



Clinical mid- to long-term outcome after autologous chondrocyte implantation for patellar cartilage lesions and its correlation with the geometry of the femoral trochlea

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ABSTRACT

Background: The aim was to investigate the clinical results after autologous chondrocyte implantation (ACI) at the patella in a mid- to long-term course, and whether trochlear dysplasia has an influence on the outcome.

Methods: Inclusion criteria were ACI for focal patella cartilage defects and preoperative magnetic resonance imaging (MRI). Patients with previous trochleoplasty or osteotomy have been excluded. Trochlea morphology was evaluated by sulcus depth, sulcus angle, lateral condyle index (LCI) and Dejour's classification for trochlea dysplasia. The clinical outcome was evaluated by a questionnaire including the Kujala- and IKDC-Scores. Survival of the ACI was analysed by the Kaplan–Meier method. A correlation analysis between morphologic parameters and clinical scores was performed.

Results: Seventy-eight patients (mean age 33.2 ± 10.7 years) were included (mean follow-up 6.5 ± 3.4 years). The mean sulcus depth was 5.0 ± 1.6 mm (normal value ≥ 5 mm), the mean sulcus angle was $153.4 \pm 9.0^\circ$ (normal value $\leq 145^\circ$) and the mean LCI was $84.9 \pm 7.5\%$ (normal value $\geq 90\%$). Major trochlea dysplasia (grades B–D) was seen in 29 patients (36.7%). Five-year survival rate was 98%, satisfaction-rate was 78.9% and the mean clinical scores were 67.6 ± 20.2 for the Kujala-Score and 64.7 ± 20.2 for the IKDC-Score. A lower LCI showed significant correlation with a lower IKDC score ($r = 0.25$; $p = 0.037$).

Conclusions: The present study reports an excellent survival rate and a good satisfaction rate in a mid- to long-term course after patella ACI. The clinical scores show a high variance and there is evidence that a pathologic trochlea correlates with inferior results.

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1. Introduction

Focal cartilage defects of the knee joint are frequent in young and active patients, and can lead to pain and impaired joint function [1]. In addition, studies have demonstrated a continuous progress of the damaged chondral tissue over time with an in-

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creased risk for the development of knee osteoarthritis [2,3]. Therefore, early detection and appropriate treatment of focal cartilage defects are crucial to prevent this development. According to several high level studies that have been conducted in the past, autologous chondrocyte implantation (ACI) has proven to be an effective long-term treatment option for focal cartilage defects in the knee joint [4–6].

Based on large-scale arthroscopic studies of the knee joint, cartilage defects of the patella are almost as frequent as cartilage defects of the femoral condyle [7–9]. However, these studies only represent prevalence of cartilage defects independent of the indication for surgical treatment. An analysis of the German Cartilage Registry (KnorpelRegister DGOU) in 2016 showed that of 1027 registered surgical cartilage treatments in the knee joint 45% had been performed on the femoral condyle while 30% had been performed at the patella [10]. One reason for this discrepancy might be orthopaedic surgeons acting cautiously with cartilage repair procedures at the patella based on heterogeneous results for this localization represented in literature. While several studies showed less favourable results and a higher failure rate for surgical cartilage repair at the patella in comparison to other localizations [11–14], more recent studies have investigated later generations of ACI and could not confirm these statements [15–17]. Besides continuous improvement of surgical technique for articular cartilage repair in recent years, a better understanding of the patellofemoral joint and increased awareness for co-pathologies might be contributory for this positive development. Several studies have demonstrated a significant association between cartilage defects of the patella and pathologic features of the patellofemoral joint geometry such as trochlea dysplasia, not only in patients with history of patellar dislocation but also in patients without patellofemoral instability [18,19].

However, it still remains unclear whether the geometric shape of the trochlea influences the postoperative result after surgical restoration of focal cartilage defects at the patella. Therefore the aim of the present study is to investigate the clinical results after ACI at the patella in a mid- to long-term course, and whether trochlea dysplasia has an influence on the outcome.

2. Material and methods

2.1. Patient cohort

All patients in our department that were treated by ACI for focal cartilage defects at the patella between 01/2002 and 12/2013 were included in the present study. An additional inclusion criterion was the availability of preoperative magnetic resonance imaging (MRI) of the operated knee joint. Exclusion criteria were previous trochleoplasties or any history of osseous realignment procedures like transfer of the tibial tuberosity, as well as presence of rheumatic disease or systemic skeletal disease.

