Survivorship of Patellofemoral Osteochondral Allograft Transplantation

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Introduction: We performed a survivorship analysis of patients treated with patellofemoral osteochondral allograft transplantation (OCA) using either a shell or plug technique and identified variables associated with graft failure. **Methods:** Consecutive patients at two institutions who underwent OCA of the patellofemoral compartment between March 1, 2001 to March 1, 2015, were retrospectively identified at minimum 2 years' follow-up. Demographic information, intraoperative findings, and postoperative data were collected. Patients were divided into two groups on the basis of surgical technique (plug group and shell group). Failure was defined as revision OCA, conversion to arthroplasty, or gross appearance of graft degeneration on second-look arthroscopy. Logistic regression analysis was performed to identify patient- and surgery-specific variables associated with survivorship. **Results:** Fifty patients were identified (36 women and 14 men; mean age 37.43 ± 8.87 years). Sixteen patients received plug allografts, whereas 34 received shell allografts. Forty percent of patients underwent a concomitant meniscal, ligamentous, malalignment, or chondral procedure. Five patients in the Plug Group (31.3%) underwent reoperation at a mean 1.37 ± 1.34 years, and 28 patients (82.4%) who received Shell OCA underwent reoperation at a mean 1.94 ± 1.92 years. Two patients in the plug group had graft failure at a mean 9.17 ± 0.93 years, whereas 13 patients in the shell group had graft failure at a mean 3.81 ± 2.78 years. Patients with plug allografts demonstrated 100% and 66% survival at 5 and 9.8 years, respectively. For the shell group, survivorship was 65.8% and 37% at 5 and 10.6 years, respectively. Increasing body mass index was associated with failure for the case series overall (odds ratio 1.33, $P = .020$). Traumatic cause was found to be protective of failure (odds ratio = 0.02, $P = .035$). **Conclusions:** Plug OCA of the patellofemoral compartment can be an efficacious procedure with quality midterm outcomes. Shell OCA led to high failure rates at midterm outcomes. Increasing body mass index may predispose patients to failure, whereas traumatic cause of their lesion was associated with improved outcomes. **Level of Evidence:** Level IV, Therapeutic case series.

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Lesions of articular cartilage in the patellofemoral compartment of the knee are a relatively common, often leading to anterior knee pain in patients.[1-3] The anatomy of the patella and its mobility create a therapeutic challenge for microfracture and debridement techniques given the difficulty in creating stable, vertical walls and avoidance of exposing subchondral bone, which has been linked to subchondral cyst formation and poor outcomes.[1,3,4] Surgical options such as debridement, microfracture, and osteochondral autograft transfer are indicated primarily for smaller lesions, generally <2 cm^2. Microfracture has been shown to have poor durability beyond 2 years in the patellofemoral joint because of the high shear stresses and inferior biomechanical properties of fibrocartilage compared to native hyaline cartilage.[5,6] In the young, active patient with a focal large (≥ 2 cm^2) patella, trochlea articular cartilage defects, or both, two surgical

techniques have been studied: autologous chondrocyte implantation (ACI) and osteochondral allograft transplantation (OCA).[7-18]

OCA is a single-stage procedure that has gained interest as a therapeutic option in the patellofemoral compartment that restores the articular surface with hyaline cartilage and underlying subchondral bone injury. Different OCA techniques have been described for treatment of large patellofemoral lesions, including dowel-plug grafts for focal lesions and shell allografts for uncontained lesions.[10-13] The shell grafts used for uncontained lesions are typically much larger than dowel plug allografts and therefore can be used to replace much larger areas with a single graft. A recent publication looked specifically at patients treated with patellofemoral OCA of both the trochlea and patella concomitantly for "bipolar" lesions, noting excellent short-term outcomes.[19] Many of the previously published studies have reported a wide range of failure rates for patellofemoral OCA (0% to 42%) yet improved subjective outcome scores and satisfaction in patients who did not have graft failure.[10-13] Variables associated with successful OCA in these patients have not been well defined. The purpose of this study was to perform a survivorship analysis of patients treated with patellofemoral osteochondral allograft transplantation (OCA) with either a shell or plug technique and identify variables associated with graft failure. The authors hypothesize that patients treated with shell OCA and dowel-plug OCA will have acceptable survivorship.

It is not a purpose of this study to directly compare the two techniques given the difference in indications. While the pathology for plug OCA is different than shell OCA, namely focal, contained lesions for plug OCA as compared to uncontained lesions for shell OCA, both OCA techniques were included in this study to evaluate if one, neither, or both techniques have acceptable survivorship to better define surgical indications going forward.

Methods

After institutional review board approval, consecutive patients who underwent fresh osteochondral allograft transplantation for restoration of articular cartilage defects within the patellofemoral joint by two knee surgeons, each with more than 20 years of cartilage restoration experience (B.J.C., J.F.) at two institutions (Midwest Orthopaedics at Rush and OrthoIndy), were retrospectively identified. All patients were evaluated and managed by the two board-certified orthopaedic knee surgeons as part of their practice. Patients undergoing OCA for International Cartilage Restoration Society grade III or IV chondral defects of the patella, femoral trochlea, or combined patella and trochlea between March 1, 2001, and March 1, 2015, with minimum 2 years' follow-up were included. Patients in this time period who had graft failure within 2 years of surgery were also included in the analysis so as not to underreport survivorship. Indications for dowel-plug OCA included focal, symptomatic chondral defects in the patellofemoral compartment refractory to nonoperative treatment or previous surgical intervention. Indications for shell OCA included extensive damage to both patellar facets and median ridge and uncontained lesions of the trochlea. Patients were not excluded for having undergone previous ipsilateral knee surgery. Exclusion criteria were applied to any patients with the following: medication-induced avascular necrosis, isolated OCA at a site other than the patella or femoral trochlea, and patients who underwent prior subchondroplasty at the site of OCA due to more guarded prognosis with compromise of the subchondral bone. Patients were not excluded for undergoing concomitant procedures at the time of OCA, including corrective realignment osteotomy, concomitant OCA in the tibiofemoral joint, meniscal allograft transplantation, previous cartilage reparative procedures of the patellofemoral compartment, meniscectomy, or ligamentous reconstruction.

