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Outcomes of bioabsorbable fixation in the treatment of osteochondral lesions of the knee in adolescent patients

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ABSTRACT

Background: Bioabsorbable fixation in managing osteochondral lesions is increasing in popularity. The purpose was to report on outcomes using bioabsorbable fixation nails for osteochondral lesions of the knee in a pediatric and adolescent population.
Methods: A retrospective review of pediatric patients undergoing surgery with bioabsorbable fixation for knee osteochondral lesions was performed. Demographic, clinical, and surgical data was collected including symptom duration, lesion location, size, use of bone grafting, and number of implants. Return to activities was documented. Patients recommended revision surgery were compared to those who were not.
Results: 47 patients with median age 13.9 years and 25.5% female were included with median clinical follow-up of 47.3 weeks. 87.2% of patients were cleared for full activities. Four male patients (8.5%) were recommended revision surgery, of whom three underwent surgery including removal of loose bioabsorbable fixation. Demographic data did not differ between the group with successful versus failed primary surgery ($p > 0.05$). Symptom duration was more acute (<1 month) in the four recommended revision surgery (75% versus 9.3%, $p = 0.008$). The group recommended revision also had larger lesion size (median 5.4 cm^2 versus 2 cm^2, $p = 0.04$). Distal femoral physeal status, lesion location, necessity for bone grafting, and number of implants did not differ between groups.
Conclusions: Adolescents had a high return to activity following bioabsorbable fixation for knee osteochondral lesions with 87.2% cleared for full return. In the 8.5% of patients who were deemed to have failed primary fixation, symptoms were more likely to be acute in nature with larger lesion sizes.

1. Introduction

Osteochondral lesions are relatively rare lesions, only occurring in less than 30 patients per 100,000 and affecting boys 2–4 times more than girls [1–4]. Symptoms of osteochondral lesions or osteochondritis dissecans (OCD) can often be subtle and nonspecific [2]. Treatment is guided by patient age and lesion location, size, and stability; stable lesions have intact subchondral bone while unstable lesions may have detached subchondral bone or fluid deep to the lesion with high signal intensity on T2-weighted magnetic resonance imaging (MRI) [5,6].

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For skeletally immature patients, a trial of non-weightbearing for 3–6 months for stable lesions is considered first-line treatment. However, given that these lesions can be a source of pain, they may require surgical intervention when conservative management has failed. Stable lesions that have failed nonoperative management can be treated with bone marrow stimulation techniques such as with drilling of the lesion [7,8].

While transarticular and retroarticular drilling is the mainstay of intact stable lesions, according to a 2017 survey of the Pediatric Orthopaedic Society of North America (POSNA), there is less consensus on the type of surgical treatment that is optimal for salvageable unstable lesions [9]. These unstable, but salvageable lesions may be treated with metal screws, pins or nails, bone pegs, suture, or a variety of bioabsorbable fixation methods [10]. Bone grafting is sometimes used in conjunction with fixation, drilling, or curettage. For unsalvageable lesions, the cartilage/bone defect may be treated with microfracture, autologous chondrocyte implantation, osteochondral autograft or allograft implantation [2,9].

Additionally, while 30% of POSNA members opt for metallic fixation [9] and many studies cite the success of treatment with metallic implants, there is concern for implant irritation, breaking, interference with MRI, lack of compression, and need for removal [11–17]. Therefore, bioabsorbable fixation devices have gained in popularity, with over 60% of surgeons in POSNA opting for their use for unstable, salvageable lesions [9]. Examples of such implants include the SmartNail (ConMed Linvatec; Largo, FL) which is a poly(L-lactic acid) (PLLA), bioabsorbable, nail-like implant with a head and barbs or the Chondral Dart (Arthrex; Naples, FL) which is also a PLLA bioabsorbable implant with double reverse barbs. However, there are still concerns with bioabsorbable fixation devices, such as the development of synovitis, loss of compression in those that generate it, and abscess formation [13,18–21].