2.2. Operative procedures

Prior to ACI all patients had undergone a thorough clinical and radiological examination to ensure that the symptoms described were derived from the cartilage defect and not caused by other pathologies. Clinical symptoms such as activity-dependent anterior knee pain, e.g. stair climbing, in combination with signs of altered cartilage at the patella in the MRI represented crucial factors for surgical indication. However, in accordance with current recommendations definitive indication for ACI was set only after the cartilage defect has been examined arthroscopically and only in patients with focal grade III or IV defects according to the classification of the International Cartilage Repair Society (ICRS) [20]. Data for size and location of the cartilage defect were also taken from the arthroscopic protocol. A further crucial aspect of pre- and intraoperative diagnostics was evaluation of patella instability and maltracking. In the synopsis of patients' history, clinical examination and intraoperative

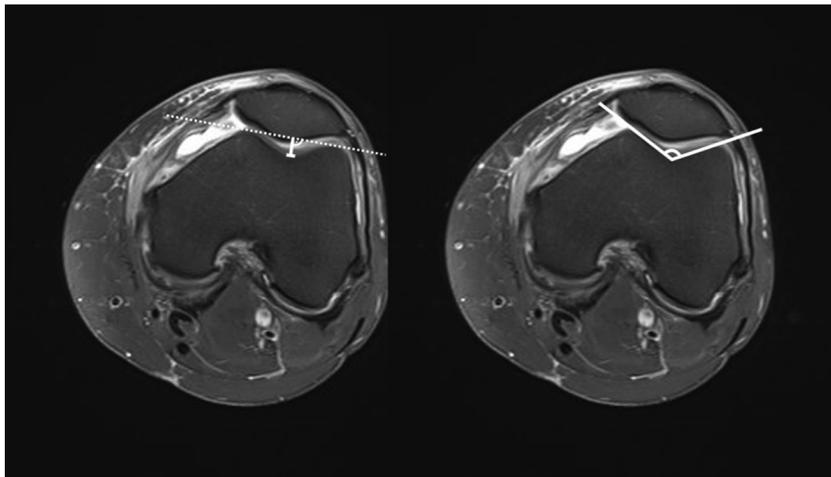


Figure 1. Measurement of sulcus depth and sulcus angle. In the axial plain with the largest anterior–posterior diameter of the femoral condyles a line is drawn tangential to the most anterior point of the medial and lateral condyle (dotted line). The distance from the deepest point of the femoral trochlea to this line determines the sulcus depth. In the same plain the sulcus angle is determined by the lines drawn along to the medial and lateral trochlear facet.

findings indication for additional patellar realignment procedures was set generously in cases with chronic patellar instability (≥ 2 patellar dislocations) or patellar maltracking like lateral tilting or shifting. Patients showing significant valgus leg axis or significantly increased tibial-tubercle–trochlear-groove index (TTTG index) with subsequent need for varisation osteotomy or tibial-tubercle osteotomy respectively were excluded as previously stated.

Furthermore, according to current recommendations, only symptomatic cartilage defects were treated by ACI. Patients with patellar instability and concomitant cartilage defects, who did not suffer anterior knee pain were therefore not treated by ACI and were not included in this study.

Summarizing, the inclusion and exclusion criteria enabled to achieve a relatively homogeneous cohort of patients, whose main preoperative problem was anterior knee pain due to a focal cartilage defect of the patella. In order to obtain a representative cohort, patients with the need for additional soft tissue realignment were still included in the present study and investigated separately.

After proving the indication for ACI, cartilage samples were taken during the first arthroscopy and sent to laboratory for cultivation of the chondrocytes for four to eight weeks. Chondrocyte implantation was performed through an open parapatellar approach.

2.3. Analysis of the femoral trochlea

Preoperative MRI of the relevant knee joint was available for every included patient. The morphology of the trochlea was assessed by measuring the sulcus depth and the sulcus angle at the axial cut with the largest diameter of the femoral condyles [21] (Figure 1). Both parameters were measured at the osseous trochlea since there are no reference values for the chondral sulcus depth and sulcus angle in literature. To evaluate the length of the lateral articular trochlea the lateral condyle index (LCI) was determined according to the method described by Biedert et al. [22] (Figure 2). In addition to that, trochlea morphology was assessed according to Dejour's grading of trochlear dysplasia [23,24]. Major dysplasia was defined as grade B or higher. All measurements were performed by two independent, MRI trained observers (1st and 2nd authors) using the imaging software IMPAX EE R20 VIII by Agfa HealthCare N.V. (Mortsel, Belgium). For the quantitative measurements the mean of both values served as final value, and in case of discrepancy regarding the Dejour classification a consensus discussion was performed to determine the final grade of dysplasia.