Demographic information, medical, or surgical history, intraoperative findings, and postoperative data were collected. All patients were contacted to collect updated reoperation and treatment failure information via phone call or in clinic. Patients were divided into two separate groups on the basis of surgical technique (shell group and plug group).

Reoperations and complications were analyzed for all groups with the reoperation rates, time to reoperation, procedure performed, and findings at time of reoperation noted. Major complications were considered deep infection, complex regional pain syndrome, and stiffness requiring surgical lysis of adhesions. Reoperation was defined as any procedure performed after the index surgery in which a patient was taken to the operating room, including second-look arthroscopy, surgical debridement, chondroplasty, hardware removal, revision OCA, or conversion to knee arthroplasty. Indications for second-look arthroscopy included stiffness, mechanical symptoms, and pain either from a traumatic event on the surgical knee or persistent pain after surgery. Failure was defined as revision OCA, conversion to arthroplasty, or gross appearance of graft degeneration on second-look arthroscopy. Survivorship was defined as any patients who did not meet the failure criteria above at time of final follow-up.

Surgical Technique

For patients with focal, contained lesions of the patellofemoral compartment, dowel-plug OCA was the preferred technique. In brief, with the patient supine on the operating table and under general anesthesia, diagnostic arthroscopy was first performed to confirm the

chondral or osteochondral defect, as well as any concomitant pathology. If concomitant procedures such as meniscectomy, meniscal allograft transplantation, ligamentous repair or reconstruction, or osteotomy are indicated, these procedures were performed before OCA to protect the graft. A lateral or medial parapatellar mini-arthrotomy was performed, and the patella was retracted with a Z-retractor exposing the defect site on either the trochlea, patella, or both (Fig 1).

At that point, the fresh osteochondral allograft was prepared on the back table in room-temperature sterilized saline solution. A cannulated, cylindrical sizing guide was placed flush on the defect(s) to quantify lesion size. A guide pin was then drilled through the sizing guide into the appropriate locations. The sizing guide was removed, and a cannulated bone reamer was placed over the guide pin and used to ream to a depth of approximately 6 mm (Fig 2).

A ruler was used to measure the depth of the reamed socket at the 3, 6, 9, and 12 o'clock positions. On the back table, a metal bushing corresponding to the diameter of the patient defect(s) was placed flush on the donor allograft at the appropriate location(s) and held in place by an assistant. A donor harvester was used to create a cylindrical allograft matching the reamed diameter. The resultant osteochondral allograft plug(s) were then cut to the corresponding depths at 3, 6, 9, and 12 o'clock using a sagittal saw. A pulsatile lavage with bacitracin-mixed sterile saline solution was used to irrigate the plug grafts. Each plug was then press-fit by hand and firmly impacted flush into place using an oversized tamp (Fig 3).

Shell Technique

Patella

The approach was the same as for the plug technique. For patellar shells, the patient's patella was freehand cut with an oscillating saw cooled with saline solution in the same manner as for patellofemoral arthroplasty (PFA)/total-knee arthroplasty patellar resurfacing. A minimum of 12 mm of patient's bone was maintained to decrease fracture risk, and a maximum of 15 mm was retained to avoid overstuffing. The cut was checked for flatness. Any areas of dense sclerotic bone were drilled with a 1/16-inch drill bit. The allograft patella was rinsed and held with a "lobster-claw" patellar clamp (DePuy Synthes, Raynham, MA). The patella was marked for a lateral and medial composite thickness of approximately 6 mm. An oscillating saw cooled with saline solution made the cut, resulting in the median ridge thickness of approximately 12 mm. The bone was checked for flatness, and bone was drilled with a 1/16-inch drill bit. If the donor patella is smaller than the patient's, the patient's bone is trimmed and vice versa if the donor patella is larger. This mismatch is typically less than 10 mm with current preoperative sizing. The donor bone was copiously flushed with saline pulsatile lavage, applied to the patient's patellar bed, and held with Kirschner wires. These wires were sequentially overdrilled and tapped. Twin-pitch headless bioabsorbable screws were inserted for compression and buried 2 to 4 mm deep to the articular cartilage surface.

Trochlea

When a macro plug was not feasible because of widespread chondral damage, a shell was considered. The patient cut was lateral to medial beginning flush, with the femur proximal to the trochlea and continuing to the level of normal cartilage, usually 1 cm proximal to the roof of the notch where the composite depth was 6 mm centrally in the trochlea. An anterior-to-posterior oblique cut was made perpendicular to the local trochlea at the level the first cut ended, which was typically 1 cm proximal to the roof of the notch. That cut freed the fragment (Fig 4A). The donor trochlea was cut in the same manner to match the recipient site. Because this was done freehand, the donor was intentionally cut larger than the recipient site, and then the cuts were gradually fine-tuned until there was a smooth match at the cut interface (Fig 4B). Because the recipient was often dysplastic and the donor had normal morphology, a perfect confluence might not be possible. In that setting, fine-tuning of the cuts allowed matching of the trochlea donor/recipient laterally and centrally as the patella entered the trochlea lateral to the midline and then coursed centrally with flexion (Fig 4C).