Studies of bioabsorbable fixation of osteochondral, lesions in the pediatric population thus far are limited to small cases series' [13,22–26]. The success of this fixation and the potential risk factors for failure are unknown. The purpose of this study was to report on outcomes with the use of bioabsorbable fixation of osteochondral lesions of the knee in a pediatric and adolescent population. The hypothesis was that bioabsorbable fixation would reliably treat adolescent knee osteochondral lesions and that larger lesions would be at greater risk of complications.

2. Materials and methods

This study was reviewed and approved by the Institutional Review Board (IRB) of the University of California San Francisco (IRB # 20-31270). This was a retrospective case series of consecutive pediatric patients who underwent knee surgery for osteochondral fixation of an osteochondral lesion or OCD lesion. Surgery was performed by the senior author (NKP), a pediatric orthopaedic surgeon who focuses on sports medicine at a single tertiary referral center from September 2011 to January 2020.

Of 203 patients between September 2011 and January 2020 who had surgery for isolated knee osteochondral lesions, 49 patients underwent bioabsorbable screw fixation according to the operative report with SmartNails (ConMed Linvatec; Largo, FL) or Chondral Darts (Arthrex; Naples, FL). These medical charts and radiographs of these 49 patients were retrospectively reviewed. 47 patients were ultimately included with minimum follow-up of three months.

2.1. Surgical technique and rehabilitation protocol

In this series, all cases were performed in an arthroscopic-assisted fashion. A standard diagnostic arthroscopy was performed, and the lesion was identified in its location corresponding to preoperative imaging (Figure 1**A;** Figure 2**A**). A probe and arthroscopic shaver were utilized to gently define the lesion and its edges. For lesions with stable bony bases, the overlying loose cartilage surface was reduced utilizing a guide sleeve to match the contour of the nearby, healthy cartilage. Pilot holes were created into the lesion into underlying bone and drill pins or K-wires were placed to maintain fragment reduction. The bioabsorbable implant was loaded into the inserter and implanted and impacted until the implant sat just below the cartilage surface by ~2 mm. This process was repeated for each implant inserted. The cartilage was gently probed to ensure appropriate fixation (Figure 1**B**).

Bone grafting was utilized at the surgeon's discretion for lesions without a stable bony base, and in these cases the arthroscopy portal corresponding to the lesion location was extended for a mini-open approach. Autogenous bone graft was taken through a small incision overlying the proximal anteromedial tibia. The pes anserine tendons were protected and care was taken to stay distal to the proximal tibial physis. A cortical window was made and approximately 10 cc of bone cancellous autograft was obtained (Figure 2**C**). The portal was extended to allow for visualization of the femoral condyle. The lesion was elevated and bone graft was impacted into the lesion base. The osteochondral lesion was reduced over the underlying bone and graft and fixed with SmartNails or Chondral Darts (Figure 2**C**). The lesion was gently probed to ensure appropriate fixation.

Figure 1 demonstrates representative images from an all-arthroscopic case and Figure 2 demonstrates representative images from a case in which bone grafting was performed.

All patients were instructed to remain non-weightbearing in a hinged knee brace, locked in extension during ambulation for six weeks postoperatively. Range of motion unlocked from 0-90 during therapy and while not ambulating was encouraged. Patients were allowed to return to play after three months postoperatively in a graduated fashion under the guidance of a physical therapist if pain was controlled and radiographs demonstrated lesion healing.