2.4. Outcome parameters

A retrospective investigation was performed in order to evaluate the clinical outcome. The included patients were contacted once in the postoperative course at least 18 months after the index surgery. By means of the Kujala-Score and the subjective knee form of the International Knee Documentation Committee (IKDC-Score) the postoperative outcome was evaluated at this time point. In order to obtain information about the postoperative course of symptoms, the patients were asked about the development of pain since the index operation and about the general satisfaction with the postoperative result. Additionally, further operations after the index operation were recorded.

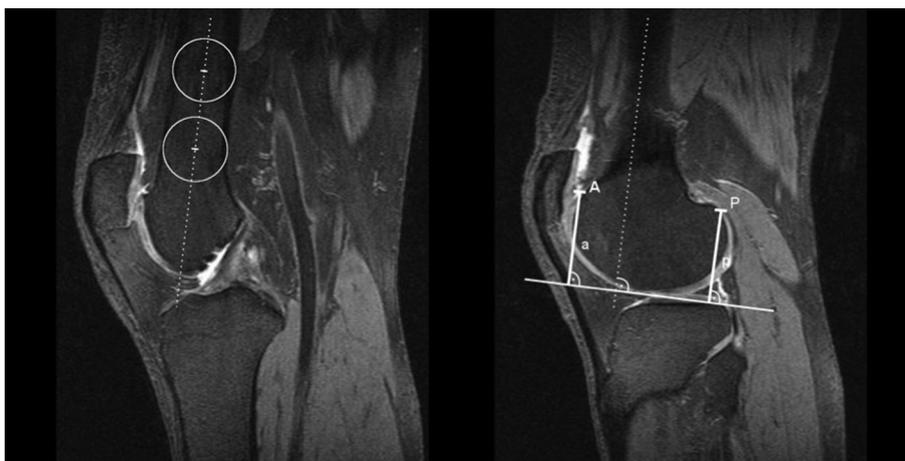


Figure 2. Measurement of the lateral condyle index. In the sagittal plain, where the anterior cruciate ligament is shown with its greatest length, the longitudinal femoral shaft axis (dotted line) is drawn as a line through the centre of two circles that fit exactly into the femoral shaft. This line is transferred to the most lateral sagittal plain, where the whole cartilage of the lateral femoral condyle can still be seen. A tangent line on the femoral cartilage is drawn perpendicular to the dotted line. In the same image, the most proximal points of both the anterior (A) and posterior (B) cartilage of the femoral condyle are defined and the distances of these two points to the tangent line are measured (distance a anterior and distance b posterior). The lateral condyle index is determined by the ratio of distance a to distance b.

2.5. Statistical analysis

Statistical analysis was performed using Microsoft Office Excel 2011, 14.7.2 (Microsoft Corp, Redmond, Washington) and IBM SPSS 24.0 for Mac OS X (SPSS Inc., Chicago, IL).

Results of quantitative variables are given as mean \pm standard deviation (SD), and the results of qualitative variables as absolute and relative frequency. Normal distribution of data was tested using the Shapiro–Wilk–Test.

Survival of the ACI until repeated cartilage surgery or until total knee arthroplasty (TKA) was analysed by the Kaplan–Meier method. Patients, who had undergone TKA were excluded from further clinical investigation.

Correlation analysis between the geometric parameters and the clinical scores was performed using the Pearson correlation coefficient for normally distributed data and using Spearman's rank correlation coefficient for not normally distributed data. Additionally, the results of the outcome parameters were compared between patients without or grade A trochlear dysplasia (Group: "Minor dysplasia") and patients with trochlear dysplasia grade B or higher (Group: "Major dysplasia") by Mann–Whitney–U Test.

All calculations were performed for the whole patient collective and separately for patients, who had additional patella realignment procedures (Group: "ACI/Realignment") and patients, who did not have additional realignment procedures (Group: "Isolated ACI") respectively. The level of significance was set at $p < 0.05$.

3. Results

3.1. Patient cohort

Seventy-eight patients met the inclusion and exclusion criteria and could be included in the present study. The most important characteristics of the cohort are given in Table 1.

Forty patients (51%) had additional soft-tissue realignment procedures of the patella. The type of surgery was chosen according to severity level of instability or malalignment, patients' age and scientific recommendation at the time of surgery. Table 2 represents an overview of the realignment procedures, which were performed simultaneously with the implantation of the chondrocytes (N = 31) or as another operation (N = 9).

3.2. Morphology of the femoral trochlea

The results of the quantitative parameters sulcus depth, sulcus angle and lateral condyle index are represented in Table 3. The results for trochlear dysplasia according to Dejour's classification are represented in Table 4.

