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# Recommendations and Treatment Outcomes for Patellofemoral Articular Cartilage Defects With Autologous Chondrocyte Implantation

## Prospective Evaluation at Average 4-Year Follow-up

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**Background:** Reported results of autologous chondrocyte implantation for chondral lesions in the patellofemoral joint have been encouraging when combined with realignment procedures.

**Purpose:** The objective of this study was to examine the clinical results of a patient cohort undergoing autologous chondrocyte implantation of the patellofemoral joint and elucidate characteristics associated with successful implantation.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** The cohort included 62 patients who underwent autologous chondrocyte implantation of the PF joint. The mean defect size was 4.2 cm<sup>2</sup> ( $\pm 1.6$ ). The average age was 31.8 years (range, 15.8-49.4), and the average follow-up was 4 years (range, 2-7). Outcomes were assessed via clinical assessment and established outcome scales, including the Lysholm, International Knee Documentation Committee, Knee Injury and Osteoarthritis Outcome Scale (KOOS; includes the 5 categories of Pain, Symptoms, Activities of Daily Living, Sport, and Quality of Life), Tegner, Cincinnati, and Short Form-12.

**Results:** Mean improvement in the preoperative to postoperative scores was significant for the Lysholm (37-63,  $P < .001$ ), International Knee Documentation Committee (31-57,  $P < .001$ ), KOOS Pain (48-71,  $P < .001$ ), KOOS Symptoms (51-70,  $P < .001$ ), KOOS Activities of Daily Living (60-80,  $P < .001$ ), KOOS Sport (25-42,  $P < .001$ ), KOOS Quality of Life (24-49,  $P < .001$ ), Short Form-12 Physical (38-41,  $P < .05$ ), Cincinnati (43-63,  $P < .005$ ), and Tegner (4-6,  $P < .05$ ), but not for the Short Form-12 Mental. There was no statistical difference between outcomes in patients with a history of a previous failed cartilage procedure compared with those patients without a prior cartilage procedure ( $P > .05$ ). Patients undergoing anteromedialization tended toward better outcomes than those without realignment. Forty-four percent of patients needed a subsequent procedure. There were 4 clinical failures (7.7%), which were defined as progression to arthroplasty or conversion to osteochondral allograft transplantation.

**Conclusion:** Autologous chondrocyte implantation is a viable treatment option for chondral defects of the patellofemoral joint. Combined autologous chondrocyte implantation with anteromedialization improves outcomes more than autologous chondrocyte implantation alone. Patients with failed prior cartilage procedures can also expect sustained and clinically meaningful improvement.

**Keywords:** autologous chondrocyte implantation (ACI); chondral lesions; patellofemoral; chondrocytes

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excessive lateral position of the patella on the trochlea. Such disorders lead to altered articular congruence between the patella and trochlea that can progress to severe cartilage damage. Surgical and nonsurgical treatment options are variable, and the correct algorithm that will greatly enhance the likelihood of a good clinical outcome has been difficult to determine.

Autologous chondrocyte implantation (ACI) has an established role in the treatment algorithm of cartilage defects, especially in patients for whom there are limited treatments options or who have failed previous nonsurgical treatment.<sup>25</sup> Many patients who undergo PF ACI have a history of a previous failed cartilage procedure; however, few studies have addressed whether patients with a failed prior cartilage procedure will benefit from ACI.<sup>27</sup>

Multiple operative procedures have been devised to correct patellofemoral malalignment. Anteromedialization (AMZ), a treatment for such abnormalities, was popularized by Fulkerson.<sup>8,9</sup> Anteromedialization decreases stress across the PF joint, especially in areas of cartilage restoration.<sup>1,5,6</sup> A review of AMZ outcomes by Pidoriano et al<sup>22</sup> revealed poor outcomes with advanced chondrosis in certain PF regions such as medial (type III), proximal or diffuse patella (type IV), and central trochlear lesions. Brittberg et al<sup>3</sup> reported that cartilage restoration of PF chondrosis with ACI had poor outcomes when PF malalignment was not corrected. Subsequently, several authors have shown that by combining AMZ and ACI, positive outcomes are possible.<sup>17,18,21</sup>

The purpose of this study is to evaluate the outcomes of PF ACI, with or without concomitant AMZ, through established outcomes scales and clinical assessment. A second purpose is to determine whether patients with a failed prior cartilage procedure experience a positive clinical benefit after ACI. Finally, an appropriate treatment algorithm for PF cartilage lesions will be suggested.