Rehabilitation Protocol

The two surgeons have differing rehabilitation philosophies detailed in separate paragraphs below. Patients were heel-touch weightbearing for the first 6 weeks after surgery if no tibial tubercle osteotomy was performed and weightbearing as tolerated otherwise as long as there was no concomitant tibiofemoral procedure that would otherwise require protected weightbearing. A hinged knee brace locked in full extension was worn for the first 2 weeks and was only removed for physical therapy. After 2 weeks, the brace was discontinued to allow progressive increase in range of motion (ROM) and exercises, especially quadriceps, hamstring, and glute strengthening. ROM is protected for the first 6 weeks. Specifically, flexion was limited to 0° to 30° for the first 2 weeks, then 0° to 60° weeks 2 to 4, and 0° to 90° weeks 4 to 6. After week 6, full ROM was encouraged, and patients are permitted to bear weight as tolerated. At 12 weeks, patients may advance activities to include elliptical training, stationary cycling, and pool-based exercises. After 6 months, patients could return to full functional activity; however, return to sport-specific and high-impact activity was typically limited until after 8 months.

After surgery, the patients were in full extension in a knee immobilizer, which was removed 8 hours per day

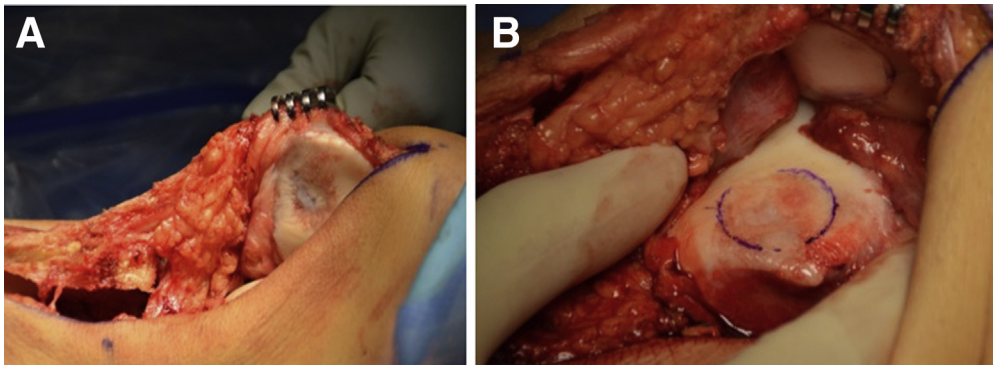

Fig 1. (A) Intraoperative image of a focal chondral defect of the lateral facet of the left patella in a 33-year-old male patient. (B) Intraoperative image of a focal chondral defect of the lateral aspect of the trochlea of the left knee of the same 33-year-old patient.

for continuous passive motion, with the goal of increasing ROM as rapidly as possible as comfort allowed. Full motion was encouraged by 6 to 8 weeks. The patients performed a core-to-floor rehabilitation program as weightbearing and ROM allowed. Weightbearing was dictated by concomitant procedures: if tibial tubercle anteromedialization was performed, then weightbearing was minimal for 6 weeks; if no tubercle surgery was performed, then weightbearing as tolerated was allowed with the knee in extension in the immobilizer. After 6 weeks the program followed the protocol above, except that patients were asked to avoid stairs for 6 months.

Statistical Analysis

Statistical analysis consisted of descriptive statistics, univariate logistic regression, and survival analysis. Univariate logistic regression analysis was performed to evaluate for demographic, preoperative, and operative variables for associated with failure of OCA. Odds ratios (OR) with corresponding 95% confidence intervals (CI) were reported for univariate regression analysis. Kaplan-Meier survival curves were generated for each group. The analysis assumed a nonparametric distribution of time-dependent survival, similar behavior between procedures that were performed at different time points, and similar survival behavior between uncensored (those patients who had not yet met failure criteria) and censored (those patients who had met failure criteria). All reported P values are 2-tailed, with an α level set at 0.05 for statistical significance (Stata 13.0 for Mac; StataCorp, College Station, TX).

Results

Demographics

Of the 63 consecutive patients who underwent patellofemoral OCA during the study period, 50 patients met inclusion criteria of minimum 2-year follow-up (36 women; mean age 37.43 $\pm$ 8.87 years). The 13 patients were excluded due to lack of 2-year follow-up information. Sixteen patients received plug allografts, whereas 34 received shell allografts. Patients who received shell allografts were older (39.75 $\pm$ 8.97) than those receiving plug allografts (32.50 $\pm$ 6.47). Seven patients in the plug group underwent isolated patellar OCA (n = 4) or isolated trochlea OCA (n = 3), and one patient received bipolar patellofemoral allografts. The remaining eight patients underwent concomitant femoral condyle OCA with either a patella or trochlear allograft. In the shell group, 16 patients received isolated patellar allografts, 2 received isolated trochlear allografts, 3 received bipolar patellofemoral allografts with concomitant medial femoral condyle allograft, 1 received a trochlea allograft with concomitant lateral femoral condyle and lateral tibial plateau allografts, and 12 received isolated bipolar patellofemoral allografts. Ten (29.4%) of the patients in

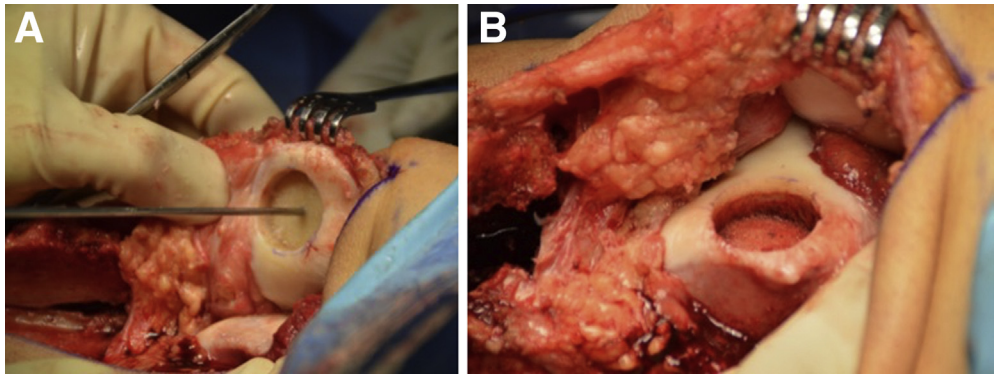

Fig 2. (A) Intraoperative image of the left lateral patella defect reamed to a depth of approximately 6 mm. (B) Intraoperative image of the left lateral trochlea defect reamed to a depth of approximately 6 mm.