3.3. Survival analysis

Survival analysis demonstrated that in the period between the index surgery and follow-up one patient had repeated ACI at the patella and five patients had undergone TKA. So six total patients (7.8%) were considered failures after a mean follow-up of 6.5 years, while the five-year survival rate of the ACI was 98%. Figure 3 shows the results of the survival analysis according to the Kaplan–Meier estimator.

3.4. Clinical outcome

At follow-up 78.9% of the patients were "very satisfied" or "satisfied" with the result of the surgery and 79.4% would undergo the same procedure again, while 21.1% were not satisfied with the result and 20.6% would not undergo the procedure again. Compared to the preoperative status an improvement of pain was reported by 51 patients (70.8%). There was no significant difference according to satisfaction and pain development between patients with and without additional patella realignment procedures.

Figures 4 and 5 represent the results of the Kujala- and IKDC-Scores. There was no significant difference between patients with and without additional patella realignment.

Table 1
Characteristics of the included 78 patients.

Gender (female/male)	46/32 (59%/41%)
Age at surgery (years)	33.2 (SD 10.7)
BMI (kg/m ²)	25.7 (SD 4.1)
Defect size (cm ²)	4.3 (SD 1.6)
Defect location (medial/lateral/ridge)	29/14/36 (36.7%/17.7%/45.6%)
Generation of ACI (1st/2nd/3rd)	4/60/14 (5%/77%/18%)
Additional patella realignment (no/yes)	38/40 (49%/51%)
FU time (years)	6.5 (SD 3.4)

Qualitative data are given in absolute and relative values. Quantitative data are given in mean and standard deviation (SD).

Table 2
Additional patella realignment procedures in 40 patients.

Procedure	Number of patients
MPFL-reconstruction	6
MPFL-reconstruction + Insall procedure	3
Insall procedure	17
Insall procedure + lateral release	2
Lateral release	10
Ali Kroggius procedure	2

MPFL = medial patellofemoral ligament.

3.5. Correlation analysis

The results of the correlation analysis between the quantitative geometric parameters of trochlea morphology and the clinical results are given in Table 5. There was a significant positive correlation between the lateral condyle index and the IKDC-Score (correlation coefficient $r = 0.25$; $p = 0.037$). All other parameters did not show any significant correlation.

The clinical results depending on the grade of trochlear dysplasia according to Dejour's classification are represented in Figure 6 (Kujala) and Figure 7 (IKDC). The clinical scores did not show significant differences in comparison between patients with no or minor dysplasia and patients with major dysplasia.

4. Discussion

The main findings of the present study are that ACI at the patella shows an excellent survival rate and a good satisfaction rate in a mid- to long-term course. However, the clinical scores show a high variance and there is evidence for a correlation of the outcome with the morphology of the femoral trochlea.

The patellofemoral joint alignment depends on different osseous, muscular and ligamentous factors. Pathological alterations of these factors can lead to focal cartilage lesions following acute patella dislocation or due to chronic patella instability or chronic overload. In particular, the shape of the femoral trochlea has been demonstrated to be highly associated with patellofemoral cartilage defects in both patients with and without patella instability [18,19,23].

Therefore, the aim of the present study was to investigate the clinical outcome after ACI at the patella on a mid- to long-term base and its correlation with the trochlea morphology.

At a mean follow-up of 6.5 years 78.9% of all included patients were satisfied with the postoperative outcome and the mean clinical scores were determined as 64.7 (SD 20.2) for the IKDC-Score and 67.6 (SD 20.2) for the Kujala-Score. The five-year survival rate of the ACI was high with 98%.

In 2014 Gomoll et al. published a prospective multicentre study with the largest cohort of patients to date after ACI at the patella on a mid- to long-term base [25]. After a mean follow-up of 7.5 years the included 110 patients showed a statistical significant improvement

Table 3
Results of the quantitative parameters for trochlea morphology.

Parameters	Ref. values	Subgroups	Normal results	Pathologic results	Mean (SD; range)	Sig.
Sulcus depth (mm)	≥5 [32]	All patients	44 (56.4%)	34 (43.6%)	5.0 (1.6; 1.0–8.2)	$p = 0.007^a$
		Isolated ACI	25 (65.8%)	13 (34.2%)	5.5 (1.4; 2.0–8.2)	
		ACI/Realignment	19 (47.5%)	21 (52.5%)	4.6 (1.6; 1.0–6.8)	
Sulcus angle (°)	≤145 [32]	All patients	45 (57.7%)	33 (42.3%)	142.7 (10.3; 115.6–172.0)	$p = 0.020^a$
		Isolated ACI	25 (65.8%)	13 (34.2%)	140.0 (8.8; 115.6–153.1)	
		ACI/Realignment	20 (50.0%)	20 (50.0%)	145.4 (11.1; 122.9–172.0)	
Lateral condyle index (%)	≥90 [22]	All patients	18 (23.1%)	60 (76.9%)	84.9 (7.5; 69.2–104.4)	n.s.
		Isolated ACI	9 (23.7%)	29 (76.3%)	84.2 (8.5; 69.2–104.4)	
		ACI/Realignment	9 (22.5%)	31 (77.5%)	85.6 (6.3; 70.8–100.3)	