## MATERIALS AND METHODS

### Patient Selection

Between January 2002 and December 2006, 62 consecutive patients (63 knees) who underwent PF ACI were enrolled in our prospective database. Approval for the study was obtained by the institutional review board at our institution, and all patients signed informed consent to participate. Indications for PF ACI were a symptomatic full-thickness cartilage defect in a patient who had failed nonoperative treatment and frequently other surgical procedures. Before ACI, lesion size and location were confirmed via diagnostic arthroscopy to define all relevant intra-articular lesions and obtain a cartilage biopsy specimen. Deciding when to perform AMZ of the tibial tuberosity was complex and based on multiple factors, including the region of PF chondrosis and the initial position of the patella relative to the trochlea and the position of the tibial tuberosity to the trochlear groove midline (ie, the tibial tuberosity to trochlear groove distance). Symptomatic defects of the patella located distally and laterally were often treated initially with an AMZ with

or without a microfracture procedure, as these have historically done well with AMZ alone as reviewed by Pidoriano et al.<sup>22</sup> At the time of this treatment, a biopsy specimen for future ACI was often obtained so that if initial treatment failed, ACI could subsequently be performed. When defects involved the central or proximal patella, especially when more medially located, modifications to the AMZ were considered. These included specific attention to avoid overmedialization, which might increase medial patellofemoral contact pressures. While panpatellar lesions treated with AMZ alone have often not faired well clinically, the addition of ACI as part of this treatment has been demonstrated to be beneficial. Finally, most defects of the trochlea were treated initially with ACI and AMZ except those truly along the medial trochlea, where concerns for increased medial load after AMZ were greatest; in those cases, the tuberosity was only anteriorized. Anteromedialization was also considered in select cases of severe chondral defects to decrease stress on the implanted cartilage area. Patellar tilt, height, and position relative to the trochlea were determined by clinical examination by the senior author. Soft tissue procedures such as lateral release and medial PF ligament reconstruction or reefing were performed according to the Fulkerson algorithm.<sup>6,10</sup>

### Patient Data

There were 52 patients (26 female and 26 male) available for assessment at a minimum of 2 years' follow-up (83% follow-up). Thirty-two patients had right knee involvement, and 20 had left knee involvement. The average age was 31.8 years (range, 15.8-49.4). The median body mass index was  $30 \pm 7.7 \text{ kg/m}^2$ . The median lesion size was  $4.19 \text{ cm}^2 (\pm 1.6 \text{ cm}^2)$ . Table 1 shows patient demographics for the study cohort. Ninety percent of the patients (47 of 52) had 1 or more previous operations (not including diagnostic arthroscopy and ACI biopsy) (Table 2). In addition to the ACI of the PF joint, 35 patients had concomitant procedures performed, including AMZ (28), lateral release (4), lateral meniscal transplant (2), and osteochondral autograft (1) (Table 3).

Twenty-eight lesions were located on the trochlea, 19 on the patella, 4 were bipolar (trochlea and patella), and 1 was a trochlear and medial femoral condyle lesion.

### Surgical Technique

Autologous chondrocyte implantation with autologous cultured chondrocytes (Carticel, Genzyme Biosurgery, Cambridge, Massachusetts) of patellar and trochlear defects was performed as previously reported.<sup>20</sup> After diagnostic arthroscopy was performed to assess the lesion's precise location, depth, size, and concomitant lesions, a 200- to 300-mg cartilage biopsy specimen was harvested from the intercondylar notch (nonweightbearing area) and then sent to Genzyme Biosurgery for chondrocyte expansion.

After approximately 6 to 12 weeks in patients who remained symptomatic, ACI with or without PF realignment was performed. Before implantation, the lesion was

**TABLE 1**  
Demographic Data of the 52 Patients Undergoing Patellofemoral Autologous Chondrocyte Implantation

Parameter	
Age (y)	31.8 ( $\pm 8.6$ )
Male/female	26/26
Body mass index ( $\text{kg}/\text{m}^2$ )	30 ( $\pm 7.7$ )
Patellar lesions	19
Trochlear lesions	28
Bipolar lesions	5
Average lesion size	4.2 $\text{cm}^2$
Patients with previous procedures	47

**TABLE 2**  
Procedures Prior to Autologous Chondrocyte Implantation<sup>a</sup>

Previous Procedures	Number of Patients
Microfracture	19
Lateral release	8
ACL reconstruction	4
AMZ	4
Chondroplasty	3
Meniscectomy	5
Hardware removal	2
Meniscal transplant	1
MPFL reconstruction	1
OATS (trochlea)	1
Medial reefing	1
Plica excision	1
Synovectomy	1

<sup>a</sup>ACL, anterior cruciate ligament; AMZ, anteromedialization; MPFL, medial patellofemoral ligament; OATS, osteoarticular transfer system.

prepared by complete excision of the damaged cartilage with a No. 15 scalpel and ring curette, leaving healthy hyaline cartilage to form vertical walls shouldering the lesion.<sup>7</sup> A periosteal patch was harvested from the medial border of the tibia as previously described,<sup>20</sup> and cut to the appropriate dimensions (according to lesion size). The patch was then sutured to the cartilage rim with dyed 6-0 Vicryl (Ethicon, Somerville, New Jersey) spaced 2 to 3 mm apart, with a small opening remaining at the top to allow injection of chondrocytes. Fibrin glue (Tisseel, Baxter Healthcare, Glendale, California) was used to seal the patch and a water-tightness test was performed to ensure no leakage of the cells would occur. The cells were suspended in a tuberculin syringe and injected into the defect, and the patch was sealed with additional sutures and fibrin glue (Figure 1).