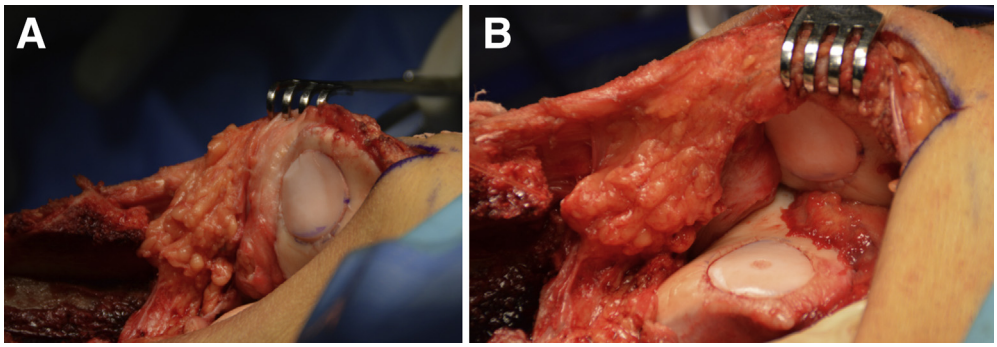

Fig 3. (A) Intraoperative image demonstrating a flush press fit of a single osteochondral allograft plug into the left lateral patella defect. (B) Intraoperative image demonstrating a flush press fit of a single osteochondral allograft plug into the left lateral trochlea defect with the patella osteochondral allograft plug visible in the background. This male patient received bipolar or "kissing" grafts.

the shell group and two (12.5%) of the patients in the plug group underwent concomitant tibial tubercle anteromedialization. Complete demographic, preoperative, and operative data are shown in Table 1.

Complications and Reoperation

Five patients in the plug group (31.3%) underwent reoperation at a mean 1.37 ± 1.34 years. Reasons for reoperation included arthroscopic irrigation and debridement for infection (n = 1), chondroplasty of the medial femoral condyle (n = 2), second-look arthroscopy for postoperative pain with no identified graft defect (n = 1), and hardware removal for concomitant high tibial osteotomy (n = 1). In the shell group, 28 patients (82.4%) underwent reoperation at a mean 1.94 ± 1.92 years. Reoperations included patellofemoral arthroplasty (n = 7), second-look arthroscopy with chondral debridement and an intact graft (n = 7), total knee arthroplasty (n = 6), hardware removal from osteotomy (n = 4), second-look arthroscopy (n = 2), and lysis of adhesion (n = 1), and microfracture of a femoral condyle (n = 1).There were no intraoperative complications. Three patients (6.0%) experienced postoperative complications. In the plug group, two patients (12.5%) experienced postoperative complications. One patient experienced a deep infection requiring an arthroscopic irrigation and debridement and intravenous antibiotics, and one patient experienced a superficial infection treated with oral antibiotics. In the shell group, one patient (2.9%) experienced a postoperative complication. This patient developed intra-articular adhesions requiring an arthroscopic lysis of adhesions.

Survivorship

Survival analysis was also performed based on surgical technique, plug (n = 16) and shell (n = 34). This analysis was not possible for each OCA location within each technique group due to sample size (Fig 5). In the plug group, 2 patients (12.5%) failed at a mean 9.17 ± 0.93 years after OCA. Cause of failure was chondral failure of the allograft in one patient who was recommended arthroplasty by an outside surgeon, and the other patient experienced progression of tibiofemoral osteoarthritis and underwent total knee arthroplasty. In the shell group, 13 patients (38.2%) failed at a mean 3.81 ± 2.78 years after OCA. Cause of failure was chondral failure of the allograft in five patients, allograft bone failure after prior bone healing in four patients, combined chondral failure an allograft bone failure in one patient, and progression of tibiofemoral osteoarthritis symptoms and chondrosis in three patients. In the shell group, seven patients were converted to patellofemoral arthroplasty and six patients were converted to total knee arthroplasty.

Kaplan-Meier survival analysis was performed to demonstrate in survivorship plug and shell groups. The plug group was found to have estimated survival rates of 100.0% and 66.0% at 5 and 9.8 years after surgery, respectively. The shell group was found to have an estimated survival of 65.8% and 37.0% at 5 and 10.6 years after surgery, respectively.

Logistic regression analysis was performed to assess for variables associated with failure within the entire cohort and the shell group, but the plug group was not large enough individually to conduct meaningful analysis. Variables evaluated included age, sex, body mass index (BMI), number of prior surgeries, cause of disease, symptom duration (years), major concomitant surgery, and defect size (Table 2). Within the entire case series, increased BMI was found to be associated with failure (OR = 1.33, $P = .020$), whereas traumatic cause was found to be protective for failure (OR = 0.02, $P = .035$). Within the shell group, increased BMI was found to be associated with failure (OR = 1.55, $P = .037$). No other variables were found to be associated with failure.