Results are given as absolute and relative frequency of normal and pathologic values with regard to the reference values and as mean with standard deviation (SD) and range. Results are given for all patients and separately for patients with isolated ACI and ACI/Realignment. Significant differences between patients with isolated ACI and ACI/Realignment regarding sulcus depth and sulcus angle. Ref. values = reference values; mm = millimetre; Sig. = significance; n.s. = not significant.

^a Significant difference.

Table 4
Results for trochlea dysplasia according to Dejour's classification.

Grade	All patients (N = 78)	Isolated ACI (N = 38)	ACI/Realignment (N = 40)	Sig.
No dysplasia	15 (19.2%)	11 (28.9%)	4 (10.0%)	$p < 0.001^a$
A	34 (43.6%)	21 (55.2%)	13 (32.5%)	
B	22 (28.2%)	5 (13.2%)	17 (42.5%)	
C	4 (5.1%)	1 (2.6%)	3 (7.5%)	
D	3 (3.8%)	0	3 (7.5%)	
Minor dysplasia	49 (62.8%)	32 (84.2%)	17 (42.5%)	$p < 0.001^a$
Major dysplasia	29 (37.2%)	6 (15.8%)	23 (57.5%)	

Values are given in absolute and relative frequency for all patients and separately for patients with isolated ACI and ACI/Realignment. Significance of the differences between the two subgroups is given in the last column. Significant higher frequency of major dysplasia in patients with ACI/Realignment. Sig. = significance.

^a Significant difference.

of the clinical scores in comparison to the preoperative status with a mean IKDC-Score of 69 (SD 20) at final follow-up, which is quite in accordance with the results of the present study. Furthermore, the determined failure rate of eight percent corresponds to our failure rate of 8.9% after 6.5 years. A more recent study that investigated ACI at the patella in 30 patients with a follow-up of up to 15 years postoperatively demonstrated good results in 83% of the cases and a failure rate of 10% after a mean of 6.3 years [26]. However it should be considered that all included patients of these two studies were treated with ACI of the first or second generation. In 2014 Filardo et al. published a study on the treatment of patellofemoral cartilage defects with matrix-assisted autologous chondrocyte transplantation (MACT), which is generally accepted as 3rd generation ACI [27]. After a mean follow-up of five years the 28 included patients with lesions at the patella showed a mean IKDC-Score of 69.7 (SD 17.6) and a mean Kujala-Score of 81.5 (SD 12.7).

In the present study 40 patients (51.3%) underwent patella realignment procedures additional to ACI because of chronic patella instability or lateral patella maltracking. These patients were investigated as an additional subgroup. To obtain a relatively homogeneous cohort only patients with soft tissue realignment procedures were included, whereas patients with concomitant osteotomies were excluded.

The subgroup analysis between patients with and without patella realignment did not show any statistical significant difference regarding the clinical outcome, suggesting that additional realignment did successfully restore patellofemoral stability and protect the ACI in the relevant subgroup. This finding supports the opinion of other authors, who state that realignment procedures are crucial for good results after patellofemoral cartilage repair [28,29]. In 2013 Trinh et al. published a systematic review that showed a significant greater improvement of the clinical scores if ACI of the patella was combined with patellofemoral realignment osteotomy [29]. In the present study, patients with significantly increased TTG were excluded based on the indication for realignment osteotomy, which might explain why a significant difference between the subgroups was not detectable.