In patients who needed an AMZ, the incision was extended 6 cm distally from the patellar tendon insertion to the tibial tuberosity. An AMZ osteotomy system (Tracker, Mitek, Raynham, Massachusetts) was used to perform the osteotomy. The osteotomy was done with a 60° slope for trochlear and medial/central patellar lesions (more anteriorization of the tibial tuberosity). For lateral patellar

**TABLE 3**  
Concomitant Procedures With Autologous Chondrocyte Implantation of Patellofemoral Joint<sup>a</sup>

Concomitant Procedures	Number of Patients
AMZ	28
Lateral release	4
Lateral meniscal transplant	2
OATS (MFC)	1

<sup>a</sup>AMZ, anteromedialization; OATS, osteoarticular transfer system; MFC, medial femoral condyle.

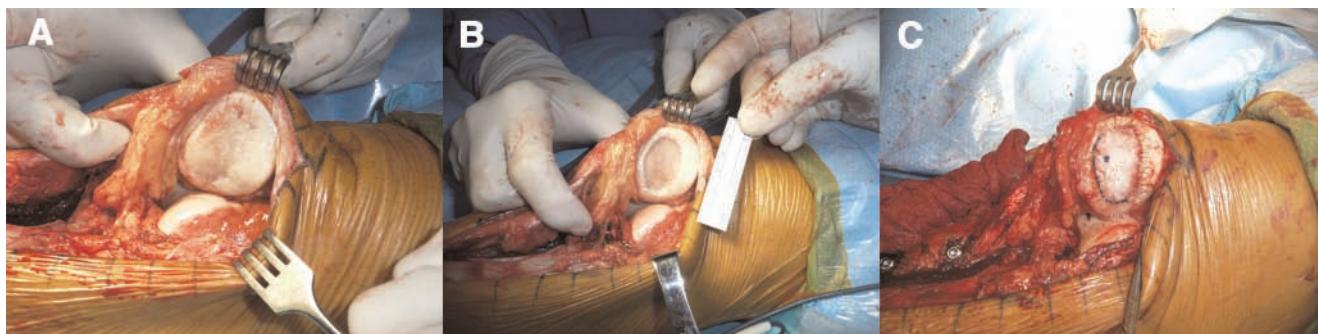
lesions, the slope was decreased to 45° (increasing medialization relative to anteriorization). After the tuberosity was repositioned up the slope of the osteotomy, it was fixed temporarily with 2 Kirschner wires. The osteotomy was then fixed with two 4.5-mm interfragmentary screws in the new position with standard AO technique (Figure 2) after the ACI was completed.

### Postoperative Rehabilitation

Patients' limbs were placed in a hinged knee brace limited to full extension. Continuous passive motion was initiated on the first postoperative day (0°-30°; 1 cycle/min) in 2-hour increments for 6 to 8 hours per day. Range of motion was advanced by 15° each week with the use of the continuous passive motion machine and unlocking of their brace. The objective was to obtain 90° of flexion by week 6 to 8, but not generally sooner than 4 weeks.<sup>13</sup> Patients who had a tibial tubercle osteotomy were nonweightbearing for the first 6 weeks. Return to full activity was not permitted until 8 months postoperatively to protect the lesion until the cartilage had sufficiently matured.

### Outcomes Assessment

Only patients with a minimum 24-month follow-up were included for analysis. A single orthopaedic surgeon performed all surgeries and conducted the baseline follow-up physical examinations. Questionnaires were administered preoperatively, 6 months postoperatively, 1 year postoperatively, and then annually. Subjective measures were based on several scoring systems including Lysholm, Tegner, Cincinnati, International Knee Documentation Committee (IKDC), Knee Injury and Osteoarthritis Outcome Score (KOOS), and Short Form-12 (SF-12).<sup>14,16,23</sup> The KOOS holds 5 separately scored subscales: Pain, Other Disease-Specific Symptoms, Activities of Daily Living (ADL) Function, Sport and Recreation Function, and Knee-Related Quality of Life (QOL).<sup>24</sup> Patients were also asked to rate the overall condition of their knee at the time of the last follow-up: 0 to 2, poor (significant limitations that affect activities of daily living); 3 to 4, fair (moderate limitations that affect activities of daily living, no sports possible); 5 to 6, good (some limitations with sports but I can participate, I compensate); 7 to 8, very good (rare limitations, able to



**Figure 1.** Surgical procedure of autologous chondrocyte implantation (ACI). A, exposure of the patellar chondral defect. B, patellar chondral defect debrided to subchondral bone with vertical walls. C, final ACI after patch is sutured and sealed.

participate); and 9 to 10, excellent (able to do whatever I wish with no problems). Patient satisfaction with surgical outcome was elicited with the following scale: completely satisfied, mostly satisfied, somewhat satisfied, and unsatisfied. Finally, patients were asked if, based on their experience, they had the same problem in the opposite knee, would they have the same surgery again.