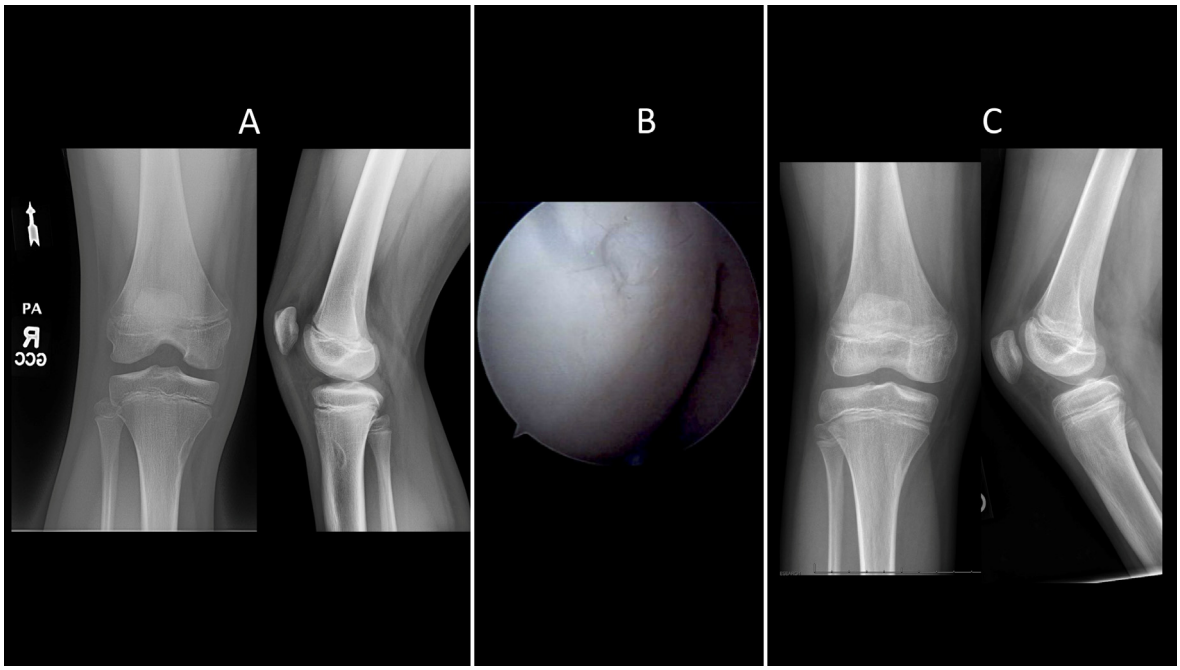

Figure 1. Representative case of an all-arthroscopically performed bioabsorbable fixation of an osteochondral lesion. **A)** Anteroposterior and lateral standing radiographs of the right knee in a patient with open physes demonstrating lucency in the medial femoral condyle consistent with osteochondral lesion. Of note, the paitent has an incidental proximal tibial non-ossifying fibroma. **B)** Arthroscopic image of the lesion after fixation with Arthrex Chondral Darts (Arthrex; Naples, FL). **C)** 6-month postoperative anteroposterior and lateral radiographs demonstrating sclerosis and resolution of lucency at the site of the prior medial femoral condyle lesion.

