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Tim Rose · Steffen Craatz · Pierre Hepp
Conrad Raczynski · Joachim Weiss · Christoph Josten
Helmut Lill

The autologous osteochondral transplantation of the knee: clinical results, radiographic findings and histological aspects

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Abstract *Introduction*: The osteochondral transplantation (OCT) is a well accepted treatment option for focal cartilage lesions in the knee joint, whereas the fate of the transplanted cartilage is still unclear and the clinical outcome is variable. The purpose of this study was to evaluate the histological character of autologous transplanted cartilage and to correlate technical aspects and the patients' history with the clinical outcome. *Material and Methods*: The OCT was performed in 27 patients (median age of 32 (22–43) years) with a focal chondral lesion at the medial femoral condyle. We investigated the clinical outcome after a median follow-up of 13.5 (5–28) months using the Lysholm-score and the integration of the transplanted plugs using an MRI-scoring system. Biopsy specimens from representative patients ($n = 8$) were evaluated with histological staining and immunohistochemistry. *Results*: The median Lysholm-score was 80 (range 45–98). The wide range of the Lysholm-score in clinical outcome did not show significant differences in: follow-up, concomitant injuries, defect size or genesis. The MRI analysis revealed in all cases a regular osseous integration of the subchondral bone, but a failed chondral integration. The congruency of the plugs to the joint surface was often incorrect, however a correlation between the MRI-score and the clinical outcome could not be shown. Histology of the transplanted cartilage revealed small changes in immunohistochemistry after a relatively short-term follow-up, whereas the cartilage has still the typical hyaline character. Often, the surrounding cartilage consists of fibrous and granulation tissue. *Conclusion*: The congruency of the joint surface can not be restored to the original status, particularly in larger defects with irregular shapes. However, we did not find any aspects which affected the function of the knee joint following OCT. It can be assumed that remaining lesions at the surrounding cartilage could maintain the inflammatory process and therefore maintain the pain and a low knee function. Further investigations are needed to specify the effects of the OCT on the transplanted cartilage and its influence on the later clinical outcome.

Keywords Cartilage defect · Osteochondral transplantation · MRI · Histology · Clinical outcome

T. Rose (✉) · P. Hepp · C. Raczynski · C. Josten · H. Lill
Department for Trauma and Reconstructive Surgery,
University of Leipzig, Leipzig, Germany
E-mail: t.rose@lrz.tum.de
Tel.: +49-89-28924471
Fax: +49-89-28924484

S. Craatz · J. Weiss
Institute of Anatomy, University of Leipzig,
Leipzig, Germany

T. Rose
Arzt für Chirurgie und Sportmedizin Oberarzt Abteilung für Sportorthopädie, Technische Universität München Klinikum Rechts der Isar, Connolly Strasse 32, 80809 München, Germany

Introduction

The healing of articular cartilage defects is limited [21] because of their avascularity and missed innervation. Different treatment options have been used to stimulate the regeneration of such defects, as subchondral drilling [2], abrasion-chondroplasty [9], and microfractures [39]. However, these techniques result only in a fibrous substitute tissue covering the cartilage defect with poor biomechanical characteristics [6]. The restoration of hyaline cartilage using autologous chomdrocyte transplantation results also mostly in hyaline-like cartilage or fibrocartilage tissue [10–20].

The osteochondral transplantation (OCT) is an option to fill a chondral defect with hyaline cartilage with a reliable osseous ingrowth. The first OCT was noted by Wagner in 1964, whereas an autologous transplantation was performed in three patients and a homologous transplantation was performed in two patients [42]. Following these promising results, several surgeons performed allogenic and autologic OCT with slightly

good results [7, 8, 18, 32, 35, 43]. At the beginning of 1990's the technique of transplantation was improved mainly by Hangody et al. [11] and Bobic [5], whereas Matsusue et al. [31] were able to use this technique for arthroscopic approach. Following middle and long term studies had shown encouraging clinical results after OCT [3, 15, 28]. Furthermore, experimental and clinical experience have shown that the transplanted hyaline cartilage has a good rate of survival [15].

The histological structure of the transplanted cartilage is an important marker for their biomechanic characteristic and their survival. Hangody et al. [12] still detected hyaline cartilage in a histological evaluation of arthroscopic biopsies 1–5 years following OCT. Cadaver studies mostly supported these findings [15, 38], but it seems that the histological properties of the transplanted cartilage are different from that of the normal articular cartilage in animal model [30]. Additionally, a chondral integration of the transplanted cartilage failed and a gap between the transplanted cartilage and the adjacent cartilage reached down to bone [15, 20]. However, the characteristic of the histological structure of the grafted cartilage in human has not been reported in detail. Furthermore, the congruency of the transplanted plugs and the osseous integration are propagated as an important requirement for the clinical satisfaction of the patient. But it is still unclear which circumstances of the injured knee really affect the clinical outcome of the patient following OCT.

The purpose of this study was to evaluate the histological character of autologous transplanted cartilage in humans at different time points, and to correlate technical aspects and the patients' history to the clinical outcome. Our hypothesis was that a focal chondral defect at the femoral condyle treated with OCT shows hyaline cartilage during the follow-up. Furthermore we assumed that the clinical outcome is be affected by the size of the chondral lesion, by concomitant lesions, genesis of the lesion, the age of the patient, and the MRI-findings within the follow-up.

