Similar Outcomes After Osteochondral Allograft Transplantation in Anterior Cruciate Ligament-Intact and -Reconstructed Knees: A Comparative Matched-Group Analysis With Minimum 2-Year Follow-Up

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Purpose: To compare failure rates and clinical outcomes of osteochondral allograft transplantation (OCA) in anterior cruciate ligament (ACL)-intact versus ACL-reconstructed knees at midterm follow-up. **Methods:** After a priori power analysis, a prospective registry of patients treated with OCA for focal chondral lesions $\geq$2 cm^2 in size with minimum 2-year follow-up was used to match ACL-reconstructed knees with ACL-intact knees by age, sex, and primary chondral defect location. Exclusion criteria included meniscus transplantation, realignment osteotomy, or other ligamentous injury. Complications, reoperations, and patient responses to validated outcome measures were reviewed. Failure was defined by any procedure involving allograft removal/revision or conversion to arthroplasty. Kaplan-Meier analysis and multivariate Cox regression were performed to evaluate the association of ACL reconstruction (ACLR) with failure. **Results:** A total of 50 ACL-intact and 25 ACL-reconstructed (18 prior, 7 concomitant) OCA patients were analyzed. The mean age was 36.2 years (range, 14-62 years). Mean follow-up was 3.9 years (range, 2-14 years). Patient demographics and chondral lesion characteristics were similar between groups. ACL-reconstructed patients averaged 2.2 $\pm$ 1.9 prior surgeries on the ipsilateral knee compared with 1.4 $\pm$ 1.4 surgeries for ACL-intact patients ($P = .014$). Grafts used for the last ACLR included bone-patellar tendon-bone autograft, hamstring autograft, Achilles tendon allograft, and tibialis allograft (data available for only 11 of 25 patients). At final follow-up, 22% of ACL-intact and 32% of ACL-reconstructed patients had undergone reoperation. OCA survivorship was 90% and 96% at 2 years and 79% and 85% at 5 years in ACL-intact and ACL-reconstructed patients, respectively ($P = .774$). ACLR was not independently associated with failure. Both groups demonstrated clinically significant improvements in the Short Form-36 pain and physical functioning, International Knee Documentation Committee subjective, and Knee Outcome Survey—Activities of Daily Living scores at final follow-up ($P < .001$), with no significant differences in preoperative, postoperative, and change scores between groups. **Conclusions:** OCA in the setting of prior or concomitant ACLR does not portend higher failure rates or compromise clinical outcomes. **Level of Evidence:** Level III, retrospective comparative study.

Fresh osteochondral allograft transplantation (OCA), which transfers viable, mature hyaline cartilage and subchondral bone into chondral or osteochondral defects, has exhibited good long-term results in the knee.[1-3] Use of a cadaveric graft allows for the treatment of large lesions (>2 cm^2) while avoiding donor site morbidity. This procedure has demonstrated 5 and 10 year survival rates of 95% and 85% for femoral condyle lesions[1] and additionally can be used to treat articular defects of the trochlea, patella, and tibia.[4-6] Although reoperation rates are approximately 40%, patient satisfaction remains high.[3,7] Furthermore, 79% of competitive athletes are able to return to sport at preinjury levels.[8] As a result, OCA has become increasingly popular for the treatment of large full-thickness chondral or osteochondral defects.

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The presence of a focal full-thickness cartilage lesion at the time of ACL reconstruction (ACLR) leads to worse patient-reported outcomes and an increased risk of later osteoarthritis (OA).[9-11] Thus, treatment of these cartilage lesions, whether concurrently or in a staged manner, is recommended. Currently, there are only a few published studies on the treatment of cartilage lesions in ACL-reconstructed knees.[12-18] The available evidence suggests that combined osteochondral autograft transfer (OAT) and ACLR for smaller chondral defects in the setting of ACL injury can have reasonable short-term outcomes.[13,14,18] However, the outcomes of OCA for large chondral defects in ACL-reconstructed knees are unknown.

The concern over transplantation of an osteochondral graft in an ACL-reconstructed knee lies in the aberrant knee kinematics that remain after reconstruction. It has been demonstrated that tibiofemoral kinematics are not fully restored to normal postoperatively, and on average there is an element of overconstraint after ACLR, resulting in increased contact stresses in both medial and lateral compartments.[19-21] Additionally, there is evidence that ACL deficiency can alter patellar tilt and lateral patellar shift, resulting in increased patellofemoral contact pressures.[22,23] These increased contact stresses after ACLR are thought to be one of several contributing factors to the onset and progression of OA observed in all compartments of the knee, despite the restoration of anterior stability.[24-27] Although the exact biomechanical risk factors for OCA failure are unknown, high stresses at the graft-host interface as well as the osteochondral interface of the plug are thought to be important contributors. Therefore, increased contact forces in ACL-reconstructed knees may lead to the early failure of implanted osteochondral grafts.