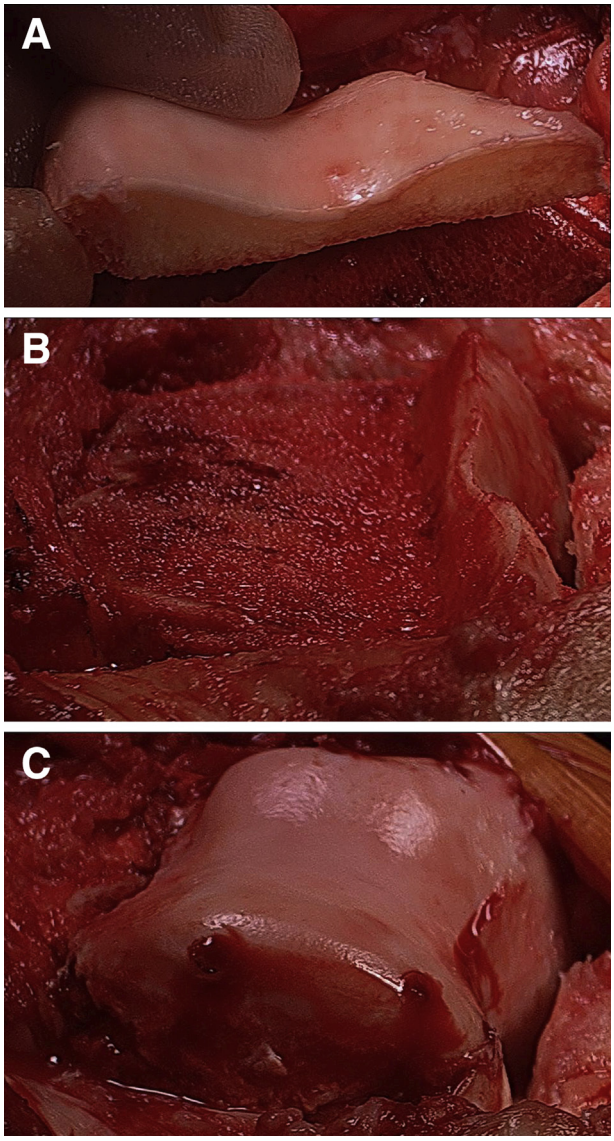

Fig 4. (A) Intraoperative photo demonstrating a cut right knee trochlea osteochondral allograft. (B) Demonstrates the cut right knee recipient trochlea that is ready to receive a shell osteochondral allograft transplant. (C) Final fixation of a right knee trochlea graft using bioabsorbable screws at the margins. Note that screws are counter-sunk approximately 2 to 4 mm below level of the cartilage.

Discussion

The principle findings of this study demonstrate a relatively high reoperation rate (31.3%) but an excellent 5- and 9.8-year survival of plug technique OCA of the patellofemoral compartment. However, patients with uncontained patellar or trochlear lesions treated with shell OCA had a high reoperation rate (82.4%) and poor survivorship of 65.8% and 37% at 5 and 10-years, respectively. Regression analysis demonstrated that increasing BMI was associated with a higher odds of failure, whereas traumatic cause of osteochondral pathology was protective against failure.

In 2013, Noyes and Barber-Westin[18] summated the literature in a systematic review regarding the treatment of advanced patellofemoral cartilage lesions in patients under age 50 and in whom the patellar defect was $\geq$4 cm^2, which included ACI, OCA, and PFA. The authors noted inconsistent outcomes and high complication and reoperation rates across all procedures because the percentage of patients who did not receive a benefit was 22% for PFA, 53% for OCA, and 8% to 60% for ACI.[18] Since this study, others have commented on the challenges of patellofemoral OCA. Lattermann et al.[14] recently stated how the anatomy and curvature of both the femoral trochlea and patellar facets make donor graft sizing and preparation exceedingly difficult, which may also influence outcomes. While exciting new research into improving the matching process for patellofemoral OCA grafts continues to be performed,[20] currently, graft matching and preparation can be quite challenging for surgeons using a plug technique to attain the curvature desired to restore smooth articulation.

Jamali et al[11] published a study in 2005 of 20 OCA procedures to the patellofemoral compartment, 12 of which were bipolar grafts and 8 that were isolated patella, but only 18 total operative reports were available for review. Fifteen patients underwent shell OCA of the patella, and three underwent plug OCA; although no survivorship analysis was done between the shell and plug techniques, there were 5 total failures (25%) and a 67% 10-year survival rate.[11] The current study demonstrated a high failure rate of patients treated with shell OCA (38.2%) and discouraging 5- and 10-year survival rates. In contrast, patients treated with plug OCA had comparable failure rates and 5- and 10-year survivorship compared with recently published series.[21,22] More recently, Mirzayan et al.[19] published a case series of 15 patients treated with bipolar plug technique OCA of both the patella and trochlea at minimum 1-year follow-up. The mean age was 28.9 years, and four patients underwent concomitant OCA to either the medial (n = 2) or lateral (n = 2) femoral condyles. All patients also underwent medial patellofemoral ligament reconstruction. The authors reported that all 15 patients had graft survival at final follow-up at a mean 32.2 months. In addition, there were significant improvements in all patient-reported outcomes scores from preoperative levels. This study contained a single patient treated with plug technique bipolar OCA for a focal osteochondral lesions caused by recurrent patellar dislocations. This was a 27-year-old woman who did not require any reoperations or complications at final 2.32-year follow-up. In the shell group, 15 patients received bipolar shell grafts. Twelve (80%) patients underwent reoperation, and two (13.3%) went on to undergo total knee arthroplasty. The remaining 10 patients who underwent reoperation

Table 1. Patient Demographic, Preoperative, and Intraoperative Variables for All Patients, Dowel-Plug, Shell Osteochondral Allograft Transplantation