Material and methods

Study design

The study was approved by the ethics commission of the University of Leipzig, Germany. The patients were included regarding the inclusion and exclusion criteria, after they were informed about the content of the study. The inclusion criteria for the study were a osteochondral lesion Grad IV of Outerbridge [34] in the weight bearing area of the medial femoral condyle. Clinical symptoms as swelling, pain, and locking of the knee joint and a positive MRI-result regarding a chondral lesion were used for a preoperative selection. Exclusion criteria were a general osteoarthritis of the knee joint, remaining knee joint instability, kissing osteochondral lesion, defects larger than 4 cm^2, and/or multiple defects. An axial mal-alignment or a knee joint instability should be corrected at the same time or previous to the OCT.

Patients

All study patients underwent an MRI previous to the surgery and during the follow-up. At the same time points the clinical examinations were evaluated with use of the score described by Lysholm and Gillquist [29]. A total of 27 patients (six female, 21 male) were included in the study with a median age of 32 (22–43) years. The median follow-up were 13.5 (5–28) months. The sizes of the cartilage defect ranges from 1.0 to 3.0 cm^2 (median 1,2 cm^2), whereas the defect was filled 16-times with one cylinder, eight times with two osteochondral cylinders and three times with three osteochondral cylinders. The size of the cylinders was between 8 mm and 11 mm. The transplantation was performed in 13 cases arthroscopically and in 14 cases with mini-arthrotomy. Only the one-cylinder-technique was made in a arthroscopic manner.

Additional therapeutic relevant lesions were found in 13 patients; we found anterior cruciate ligament (ACL) rupture in two patients, meniscal lesion in six patients, and the combination of a meniscal lesion and an ACL-rupture in five patients. If the cruciate ligament was turned, an ACL-reconstruction was performed at the same time of OCT or in a previous procedure. In six cases the meniscus was partially resected and in five cases the meniscus was refixed using an inside-out technique.

Eight patients underwent a re-arthroscopy for evaluation of the operative result between 5 and 21 months. A biopsy, using a metal-needle with a diameter of 2.8 mm, for histological assessment was harvested from the centre of the osteochondral plug and from the transition zone between the transplanted cylinder and the recipient site. The histological slides were evaluated by a histologist who was blinded with regard to patient allocation.

All chondral lesions were a grade IV lesion regarding the Outerbridge-classification [34] with a total loss of cartilage. The indication for the OCT were in four cases an acute lesion (less than 6 weeks before transplantation) with trauma. A chronic lesion ($n = 23$) was defined as a traceable lesion which exists longer than 6 weeks, whereas in 16 cases a trigger trauma was reproducible. In seven cases an osteochondrosis dissecans was the indication of the need for OCT. The median size of the chondral lesions was 12 mm (range: 9–30). The OCT was performed at the medial femoral condyle of the knee joint over a 3-year period using one ($n = 16$), two ($n = 8$) or three ($n = 3$) graft cylinders. The harvesting site of the cylinders was in case of an arthroscopic approach to the femoral notch. The anterior lateral condyle and the femoral notch were used for the donor cylinders in case of an open approach. Concomitant intra-articular injuries included nine injuries to the medial meniscus and five injuries to the lateral meniscus (six refixed). An

anterior instability of the knee joint was present in seven cases, which required a reconstruction of the anterior cruciate ligament.

Surgical technique

All operations were performed by the same surgeon, who had extensive experience in the OCT-procedure (open and arthroscopic), prior to the study period. The arthroscopic assessment of the defect size led to the decision regarding the number of the used osteochondral cylinders. The shape of the recipient surface was followed for harvesting the osteochondral graft to allow a correct remodeling. The Osteochondral Autologous Transplantation System (OATS, Arthrex, Karlsfeld, Germany) was used for harvesting and implantation of the osteochondral cylinders at the recipient and donor site. The diameter of the recipient site was 1 mm smaller compared with the donor site, so that a press-fit fixation of the implanted osteochondral cylinder could be achieved. Therefore an additional fixation was not necessary. This process was repeated in succession for the coverage of larger defects, which required two or three osteochondral cylinders (Fig. 1). The medial arthrotomy was used in all open procedures.

Rehabilitation

Full weight-bearing was allowed from the first day post-surgery, if no refixation of the meniscus was applied. Otherwise a weight bearing of 20 kg was allowed within the first 6 weeks. In the phase immediately following surgery (days 1–4), continuous passive motion (CPM) was performed using a motorized CPM device to improve the nutrition of the cartilage [22]. Analgesic treatment was given, when necessary, in combination with local cooling and anti-inflammatory medication. From the fifth day onward, the CPM device was used to obtain up to 90° in flexion and full extension of the knee. No knee brace was provided. A more intensive training therapy for specific muscle development was initiated in the third week using muscle sequences and closed-chain exercises. Beginning at week 7 post-surgery, coordination exercises were introduced to improve proprioception. Sports activities (e.g., running and open chain exercise) were permitted after 12 weeks and contact sport was permitted after 6 months of rehabilitation.