The purpose of this study was to compare failure rates and clinical outcomes of OCA in ACL-intact versus ACL-reconstructed knees at midterm follow-up. The hypothesis of this study was that OCA in ACL-reconstructed knees would exhibit higher failure rates and worse clinical outcomes compared with OCA in ACL-intact knees.

Methods

In 1999, a prospective registry dedicated to the tracking of patient outcomes after articular cartilage restoration procedures was implemented at this study's institution. An institutional review board approved the registry, and all patients sign an informed consent form before participation. Patients included in the registry were evaluated preoperatively and were prospectively followed at 1, 2, 3, 4, 5, and 10 years postoperatively. A total of 1,902 registry patients from 17 surgeons were screened for this study.

Inclusion and Exclusion Criteria

Inclusion criteria included (1) skeletal maturity, (2) symptomatic focal cartilage lesions in the knee that were classified as Outerbridge grade III or IV lesions at the time of arthroscopic surgery and did not involve substantial bone loss requiring additional bone grafting, and (3) treatment with fresh osteochondral allograft. To be eligible for analysis, patients were required to have a minimum of 2 years of follow-up. Exclusion criteria for this cartilage procedure were grade 2 or higher OA according to the Kellgren and Lawrence classification, simultaneous multiligamentous reconstruction, inflammatory arthritis or autoimmune conditions, age <13 or >65 years, and inability to comply with the postoperative rehabilitation protocol. Additionally, OCA patients who underwent prior or concomitant meniscus transplantation, realignment osteotomy, or non-ACL ligament repair or reconstruction were excluded.

Surgical Indications for OCA

Fresh OCA was selected as the treatment option for these patients based on clinical judgement of defect complexity, defect size, and failure of previous surgical or nonsurgical treatments. Generally, OCA was performed for focal chondral defects of ≥ 2 cm^2 size diagnosed on magnetic resonance imaging (MRI) or prior arthroscopy. Prior failure of other cartilage restoration procedures such as microfracture was not a contraindication. Autologous chondrocyte implantation (ACI) was rarely performed at this study's institution due to its 2-stage process and slower rehabilitation compared with that for osteochondral grafting.

Patients

Demographic, preoperative, intraoperative, and postoperative data were collected for all patients. Demographic data included age, sex, and body mass index (BMI). Preoperative data included the number and type of prior ipsilateral knee surgical procedures, including meniscus and ligamentous procedures. Data on prior ACLR and partial meniscectomy were gathered from operative reports and confirmed with preoperative MRI. Standing lower limb alignment was assessed and recorded during the preoperative office visit. For the majority of patients, long-leg radiographs were obtained only if gross malalignment was detected and osteotomy was being considered. Intraoperative data included laterality, exam under anesthesia (alignment, range of motion, ligamentous stability), compartment, size and depth of the chondral defect(s), ACL status, meniscus status, and concomitant procedures performed. Postoperative data included complications, reoperations, and patient-reported outcome scores at a minimum of 2 years after surgery.

Surgical Technique

All surgical procedures were performed by fellowship-trained orthopaedic surgeons at a single institution with extensive experience in cartilage repair procedures. After an exam under anesthesia, patients were treated with an initial diagnostic arthroscopy of the joint for assessment of the chondral lesion as well as the other articular surfaces, menisci, and ligaments. If the patient had a prior ACLR, the integrity and integration of the graft were visually and manually assessed with a probe. Any meniscus tears were addressed with partial meniscectomy or repair. Any ACL insufficiency diagnosed through patient history, physical exam, and MRI findings in the office was confirmed by exam under anesthesia and addressed with an arthroscopically assisted primary or revision ACLR.

Fresh cold-stored osteochondral allografts were obtained from commercially available sources. Donor tissue was screened and processed according to American Association of Tissue Banks standards.[28] Preoperatively, donor and recipient were matched on the basis of size using standard anteroposterior radiographs. Grafts were transplanted between 16 and 30 days after harvest depending on serologic testing and patient availability. OCA was performed via the dowel technique described by Williams et al.[2] Briefly, chondral lesions were exposed via a small parapatellar arthrotomy and debrided to a stable rim. Lesions were then sized and reamed to a bed of normal bone, and an appropriate graft was taken from the corresponding region of the osteochondral allograft. Lesion depth was carefully measured at 3 to 4 points around the lesion, marked, and matched on the donor tissue. Grafts were then gently impacted into place for press-fit fixation. Grafts were a single or dual circular dowel shape in most cases, depending on lesion shape.