	All Patients (n = 50)	Plug (n = 16)	Shell (n = 34)
Age (Years)	37.43 ± 8.87	32.50 ± 6.47	39.75 ± 8.97
BMI, kg/m^2	27.68 ± 6.31	25.97 ± 3.43	28.63 ± 7.32
Kellgren-Lawrence Grade	0.71 ± 0.77	0.90 ± 0.88	0.64 ± 0.73
Side			
Left	21 (42.0%)	6 (37.5%)	15 (44.1%)
Right	29 (58.0%)	10 (62.5%)	19 (55.9%)
Sex			
Female	36 (72.0%)	7 (43.7%)	29 (85.3%)
Male	14 (28.0%)	9 (56.3%)	5 (14.7%)
Workers' Compensation	8 (16.0%)	6 (37.5%)	2 (6.0%)
Symptom duration (Years)	6.23 ± 5.14	5.24 ± 4.09	6.71 ± 5.58
Follow-up (Years)	4.85 ± 2.83	4.87 ± 2.71	4.84 ± 2.93
No. of previous surgeries	2.73 ± 2.00	2.81 ± 1.64	2.69 ± 2.18
No. of OCA sites	1.68 ± 0.82	1.88 ± 0.96	1.59 ± 0.74
Allograft Sites			
Isolated Patella	20 (40.0%)	4 (25.0%)	16 (47.1%)
Isolated Trochlea	5 (10.0%)	3 (18.8%)	2 (5.9%)
Patella and Trochlea	13 (26.0%)	1 (6.3%)	12 (35.3%)
Patella, Trochlea, MFC	3 (6.0%)	0 (0.0%)	3 (8.8%)
Trochlea and MFC	4 (8.0%)	4 (25.0%)	0 (0.0%)
Trochlea and LFC	2 (4.0%)	2 (12.5%)	0 (0.0%)
Trochlea, LFC, LTP	3 (6.0%)	2 (12.5%)	1 (2.9%)
Defect Area, (cm^2)	7.47 ± 4.78	7.17 ± 5.29	7.63 ± 4.57
Major concomitant surgery			
Lateral Release	4 (8.0%)	0 (0.0%)	4 (11.8%)
AMZ	12 (24.0%)	2 (12.5%)	10 (29.4%)
Microfracture			
Trochlea	1 (2.0%)	0 (0.0%)	1 (2.9%)
Patella	1 (2.0%)	1 (6.3%)	0 (0.0%)
LTP	1 (2.0%)	1 (6.3%)	0 (0.0%)
ACL Reconstruction	4 (8.0%)	2 (12.5%)	2 (5.9%)
Meniscal Transplant	6 (12.0%)	5 (31.3%)	1 (2.9%)
HTO	1 (2.0%)	0 (0.0%)	1 (2.9%)
DFO	0 (0.0%)	0 (0.0%)	0 (0.0%)
No. of reoperations	1.10 ± 1.05	0.44 ± 0.73	1.41 ± 1.05
Time to first reoperation (Years)	1.85 ± 1.84	1.37 ± 1.34	1.94 ± 1.92

ACL, Anterior cruciate ligament; AMZ, tibial tubercle anteromedialization; BMI, body mass index; DFO, distal femoral osteotomy; HTO, high tibial osteotomy; LFC, lateral femoral condyle; LTP, lateral tibial plateau; MFC, medial femoral condyle; OCA, osteochondral allograft transplantation.

predominantly underwent second-look arthroscopy with intact OCA. The results of this study demonstrate a higher reoperation and failure rate for patients with shell OCA as compared with the study by Mirzayan et al.,[19] suggesting that bipolar OCA may be more efficacious in patients with focal defects amenable to plug OCA. In a comprehensive systematic review by Chahla et al.[23] from 2018, eight studies containing a total of 129 patients who received patellofemoral OCA including shell technique or dowel-plug technique were reviewed at a minimum 18 months' follow-up. Most of these 129 patients received dowel-plug allografts. The authors reported overall good survivorship at 5 years (87.9%) and 10 years (77.2%) in addition to significant improvements in patient-reported outcome measures from preoperative to postoperative status. Subanalysis of survivorship and clinical outcome by patellofemoral OCA technique was not performed. The survivorship of plug OCA in this study, 100.0% and 66.0% at 5 and 9.8 years, respectively, corroborates the survivorship results of the study by Chahla et al.[23]

Several recent series have been published about patients who underwent either isolated patellar OCA or isolated trochlea OCA. Cameron et al.[12] and Gracitelli et al.[13] published separate case series of isolated trochlea OCA and isolated patellar OCA in the largest single cohorts to date. Gracitelli et al.[13] identified 28 knees in their database with minimum 2-year follow-up who underwent isolated patellar OCA with shell technique for lesions >10 cm^2 and plug technique for lesions <10 cm^2. Although subanalysis between shell and plug was not conducted, the authors reported an overall survival rate of 78.1% at 5 and 10 years. In addition, patients reported significant improvement in all patient-reported outcome scores at final follow-up. Similarly, Cameron et al.[12] reported a series of 29 knees who