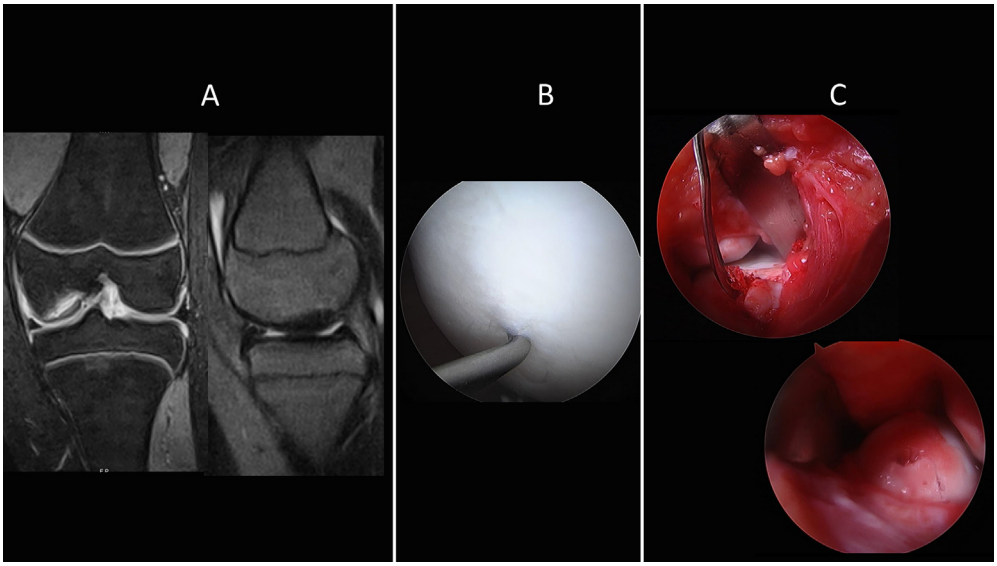

Figure 2. Representative case of an arthroscopically-assisted, mini-open procedure involving osteochondral lesion base bone grafting in combination with bioabsorbable fixation. **A**) Selected coronal and sagittal T2-weighted magnetic resonance imaging slices in a patient with open physes demonstrating an unstable osteochondral lesion of the left medial femoral condyle. **B)** Arthroscopic image demonstrating utilizing the probe to define the lesion edges. **C)** Intraoperative image demonstrating obtaining bone graft from the proximal tibia (top) and the lesion after bone grafting and bioabsorbable fixation (bottom).

2.2. Outcomes and measures

Data recorded included: age at surgery, sex, laterality, race, weight, insurance status, past medical history, duration of symptoms (classified as acute or chronic with acute being less than one month of symptoms), location of lesion, size of lesion

on MRI and intraoperative, use of bone grafting, implant type and number, preoperative and postoperative examination, radiographic resolution, time to clearance, length of follow-up, and post-operative complications.

The radiographic outcome for success was defined as sclerosis or resolution of lucency on standing weightbearing radiographs of the knee (Figure 1**C**) Patients were evaluated for return to desired activity and were classified as one of the following: returned to full activities, being "on-track" to return to activity, recommended to avoid high impact activities, and recommended revision surgery. Being "on-track" to return to activities included patients who were doing well from a surgical perspective were told at most recent follow-up they could progress activity to full play but did not return to the clinic following return to full sports. Those recommended to avoid high impact activities had minimal pain at baseline but intermittent pain with activity.

Patients who underwent revision surgery or were recommended to undergo revision surgery following surgery were defined as "failed primary fixation." Reasons for failure included lack of healing with persistent symptoms or issues with hardware.

2.3. Data analysis

Descriptive statistics were utilized to characterize the data. Comparisons were made between the group undergoing primary surgery and the group that failed primary fixation. Shapiro-Wilk test was utilized to assess normality for continuous variables. Variables normally distributed (age) were reported as mean ± standard deviation. Variables that violated assumption of normality were reported as median with interquartile range (IQR). Continuous variables normally distributed were analyzed with unpaired, two independent sample t-tests whereas those not normally distributed were analyzed with Mann Whitney U test. Categorical variables were compared utilizing Fisher's Exact test. All statistical analyses were performed using STATA v16.1 (StataCorp; College Station, TX). Two-tailed level of significance was set at < 0.05.

3. Results

A total of 47 patients were treated with bioabsorbable fixation for an unstable knee osteochondral lesion. The cohort average age was 13.9 ± 2.0 years (range, 10.3–18.1 years) and 25.5% of patients were female (Table 1). The distal femoral physis was open in 68.1% of patients. Median clinical follow-up was 47.3 weeks (IQR, 24.4–67.8). The three most common racial/ethnic categories were 38.3% white, 29.8% black, and 10.6% Hispanic. 27.7% of patients had a medical history of asthma.

14.9% of all patients reported symptoms classified as acute to surgery (Table 2). Median lesion size was 2 cm^2 (IQR, 1.2–3.75), most commonly located on the medial femoral condyle (61.7%), and median number of fixation implants was 4 (IQR, 3–5).

In total, 87.2% returned to full activities or were permitted to return without restriction. Two patients (4.3%) were recommended to limit high impact activities due to intermittent pain episodes.

Four patients (8.5%) were recommended revision surgery for unsuccessful clinical outcome, of which three (75%) patients underwent revision surgery. 75% of the patients recommended revision had acute symptoms, compared to 9.3% of those with

Table 1
Demographic characteristics of the cohort. Categorical data are reported as n (%). Continuous data are reported as mean ± standard deviation with range when normally distributed (age) and median (interquartile range) when not normally distributed. Boldface values denote statistical significance ($p < 0.05$).