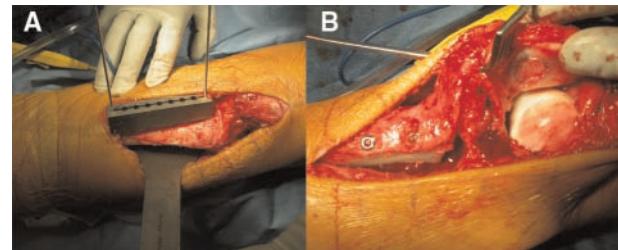
Surgical failures were defined as (1) poor clinical outcome accompanied by evidence of graft failure due to delamination from adjacent cartilage and subchondral bone, and (2) need for conversion to knee arthroplasty or osteochondral allograft.

#### Analysis of Subgroups

Patients were subcategorized into 3 different groups: (1) isolated ACI treatment, (2) ACI with a realignment procedure, or (3) ACI plus realignment procedure with history of a failed microfracture procedure (Table 4). From the 52 patients, 23 had no prior treatment of which 11 patients had only ACI (group 1) and 12 patients had ACI with a realignment procedure (group 2). Nineteen patients had a history of previous failed microfracture procedure; 14 were subsequently treated with ACI in association with an AMZ (group 3) and 5 with an ACI alone. Ten patients with different combined procedures (ACI with previous failed soft tissue procedure [ $n = 1$ ], ACI with AMZ with previous failed soft tissue procedure [ $n = 5$ ], and ACI with failed previous AMZ [ $n = 4$ ]) were included in the overall outcomes but not included in the subgroup analysis. Only the 3 defined subgroups had high enough statistical power to make a comparison between groups. To achieve 80% power with an effect size of 0.4 and  $\alpha = .05$ , 10 patients were required per group for an analysis of variance design.

#### Statistical Assessment

Descriptive statistics were calculated according to standard methods, including frequencies, means, standard deviations, and ranges when appropriate. Clinical outcome scores were analyzed at 2 time points: preoperatively and at the most recent follow-up. Score improvement was



**Figure 2.** Steps of tibial tubercle osteotomy. A, anteromedialization (AMZ) cutting jig placement at an appropriate angle depending on location of patellofemoral defect. B, anteromedialization of the tibial tubercle and patella with final fixation.

calculated using a paired  $t$  test. Factor analysis of patient age, defect area, previous failed microfracture procedure, and time to follow-up was performed using Pearson correlation post hoc  $t$  testing. Subgroup analysis was performed by 1-way analysis of variance with the Tukey post hoc test to determine differences among subgroups. Statistical significance was set at  $P < .05$ . Statistics were performed using GraphPad software (GraphPad Software, La Jolla, California), SPSS version 15.0 (SPSS, Chicago, Illinois), and the G\*Power statistical program.

## RESULTS

#### Clinical Assessment

The average patient follow-up was 4 years (range, 2-7). Overall, statistically significant improvement (preoperative to postoperative) was seen for the Lysholm (37 to 63,  $P < .001$ ), IKDC scores (31 to 57,  $P < .001$ ), KOOS Pain (48 to 71,  $P < .001$ ), KOOS Symptoms (51 to 70,  $P < .001$ ), KOOS ADL (60 to 80,  $P < .001$ ), KOOS Sport (25 to 42  $P < .01$ ), KOOS QOL (24 to 49,  $P < .001$ ), Cincinnati (43 to 63,  $P < .05$ ), Tegner (4 to 6,  $P < .05$ ), and SF-12 Physical (38 to 41,  $P < .05$ ). No statistical improvement was seen for the SF-12 Mental (50 to 54  $P = .054$ ). Detailed overall results are shown in Table 5 and Figure 3.

**TABLE 4**  
Stratification of Patients According  
to Procedure Performed<sup>a</sup>

Procedures	Number of Patients	Subgroup
ACI alone	11	1
ACI with AMZ	12	2
Failed mfx with subsequent ACI with AMZ	14	3
Failed mfx with subsequent ACI	5	-
Failed AMZ with subsequent ACI	4	-
Failed soft tissue with subsequent ACI with AMZ	5	-
Failed soft tissue with subsequent ACI	1	-

<sup>a</sup>ACI, autologous chondrocyte implantation; AMZ, anteromedialization; mfx, microfracture.

### Patient Satisfaction

Patients reported the overall condition of their knee as excellent, very good, or good in 71% of the cases (8% excellent, 37% very good, and 27% good) (Figure 4). The majority of patients (82%) rated that they were completely satisfied (14 of 52 patients), mostly satisfied (17 of 52 patients), or somewhat satisfied (12 of 52 patients) with the procedure. Based on their experience, 72% would have the surgery again.

### Analysis of Subgroups

Subgroup analysis revealed no differences in patient age at implantation ( $P = .7$ ), gender ( $P = .7$ ), or defect size ( $P = .25$ ) (Table 6). All 3 groups had significant improvements in Lysholm and IKDC scores with no statistical improvement in Cincinnati or SF-12 scores. Both groups 2 and 3 had statistically significant improvements in all KOOS categories, whereas group 1 only had improvement in KOOS ADL scores (Figure 5). Only group 2 had statistically significant improvement in the Tegner scores ( $P = .01$ ). Table 7 shows outcome scores for all 3 subgroups. Using analysis of variance to compare results between the 3 groups, there was only a statistically significant difference ( $P < .05$ ) in KOOS Pain and KOOS ADL scores between group 3 and the other groups. No other significant differences could be detected between the 3 groups.