Postoperatively, patients remained touchdown weight bearing in a hinged knee brace for 1 week, followed by progression to full weight bearing as tolerated. During this initial period, patients were permitted to begin active-assisted range of motion exercises, quadriceps sets, straight leg raises, and patellar mobilization. Immediate full range of motion was permitted and encouraged with the use of a continuous passive motion device. A hinged knee brace was used for a minimum of 2 weeks. Total duration of bracing was dependent on the restoration of quadriceps control and strength, which usually ranged from 2 to 6 weeks. Patients treated with concomitant OCA and ACLR required more time for return of quadriceps control and strength and thus were typically braced for longer periods of time compared with patients treated with isolated OCA. A supervised physical therapy program was undertaken postoperatively in all cases. The duration of the postoperative physical therapy program was dependent on the restoration of normal gait, return of quadriceps function, and performance of sport-specific skills. Return to higher-level activities and athletics was initiated on an individual patient basis, typically starting with a running program at 6 months. Sports-specific training and unrestricted activities were then progressed thereafter depending on return of lower extremity strength. Return to sport was typically permitted at 6 to 12 months after isolated OCA and 8 to 12 months after combined ACLR and OCA.

Assessment of Clinical Outcomes

All complications and reoperations after the index OCA were documented. A reoperation was defined as any subsequent surgery on the ipsilateral knee, including arthroscopic debridement, chondroplasty, removal of loose bodies, lysis of adhesions, and hardware removal. Failure of the allograft was defined as any procedure that involved removal or revision of the allograft, unicompartmental knee arthroplasty (UKA), or total knee arthroplasty (TKA).

The general health outcome for each patient was assessed with use of the Short Form-36 (SF-36; ver. 1.0),[29] which has the ability to evaluate 8 domains of general well-being. Only the general health, pain, and physical functioning domains were assessed in this study. Knee function was assessed with use of the International Knee Documentation Committee (IKDC) subjective form, Knee Outcome Survey—Activities of Daily Living (KOS-ADL), and subjective components of the Cincinnati Knee Rating System. The IKDC score is a reliable and valid knee-specific measure of symptoms and function and has been shown to provide a good overall measure of knee-related disability in patients who have undergone a cartilage restoration procedure.[30,31] Similarly, the KOS-ADL and Cincinnati Knee Rating System have been shown to have high reliability, validity, and responsiveness in athletic patients with various knee conditions.[32] Patient activity level was assessed with use of the Marx Activity Rating Scale[33] and the Sports Activity Scale of the Cincinnati Knee Rating System.[8,34] Independent full-time research assistants performed postoperative data collection for all clinical outcome instruments. All of these knee-specific outcome instruments have been used previously to prospectively evaluate articular cartilage procedures in the knee.[8,32,35-37]

Statistical Analysis

An a priori power analysis was performed to determine the number of patients needed in each group to demonstrate a minimal clinically important difference (MCID) between groups with an effect size of 0.87 (IKDC)[38] and 0.72 (KOS-ADL)[39] and an alpha of 0.05. After determining patients in the ACL-reconstructed group, patients in the ACL-intact group were chosen by matching on the basis of sex, age, and primary chondral defect location. Comparisons of baseline patient characteristics between the 2 groups were conducted using the nonparametric Mann-Whitney tests for continuous variables and χ^2 or Fisher exact tests for

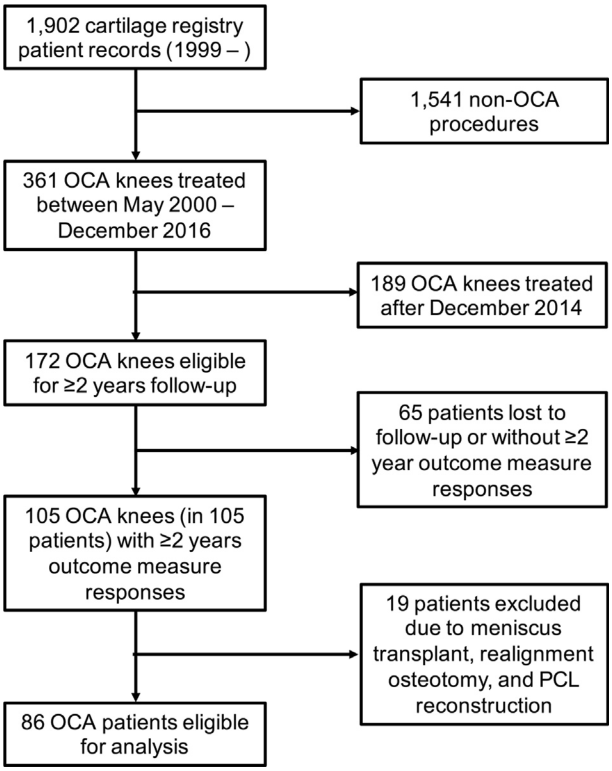

Fig 1. Patient search results from cartilage registry. (ACL, anterior cruciate ligament; OCA, osteochondral allograft transplantation; PCL, posterior cruciate ligament.)