	All (n = 47)	Successful Clinical Outcome (n = 43)	Failed Primary Fixation (n = 4)	p-value
Sex (Female)	12 (25.5%)	12 (27.9%)	0 (0%)	0.56
Age (years)	13.9 ± 2.0 Range: 10.3–18.1	13.9 ± 2.0 Range: 10.3–18.1	14.2 ± 2.0 Range: 12.2–16.4	0.85
Laterality-Left	22 (46.8%)	21 (48.8%)	1 (25.0%)	0.61
Race/Ethnicity				0.38
White	18 (38.3%)	16 (37.2%)	2 (50%)	
Black	14 (29.8%)	14 (32.6%)	0 (0%)	
Hispanic	5 (10.6%)	5 (11.6%)	0 (0%)	
Asian	2 (4.3%)	2 (4.7%)	0 (0%)	
Other/Declined	8 (17.0%)	6 (14.0%)	2 (50%)	
Weight (kg)	61.2 (IQR 48.8–90)	61.2 (IQR, 49.2–90.7)	56.2 (IQR, 38.3–72.9)	0.33
Weight (Percentile)	87.1 (IQR, 55.6–99)	92.1 (IQR, 57.1–99)	58.6 (IQR, 26.9–84.4)	0.11
History of Asthma	13 (27.7%)	12 (27.9%)	1 (25.0%)	1.00
Insurance				0.53
Private	22 (47.8%)	19 (44.2%)	3 (75.0%)	
Medi-Cal	14 (30.4%)	14 (32.6%)	0 (0%)	
State	8 (17.4.4%)	7 (16.3%)	1 (25.0%)	
Unknown	3 (6.4%)	3 (7.0%)	0 (0%)	
Distal femoral physeal status				0.58
Open	32 (68.1%)	30 (69.8%)	2 (50%)	
Closed	15 (31.9%)	13 (30.2%)	2 (50%)	
Clinical follow-up (weeks)	47.3 (IQR, 24.4–67.8)	42.6 (IQR, 24.2–62.0)	103.1 (IQR, 75.2–207.9)	**0.006**
Radiographic follow-up (weeks)	41.9 (IQR, 21.9–68.0)	40.2 (IQR, 21.4–62.0)	103.1 (IQR, 75.2–207.9)	**0.006**

Table 2
Symptoms, lesion characteristics, surgical treatment types, and radiographic and clinical outcomes. Categorical data are reported as n (%). Continuous data in this table were all not normally distributed and are reported as median (interquartile range). Boldface values denote statistical significance ($p < 0.05$).

	All (n = 47)	Successful Clinical Outcome (n = 43)	Failed Primary Fixation (n = 4)	p-value
Duration of Symptoms				**0.008**
Acute	7 (14.9%)	4 (9.3%)	3 (75%)	
Chronic	40 (85.1%)	39 (90.7%)	1 (25%)	
Location				1.0
LFC	16 (34.4%)	15 (34.9%)	1 (25%)	
MFC	30 (63.8%)	27 (62.8%)	3 (75%)	
MFC/LFC combined	1 (2.1%)	1 (2.3%)	0 (0%)	
Size (cm^2)	2 (IQR, 1.2–3.75)	2 (IQR, 1–3.6)	5.4 (IQR, 3–6.25)	**0.04**
Index Procedure Bone Grafting	8 (17.0%)	6 (14.0%)	2 (50%)	0.13
# of Implants	4 (IQR, 3–5)	4 (IQR, 3–5)	5 (IQR, 4–6.5)	0.16
Radiographic Sclerosis / Resolution of Lucency	45 (95.7%)	43 (100%)	2 (50%)	**0.006**
Clinical Outcome				**<0.0001**
Full Return	33 (70.2%)	33 (76.7%)		
On track	8 (17.0%)	8 (18.6%)		
Avoid Impact	2 (4.3%)	2 (4.7%)		
Revision	4 (8.5%)	0 (0%)	4 (100%)	

successful clinical outcomes ($p = 0.008$) (Table 2). The group recommended revision had larger lesion size of median 5.4 cm^2 (IQR, 3–6.25) compared to the successful clinical outcome group (median lesion size 2 cm^2, IQR 1–3.6) ($p = 0.04$). The total number of implants utilized was 196 among the full series of patients. Number of implants utilized did not differ between subgroups ($p = 0.16$) and neither did bone grafting at index procedure ($p = 0.13$). However, the group recommended revision had a lower likelihood of demonstrating radiographic sclerosis or resolution of lucency.