On the basis of a further literature review Mouzopoulos et al. developed an algorithm for the treatment of patella cartilage defects [30]. Considering defect grade, defect localization and presence of patella malalignment they recommended either isolated cartilage repair or a combination with additional realignment procedures like lateral release or tibial tubercle osteotomy. The

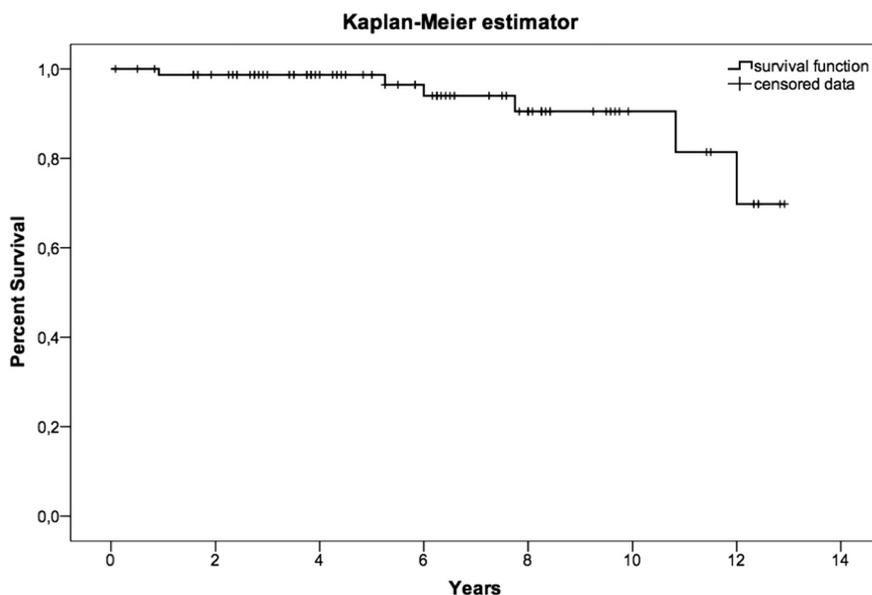


Figure 3. Kaplan–Meier estimator for survival rate of the ACI.

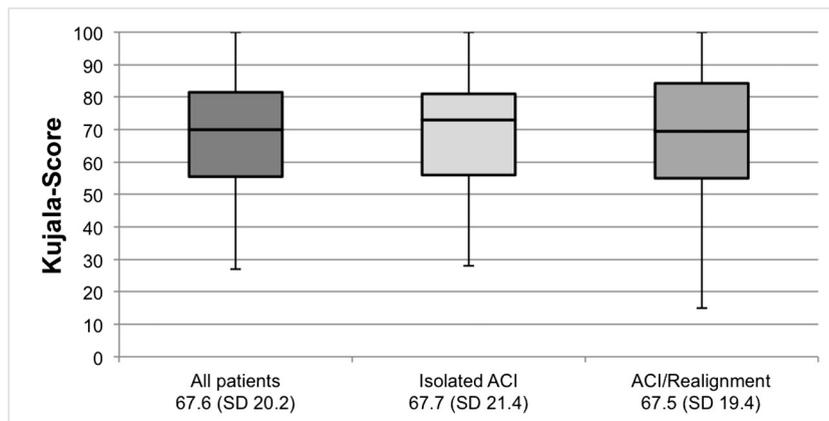


Figure 4. Results of the Kujala-Score. Results of the Kujala-Score given as mean and SD and presented in box plots. No significant differences between patients with and without additional realignment.

morphology of the femoral trochlea as a relevant co-factor in the development of patella cartilage defects, however, was not taken into account in this algorithm.

Dejour was the first to grade trochlea morphology on the basis of conventional radiographs and his classification in four types of dysplasia is still a widely-used standard [23]. Meanwhile several studies have demonstrated that MRI is an excellent device to determine trochlear dysplasia and Dejour's classification has been transferred accordingly [21,24,31]. Furthermore, in the present study trochlear morphology was assessed in different spatial dimensions using sulcus angle, sulcus depth and the lateral condyle index as more objective quantitative parameters.

The results of the present study revealed that of all included patients 43.6% showed pathologic results for sulcus depth, 42.3% showed pathologic results for sulcus angle and 76.9% showed pathologic results for the LCI with regard to reference values presented in literature. Furthermore, 37.2% of all patients were classified as major dysplasia according to Dejour's type B, C or D. As must be expected, the proportion of pathologic parameters was significantly higher in the subgroup of patients who received additional realignment procedures. However, there were still a relevant number of pathologic features in patients without preoperative symptoms of instability or maltracking, which is consistent with previous studies that have investigated the association between patella cartilage defects and trochlea morphology [18,19]. These findings lead to the question whether a pathologic shape of the femoral trochlea leads to minor results after ACI at the patella.

The correlation analysis of the present study revealed a significant correlation of the lateral condyle index with the IKDC score, whereas all further measured quantitative parameters did not show significant correlation. The comparison between patients with no or minor trochlea dysplasia and patients with major dysplasia did not reveal significant differences regarding the clinical outcome. However, as the box plots in Figures 6 and 7 represent, there was a higher variance of clinical results in patients with major dysplasia indicating a less predictable outcome after ACI at the patella in these patients. Summarizing the results there is evidence for a negative influence of altered trochlea morphology on the clinical outcome. In the present cohort a less developed lateral trochlea facet seems to be a crucial factor for minor clinical results.