categorical variables. Kaplan-Meier survivorship analysis was performed for failures. Comparison of survival between groups was conducted using the log-rank test. ACLR was entered into a multivariate Cox proportional hazards regression along with age, sex, BMI, number of prior surgeries, primary chondral defect location, and prior or concomitant meniscectomy in the same compartment as the implanted OCA to assess for any association of ACLR with failure while adjusting for these factors. Differences in the subjective patient outcome scores (SF-36, IKDC, KOS-ADL, Cincinnati Knee Rating System, and Marx Activity Rating Scale) between the 2 groups were assessed using the nonparametric Mann-Whitney test. Changes in subjective patient outcome scores between preoperative and postoperative time points in each group were assessed using the nonparametric Wilcoxon signed rank test. Two-tailed tests were used for all statistical analyses with a critical α value set to 0.05.

Results

In total, 105 patients treated between 2000 and 2014 met the inclusion and exclusion criteria and had a minimum follow-up of 2 years (Fig 1). Nineteen patients were excluded due to prior or concomitant procedures (7 high tibial osteotomy, 4 distal femoral osteotomy, 1 tibial tubercle osteotomy, 6 meniscus transplant, and 1 posterior cruciate ligament reconstruction). Among the resultant 86 patients, 25 had a history of an ACL-deficient knee that was treated with ACLR (18 prior to and 7 concomitant with OCA). A power analysis demonstrated that with 25 patients in the ACL-reconstructed group, 50 patients were needed for the ACL-intact group to achieve a power of $\geq$0.80. Therefore, after matching, a total of 75 patients from 4 surgeons were analyzed: 50 had ACL-intact knees at the time of OCA, and 25 had prior or concomitant ACL-reconstructed knees at the time of OCA.

The mean duration of follow-up was 4.1 years (range, 2-14 years) in the ACL-intact group and 3.7 years (range, 2-7 years) in the ACL-reconstructed group (P = .818). Overall mean duration of follow-up was 3.9 years. Patient demographics and chondral lesion characteristics were similar between the 2 groups (Table 1). The only significant difference between the 2 groups was the mean number of prior surgeries on the ipsilateral knee. The ACL-reconstructed group averaged almost one more prior surgery on the ipsilateral knee than the ACL-intact group (P = .014). Eighteen knees in the ACL-intact group (36%) and 12 knees in the ACL-reconstructed group (44%) had previously undergone cartilage restoration procedures, including pinning (n = 3), microfracture (n = 19), OAT (n = 2), ACI (n = 3), and synthetic scaffold (n = 4).

Of the 25 patients in the ACL-reconstructed group, 7 (28%) underwent combined OCA and ACLR (2 primary and 5 revision), and 18 (72%) had undergone ACLR prior to OCA. Of the 2 patients who underwent combined OCA and primary ACLR, mean time from injury to surgery was 20.0 ± 7.1 years. Of the 5 patients who underwent combined OCA and revision ACLR (all single stage), 4 patients had first-time revision ACLRs, and one patient had his fifth revision ACLR at the time of OCA. Mean time from the last ACLR to surgery for these 5 patients was 5.0 ± 3.2 years (data on time on injury were not available for 4 of these 5 patients because their initial ACLRs were performed at outside institutions). Of the 18 patients who had undergone ACLR prior to OCA, 16 patients had primary ACLRs and 2 patients had a single revision ACLR. Mean time from the last ACLR to index OCA for these patients was 7.4 ± 6.9 years (data available for only 16 of 18 patients). Grafts used for the last ACLR included bone-patellar tendon-bone autograft (n = 2), hamstring autograft (n = 6), Achilles tendon allograft (n = 2), and tibialis allograft (n = 1; data available for only 11 of 25 patients). Documented Lachman and pivot shift grades at the time of exam under anesthesia were 1A and 0-1, respectively, for all patients who had previously undergone an ACLR and did not require a revision ACLR at the time of OCA. No patients received a lateral extra-articular tenodesis or anterolateral ligament reconstruction.