Fig. 1 Example for a mosaicplasty using three osteochondral plugs at the medial femoral condyle within the weight bearing zone. One plug was harvested at the intercondylar notch

MRI analysis

The morphological evaluation after the OCT was performed using an MRI as a noninvasive method. Assessment of transplant vitality, osseous fixation, and stability is possible [17]. Furthermore the congruence of the transplant and the junction between transplant and local cartilage can be assessed.

Table 1 describes the scoring system which was developed for the evaluation, modified according to the descriptions by Sanders et al. [36]. The MRI was reviewed by two examiners and consensus was reached for all findings. The clinical outcome in all cases were concealed from the examiners. Surface congruency was graded as good, moderate, and poor. The protuberance was measured as the distance from the surface of the cylinder above the adjacent articular surface. The subchondral edema of the osteochondral cylinder was characterized as no edema, edema at the central part of the transplant, or a general edema of the transplant. Graft cartilage thickness was compared to the adjacent cartilage thickness and was graded as similar (100%), thinner ($<100\%$), or less than the half ($<50\%$) of the adjacent articular cartilage thickness. No visible margin between the transplanted bone and the adjacent bone is determined as a good osseus integration without separation. The osseus integration is incomplete when a visible margin can be identified, and no bony integration or graft loosening is present if fluid is around the cylinder.

Histological analysis

The osteochondral cylinders for the histological evaluation were fixed directly after harvesting with BOUIN-solution. The next step was to decalcify the bone using a Chelaplex-solution following by dehydration and bedding in paraffin. The paraffin-block was cut in 7 μm slides using longitudinal sections. The histological staining included: Hematoxylin-Eosin staining for the

Table 1 MRI-scoring system. Each MRI at the follow-up was evaluated and the points were distributed and added regarding the findings by the examiner. The lowest score (0) represents the best result

	Points		
	0	1	2
Surface congruency	Good	Moderate	Poor
Protuberance of the cylinder	No	< 2 mm	2 mm and more
Edema of the cylinder	No	Center	General
Cartilage thickness	100%	< 100%	<50%
Osseous integration	Complete	Visible margin	Surrounding fluid

overview and to evaluate the chondrocytes and Crossman-staining to evaluate the fibrous tissue, silver-GOMORI-staining to differentiate collagen type I and III, and alcia blue staining to mark the matrix of the cartilage.

Immunohisochemistry was performed following the peroxidase-anti-peroxidase-method (PAP method) developed by Sternberger [40]. The endogen activity of the tissue peroxides were blocked using 3% hydrogen peroxide at the deparaffined slides before they were prepared using a protein binding solution (0.25% Casein in Phosphate-buffered saline with 0.015 molar sodium acid (DAKO, Glostrup, Denmark). A monoclonal mouse antibody—antihuman—was used (Lot.-Nr.: 0696; DPC Biermann, Bad Nauheim, Germany) to detect aggrecan, a typical marker in the cartilage matrix.

Furthermore we used to evaluate:

Collagen type I	primary antibody (mouse), AntihCL(I), monoclonal antibody to human, Clone No.: I-8H5—Lot. Nr. IX 1 229-1 (DPC Biermann, Bad Nauheim, Germany)
Collagen type II	primary antibody (mouse), AntihCL(II), monoclonal antibody to human, Clone No.:II-4C11—Lot. Nr. GU 1219-1 (DPC Biermann, Bad Nauheim, Germany)
Collagene type III	primary antibody (mouse), monoclonal Antihuman Collagen Type III, Lot-Number: 2707B (ICN Biomedicals, Shelton, USA)
Factor VIII	primary antibody (rabbit) anti-human von Willebrandt factor (factor VIII) polyclonal Lot. Nr. 105 (DAKO, Glostrup, Denmark) to mark the blood vessels

Statistical analysis

Data are presented by descriptive statistics (i.e., mean, standard deviation, median, range). The nonparametric Mann-Whitney *U* test was used to assess variance in the performance scores used to identify possible differences between two groups. All significance tests were two-tailed and statistical significance was set at 0.05.

Results

Clinical results

The median Lysholm-score was 80 (range 45–98). The wide range of the Lysholm-score in clinical outcome did not show significant differences in: follow-up, concomitant injuries, defect size, or genesis (Fig. 2a–d). Postoperative, three patients needed a revision because of an haemarthros. Technical problems were once a broken osteochondral cylinder, another time a chondral defect at the graft cylinder, and at another time a cartilage defect at the adjacent cartilage, detected during a re-arthroscopy after 10 months.

MRI analysis

The MRI analysis revealed in all cases a regular osseous integration of the subchondral bone. Only in one case, a clear visible border remained 6 months postoperative. A subchondral edema was detected during the earlier follow-up (up to 1 year). However, often the cartilage congruency was moderate or poor, and/or the cartilage thickness reached less than 100% of the donor cartilage. A protuberance of the cylinder exist in 15 cases up to 2 mm. Only in three cases the protuberance reached at least than 2 mm. A correlation between the MRI-score and the clinical outcome (Lysholm-Gillquist score) could not be shown (Fig. 3a + b).

Results in re-arthroscopy

Macroscopic findings

At all time points between 6 and 21 months after transplantation, a slight gap around the implanted osteochondral plug was still visible. The cartilage around the transplant had a soft consistency three times. In one case the cartilage on the recipient site had a lesion (diameter: 8 mm) starting from the transition zone to the transplanted cylinder. The transplanted cartilage itself was smooth and showed the typical biomechanical character and color of hyaline cartilage. No loosing or dislocation of the osteochondral plugs were seen at the follow-up. The harvest site always was filled with fibrous cartilage.