All four of the patients who were recommended revision were male (Table 3). Three of the four patients recommended revision eventually underwent surgery. Bone grafting was performed in 2 of 3 revision surgical cases. 75% of the lesions were atraumatic. In all three patients with revision procedures, at least one SmartNail was removed; in one case there was frank breakage of one implant, another case had two bent implants, and in the last case the implant was prominent but not broken or bent. Considering these four known SmartNail failures out of the total 196 implants used in this series, the clinical implant failure was 2.0%. One of these patients was noted to have a large cartilage lesion (size: 6.25 cm^2) but was able to return to play without pain. The other two had Outerbridge grade II changes, but after the prominent nail was removed, were able to return to full play. The remaining patient with a failed lesion did not present for treatment, despite recurrence of symptoms and was lost to follow-up. Repeat MRI on this patient did not demonstrate obvious breakage or failure of the implant, but there was persistent edema around the fragment.

4. Discussion

The purpose of this study was to present a large case series of bioabsorbable fixation of knee osteochondral lesions in the adolescent population and report on outcomes, with 87.2% of patients either returning to full activities or permitted to return to full activities. This study is a large case series compared to current literature. 8.5% of patients were recommended revision surgery, and these patients had larger lesion sizes and higher acuity of symptoms with limited sclerosis or radiographic resolution of lucency.

The primary finding of this study is the favorable success rate with bioabsorbable fixation of knee osteochondral lesions in the adolescent population. This study corroborates findings from other published case series [23,27]. In the appropriately indicated patient, bioabsorbable nails appears to be a safe procedure with reliable outcomes. In this series, those recommended revision had larger lesion sizes. This may indicate that larger lesions are more difficult to successfully treat with bioabsorbable fixation. In general, data demonstrates that larger lesions are less likely to heal with nonoperative management [5]. One prior case series evaluating fixation, however, found no difference in healing after fixation [22]. Further data and larger numbers are needed to understand the impact of lesion size on outcomes after bioabsorbable fixation. It is unknown whether metal fixation screws may have been beneficial in these cases with larger lesions. Prior to the use of bioabsorbable fixation, metal implants were utilized with satisfactory rates of cartilage lesion union with success rates cited around 80% [14–17]. However, with metal implants concerns include hardware prominence and necessity for removal. Head-to-head studies on metal compared to bioabsorbable fixation implants may shed light on this question. Some surgeons prefer to treat unstable but salvageable lesions with an autologous transfer compared to fixation, while others have shown good second look arthroscopic and MRI results with stabilization of large lesions [9,28–31]. While this study is not conclusive, consideration of size and subchondral bone health is vital in management of these lesions. In this series, bone grafting at index procedure and number of implants utilized for fixation did not differ between groups, although larger numbers may be needed to detect these differences.

Table 3
Characteristics of the group undergoing revision surgery. MFC: medial femoral condyle. LFC: lateral femoral condyle. MRI: magnetic resonance imaging. OAT: osteochondral auto or allograft transfer.

Sex	Age (years)	Physis	Weight Percentile	Symptom Duration	Location	Lesion Size (cm^2)	Index Procedure Bone Grafting	# Implants	Traumatic vs Atraumatic	Time from index procedure to failure (weeks)	Surgical / Additional Notes
Male	16.4	Closed	83.4	Chronic	MFC	4.5	No	7	Traumatic	35.9	Removed broken SmartNail. Outerbridge 2 changes in MFC. MRI 2.5 years post revisions shows healed OCD, but patient with chronic knee pain. Played collegiate football
Male	12.2	Open	20	Acute	MFC	6.25	Yes	4	Atraumatic	48.9	Removed prominent and bent SmartNails (two) Outerbridge 1 + 2 changes in medial compartment. Returned to basketball and cross country without pain for almost five years then had osteochondral autograft transfer at approximately six years postoperatively
Male	15.4	Closed	85.4	Acute	LFC	6.25	Yes	6	Atraumatic	51.3	Revision recommended but patient never returned for treatment. Goal was to return to recreational activities and skateboarding, but did not return for follow-up
Male	12.8	Open	33.7	Acute	MFC	1.5	No	4	Atraumatic	58.4	Removed prominent SmartNail; Outerbridge 2 changes in MFC. Cleared to return to all activity including running and physical education

