Osteochondral Allograft for Unsalvageable Osteochondritis Dissecans in the Skeletally Immature Knee

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Background: While an excellent option for osteochondral defects in the adult knee, fresh osteochondral allograft (FOCA) in the skeletally immature adolescent knee has been infrequently studied.

Purpose: To compare radiographic and patient-reported outcomes (PROs) in skeletally mature and immature adolescents after FOCA in the knee for treatment of unsalvageable osteochondritis dissecans (OCD).

Study Design: Cohort study; Level of evidence, 3.

Methods: Included were 34 patients (37 knees) who underwent size-matched FOCA of the knee for unsalvageable OCD lesions. All patients were aged $\leq$19 years and had a minimum of 12 months of follow-up. Patient characteristics, lesion characteristics, reoperations, and PROs were evaluated and compared between patients with open physes (skeletally immature; n = 20) and those with closed physes (skeletally mature; n = 17). Graft failure was defined as the need for revision osteochondral grafting. Postoperative radiographs were analyzed at 1 year and the final follow-up for graft incorporation and classified as A (complete), B ($\geq$50% healed), or C ($<$50% healed).

Results: The mean patient age was 15.4 years (range, 9.6-17.6 years), and the mean follow-up was 2.1 years (range, 1-5.3 years). The mean graft size was 5.0 cm^2 and did not differ significantly between the study groups. Patients with open physes were younger (14.7 vs 16.2 years; $P = .002$) and more commonly male (80% vs 35%; $P = .008$). At the 1-year follow-up, 85% of immature patients and 82% of mature patients had radiographic healing grades of A or B. Patients with open physes were more likely to achieve complete radiographic union at 1 year (65% vs 15%; $P = .007$) and demonstrated better Knee injury and Osteoarthritis Outcome Score (KOOS) Daily Living (96.8 vs 88.5; $P = .04$) and KOOS Quality of Life (87.0 vs 56.8; $P = .01$) at the final follow-up. Complications were no different in either group, and graft failure occurred in only 1 skeletally mature patient with a trochlear lesion.

Conclusion: FOCA treatment for unsalvageable OCD in the young knee may be expected to yield excellent early results. Despite the presence of open physes and immature epiphyseal osteochondral anatomy, equivalent or improved healing and PRO scores compared with those of skeletally mature patients may be expected.

Keywords: osteochondral allograft; knee cartilage; osteochondritis dissecans; skeletally immature; radiographic incorporation

Chondral and osteochondral lesions in the knee are problematic as a source of pain and significant impairment.[24] Osteochondritis dissecans (OCD) is a known pathology resulting in symptomatic osteochondral lesions in pediatric and adolescent knees with risk of future arthrosis when left untreated.[1,2,25,43,44] While activity modification, off-loading the lesion, surgical stimulation for healing, and stabilization of unstable lesions are treatment options to salvage the pathologic lesion, the treatment of unsalvageable defects presents a challenging problem, particularly in the young knee.

In OCD lesions, a loss of subchondral bone underlying articular cartilage results in lesion depth and loss of the functional osteochondral unit. Many chondral treatments in the knee may not adequately restore this structure. Subchondral marrow stimulation promotes formation of fibrocartilage, which may provide clinical benefit in small lesions; however, it lacks the long-term durability of hyaline cartilage required for larger lesions.[22,51] Newer biologic methods such as autologous chondrocyte implantation (ACI) or matrix-associated ACI (MACI), have been utilized to replace hyaline cartilage in the defect. These techniques may require additional cancellous bone grafting in the depth of lesions, such as those secondary to unsalvageable OCD.[35,40]

Osteochondral grafting, by comparison, can be utilized to treat lesions with subchondral and cancellous bone loss and

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has the benefit of providing hyaline cartilage, a cartilage tidemark to a subchondral plate, and cancellous replacement for cavitary loss. Osteochondral autografts (OATS) have the benefit of ready availability; however, the limited size and number of grafts that can be harvested from the patient and donor-site morbidity are limitations.[4,8] Fresh osteochondral allograft (FOCA) utilization allows for the selection of larger grafts from size-matched donors with elimination of OATS donor-site morbidity.