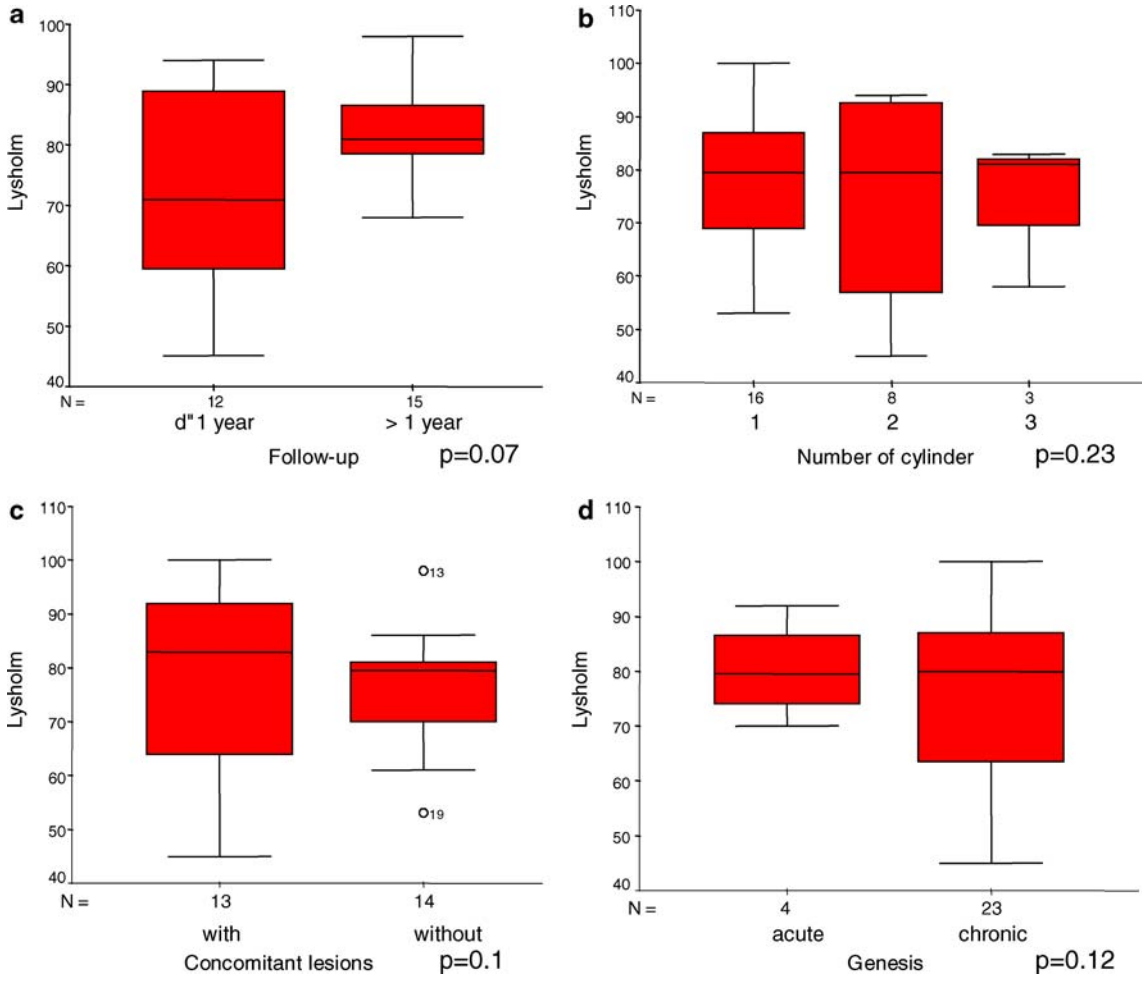

Fig. 2 a–d Median values of the Lysholm-score divided by: **a** Follow-up; **b** Number of transplanted cylinders; **c** Concomitant lesions; **d** Genesis. No significant differences were found between these groups regarding the Lysholm-score

Histological findings

We did not find time-depending differences in the histological evaluation during the follow-up. Overall, the structure of the cartilage had shown hyaline cartilage in HE staining with characteristic superficial tangential, middle, and deep zones. The subchondral bone of the graft was already united with the subchondral bone of the host site. The cartilage surface has shown irregular structure and was partially fissured (Fig. 4a) with separation of cartilage fragments. The chondroid structure dissolved at the apical and the margin of the transplant, meanwhile the cell density decreased excepting the basal zone of the cartilage, where the cell density increased (Fig. 4b). Mostly the tidemark was preserved in a good condition, but it was penetrated from single blood vessels (Fig. 4c). These reactions of articular cartilage were seen in the entire region of the implanted graft.