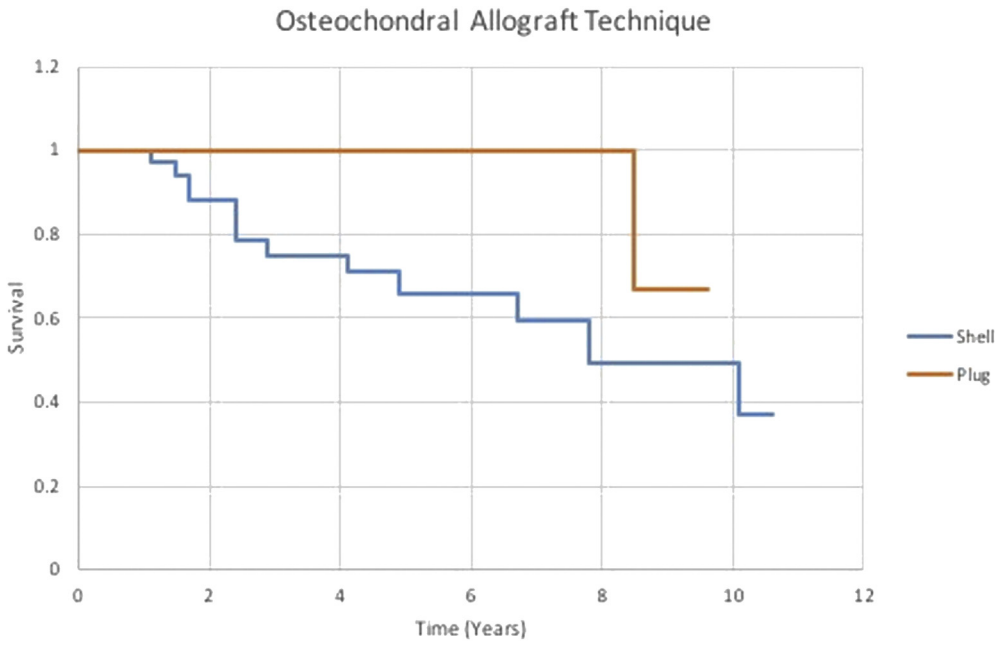

Fig 5. Kaplan-Meier Survival Curve of patellofemoral osteochondral allograft transplantation by technique. In the plug technique (red curve), two patients failed at a mean 9.17 ± 0.93 years. Survival probabilities 100.0% and 66.0% at 5 and 9.8 years after operation, respectively. The Shell Group was found to have an estimated survival of 65.8% and 37.0% at 5 and 10.6 years postoperatively, respectively.

underwent isolated trochlea OCA with a follow-up of 7 years (range 2.1-19.9). The authors noted graft survivorship of 100% at 5 years and 91.7% at 10 years. The mean age in this series was 30.2 years,[12] and the mean age in the series by series by Gracitelli et al.[13] was 33.7 years, significantly younger than shell group in this study but comparable to the plug group. The younger age of patients in these two studies highlight the importance of early identification and treatment of patellofemoral chondral lesions. This study did not corroborate these findings because no association between patient age or symptom duration was found to be associated with survivorship of OCA. However, traumatic cause was shown to be protective of failure in this study. This may be attributable to fewer degenerative changes within the knee and an earlier time to treatment.

It is our experience that many of these patients suffer from concomitant injury including but not limited to focal chondral lesions in the tibiofemoral compartments, malalignment, maltracking of the patella, and meniscal deficiency. This has been well described by others, including Chahla et al.[23] in their systematic review. A significant number of patients in this study were treated for concomitant pathology at the time of

Table 2. Univariate Logistic Regression Analysis of Demographic, Preoperative, and Operative Variables Associated With Failure of Patellofemoral Osteochondral Allograft Transplantation

Factor	Odds Ratio (β)	95% CI	*P* Value
Risk factors for failure for overall cohort			
Age	1.06	0.90−1.24	.492
Sex	0.76	0.07−8.61	.824
BMI	1.33	1.04−1.69	.020
No. of prior surgeries	0.62	0.25−1.53	.295
Traumatic cause	0.02	<0.01−0.77	.035
Symptom duration	1.23	0.97−1.58	.094
Major concomitant surgery	1.36	0.09−19.73	.820
Defect size	1.00	0.99−1.00	.327
Risk factors for failure for shell grafts			
Age	1.14	0.83−1.58	.419
Sex	0.24	<0.01−36.41	.578
BMI	1.55	1.04−2.32	.037
No. of prior surgeries	0.55	0.14−2.20	.399
Traumatic cause	0.02	<0.01−3.25	.130
Symptom duration	1.36	0.91−2.02	.131
Major concomitant surgery	0.50	0.01−20.99	.717
Defect size	1.00	0.99−1.00	.268

BMI, Body mass index; CI, Confidence Interval.

OCA, which provides a challenge in determining whether failure or persistent pain is attributable to patellofemoral OCA or an alternative source.

Strengths of this study include the relatively large case series size given previous literature to date. In addition, at a mean 4.82 years' follow-up, this case series allows for better understanding of the mid-term survivorship and helps guide surgeon decision-making of OCA in patients with patellofemoral lesions.

Limitations

There are several limitations to this study. First, as authors have previously described,[24-26] it is not uncommon to have concomitant pathology such as meniscal injury or deficiency, ligamentous instability, or malalignment, which is addressed surgically at the time of OCA and is thus difficult to control for. This study is no exception, with 20 (40%) of patients undergoing a concomitant procedure at the time of OCA, which may confound the ability to attribute knee joint preservation and symptom modification or lack thereof directly to the OCA procedure. In addition, there was heterogeneity in the locations of the allografts with regard to isolated patella, isolated trochlea, concomitant trochlea and patella, or femoral condyle with patella or trochlea. Furthermore, this study is limited by its retrospective design and the number of patients particularly as it pertains to the plug allograft group. In addition, patient-reported outcome measures were inconsistently obtained and therefore were not able to be included and analyzed as part of this study. This may lead to under-reporting of poor outcomes because patients who did not go on to failure may still have reported dissatisfaction or poor functional outcome on patient-reported outcome measures. Similarly, postoperative imaging including radiographs and magnetic resonance imaging were inconsistently available for patients and thus were not able to be used in the analysis. Finally, patients in this study came from two independent surgeons at two separate institutions and who may have differing approaches to surgical technique and rehabilitation protocols.