FOCAs have been utilized in adult knees with relative success, with reported rates of reoperation from 23% to 39.7% and failure rates from 5.1% to 11.8%.[11,30,41,46] Little, however, has been published on outcomes of FOCA in pediatric and adolescent patients. Outcomes in a small group of 11 patients, with an average age of 15.2 years (range, 13-20 years), were reported by Lyon et al.[32] They found that all patients were able to return to sports within 9 to 12 months postoperatively and showed full graft incorporation on 2-year follow-up radiographs. Murphy et al[37] published their cohort of 43 knees in adolescents (average age, 16.4 years; range, 11-17.9 years), reporting an 11% failure rate and a 90% 10-year survival rate. Clinical outcome scores improved postoperatively, with 88% good or excellent scores at the final follow-up. While both studies were suggestive of positive outcomes for use of FOCA in younger patients, neither of these specifically investigated wide use in a population with open physes.

The purpose of this study was to compare clinical and radiographic outcomes of fresh size-matched osteochondral allografts for unsalvageable OCD in skeletally immature and mature adolescent knees in order to demonstrate the safety and clinical outcomes of this procedure, when indicated, in a skeletally immature patient.

METHODS

After receiving institutional review board approval, we retrospectively reviewed data on all patients undergoing FOCA of the knee in a single academic pediatric sports medicine practice between January 2006 and March 2019. Patients were identified via review of osteochondral graft orders and were included if they were age $\leq$19 years at the time of treatment of a knee unsalvageable OCD lesion with a fresh, size-matched osteochondral allograft. Exclusion criteria were cause other than OCD and <1 year of clinical follow-up. Of the 63 consecutive adolescent knees undergoing FOCA of the knee in this time period, 19 were excluded on the basis of insufficient follow-up of <1 year and 7 for surgical indication other than OCD. This resulted in a total of 37 knees in 34 patients available for study (Figure 1). Patients and parental guardians provided informed assent and consent, respectively, for data collection.

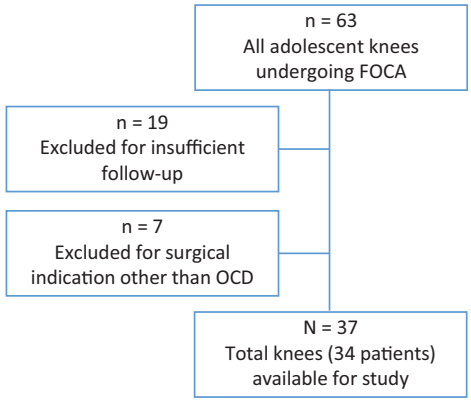

Figure 1. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) flowchart of patient enrollment. FOCA, fresh osteochondral allograft; OCD, osteochondritis dissecans.

Patient characteristics, comorbidities, lesion characteristics, surgical procedures, complications, and reoperations were recorded from review of the electronic medical record. Graft failure was defined as the need for revision osteochondral grafting. Complications were stratified in severity according to the Clavien-Dindo system.[13] Clinical outcome was evaluated at pre- and postoperative visits using the pediatric International Knee Documentation Committee (Pedi-IKDC), Knee injury and Osteoarthritis Outcome Score–Joint Replacement (KOOS-JR), and the Hospital for Special Surgery Pediatric Activity Brief Scale (HSS Pedi-FABS) scores.[16,17,29,31,38]

Surgical Procedure

Patients were indicated for FOCA surgery when an OCD lesion was deemed not amenable to repair via alternative methods because of osteochondral necrosis or degree of fragmentation. Specimens were size-matched for the patient to a radius of curvature within 2 mm of established condylar measurements from a knee magnetic resonance imaging (MRI) scan that was used by an allograft distributor (Joint Restoration Foundation) in conjunction with the procurement and supplying nonprofit entity (AlloSource).[42] All grafts were implanted within 27 days of procurement per standard industry and surgical best practice. All grafts

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Ethical approval for this study was obtained from UT Southwestern Medical Center (ref. No. STU 062017-100).