The surrounding cartilage of the transplanted plug often consist of fibrous and granulation tissue (Fig. 5a) and contain a high percentage of collagen type I (Fig. 5b). The remodeling and degeneration process was marked due to the ingrowth of the blood vessels starting from the graft (Fig. 5c)

Immunohistochemistry

The special immunhistochemistry staining could detect the characteristic collagen types for bone, hyaline cartilage or fibrous cartilage. The collagen type I was mainly present in subchondral bone and the transplanted cartilage never contained collagen type I (Fig. 6a), whereas the detection of collagen type II in the osteochondral transplant was a typical marker for hyaline cartilage (Fig. 6b). The increased occurrence of collagen type III around the chondroids is also characteristic of hyaline cartilage. The bone and the cartilage within the gap showed no positive staining for collagen type II or collagen type III.

The adjacent original cartilage around the transplant has shown a focal clustering of proliferating hypertrophic chondrocytes. The splitting surface was marked with micro fissures and the tidemark was crossed by blood vessels and showed mesenchymal tissue. The staining was lighter in the surface area,

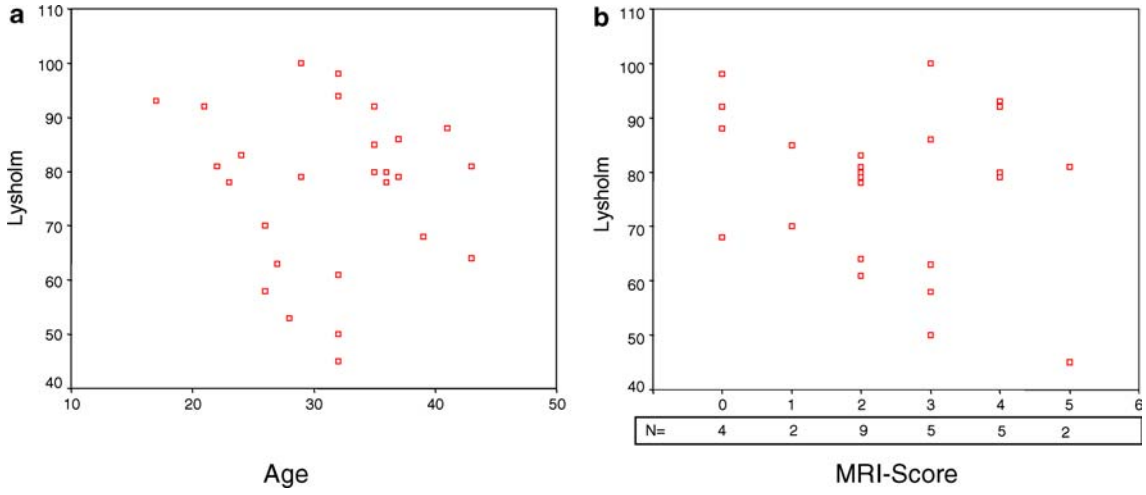

Fig. 3 The Lysholm-score at the follow-up did not show any correlation to the a) age of the patients or b) to the calculated MRI-score

whereas the fibre-like degeneration was characterized by the de-masking of the collagen fibre within all zones. We have seen the most fibre density around the chondrocyte clusters.

Discussion

The clinical results after autologous OCT were mostly good and excellent and the complication rate was very low [1, 16, 24, 25, 28]. Therefore this procedure can be recommended for local cartilage lesions grade IV if the surrounding cartilage remains intact and when the