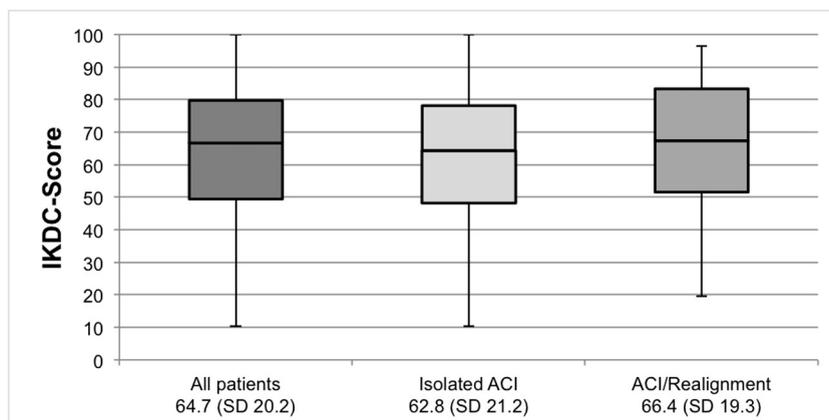


Figure 5. Results of the IKDC-Score. Results of the IKDC-Score given as mean and SD and presented in box plots. No significant differences between patients with and without additional realignment.

Table 5
Correlation analysis between trochlea morphology and clinical scores.

	Parameter	Kujala-Score		IKDC-Score	
		r	Sig.	r	Sig.
All patients (N = 73)	Sulcus depth	0	n.s.	-0.10	n.s.
	Sulcus angle	0.06	n.s.	0.15	n.s.
	Lateral condyle index	0.20	n.s.	0.25	<i>p</i> = 0.037 ^a
Isolated ACI (N = 35)	Sulcus depth	-0.09	n.s.	-0.04	n.s.
	Sulcus angle	0.18	n.s.	0.13	n.s.
	Lateral condyle index	0.25	n.s.	0.31	n.s.
ACI/Realignment (N = 38)	Sulcus depth	0.04	n.s.	-0.05	n.s.
	Sulcus angle	0.10	n.s.	0.13	n.s.
	Lateral condyle index	0.10	n.s.	0.12	n.s.

r = correlation coefficient; Sig. = significance; *p* = *p*-value; n.s. = not significant.
^a Significant correlation.

In the present study no patients, even with high-grade trochlea dysplasia, were treated by trochleoplasty, because of a cautious restraint towards this invasive procedure in combination with ACI. Instead less invasive soft-tissue procedures were performed in order to address patella instability and alignment and trying to compensate for dysplasia. Trochleoplasty has become more and more popular in recent years with good results in the treatment of chronic patella instability; however data about a combined procedure of trochleoplasty and ACI are rare. Gillogly and Arnold conducted a clinical trial on 23 patients with cartilage defects of the patella treated by ACI in combination with tibial tubercle osteotomy and lateral release, while four patients (17%) underwent additional trochleoplasty because of trochlear dysplasia. After a mean follow-up of 7.6 years good results in 83% was observed along with only one failure. However, in comparison with the preoperative status the patients with additional trochleoplasty did not show a significant improvement in the clinical scores, while the patients without trochleoplasty did.

The findings of the present study are of distinct clinical relevance, as they demonstrate evidence for a correlation of altered trochlea morphology with worse clinical results after ACI at the patella. As Dejour's classification alone seems to be too vague, a more detailed investigation of the trochlea morphology preoperatively is necessary, especially considering the lateral trochlea facet. Even though soft-tissue realignment procedures like medial patellofemoral ligament (MPFL) reconstruction are able to compensate dysplastic trochlea to a certain extent, indications for trochleoplasty might be considered in severe cases.

Along with certain strengths, there are some limitations of this study. The study design is retrospective and based on clinical evaluation at follow-up as well as on morphological characteristics in preoperative MRI. Nevertheless, to acquire information about the post-operative course, the patients were asked about satisfaction with the postoperative result and about the development of the main symptom pain. Furthermore the success of the operation was evaluated by Kaplan–Meier survival analysis, which is independent of preoperative clinical scores.