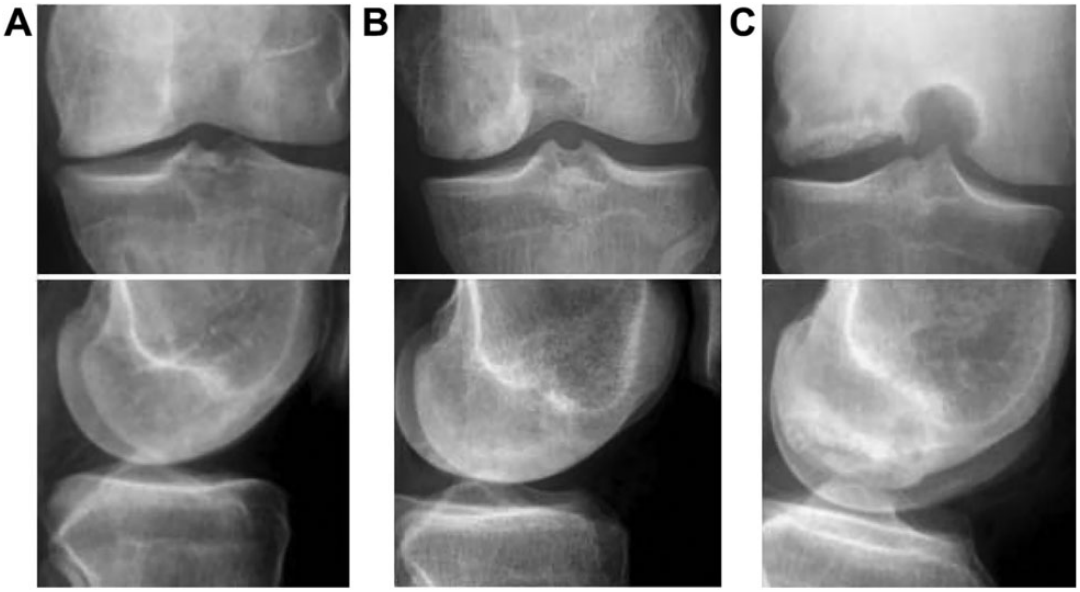

Figure 2. Radiographic incorporation scale of osteochondral allografts on postoperative radiographs. (A) 100% healed: entire graft appears incorporated with no lucency within or surrounding the graft; (B) ≥50% incorporation: continuous radiodensity surrounding and within ≥50% of graft margins; (C) <50% incorporation: continuous radiodensity surrounding and within <50% of graft margins.

were a maximum donor age of 25 years by surgeon practice protocol. The grafts were typically prepared and implanted using the assistance of a commercially available jig system (standard dowel allograft, Bio-Uni graft set; Arthrex) or via freehand preparation in the case of shell graft. The grafts were press-fit, and occasionally headless screws were utilized in cases of shell graft, marginal graft location, or multiple graft use at the surgeon's discretion. Procedures on patients were performed as same-day outpatient surgery or 23-hour observation status.

Rehabilitation Protocol

The 2 surgeons (H.B.E., P.L.W.) employed a similar protocol of early full range of motion and toe-touch weightbearing for 6 weeks. The patients then moved on to concentric strengthening and nonimpact activities and were released to full sporting activities between 4 and 8 months, when they were symptom-free and radiographs were appropriate in appearance.

Radiographic Review

Preoperative radiographs were examined to determine each patient's skeletal maturity. Skeletal immaturity was defined as the presence of any open physes about the knee at the time of treatment. Femoral condyle lesions were localized within the condyle in the coronal and sagittal planes using the Cahill and Berg classification.[10] Size was normalized using the defect size condylar ratio as described by Lee et al.[30]

An assessment of radiographic graft incorporation was made using a novel 3-tier classification scheme. Grade A was assigned when continuous radiodensity was present throughout the graft and all margins were judged to be 100% healed (Figure 2A). Grade B indicated continuous radiodensity in the graft and surrounding margins of ≥50%, but it was judged to be incomplete to some degree (Figure 2B). A graft with continuous radiodensity present in <50% of the graft area and surrounding graft margins was assigned grade C (Figure 2C). Radiodensity was defined as any radiodensity regardless of intensity, and lucency was defined as absolute lucency without radiographic bone. To evaluate radiographic reliability, 1 board-certified, fellowship-trained pediatric orthopaedic surgeon (P.L.W.) and a third-year orthopaedic resident (B.T.) reviewed a randomized subset of 20 patients. Each rater evaluated the images in a blinded and uniquely randomized order twice, with a minimum of 2 weeks between exposures. For data analysis, all radiographs were reviewed and scored by the resident reviewer (B.T.), who did not participate in the procedures or have knowledge of the patients' clinical course.