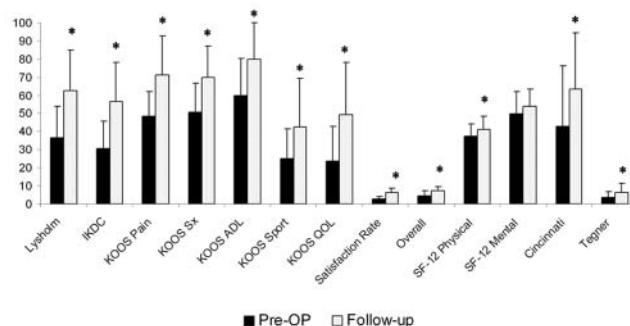
There was a significant difference in time of follow-up between group 1 (2.5 years) and the other 2 subgroups (group 2 = 4.3 years, group 3 = 4 years) (Levene test for equality of variance,  $P = .038$ ; analysis of variance,  $P < .029$ ).

**Group 1.** Patients in group 1 (ACI only,  $n = 11$ ) had statistical improvement in Lysholm, IKDC, KOOS Symptoms, and KOOS ADL scores. Seven patients (64%) said that they would have the procedure again if they had the same problem in the opposite knee. Only 5 patients (45%) were completely or mostly satisfied with the procedure. Eight patients (73%) thought that the results of the procedure were good, very good, or excellent (6 or more on a scale

**TABLE 5**  
Preoperative and Final Follow-up Outcome  
Scores for All Patients<sup>a</sup>

Knee Scoring System	Preoperative $\pm$ SD	Follow-up $\pm$ SD	P Value
Lysholm	37 $\pm$ 17	63 $\pm$ 22	<.001
IKDC	31 $\pm$ 15	57 $\pm$ 21	<.001
KOOS Pain	48 $\pm$ 14	71 $\pm$ 21	<.001
KOOS Symptoms	51 $\pm$ 16	70 $\pm$ 17	<.001
KOOS ADL	60 $\pm$ 21	80 $\pm$ 20	<.001
KOOS Sport	25 $\pm$ 16	42 $\pm$ 27	<.001
KOOS QOL	24 $\pm$ 19	49 $\pm$ 29	<.001
Symptoms	3 $\pm$ 1	6 $\pm$ 2	<.001
Overall satisfaction	5 $\pm$ 3	7 $\pm$ 3	<.001
SF-12 Physical	38 $\pm$ 7	41 $\pm$ 7	<.05
SF-12 Mental	50 $\pm$ 12	54 $\pm$ 10	.054
Cincinnati	43 $\pm$ 33	63 $\pm$ 31	<.05
Tegner	4 $\pm$ 3	6 $\pm$ 5	<.05

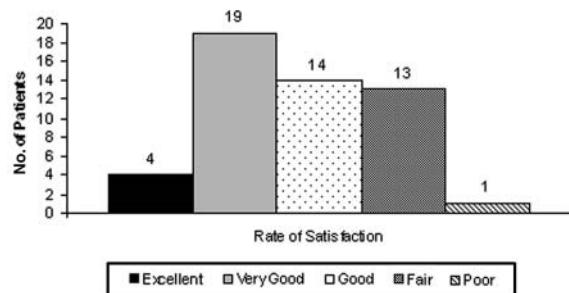
<sup>a</sup>SD, standard deviation; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; ADL, Activities of Daily Living; QOL, Quality of Life; SF-12, Short Form-12.



**Figure 3.** Bar graph representation of preoperative and follow-up scores for all patients for all outcome scores measured. \* $P < .05$ . IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; Sx, symptoms; ADL, Activities of Daily Living; QOL, Quality of Life; SF-12, Short Form-12. All values are statistically significant, except for SF-12 Mental.

from 0-10). Three patients had additional procedures. Two were considered failures and converted to a total knee replacement. One patient had a subsequent scope due to graft hypertrophy.

**Group 2.** Patients who had an ACI with an AMZ concomitantly ( $n = 12$ ) had statistical improvement in Lysholm, IKDC, KOOS Pain, KOOS Symptoms, KOOS ADL, KOOS Sport, and KOOS QOL scores. Nine of these patients (75%) were completely or mostly satisfied with the procedure and 75% said that they would have the procedure again if they had the same problem in the opposite knee. Ten patients (83%) thought that the results of the procedure were good, very good, or excellent (6 or more on a scale



**Figure 4.** Overall condition of the knee in patients undergoing patellofemoral autologous chondrocyte implantation (ACI): 0 to 2, poor (significant limitations that affect activities of daily living), 3 to 4, fair (moderate limitations that affect activities of daily living, no sports possible); 5 to 6, good (some limitations with sports but I can participate, I compensate); 7 to 8, very good (rare limitations, able to participate); and 9 to 10, excellent (able to do whatever I wish with no problems).