Table 1. Patient and Surgery Characteristics Between Study Groups

	ACL Intact (n = 50)	ACL Reconstructed (n = 25)	P Value
Patient characteristics			
Age, yr	34.9 (14-61)	38.6 (21-62)	.212
Sex (male/female), n	34/16	14/11	.321
Body mass index	26.1 (18.9-38.3)	25.6 (20.3-35.2)	.563
Laterality (right/left), n	27/23	11/14	.459
No. of prior surgeries	1.4 (0-6)	2.2 (1-10)	.014
Follow-up, yr	4.1 (2-14)	3.7 (2-7)	.818
Lesion characteristics			
OCA location, n			.338
Medial femoral condyle	25	15	
Lateral femoral condyle	19	9	
Trochlea	12	10	
Patella	3	2	
Chondral defect area, cm^2	5.4 (0.8-9.5)	6.6 (2.0-15.3)	.213
No. of plugs used	1.5 (1-4)	1.5 (1-3)	.877
ACL reconstruction, n			
Prior to OCA	—	18	
Concomitant with OCA	—	7	

NOTE. Values are reported as the mean with the range in parentheses unless otherwise indicated.
ACL, anterior cruciate ligament; OCA, osteochondral allograft transplantation.

Normal alignment was documented in 46 knees in the ACL-intact group (92%) and 20 knees in the ACL-reconstructed group (80%). Less than 5° of varus malalignment was documented for 2 knees in the ACL-intact group (4%) and 5 knees in the ACL-reconstructed group (20%), and less than 5° of valgus malalignment was documented for 2 knees in the ACL-intact group (4%). Osteotomy was not performed for these patients due to the small magnitude of malalignment or because the mechanical axis did not fall through the region of the planned cartilage restoration procedure. Patellar tracking was normal (<2 quadrants of patellar translation) in all knees. Finally, the medial and lateral menisci were at least partially preserved in all knees, with none having undergone total or subtotal meniscectomy.

Complications, Reoperations, and Failures

In total, 19 (25%) knees underwent reoperation after OCA: 11 (22%) in the ACL-intact group and 8 (32%) in the ACL-reconstructed group. Of these, 8 knees underwent procedures that did not require allograft removal or were unrelated to the index OCA. These included arthroscopic debridement, chondroplasty, or removal of loose bodies (n = 8); arthroscopic lysis of adhesions (n = 2); and removal of hardware (n = 2). One knee in the ACL-intact group sustained a postoperative septic joint after an arthroscopic lysis of adhesions. This was treated with arthroscopic irrigation and debridement. Two knees in the ACL-intact group required manipulation under anesthesia at an average of 2 months postoperatively for arthrofibrosis.

There were 10 documented failures: 8 (16%) from the ACL-intact group (2 partial graft removals, 1 revision OCA, 2 UKAs, and 3 TKAs) and 4 (16%) from the ACL-reconstructed group (4 TKAs). The mean time to failure was 2.7 years (range, 0.8-6.0 years) in the ACL-intact group and 3.4 years (range, 1.2-6.8 years) in the ACL-reconstructed group. OCA survivorship was 90% and 96% at 2 years and 79% and 85% at 5 years in the ACL-intact and ACL-reconstructed groups, respectively. Kaplan-Meier analysis revealed no significant differences in failure rates between groups (P = .774; Fig 2). Multivariate Cox regression analysis revealed that ACLR did not independently correlate with failure (P = .288), while age (P = .006, hazard ratio [HR] = 1.10 per increase in 1 year, 95% confidence interval [CI], 1.03-1.24) and number of prior surgeries (P = .023, HR = 1.64 per increase in one surgery, 95% CI, 1.22-3.45) independently correlated with failure (Table 2).

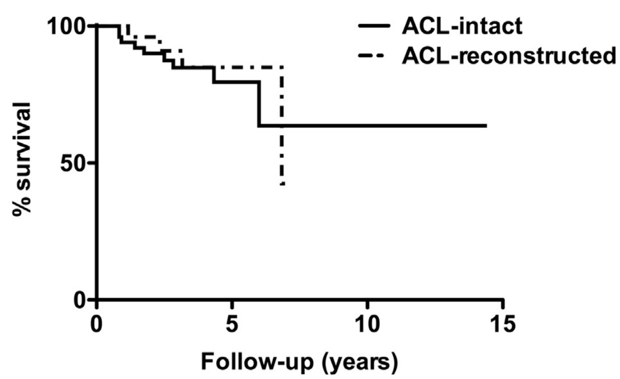

Fig 2. Survivorship of ACL-intact and ACL-reconstructed groups. Comparison between curves revealed no statistically significant difference (P = .156). (ACL, anterior cruciate ligament.)