Statistical Methods

Variables were compared between the skeletally immature and mature cohorts. Descriptive statistics were reported as mean and SD. All continuous variables were compared using nonparametric tests, such as the Kruskal-Wallis and Mann-Whitney U tests, as appropriate. For categorical variables, Fisher exact test was utilized. Statistical significance was set at $P < .05$. Missing data were excluded from analyses, and the number of patients available for each variable was noted. The Cohen kappa statistic (κ) was used to calculate intra- and interrater reliability of radiographic

TABLE 1
Patient Characteristics[a]

	Open Physes (n = 20; 54.1%)	Closed Physes (n = 17; 45.9%)	*P* Value
Sex			**.01**
Male	16 (80)	6 (35.3)	
Female	4 (20)	11 (64.7)	
Age, y	14.7 (9.58-17.6)	16.2 (14.4-17.3)	**.002**
BMI percentile	73.0	83.1	.27
Race			.32
White non-Hispanic	15 (75)	11 (64.7)	
Hispanic	3 (15)	2 (11.8)	
Black	1 (5)	4 (23.5)	
Other	1 (5)	0	
Duration of follow-up, y	2.14 (1-5.33)	2.01 (1-3.3)	.87

[a]Data are reported as n (%) or mean (range) unless otherwise indicated. Bolded *P* values indicate a statistically significant difference between groups ($P < .05$). BMI, body mass index.

TABLE 2
Lesion and Surgical Characteristics[a]

	Open Physes	Closed Physes	*P* Value
Mean graft size			
Area, cm^2	4.7	5.2	.35
Defect size condylar ratio	0.18	0.16	.37
Depth, mm	8.0	8.13	.81
Location			
MFC	5 (25)	11 (64.7)	.05
LFC	9 (45)	6 (35.3)	.55
Patella	2 (10)	0	.49
Trochlea	4 (20)	0	.11
Contralateral knee OCD	11 (55)	10 (58.8)	.82
Same location	9 (81.8)	10 (100)	.48
Requiring FOCA	3 (27.2)	5 (50)	.42
Prior knee surgery	18 (90)	15 (88.2)	>.99
Concomitant procedure	4 (20)	3 (17.6)	>.99
Realignment procedure	7 (35)	3 (17.6)	.29
Return to operating room			
Planned	5 (25)	4 (23.5)	.92
Unplanned	2 (10)	5 (29.4)	.14

[a]Data are reported as n (%) unless otherwise indicated. FOCA, fresh osteochondral allograft; LFC, lateral femoral condyle; MFC, medial femoral condyle; OCD, osteochondritis dissecans.

scoring. Statistical analysis was performed using SAS version 9.4 (SAS Institue, Cary, NC).

RESULTS

Patient Characteristics

A total of 34 patients (37 knees) met inclusion criteria, with an average follow-up of 2.1 years (range, 1-5.3 years) (Table 1). The mean age at surgery was 15.4 years (range, 9.6-17.6 years), and the mean body mass index percentile was 77.6%. The cohort was 59.5% male and predominantly White non-Hispanic (70.3%). The most common chondral defect location was the medial femoral condyle (43.2%), followed by the lateral femoral condyle (40.5%), trochlea (10.8%), and patella (5.4%). The majority of patients had undergone prior operative intervention to the ipsilateral knee (89.2%). The index OCD lesion had prior treatment in 15 (40.5%) knees, including 1 patient who had a failed osteochondral allograft performed at an outside facility. Staging procedures (diagnostic arthroscopy with or without chondroplasty) were performed in 21 (56.8%), and preoperative realignment procedures were performed in 8 (21.6%) knees. Meniscal pathology, specifically lateral discoid meniscus, was surgically treated in 5 knees (13.5%), all of which were associated with lateral femoral condyle OCD lesions.

Open Versus Closed Physes

Patient characteristics did not vary significantly with physeal status except expected younger age (14.7 vs 16.2 years; $P = .002$) and male predominance (80% vs 35%; $P = .008$) in the patients with open physes (Table 1).

In patients with open physes, the most common lesion location was lateral femoral condyle (45%), whereas the medial femoral condyle (64.7%) was most common in the patients with closed physes (Table 2). Other lesion characteristics including graft size did not differ. The incidence of contralateral lesions and additional surgical procedures is described in Table 2.

Realignment

Realignment procedures were performed in 7 (35%) skeletally immature and 3 (18%) skeletally mature knees ($P = .29$). All 3 skeletally mature knees were treated with distal femoral osteotomy before the index FOCA procedure. In the setting of open physes, guided growth realignment was performed; 3 knees were treated preoperatively; 1, concomitantly; and 2, at both time points. One knee in the skeletally immature group was treated 2.4 years postoperatively with realignment osteotomy.

Complications and Reoperations

Seven patients (2 with open physes and 5 with closed physes) experienced a total of 8 complications. All were grade 2 or 3 using the Clavien-Dindo classification (Table 3). There were no complications associated with physeal arrest or acquired angular or limb length deformity. Only 1 patient, a skeletally mature boy with a trochlear lesion, experienced complete graft failure, requiring revision grafting about 1.3 years postoperatively.