**TABLE 6**  
Patient Characteristics for the Different Subgroups

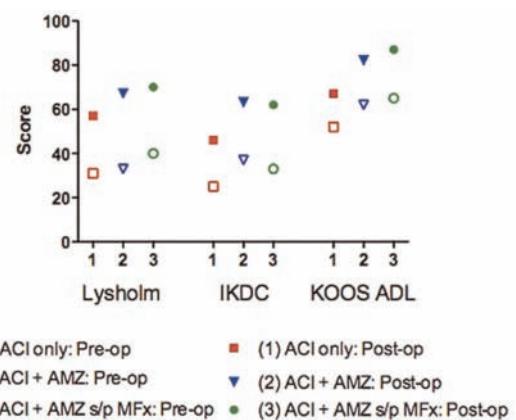
	Group 1	Group 2	Group 3
Patients	11	12	14
Male:female	9:2	7:5	9:5
Age (y)	35 ± 6	33 ± 8	30 ± 7
Lesion size (cm <sup>2</sup> )	4.3 (±1.3)	3.9 (±2.0)	4.70 (±2.7)
Follow-up (y)	2.5	4.3	4

from 0-10). Three patients from this group had additional procedures after the ACI was performed, 1 of them due to failure (conversion to osteochondral allograft). The other 2 additional procedures were microfractures—1 in an area of the trochlea that did not have cartilage fill after ACI and another of the femoral condyle.

**Group 3.** Patients with a history of previous failed microfracture subsequently treated with ACI and AMZ ( $n = 14$ ) showed improvement in almost all scores. The Lysholm, IKDC, KOOS Pain, KOOS Symptoms, KOOS ADL, KOOS Sport, and KOOS QOL scores all showed statistically significant improvement. Ten of the 14 patients (71%) said that they would have the procedure again if they had the same problem in the opposite knee. Twelve patients (86%) were completely or mostly satisfied with the procedure. Six of 14 patients (43%) thought that the results of the procedure were good, very good, or excellent (6 or more on a scale from 0-10). Five patients needed additional procedures—3 for graft hypertrophy and 2 for microfracture of the femoral condyle (Table 8). There were no failures in this group.

#### Subsequent Procedures

In total, 23 patients (44%) had subsequent surgical procedures. The most common reason for or finding of these operations was periosteal graft hypertrophy in 13 patients,



**Figure 5.** Selected outcome scores preoperatively and at final follow-up for the 3 subgroups. IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; ADL, Activities of Daily Living; ACI, autologous chondrocyte implantation; AMZ, anteromedialization; MFx, microfracture.

painful hardware necessitating removal in 2 patients, and a new cartilage lesion in the femoral condyle (treated successfully with a microfracture procedure) in 2 patients. Only 1 patient required loose-body removal with concomitant microfracture of the medial and lateral femoral condyle after a traumatic event. One patient had some cartilage loss in the previous trochlea ACI area with a concomitant new medial femoral condyle lesion; both lesions were treated with a microfracture procedure. An additional complication that did not warrant surgical intervention was complex regional pain syndrome. Four patients needed subsequent procedures due to failure as discussed below.

#### Failures

There were a total of 4 failures (7.7%). Two patients from the ACI group (group 1) had clinical failure and were converted to a total knee replacement. One patient from the ACI with AMZ group (group 2) failed and was converted to an osteochondral allograft. One patient who was not included in any of the subgroups (failed AMZ with subsequent ACI) was converted to an osteochondral allograft.

#### DISCUSSION

Treatment of symptomatic PF cartilage injuries is challenging secondary to diagnostic and therapeutic dilemmas. Often the cartilage lesion is associated with subluxation or tilt of the patella, synovitis, or inflammation of surrounding tissues and other concurrent knee lesions. Typically, symptomatic cartilage injuries are treated with a marrow stimulation procedure as a first-line treatment. However, despite its widespread use, there are no published reports on microfracture alone for trochlear or patellar cartilage defects. Additionally, treatment options such as AMZ,

**TABLE 7**  
**Outcome Score Changes in the 3 Subgroups From Preoperative Results to Final Results, With P Value for All Outcome Scales<sup>a</sup>**

Outcome Scale	Group 1			Group 2			Group 3		
	Preop	Final	P Value	Preop	Final	P Value	Preop	Final	P Value
Lysholm	31	57	.02	33	67	.001	44	70	.001
IKDC	25	46	.02	37	63	.001	33	62	<.001
KOOS Pain	42	60	.12	44	74	.02	58	82	<.001
KOOS Symptoms	46	65	.12	47	73	<.001	58	78	<.001
KOOS ADL	52	67	.03	60	82	.01	65	87	.03
KOOS Sport	24	36	.22	23	52	.03	29	46	.04
KOOS QOL	24	37	.22	18	57	.04	29	46	.001
Symptoms	3	6	.03	5	8	.13	5	7	.29
Overall	2	5	<.01	3	7	<.001	3	7	.001
SF-12 Physical	38	40	.53	40	41	.57	36	41	.62
SF-12 Mental	43	53	.16	52	54	.31	55	57	.92
Cincinnati	42	55	.47	56	71	.13	38	70	.46
Tegner	4	5	.72	5	8	.01	4	8	.78

<sup>a</sup>IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; ADL, Activities of Daily Living; QOL, Quality of Life; SF-12, Short Form-12.

medial PF ligament reconstruction, and lateral release, with or without microfracture, have to be considered as well as treatments for structural abnormalities of the extensor mechanism in patients with chondral defects in the PF joint. Results with these procedures alone have been poor.<sup>2,22</sup> Thus, the optimal treatment algorithm for these lesions is unknown.