Interestingly, patients who were recommended revision were more likely to have acute as opposed to chronic symptoms ($p = 0.008$). Cartilage injury often has a delay in diagnosis often due to vague symptoms in an otherwise health adolescent. Perhaps more acute presentation indicates the degree that patients were symptomatic, but we are unable to determine the why the seemingly more acute symptoms were more likely to fail based on the parameters in this study. When patients required a revision, the revision procedure required removal of a loose body or concern for prominent implant. This is consistent with revision procedures in the skeletally mature knee [24,25,32]. For example, Camathias et al. reported a screw (SmartScrew; ConMed Linvatec) breakage rate of 14/61 (23%) in a study with serial MRI follow-up. Interestingly, not all patients were symptomatic when MRI detected screw failure [25]. Therefore, it is possible in this study without serial MRI follow-up that more implants were broken and undetected or differences in breakage rates may differ between implants. In the three who underwent second arthroscopic procedures, one SmartNail was frankly broken in one case, two were bent in another, and one was prominent without breakage or bending in the last case; however, the authors are not able to discern whether this prominence would have met criteria for breakage or impending breakage as defined by Camathias et al. [25]. Longer term follow-up in the time frame of decades will be needed to determine the ultimate result of cartilage salvage in the adolescent population.

While the first line treatment for juvenile osteochondral lesions is nonoperative, the rate of healing with immobilization is about 50% [33]. Juvenile osteochondral lesions treated with fixation have historically had excellent healing potential, while

thought to be less reliable in adults or those with closed physes [23,24,27,34,35]. In this study, there was no statistically significant difference between successful surgeries and those that failed primary fixation in patients with open physes (69.8% versus 50%); however, the small number of patients the failed primary fixation may be the reason for lack of significant findings and further data evaluating the impact of physeal status would be beneficial.

4.1. Limitations

There are several limitations to this study. While median clinical follow-up was close to one year, several patients in this study did not return after they were cleared to return to play. While the electronic medical record (EMR) improves our ability to follow these patients at outside institutions, patients may seek future care outside of the institutions with compatible EMR. Patients who were considered a success often did not follow-up after their clearance to return to sport, and it is difficult to discern whether they continued to do well or sought care elsewhere. While follow-up is challenging in many populations, pediatric patients are particularly challenging as visits require both transportation and time away from school. The accuracy of timing of symptoms is limited in that symptoms were classified broadly as acute versus chronic with acute being assigned to those presenting with <1 month of symptoms. While these categories help understand some extent of the duration of symptoms, the breadth of the categories makes comparison difficult to interpret with a substantial degree of precision. The small number of patients in the comparison group being recommended revision is likely underpowered to detect differences between the groups; conclusions of statistical analyses should therefore be approached with hesitation. Furthermore, this study primarily utilized the ConMed Smart Nail with several of the more recent patients with Arthrex Chondral Darts. Due to small numbers, no comparison was formally performed between the two, and results may not be widely applicable to other bioabsorbable fixation devices.

Future studies should include longer follow-up of the patients who undergo fixation, and this follow-up could include MRI studies to better investigate the healing of the osteochondral lesion. Investigation of patients who are in need of osteochondral allograft or autograft and history of prior osteochondral fixation will also help increase the understanding of how fixation of osteochondral lesions in skeletally immature patients due in the long-term. Interestingly, in this series of 47 patients with unstable osteochondral lesions, over ¼ of the patients had a history of asthma. The estimated prevalence in children under the age of 17 in the United States is less than 10% [36]. While this is not the objective of this study, in future studies we could investigate this finding further.

5. Conclusions

Adolescents had a high return to activity following bioabsorbable fixation for knee osteochondral lesions with 87.2% cleared for full return. In the 8.5% of patients who were deemed to have failed primary fixation, symptoms were more likely to be acute in nature with larger lesion sizes.

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Declaration of Competing Interest

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