Table 2. Multivariate Cox Regression Analysis for Failure

Covariate	Hazard Ratio	95% Confidence Interval	*P* Value
Age (per increase in 1 year)	1.10	1.03-1.21	.006
No. of prior surgeries (per increase in one surgery)	1.64	1.07-2.62	.023
Primary chondral defect location			.089
PF/LFC	10.79	1.11-308.99	.039
MFC/LFC	1.76	0.20-37.27	.621
ACL reconstruction (yes/no)	0.45	0.09-1.92	.288
Body mass index (per increase in 1 kg/m^2)	0.93	0.77-1.11	.456
Meniscectomy in same compartment as implanted OCA (yes/no)	1.5	0.23-13.27	.677
Sex (male/female)	1.19	0.20-9.55	.853

NOTE. ACL reconstruction is not independently associated with failure.

ACL, anterior cruciate ligament; LFC, lateral femoral condyle; MFC, medial femoral condyle; OCA, osteochondral allograft; PF, patellofemoral.

Outcome Scores

Comparison of SF-36 general health, pain, and physical functioning scores between the 2 groups revealed no significant differences at either the preoperative or postoperative time point. Similarly, comparison of IKDC, KOS-ADL, Cincinnati Knee Rating System, and Marx Activity Rating Scale scores between the 2 groups revealed no significant differences at either the preoperative or postoperative time point (Table 3). Postoperative SF-36 pain and physical functioning, IKDC, and KOS-ADL scores improved significantly from preoperative scores in both groups ($P < .003$ for all; Fig 3). The mean improvements in SF-36 pain and physical functioning scores were 20.3 and 20.3, respectively, in the ACL-intact group and 21.0 and 28.3, respectively, in the ACL-reconstructed group. These SF-36 physical functioning score improvements were above the reported MCID of 17.5.[38] The mean improvement in IKDC and KOS-ADL scores were 24.1 and 20.2, respectively, in the ACL-intact group and 19.2 and 16.0, respectively, in the ACL-reconstructed group. These IKDC and KOS-ADL score improvements were above the reported MCIDs of 16.7 and 10.6, respectively.[38,39] Postoperative symptom rating scale scores ($P = .020$ for ACL intact, $P = .011$ for ACL reconstructed) and patient perception of overall condition scores ($P < .001$ for ACL intact, $P = .010$ for ACL reconstructed) of the Cincinnati Knee Rating System improved significantly from preoperative scores in both groups. No significant differences in change scores were found between groups for any of the outcome measures ($P > .150$).

For patient activity level scores, postoperative change in the Marx Activity Rating Scale in the ACL-intact group was statistically significant ($P = .038$) but likely not clinically important (-1.3). Postoperative change in the Marx Activity Rating Scale in the ACL-reconstructed group was not significant ($P = .146$). Additionally, postoperative change in the sports activity scale of the Cincinnati Knee Rating System was not significant in either group ($P = .581$ for ACL intact, $P = .270$ for ACL reconstructed).

Discussion

The principal findings of this study are (1) OCA in the setting of prior or concomitant ACLR does not portend

Table 3. Comparison of Preoperative and Postoperative Outcome Scores Between Study Groups

	Preoperative Outcomes			Postoperative Outcomes*		
Outcome Measure	ACL Intact	ACL Reconstructed	*P* Value	ACL Intact	ACL Reconstructed	*P* Value
SF-36						
General health	73.8 ± 17.0	71.7 ± 18.3	.683	77.5 ± 18.2	79.6 ± 18.2	.517
Pain	54.3 ± 22.2	52.1 ± 21.1	.417	74.6 ± 24.1	73.1 ± 23.2	.700
Physical functioning	62.6 ± 17.6	53.8 ± 23.3	.153	82.9 ± 18.9	82.1 ± 17.4	.849
IKDC	43.6 ± 12.6	46.2 ± 16.0	.411	67.7 ± 19.2	65.4 ± 20.2	.727
KOS-ADL	63.2 ± 13.5	62.8 ± 16.2	.989	83.4 ± 10.4	78.8 ± 15.6	.340
Cincinnati Knee Rating System						
Sports activity scale	66.8 ± 30.0	64.1 ± 28.8	.872	74.0 ± 17.8	76.9 ± 23.0	.180
Symptom rating scale	4.0 ± 2.0	5.2 ± 2.2	.081	6.9 ± 2.2	6.2 ± 2.5	.385
Patient perception of overall condition	4.5 ± 1.4	3.8 ± 1.7	.089	7.1 ± 1.9	7.0 ± 2.0	.980
Marx Activity Rating Scale	5.8 ± 6.3	6.0 ± 6.4	.592	4.5 ± 4.7	4.4 ± 4.5	.948

NOTE. Values represent the mean and the standard deviation, in points.