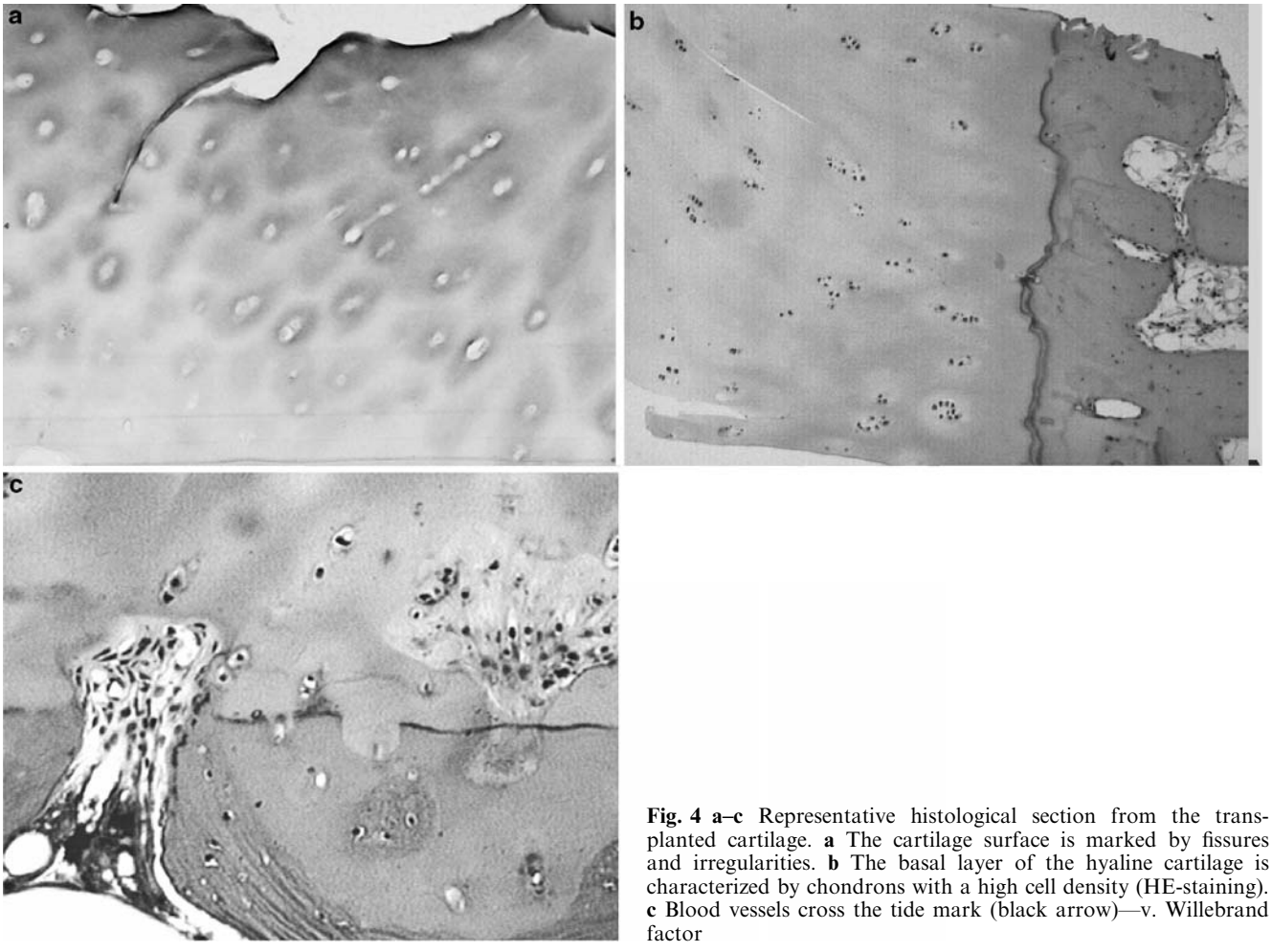

Fig. 4 a–c Representative histological section from the transplanted cartilage. **a** The cartilage surface is marked by fissures and irregularities. **b** The basal layer of the hyaline cartilage is characterized by chondrons with a high cell density (HE-staining). **c** Blood vessels cross the tide mark (black arrow)—v. Willebrand factor