The reoperation rate was not significantly different between the subgroups (open physes, 35% vs closed physes, 52.9%; $P = .28$). Complications accounted for 7 unplanned subsequent surgeries. There were 9 cases of planned return to the operating room, 5 of which were in the open physes group, most commonly for hardware removal or to address meniscal pathology (Figure 3).

TABLE 3
Postoperative Complications[a]

Age, y	Sex	FOCA Location	Time to Reoperation, y	Complication	Intervention	Clavien-Dindo Grade
				Open Physes		
15.1	M	LFC	0.3	Knee stiffness	Arthroscopic lysis of adhesions and manipulation	3
15.2	M	LFC	2.4	Incomplete graft incorporation	Distal femoral varus-producing osteotomy	3
				Closed Physes		
17.3	M	MFC	0.1	Retained K-wire near articular surface	Retained implant removal	3
			1.4	Synovitis and incomplete incorporation between previous intersecting ("snowman") 22.5-mm dowels	Steroid injection	2
16.9	F	MFC	0.3	Knee stiffness	Arthroscopic lysis of adhesions and manipulation	3
15.8	F	LFC	1.8	Incomplete graft incorporation	Chondroplasty, loose-body removal	3
17.2	M	LFC	0.1	Fracture of tibial tubercle osteotomy	ORIF tibial tubercle	3
15.8	M	Trochlea	1.3	Graft failure	Revision FOCA	3

[a]F, female; FOCA, fresh osteochondral allograft; LFC, lateral femoral condyle; M, male; MFC, medial femoral condyle; ORIF, open reduction internal fixation.

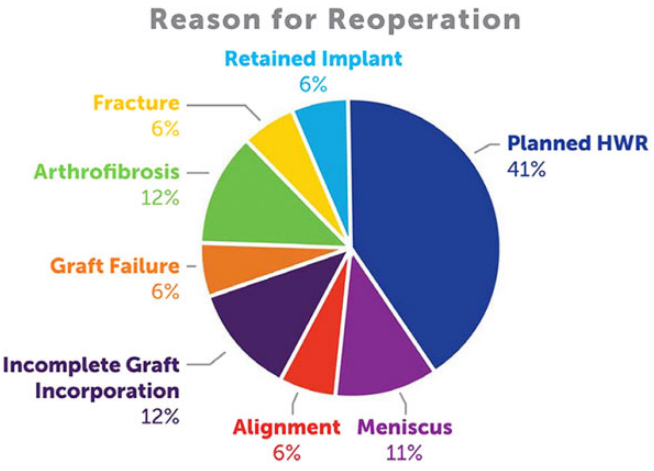

Figure 3. Indications for reoperation. HWR, hardware removal.

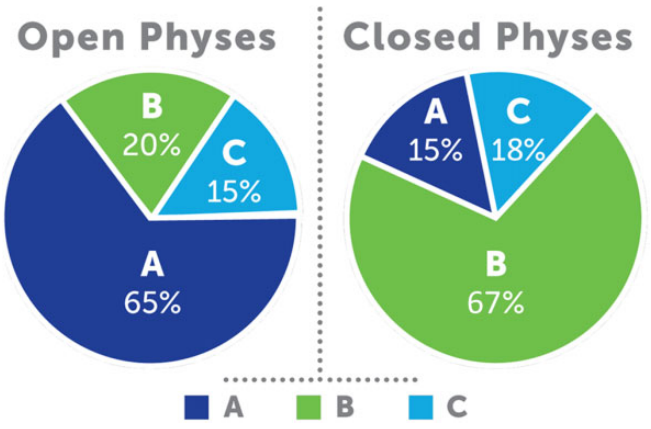

Figure 4. Radiographic incorporation of graft at 1-year follow-up by skeletal maturity. Grade A, 100% incorporation; grade B, ≥50% incorporation; grade C, <50% incorporation.

Radiographic Outcomes

A novel radiographic scoring scale of osteochondral incorporation was demonstrated to have substantial interrater reliability ($\kappa = 0.730$) and intrarater reliability ($\kappa = 0.789$ and $\kappa = 0.867$).

Patients with open physes at the time of treatment were more likely to achieve complete radiographic union at 1 year (65% vs 15% [closed physes]; $P = .007$). At 1 year, acceptable radiographic outcomes, defined as grades A and B, were achieved in the majority of patients in both groups (open vs closed physes: 85% vs 82%) (Figure 4). Poor graft incorporation represented the smallest proportion in both groups and was not predictive of complications ($P = .32$) or unplanned return to surgery ($P = .32$).

