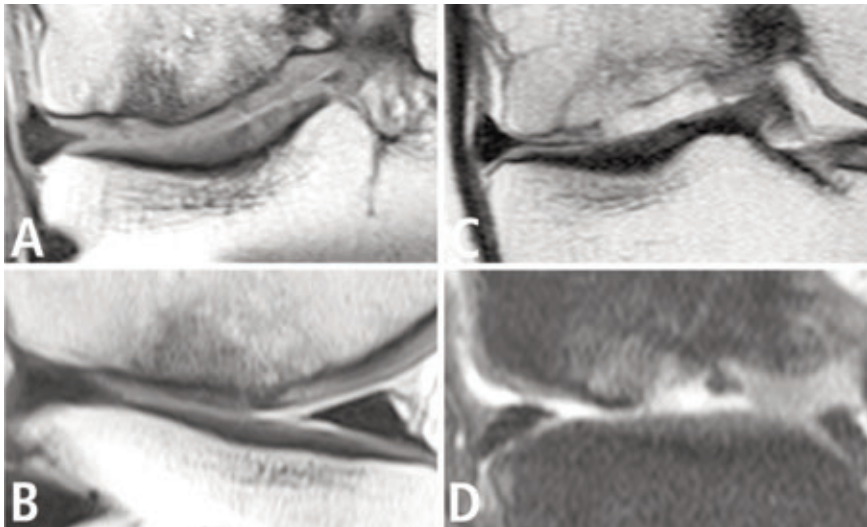


Figure 3. Post- and preoperative magnetic resonance imaging of patient 2. A) Coronal view 2 years after surgery; B) sagittal view 2 years after surgery; C) coronal view before surgery, D) sagittal view before surgery.

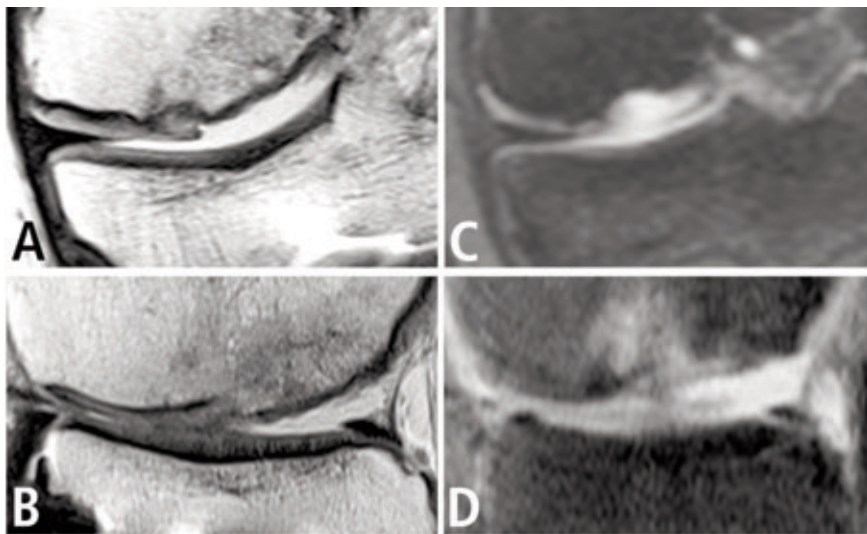


Figure 4. Post- and preoperative magnetic resonance imaging of patient 3. A) Coronal view 2 years after surgery, B) sagittal view 2 years after surgery, C) coronal view before surgery, D) sagittal view before surgery.

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