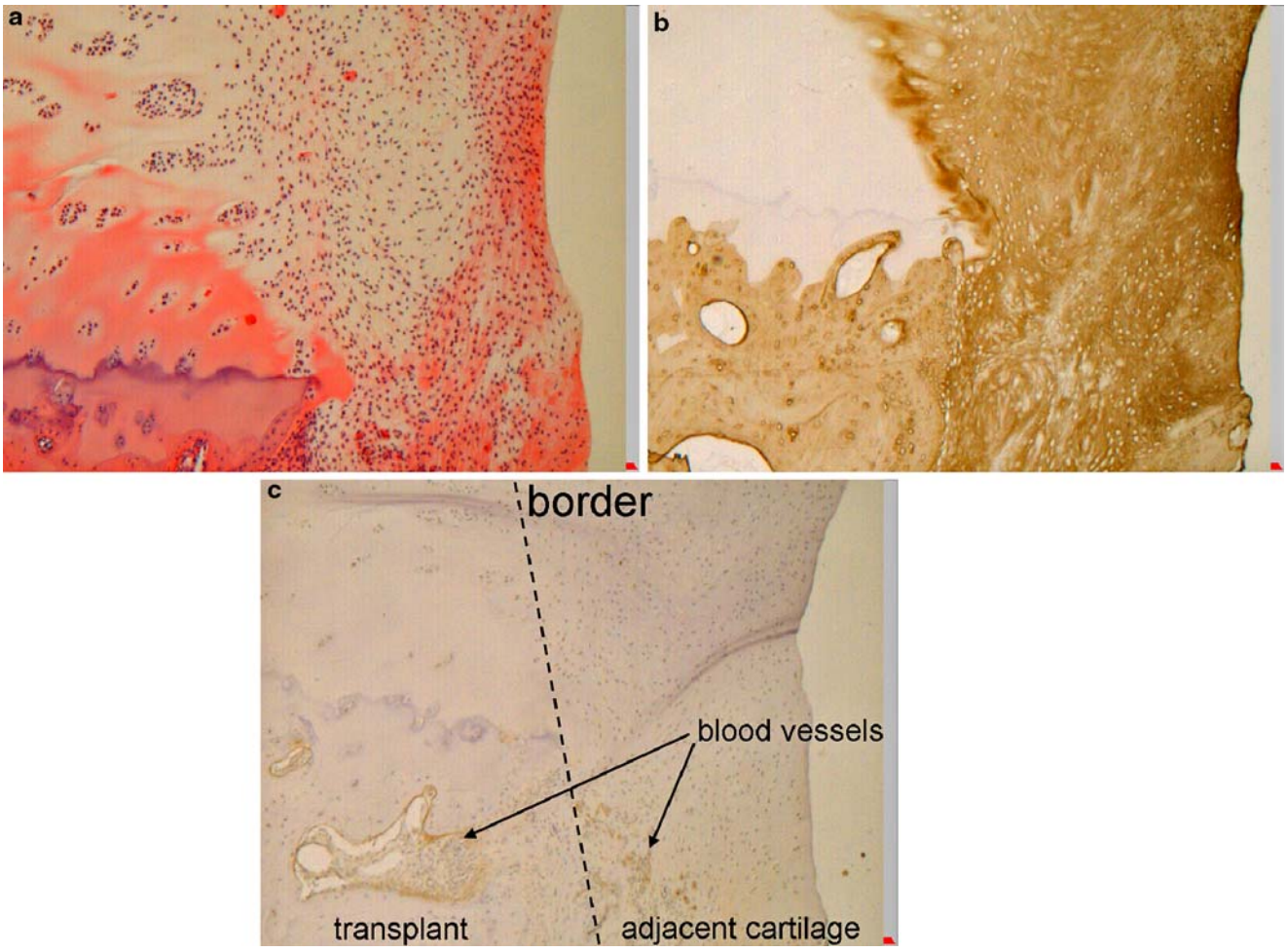

Fig. 5 a–c Interface between the transplanted plug and the surrounding host cartilage. The adjacent cartilage consists of granulation tissue. **a** HE-staining. **b** Collagen type I can be identified in this area. **c** Degeneration and remodeling of the surrounding tissue is characterized by the migration of the blood vessels (v. Willebrand factor)

indications are the same as those used in the present study [22]. The osteochondral lesions mostly originate from severe traumatic events regarding the knee joint, and therefore the coexistence of concomitant lesions could need additional treatment procedures. In this study the major lesions beside the cartilage lesion were ruptures of the anterior cruciate ligament and meniscus lesions. It seems that the presence of concomitant lesions did not correlate with the clinical outcome and should not be considered as a contraindication for this procedure. The MRI is a well accepted tool to evaluate the integrity of the transplanted osteochondral cylinders and to analyze the cartilage surface [14, 37]. However, we found no correlation between the MRI findings and the patients' satisfaction as well as their knee function. The idea of the OCT is the restoration of the cartilage defect with hyaline cartilage, which was underlined due to the histological findings. However, small changes in immunohistochemistry after a relative short-term follow-up reveal a starting remodeling of the transplanted cartilage, whereas the cartilage has still the typical hyaline character.

There are many reports about short-term results following OCT, which mostly have shown good and excellent results [12]. Similar results will be achieved by using microfractures and pridie drilling, despite the fact that cartilage will be restored by fibrocartilage with less biomechanical properties [39]. However a recent report about a 10 year clinical and experimental experience has shown that the OCT provides a substantial better clinical outcome than the other procedures in long-term follow-up [15]. The clinical results are mostly good and excellent with a low percentage of complications, which could be confirmed in this study. However, there was a wide range at the Lysholm-score (45–98). The different results between the patients finally led to a relatively low Lysholm-score of 80. The short follow-up of this study could explain this result and probably a longer follow-up could show a better functional benefit after that time. It is comprehensible that the existent of concomitant injuries or differences in the defect size could lead to different clinical results. We could not confirm these suggestions in our study. Furthermore, it seems that the follow-up time and the genesis of the cartilage defect do not affect the function of the knee joint following OCT.

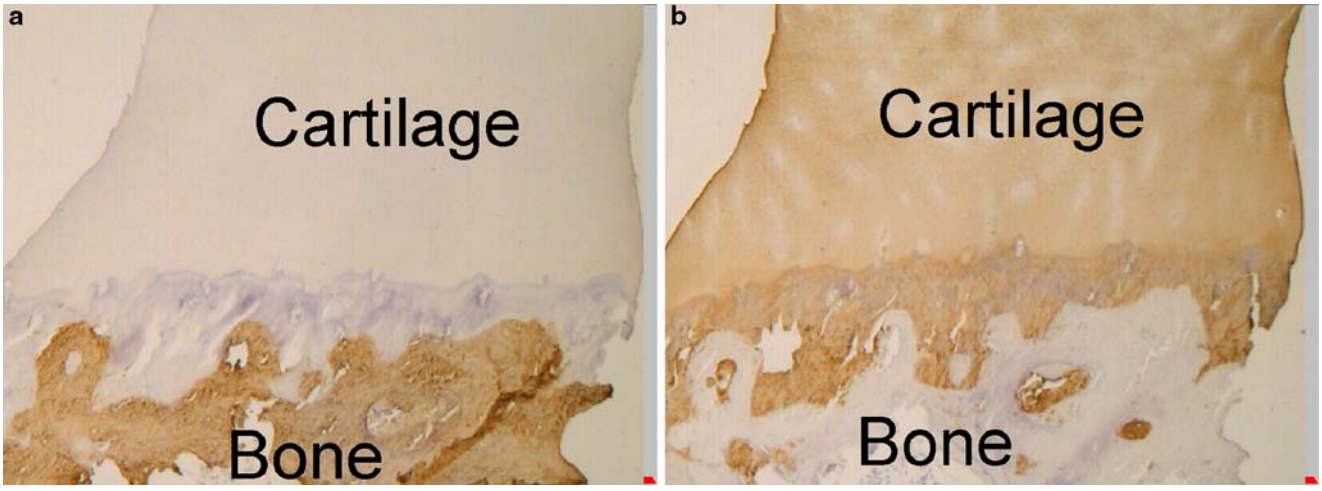

Fig. 6 a, b Histology from the central part of a transplanted osteochondral plug 10 months after transplantation. **a**Staining for collagen type I, which mainly exists in bone. No detection within the hyaline cartilage. **b** Staining for collagen type II, which mainly exists in the hyaline cartilage

Different authors described a age-limitation to the OCT because of the bad outcome in older patients [15, 23]. The authors pointed out the importance of having an age limitation for the procedure (an upper limit of 50 years). The age in this study did not exceed 43 years, therefore the results are reproducible using this standardized technical procedure. Within these patients, no correlation was found between the patients' age and the clinical outcome. But the age of the patients in this study is young, and it can be assumed following the literature [15, 23] that the patients' satisfaction will be decreased in a older population.