Radiographs were available for review at the final follow-up in 76% of knees, and all but 2 knees demonstrated acceptable (grade A or B) graft incorporation. While 28.5% demonstrated continued improvement with time, final scores did not differ significantly from those at 1 year ($P = .06$).

Clinical Outcomes

At baseline, there was no significant difference across all preoperative patient-reported outcomes (PROs), and all

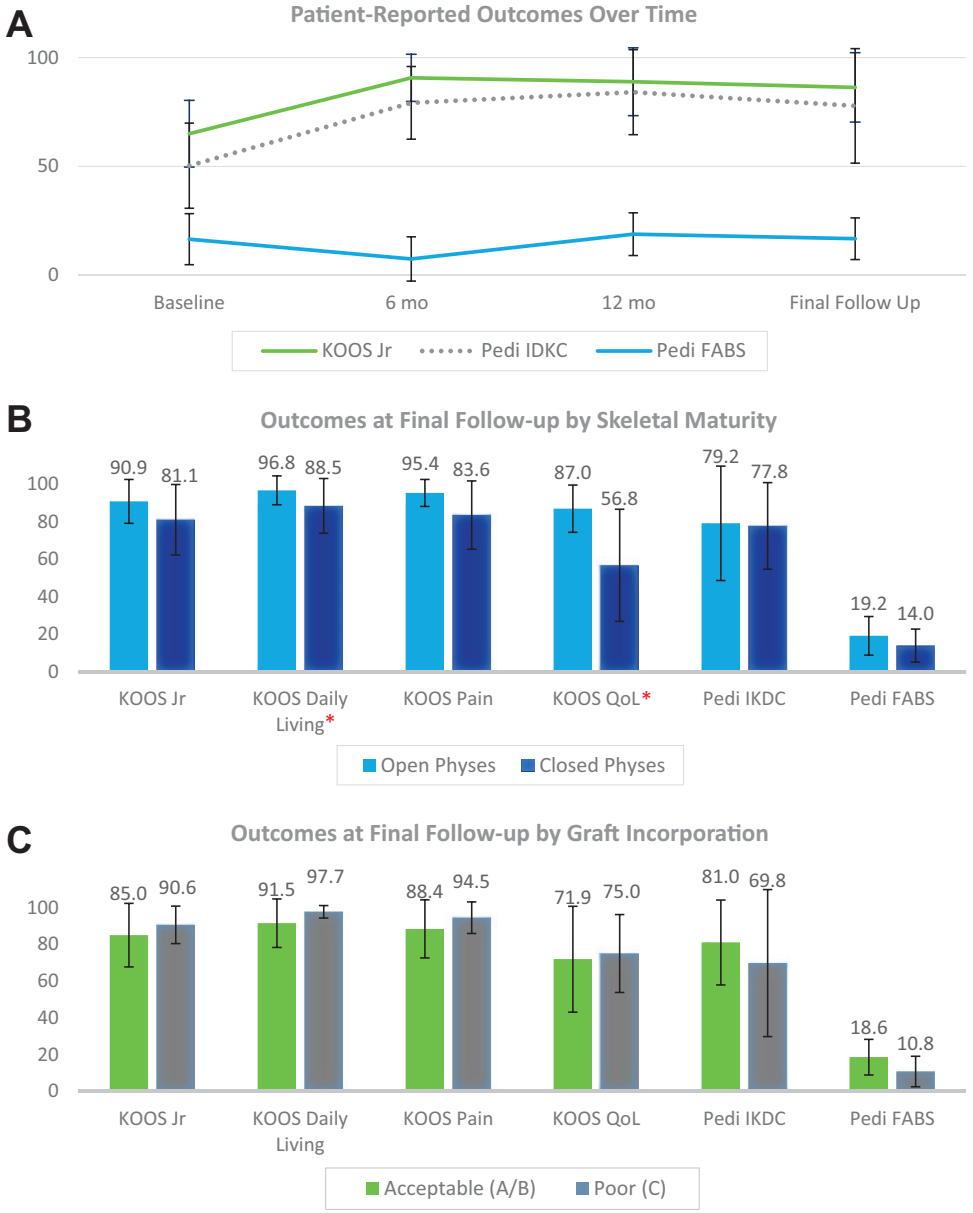

Figure 5. Patient-reported outcomes (A) over time and at final follow-up by (B) skeletal maturity and (C) graft union on radiographs. Error bars indicate SDs. *Statistically significant difference ($P < .05$). KOOS Jr, Knee injury and Osteoarthritis Outcome Score–Joint Replacement; Pedi-FABS, Hospital for Specialty Surgery Pediatric Functional Activity Brief Scale; Pedi-IKDC, Pediatric International Knee Documentation Committee; QoL, Quality of Life subscale.