Conclusion

Plug OCA of the patellofemoral compartment can be an efficacious procedure with quality mid-term outcomes. Shell OCA led to high failure rates at mid-term outcomes. Increasing BMI may predispose these patients to failure, whereas traumatic cause of their lesion was associated with improved outcomes.

References

1. Mosier BA, Arendt EA, Dahm DL, Dejour D, Gomoll AH. Management of patellofemoral arthritis: From cartilage restoration to arthroplasty. *J Am Acad Orthop Surg* 2016;24:e163-e173.
2. Curl WW, Krome J, Gordon ES, Rushing J, Smith BP, Poehling GG. Cartilage injuries: Areview of 31,516 knee arthroscopies. *Arthroscopy* 1997;13:456-460.
3. Brophy RH, Wojahn RD, Lamplot JD. Cartilage restoration techniques for the patellofemoral joint. *J Am Acad Orthop Surg* 2017;25:321-329.
4. Galloway MT, Noyes FR. Cystic degeneration of the patella after arthroscopic chondroplasty and subchondral bone perforation. *Arthroscopy* 1992;8:366-369.
5. Mithoefer K, McAdams T, Williams RJ, Kreuz PC, Mandelbaum BR. Clinical efficacy of the microfracture technique for articular cartilage repair in the knee: An evidence-based systematic analysis. *Am J Sports Med* 2009;37:2053-2063.
6. Frank RM, Cotter EJ, Nassar I, Cole B. Failure of bone marrow stimulation techniques. *Sports Med Arthrosc Rev* 2017;25:2-9.
7. Gomoll AH, Gillogly SD, Cole BJ, et al. Autologous chondrocyte implantation in the patella: A multicenter experience. *Am J Sports Med* 2014;42:1074-1081.
8. Mandelbaum B, Browne JE, Fu F, et al. Treatment outcomes of autologous chondrocyte implantation for full-thickness articular cartilage defects of the trochlea. *Am J Sports Med* 2007;35:915-921.
9. Petri M, Broese M, Simon A, et al. CaReS (MACT) versus microfracture in treating symptomatic patellofemoral cartilage defects: A retrospective matched-pair analysis. *J Orthop Sci* 2013;18:38-44.
10. Torga Spak R, Teitge RA. Fresh osteochondral allografts for patellofemoral arthritis: Long-term follow-up. *Clin Orthop Relat Res* 2006;444:193-200.
11. Jamali AA, Emmerson BC, Chung C, Convery FR, Bugbee WD. Fresh osteochondral allografts: Results in the patellofemoral joint. *Clin Orthop Relat Res* 2005:176-185.
12. Cameron JI, Pulido PA, McCauley JC, Bugbee WD. Osteochondral allograft transplantation of the femoral trochlea. *Am J Sports Med* 2016;44:633-638.
13. Gracitelli GC, Meric G, Pulido PA, Gortz S, De Young AJ, Bugbee WD. Fresh osteochondral allograft transplantation for isolated patellar cartilage injury. *Am J Sports Med* 2015;43:879-884.
14. Lattermann C, Kremser V, Altintas B. Use of fresh osteochondral allografts in the patellofemoral joint. *J Knee Surg* 2018;31:227-230.
15. Krishnan SP, Skinner JA, Bartlett W, et al. Who is the ideal candidate for autologous chondrocyte implantation? *J Bone Joint Surg Br* 2006;88:61-64.
16. Gillogly SD, Arnold RM. Autologous chondrocyte implantation and anteromedialization for isolated patellar articular cartilage lesions: 5- to 11-year follow-up. *Am J Sports Med* 2014;42:912-920.
17. Vasiliadis HS, Lindahl A, Georgoulis AD, Peterson L. Malalignment and cartilage lesions in the patellofemoral joint treated with autologous chondrocyte implantation. *Knee Surg Sports Traumatol Arthrosc* 2011;19:452-457.
18. Noyes FR, Barber-Westin SD. Advanced patellofemoral cartilage lesions in patients younger than 50 years of age: Is there an ideal operative option? *Arthroscopy* 2013;29:1423-1436.
19. Mirzayan R, Charles MD, Batech M, Suh BD, DeWitt D. Fresh osteochondral allografts: Results in the patellofemoral joint. *Cartilage* 2018:1947603518796124.

20. Determann JR, Fleischli JE, D'Alessandro DF, Piasecki DP. Patellofemoral osteochondral allografts: Can we improve the matching process? *J Knee Surg* 2017;30:835-841.
21. Frank RM, Lee S, Levy D, et al. Osteochondral allograft transplantation of the knee: Analysis of failures at 5 years. *Am J Sports Med* 2017;45:864-874.
22. Assenmacher AT, Pareek A, Reardon PJ, Macalena JA, Stuart MJ, Krych AJ. Long-term outcomes after osteochondral allograft: A systematic review at long-term follow-up of 12.3 years. *Arthroscopy* 2016;32:2160-2168.
23. Chahla J, Sweet MC, Okoroha KR, et al. Osteochondral allograft transplantation in the patellofemoral joint: A systematic review. *Am J Sports Med* 2018:363546518814236.
24. Harris JD, Hussey K, Wilson H, et al. Biological knee reconstruction for combined malalignment, meniscal deficiency, and articular cartilage disease. *Arthroscopy* 2015;31:275-282.
25. Frank RM, Cotter EJ, Strauss EJ, Gomoll AH, Cole BJ. The utility of biologics, osteotomy, and cartilage restoration in the knee. *J Am Acad Orthop Surg* 2018;26:e11-e25.
26. Wang D, Eliasberg CD, Wang T, et al. 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. *Arthroscopy* 2017;33:2198-2207.