Several authors propose other techniques e.g., the harvesting of the donor cylinders using a diamond bone cutting system [27] or transplanting many small cylinders compared to less larger cylinders to reach a better congruency of the cartilage surface [15]. However, we believe that harvesting the cylinders using a chisel of the OATS leads to a higher accuracy of the harvested cylinders and allows an implantation in press fit technique. We have never seen any problems which were direct related to the harvesting site of the cylinders, therefore both the notch and the anterior lateral femoral condyle are appropriate. Furthermore, the disadvantage of using many small cylinders is the space between the implanted grafts, which will be filled finally with fibrous tissue. If the surgeon uses larger cylinders, he should take into account the profile of the recipient and the donor site to avoid an unfitting of the transplanted cylinder. Because, in technical notes for the OCT the literature emphasizes the importance of the fitting of the transplanted plug to the cartilage layer [16, 22, 28]. *Surprisingly*, a higher incongruency of the cartilage surface or a higher protuberance between the donor and host cartilage as seen in the MRI-analysis obviously did not lead to a decrease of the knee function in the midterm follow-up. *Several* authors assume that the ongoing destruction of the cartilage could be accelerated when the surface do not fit to the original contour of the joint [4, 19]. We saw one case during re-arthroscopy, where a secondary chondral lesion occurred beside an OCT at the adjacent cartilage. The cause could be an incorrect technical procedure during the transplantation, an initial remaining cartilage lesion, or a secondary cartilage lesion during the follow-up. In all the cases, the transplanted cartilage showed a similarl signal intensity compared to the host cartilage and the harvested osteochondral cylinders never failed for osseous integration [19]. The existing edema of the subchondral bone is a typical phenomena following OCT at least 1 year postoperative [19] but it disappears over time.

A second look arthroscopy was performed in eight patients. The cartilage surface remained intact, but the junction between the donor and recipient plug sites was still visible [24]. The histological evaluation confirmed the failed junction between the donor and host cartilage. However, the OCT in animal models mostly show a integration of the transplanted cartilage [30], which is different from the findings in human [19, 20]. The reason for the failed non-union in humans could be the thicker cartilage compared to the cartilage of the used animal model, which is followed by a less regeneration capacity. Furthermore, the surrounding host cartilage mostly consists of fibrous and granulation tissue and could also be the reason for the failed cartilage integration. The genesis of the abnormal cartilage structure around the transplant is unclear. It could be caused by the ongoing degeneration after transplantation within the surrounding cartilage, or because the transplantation was not performed in a healthy cartilage. It is known that the harvest of the osteochondral cylinders using a punch leads to the damage of chondrocytes [33]. However, it seems that the press fit technique is not the cause of this degeneration, because the use of a punch in animal studies revealed a normal integration of the cartilage [30].

The OCT in animal model has shown that the hyaline cartilage retains its structural and biomechanical properties [13, 26]. Short term evaluation of autologous transplanted cartilage in a rabbit model revealed changes of the extracellular matrix cartilage and a increasing cell

density of the transplant [30]. A further animal study in sheep showed that the cartilage begins to degenerate following transplantation [41]. They found that the tidemark of the transplant was crossing by blood vessels and a cell cloning started in the superficial layer [41]. This correlated with the microscopic evaluation in this study—the cartilage had the main properties of hyaline cartilage and the matrix mostly contained collagen type II, but the increased cell density in the deeper layer, fissures at the surface, and at the crossing blood vessels at the tight mark point out a possible remodeling of the cartilage.

We proved our hypothesis that the transplanted cartilage is still hyaline cartilage, but a slight degeneration was seen during the follow up. However we disproved the second part of our hypothesis. We could not find any correlation between the clinical outcome and the size of the chondral lesion or the concomitant lesions or the genesis of the lesion or the age of the patient, or the MRI-findings within the follow-up.

The congruency of the joint surface can not be restored to the original status, particularly in larger defects with irregular shapes. However, the restoration can be reach a nearly normal state if the surgeon pays attention to the joint anatomy. The OCT can lead to a very good clinical outcome despite the incongruency of the transplanted plugs, whereas a perfect grafting is not a guaranty for a patient's satisfaction. We did not find any aspects, which really affected the function of the knee joint following OCT. We assume that the immediate filling of the defect with OCT stops the inflammatory process at the chondral defect and leads to a decrease in the pain and an increase of the knee function. Furthermore, it can be assumed that remaining lesions at the surrounding cartilage could maintain the immunological process and therefore maintain the pain and the low knee function. In our opinion, the complete cartilage defect should be restored by the OCT and no degenerative cartilage should remain. The transplanted cartilage might be possibly remodeled overtime or a degeneration process of the osteochondral plugs could occur during a longer follow-up time period. Further investigations are needed to specify the effects of the OCT on the transplanted cartilage and their influence on the later clinical outcome.

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