improved postoperatively in both groups (Figure 5A), although the skeletally immature group had higher scores in all categories. While there was no difference compared with the mature cohort at 1 year, open physes were associated with significantly improved KOOS Daily Living subscale (open vs closed physes: 96.8 ± 7.7 vs 88.5 ± 14.6; $P = .04$) and KOOS Quality of Life subscale (open vs closed physes: 87.0 ± 12.6 vs 56.8 ± 29.9; $P = .01$) at the final follow-up (Figure 5B). At the final follow-up, there was no difference in functional or activity scores between patients with acceptable (grades A and B) and poor (grade C) graft incorporation on radiographs (Figure 5C).

DISCUSSION

In a pediatric and adolescent population of 34 patients with unsalvageable OCD of the knee, clinical and radiographic outcomes were compared between skeletally immature and mature subsets treated with FOCAs. At an average 2.1-year follow-up, there were no graft failures in the group with open physes and 1 failure in the group with closed physes, although a high reoperation rate was observed in both groups. Patients with open physes at the time of surgery were more likely to have complete radiographic graft incorporation by 1 year and reported improved and

significantly better knee-specific PRO scores than did those with closed physes.

Osteochondral allografts are utilized by surgeons in the treatment of difficult, large, fragmented, or unsalvageable osteochondral lesions. The ability to replace underlying bony architecture in addition to articular hyaline cartilage makes FOCA an attractive option in the knee. In 2018, a total of 4700 FOCAs were requested from tissue banks in the United States, with the medial femoral condyle being the most commonly requested source.[19] Other treatment options, including microfracture and ACI or MACI, may have inferior outcomes with larger and deeper lesions.[6,14,40,51] FOCA, on the other hand, is used in adults for large lesions averaging 3.45 to 8.7 cm^2.[15,21,26,30,41,46-49] Outcomes after FOCA in young adults have been shown to be independent of lesion size and have long survivorship, rendering it a cost-effective option.[30,36,46] In our study, lesions requiring large grafts (average, 5.0 cm^2) were common in both the skeletally immature and the skeletally mature adolescents.

Patient characteristics of those indicated for FOCA of the knee were no different in those with open as opposed to closed physes other than expected younger age. There was also a male predominance in the skeletally immature, as girls tend to reach skeletal maturity at a younger age than do boys.[33] In both groups, a prolonged treatment course with multiple surgeries to the ipsilateral knee was common. Prior surgical attempts at chondral healing were performed in 40.5% of knees, including 1 patient who underwent failed osteochondral allograft at an outside facility. When comparing primary FOCA to that performed after failed subchondral marrow stimulation, Gracitelli et al[20] showed improvement in both pain and function scores, but FOCA as a secondary treatment attempt was accompanied by significantly more reoperations (44% vs 24%). Cartilage restoration procedures have themselves been deemed a risk for repeat ipsilateral knee arthroscopy.[7] The overall reoperation rate of 43.2% in our population did not differ with skeletal maturity or radiographic union and was comparable with that described in the adult population (23%-39.7%).[5,18,30,41]

In the skeletally immature population, the majority (71.4%) of these reoperations were planned procedures, either for hardware removal or to address associated malalignment or meniscal pathology, rather than for complications. Concomitant malalignment, which by the mechanical hypothesis may predispose the affected compartment to OCD, may in theory also cause abnormal stress on the respective meniscus. Of lateral femoral condyle lesions, 33% were seen with a discoid meniscus in the affected compartment, an association described in the literature that may require concurrent or secondary arthroscopic treatment.[9,23,45]

The need for realignment procedures in this population was consistent with a significant association demonstrated between mechanical axis deviation and osteochondral defect presence in the affected compartment.[28] Malalignment has been demonstrated as a risk factor for graft failure.[9] Both growth modulation and realignment osteotomies, for patients with open and closed physes, respectively, may result in additional planned reoperations for elective hardware removal, as is routine practice in the pediatric population. Planned removal in this cohort also included both extra-articular and intra-articular (headless graft compression screws) hardware. Of skeletally immature patients in whom these headless screws were used for fixation of unstable OCD lesions, 50% subsequently underwent hardware removal in a 2013 study.[50]