ACL, anterior cruciate ligament; IKDC, International Knee Documentation Committee Subjective Knee Evaluation Form; KOS-ADL, Knee Outcome Survey— Activities of Daily Living; SF-36, Short Form-36.

*Scores at latest follow-up.

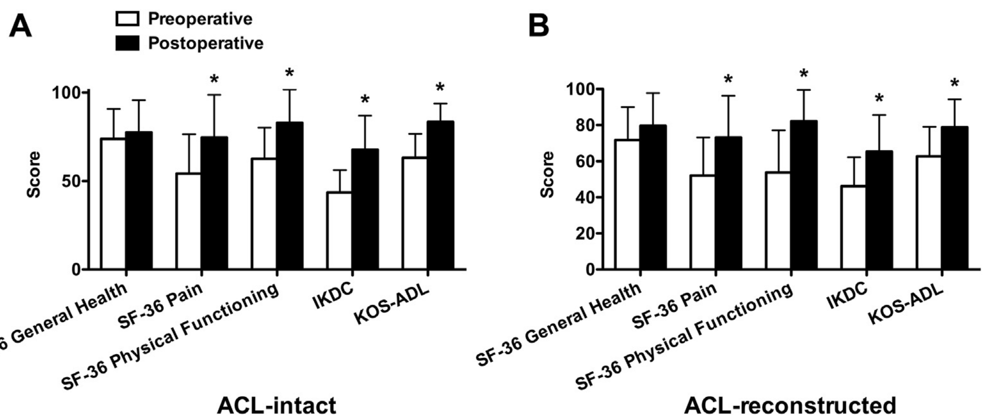

Fig 3. Comparison of preoperative and latest postoperative clinical outcome scores for (A) ACL-intact and (B) ACL-reconstructed groups. *Statistical significance compared with respective preoperative score. ACL-intact group: $P = .1895$ for SF-36 General Health; $P < .001$ for SF-36 Pain, SF-36 Physical Functioning, IKDC, and KOS-ADL. ACL-reconstructed group: $P = .059$ for SF-36 General Health; $P = .002$ for SF-36 Pain; $P < .001$ for SF-36 Physical Functioning, IKDC, and KOS-ADL. (ACL, anterior cruciate ligament; IKDC, International Knee Documentation Committee Subjective Knee Evaluation Form; KOS-ADL, Knee Outcome Survey—Activities of Daily Living; SF-36, Short Form-36.)

higher graft failure rates and (2) clinical outcomes after OCA are similar between patients with ACL-intact and ACL-reconstructed knees. The former finding was obtained while adjusting for age, sex, BMI, number of prior surgeries, primary defect location, and prior or concomitant meniscectomy in the same compartment as the implanted graft. This refutes the study's hypothesis that OCA in ACL-reconstructed knees exhibits higher failure rates and worse clinical outcomes compared with OCA in ACL-intact knees.

The concurrence of articular cartilage and ACL injuries is well recognized. In acute ACL injuries, cartilage damage likely occurs during the initial trauma. Conversely, in chronic ACL injuries, cartilage damage may be caused by several factors including aberrant knee biomechanics and mechanical damage from recurrent episodes of instability. Many studies have identified articular cartilage damage as one of the most important predictors of poor outcomes after ACLR.[9-11] However, although few clinicians would dispute the need to address a focal chondral defect within an ACL-injured knee, the current literature on combined articular cartilage repair and ACLR is mostly limited to small case series.[14-18,40] Several groups have reported their results after combined OAT and ACLR. Klinger et al.[18] reported a case series of 21 patients who underwent combined OAT and ACLR with bone-patellar tendon-bone graft. The average time from ACL injury to operation was 10 months. At a mean follow-up of 38 months, Lysholm and Tegner had significantly improved, and 90% of patients had returned to full activities. Gudas et al.[13] prospectively randomized patients diagnosed with medial femoral condyle chondral defects and ACL injury to OAT, microfracture, or debridement combined with ACLR. Each group contained 34 patients. Average time from ACL injury to operation was 19 months. At a mean follow-up of 36 months, combined OAT and ACLR patients reported superior subjective IKDC scores than combined microfracture or combined debridement and ACLR patients. The results of these studies suggest that OAT in the setting of ACLR offers good intermediate-term results. However, for larger defects in which OAT is not an option, OCA still offers a solution that involves the replacement of full-thickness cartilage defects with mature, functional hyaline cartilage.