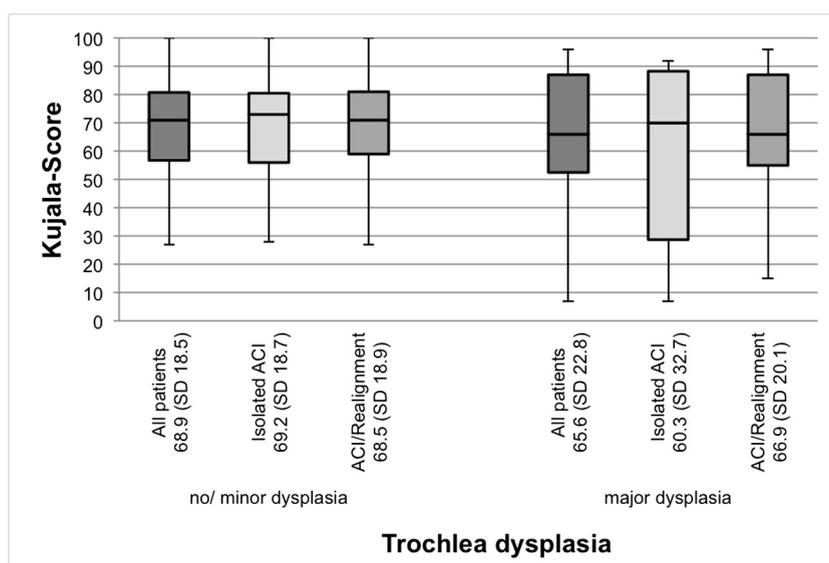


Figure 6. Kujala-Score depending on the grade of trochlea dysplasia. Results given as mean and SD and presented in box plots. No significant differences between patients with no or minor dysplasia and patients with major dysplasia.

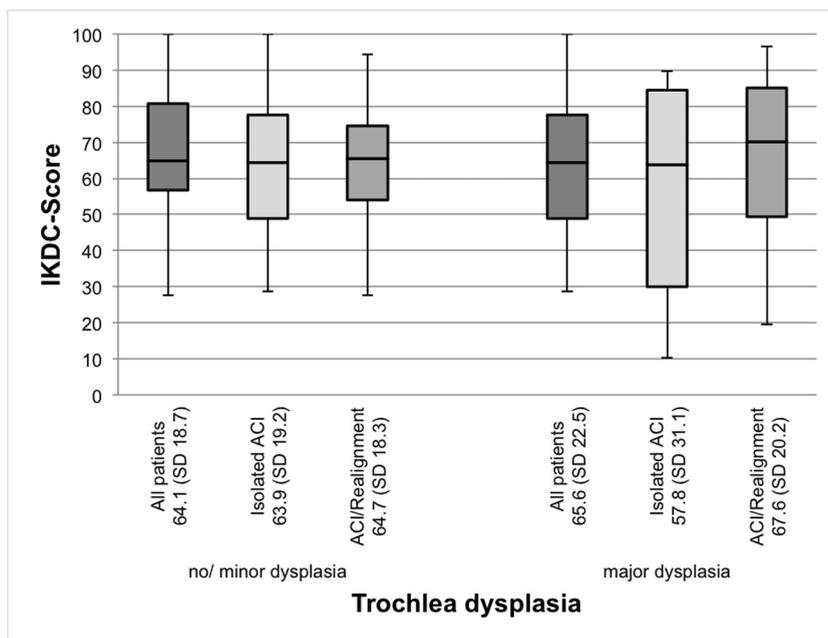


Figure 7. IKDC-Score depending on the grade of trochlea dysplasia. Results given as mean and SD and presented in box plots. No significant differences between patients with no or minor dysplasia and patients with major dysplasia.

A further limitation is the inclusion of different surgical methods for patella stabilization. Patients with need for additional osteotomies were excluded in order to minimize this inhomogeneity. However, to keep the study group as large as possible the inclusion of different soft-tissue stabilizing techniques was accepted.

Additionally, the cohort size has to be mentioned as possible limitation, since it might be too small for the detection of further significant correlations.

5. Conclusions

This study reports an excellent survival rate and a good satisfaction rate in a mid- to long-term course after ACI at the patella. However, the results of the clinical scores show a high variance and there is evidence that a pathologic morphology of the femoral trochlea has negative influence on the outcome. Especially a less developed lateral trochlea facet seems to be a crucial factor. Soft-tissue procedures for patella realignment are able to compensate dysplastic trochlea to a certain extent. Further studies investigating the correlation between trochlea morphology and the outcome after ACI in a larger patient collective are needed to draw further conclusions.

Compliance with ethical standards

Conflict of interest

All authors declare that they have no conflict of interest.

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Ethical approval

The present study has been approved by the local ethics committee (ID-number: 116/15).

Informed consent

Informed consent was obtained from all individual participants included in the study.

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