A number of recent studies have addressed the effectiveness of ACI in treating PF cartilage defects with heterogeneous results. Most studies either determined the outcomes for PF ACI alone or PF ACI with concomitant realignment, making comparisons between the 2 procedures difficult to assess. Minas and Bryant<sup>18</sup> described 71% good to excellent results in 45 patients treated with ACI. Although they reported that 62% of their patients had concomitant AMZ, they did not compare these patients with those who had an isolated ACI. In contrast to our study, they selected different subgroups based on the anatomic locations of the defect.<sup>12,18</sup>

Farr<sup>5</sup> reviewed 38 patients with patellar and/or trochlear cartilage lesions, of whom 28 (74%) underwent distal realignment before or simultaneously with ACI. In contrast to our study, only 3 patients had a history of failed microfracture procedure, and comparisons between ACI alone and ACI with AMZ were not assessed. The majority of patients (80%) rated their overall condition (modified Cincinnati) as good, very good, or excellent. Farr suggested combining ACI with corrective osteotomies to treat knees with symptomatic PF chondral lesions.<sup>5</sup>

Gobbi et al<sup>11</sup> also reported the results of second-generation ACI (using a hyaluronic acid synthetic scaffold) for PF chondral lesions. No patients had a concomitant AMZ. At 2 years' follow-up, 90% of patients were classified as normal or nearly normal by IKDC score. Mandelbaum et al<sup>17</sup> reported statistical improvement in patients treated with isolated trochlear ACI with regard to pain, swelling, and

**TABLE 8**  
**Additional Procedures Performed in Each of the 3 Subgroups<sup>a</sup>**

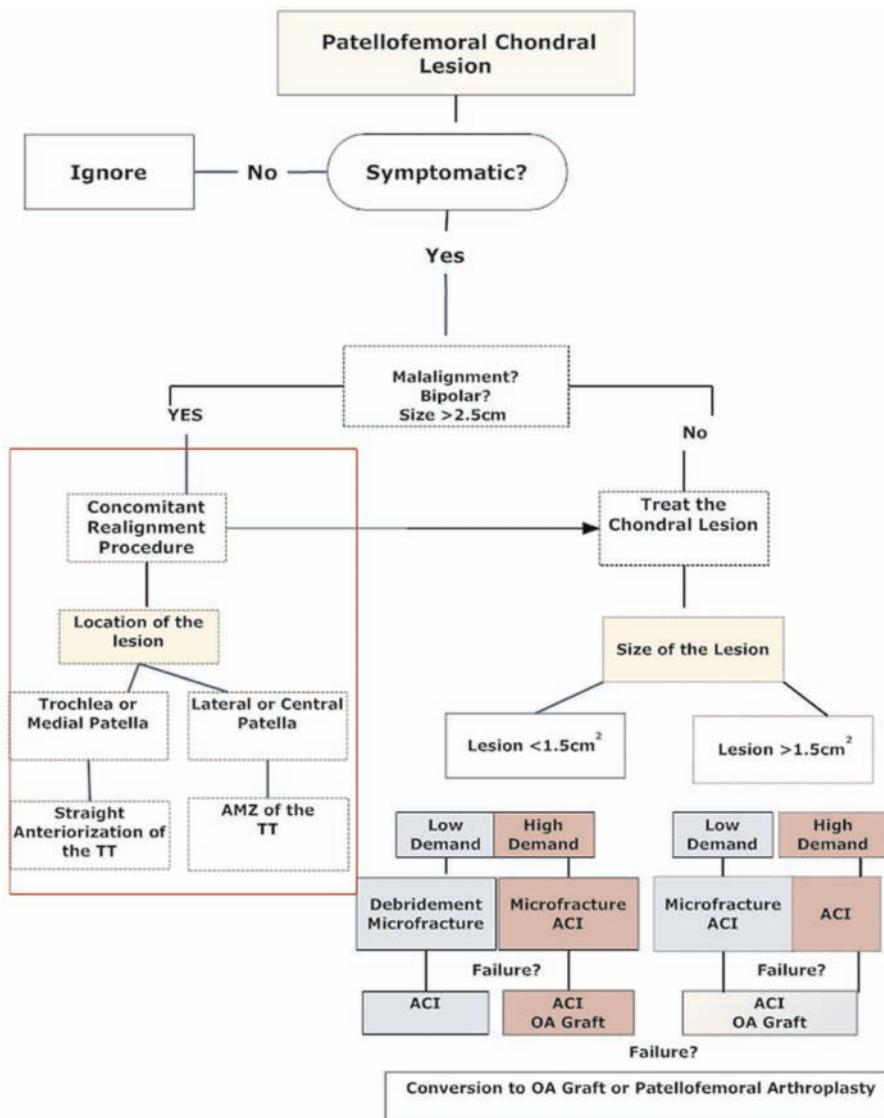
Group	Number of Patients With Subsequent Procedures	Type of Procedure
1	3	2 TKR, 1 scope
2	3	2 mfx (1 NRIL), 1 OA graft
3	5	3 scope/2 mfx (NRIL)

<sup>a</sup>TKR, total knee replacement; mfx, microfracture; NRIL, non-relevant intra-articular lesion; OA graft, osteochondral allograft.

overall function. However, only 28% of these patients received AMZ, so the role of tibial tubercle osteotomy could not be determined.