Although prior studies have reported favorable outcomes following combined OCA and meniscus transplantation or osteotomy,[41-43] no studies have specifically examined outcomes following combined OCA and ACLR. The majority of published OCA case series describe very few patients who received concomitant ACLR, even fewer than those who received concomitant meniscus transplantation or high tibial osteotomy.[3,7,44,45] Thus, surgeons currently may be reluctant to perform this combined procedure. Additionally, while some of these studies consider the number of previous surgeries to the ipsilateral knee as a potential risk factor, none report the percentage of knees with prior ACLR. In 2 large case series consisting of more than 120 OCA patients each, Levy et al.[3] and Frank et al.[7] report that an increased number of prior surgeries correlates with failure. However, the majority of prior operations described in the Levy et al. study were chondral debridement and drilling/microfracture (and no ACLR), whereas the types of prior operations were not specified in the Frank et al. study. Similarly, in our multivariate analysis, an increased number of prior surgeries correlated with a higher risk of failure, but ACLR did not. This suggests that ACLR does not negatively affect the outcomes of OCA, although prospective studies with longer-term follow-up are needed to confirm this finding.

This study's initial hypothesis was based on existing knowledge that increased contact stresses still remain in the knee after ACLR. Given our results, it may be possible that ACLR sufficiently limits the forces below the threshold levels needed for osteochondral grafts to fail. In a cadaver study, Imhauser et al.[19] reported that the increased mean contact stresses in the posterior sectors of the medial and lateral compartments in the ACL-deficient knee were reduced with ACLR. However, with combined abduction and internal rotation moments, abnormal contact stresses after ACLR were still observed across all loading conditions and flexion angles, with increases in contact pressures of up to 52%. Current research on the long-term survival of OCA has focused on the intrinsic biologic attributes of the graft, such as chondrocyte viability and extracellular matrix homeostasis,[46,47] whereas the extrinsic risk factors, such as mechanical loading across the graft, have not been extensively studied. More work on the biomechanical modes of osteochondral graft failure is needed to identify which knees, despite correction of any ligamentous instability, meniscal deficiency, or malalignment, would be unsuitable for OCA.

Limitations

As with any retrospective study, patients were not randomized to the treatment groups, which may have introduced selection bias. Despite the lack of randomization, the patient groups were matched and had comparable demographics and baseline scores. No differences in age and number of prior surgeries, which have been shown in other studies to affect outcomes,[3,7] were detected between groups. The ACL-reconstructed group was heterogenous with regards to the timing of ACLR to OCA and whether a primary or revision ACLR was performed. Nevertheless, all of these knees theoretically share the same characteristic of having aberrant kinematics and increased contact forces. Additionally, while the inclusion of revision ACL-reconstructed knees, which typically are more unstable with higher shear loads to the articular surfaces, would be expected to further increase failure rates in the ACL-reconstructed group, this was not the case. Cartilage injuries in the ACL-reconstructed group were likely sustained during the initial trauma or over a period of chronic instability, whereas those in the ACL-intact group may have more nontraumatic origins, such as osteochondritis dissecans or avascular necrosis. Volume loss from prior or concomitant meniscectomy was not assessed; this may better correlate with the risk of graft failure than simply with whether or not a prior meniscectomy was performed. Patients in both groups consisted of an assortment of femoral condyle, trochlea, and patella OCAs. Although the outcomes following patellofemoral OCA were traditionally thought to be suboptimal, recent studies suggest high survivorship (80%-92% at 10 years) and high patient satisfaction.[4,5] Furthermore, due to evidence of increased patellofemoral chondrosis after ACLR,[24] patients treated with patellofemoral OCA still fit within the context of this study and thus were included in the analysis. The definition of failure used in this study (any subsequent procedure involving removal or revision of the allograft, UKA, or TKA) is consistent with that used in most published studies on OCA.[3,5,6,41,42,48,49] However, a more appropriate definition of failure in a young, athletic patient population would be a failure to achieve an MCID on patient-reported outcome measures. Currently, MCIDs for the IKDC and KOS-ADL in patients treated using osteochondral grafts do not exist; the MCID for the IKDC reported by Greco et al.[38] (and used in this study for the power analysis) was derived from patients treated with other cartilage procedures (debridement, shaving, drilling, abrasion arthroplasty, microfracture, ACI, and cell therapy) that have vastly different indications and outcomes compared with OCA. Moreover, the KOS-ADL has not yet been validated for articular cartilage disorders in the knee. Clearly, more work is needed to validate and define an MCID for these outcome measures in patients treated with OCA.

Conclusions

OCA in the setting of prior or concomitant ACLR does not portend higher failure rates or compromise clinical outcomes.

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