There were no graft failures in the open physes group and only 1 in the closed group, with an overall failure rate of 2.7%. While the current study's follow-up was shorter in duration, this was lower than the 11% failure rate previously reported in the study by Murphy et al[37] of 43 knees (average age, 16.4 years) treated with FOCA. While they presented a comparably sized cohort of adolescent patients, they did not evaluate skeletal maturity. This distinction may be important in considering osteochondral grafting in this population. The presence of open physes, compliance and activity level challenges, and altered cartilage thickness due to persistence of epiphyseal cartilage underlying the articular cartilage all may be relative concerns to the treating surgeon for these large and difficult lesions. While treatment of chondral defects and OCDs has been shown to have improved healing rates in knees with open physes, surgeons may be reluctant to proceed with osteochondral grafting in this population, as previous results and risks have been unclear.[3,12,27,39]

A smaller study of 11 patients with variable skeletal maturity status (average age, 15.2 years) by Lyon et al[32] also reported on FOCA in the adolescent population. In that study, all patients were described to have complete radiographic graft incorporation at the 2-year follow-up. Radiographic graft incorporation in our study was determined via a novel 3-tier grading scheme utilizing plain radiographs with good interrater reliability ($\kappa = 0.73$). Although a classification exists to describe postoperative graft incorporation on knee MRI scans,[34] no such grading system exists utilizing less expensive and more routinely obtained plain radiographs. The MRI scheme, titled Osteochondral Allograft Magnetic Resonance Imaging Scoring System, assesses 13 graft characteristics. By defining incorporation utilizing radiodensity, our scheme offers a simple but objective assessment of graft healing that can be applied without additional imaging cost. Further study utilizing this radiographic graft incorporation classification to assess correlation with graft survival and outcomes at longer-term follow-up may be warranted.

While the open physes group was more likely to have complete graft incorporation, the majority of knees (82%-85%) had radiographic healing grades of A or B, indicating acceptable union, at 1 year postoperatively. Progression of radiodensity in grafts rated as B or C may be expected over time but was beyond the scope of the current study. There was no significant correlation between radiographic outcome and PROs at early- and intermediate-term follow-up, but a positive association was observed between the open physes group and improved PROs. IKDC outcome scores after FOCA have been shown to predict patient satisfaction, and outcomes have not been reported to degenerate over time.[48] Overall satisfaction after FOCA has been

reported to be 89% in both adult and adolescent cohorts.[37,48] PROs improved from baseline regardless of skeletal maturity, confirming the beneficial effect of FOCA on pain and function seen in previous adolescent studies and proving the utility in the treatment of knees with open physes.[32,37]

There were several limitations in this study. Although this was a smaller sample size than that in reports on FOCA in adult populations, this study was one of the largest series of adolescent knees treated with FOCA for unsalvageable OCD and the only study, to our knowledge, to specifically isolate skeletally immature patients. Given the small proportion of grafts with poor incorporation (grade C), the radiographic outcome comparison may have included too small a sample size to see a statistically significant relationship between inferior radiographic outcome and patient-reported clinical outcomes, if one exists. Additionally, the retrospective nature of the study subjected it to the flaws of that study subtype, including some variability in timing and collection of PROs inherent to the wide range of follow-up. Additionally, varying lesion location and patient sex distribution in the 2 cohorts may have introduced the possibility of confounding. The average follow-up of 2.1 years, while in keeping with other adolescent studies, may have been too short a time frame to adequately capture the total graft failure rate; however, the radiographic grading at 1 year provides the treating surgeon with some comparison data when evaluating and counseling adolescents after FOCA.

Areas of future research include longer-term follow-up of outcomes and failures as this cohort continues to mature. Further evaluation of mechanical alignment and concomitant pathology contributing to the treatment course in this unique age group is also planned.

CONCLUSION

Despite the presence of open physes and immature epiphyseal osteochondral anatomy, equivalent or improved healing and excellent PROs comparable with those of skeletally mature patients may be expected, even when grafting large, unsalvageable OCD defects. While reoperation for implant removal or guided growth was relatively common (30%), complications were lower than those reported in other cohorts, and there were no graft failures in skeletally immature patients at a minimum 1-year follow-up. A high degree of radiographic graft incorporation may be expected even at 1 year, and data within this study may serve as guidance for the surgeon treating and counseling adolescents after FOCA.

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