In our study, AMZ was performed concomitantly with ACI in 26 of 52 patients (50%), 14 of whom had a previous failed microfracture procedure. We directly compared the outcome of patients with ACI alone, and ACI with AMZ (with and without a previous failed microfracture procedure). All 3 groups showed statistical improvement in most of the outcome scores at the time of follow-up. However those patients who received an ACI with AMZ with a history of failed microfracture procedure showed a statistically higher clinical score than those with ACI alone (KOOS Pain and KOOS ADL). In addition, 86% of these patients reported they were mostly or completely satisfied with the procedure. In contrast, only 45% of the patients who received an ACI alone reported they were mostly or completely satisfied with the procedure. Similarly, Henderson and Lavigne<sup>15</sup> reported better results in patients who had ACI concomitantly with AMZ, as compared with ACI alone, suggesting a beneficial effect of unloading the repaired area.

As ACI is considered a second-line treatment option for patients who have failed microfracture, we also assessed



**Figure 6.** Algorithm for treating patients with patellofemoral grade 3 and 4 chondral lesions.

the effect of a positive history of failed microfracture procedure. Minas et al<sup>19</sup> recently suggested that microfracture, in particular, may compromise subsequent revision surgery (such as ACI) due to damage to the subchondral plate. They included patients treated with ACI and grouped them according to whether they had undergone prior treatment with microfracture. Results were assessed according to simple lesions (<4 cm<sup>2</sup>), complex lesions (>4 cm<sup>2</sup>), and salvage procedures (signs of osteoarthritis). In contrast to our study, they included both PF and femoral condylar lesions. Interestingly, they found that defects that had prior treatment affecting the subchondral bone failed at a rate 3 times that of nontreated defects. However, the failure rate was not assessed if the lesion was less than 4 cm<sup>2</sup>. This would be consistent with our study, as the median size of our lesions was 4 cm<sup>2</sup>. One other study has addressed the role of ACI after failed surgical treatment for cartilage defects.<sup>27</sup> Similar to our

results, they found that 77% of patients with a previous failed cartilage procedure can expect a sustained and clinically meaningful improvement in pain and function after ACI. Only 20% of their patients had a trochlear defect, whereas 56% of our patients had trochlear lesions, which perhaps explains their higher outcome success rate (77% vs 71%).

In this study, we considered the overall results of PF ACI; additionally, we analyzed different subgroups based on concomitant or prior procedures. The main weakness in our study is that we were not able to have a control group to compare with our 3 groups of patients. In our study, we had to use each subgroup for comparison and statistical analysis to determine clinical comparisons. A control group would have allowed further analysis to determine true improvement of each subgroup. Because of the nature of the study, we were not able to randomize the groups. To truly determine whether AMZ is beneficial concomitantly with PF ACI, a blinded

randomized study with ACI alone or ACI with AMZ is needed. Another weakness in our study is a small number of patients in each subgroup analyzed and that the ACI group had less time to final follow-up in comparison with the other subgroups (30 months vs 4 years). Because ACI normally undergoes a process of maturation that in the majority of cases takes longer than 18 months, several studies have indicated that patients undergoing ACI should have a minimum follow-up of at least 2 years, after which the clinical improvement plateaus.<sup>21</sup> However, the ACI group did statistically worse than patients treated with both AMZ and ACI, despite the shorter follow-up. One would expect the converse, perhaps indicating that AMZ together with ACI might prolong the effects of ACI. Additionally, there might have been a larger difference in outcomes between patients with ACI alone versus ACI with AMZ if the follow-up had been longer in patients with ACI alone.

In conclusion, this study evaluated the clinical outcomes of ACI in the PF joint in a large patient cohort treated by a single surgeon. Outcomes demonstrated a reduction of symptoms and increase in function over a mean follow-up of 4 years. Overall, our results were similar to previous reports on the functional outcomes of the treatment of PF cartilage defects, with 71% of the patients reporting satisfaction with the procedure and a majority of patients having statistically significant improvement after ACI of the PF joint. Patients undergoing a concomitant AMZ with or without a history of previous failed microfracture were more satisfied with the procedure in comparison with those with an ACI alone. These findings support the algorithm that recommends ACI with concomitant AMZ for patients who have an inadequate response to a previous microfracture procedure for the treatment of PF cartilage defects. We cannot currently make a recommendation regarding whether AMZ should be performed in isolation before ACI versus concomitantly with ACI (Figure 6).

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