Functional and Radiographic Outcomes of Juvenile Osteochondritis Dissecans of the Knee Treated With Extra-Articular Retrograde Drilling

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Background: Osteochondritis dissecans (OCD) lesions of the medial femoral condyle in the adolescent population can cause significant impairment and restriction in physical activity. Studies have established the efficacy of transarticular antegrade drilling for juvenile OCD lesions of the knee, although concerns of consequences from drilling through the articular cartilage remain. Alternatively, retrograde extra-articular drilling avoids drilling the cartilage while ensuring adequate channels for revascularization and healing.

Purpose: The authors present the results of 31 skeletally immature patients who underwent retrograde drilling of OCD lesions of the knee with an average follow-up of 4 years.

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

Methods: The procedure consisted of a standard arthroscopic evaluation of the knee and subsequent percutaneous retrograde drilling obliquely through the condylar epiphysis starting distal to the physis and ending in the center-center of the OCD lesion. Outcome measures included radiographic signs of healing, Lysholm scoring and the Tegner activity scale to measure performance and activity restriction, and visual analog scale (VAS) pain scores.

Results: Average follow-up for the 31 patients was 4 years (range, 1.5-7 years). Sixteen of the 34 lesions were grade I or II based on radiographic findings with signs and symptoms greater than 6 months. The remaining 18 were grade III secondary to a sclerotic rim surrounding the defect. Overall, improvement in Lysholm scores (70 to 95; standard deviation [SD] ± 14.95), Tegner scores (4 to 7; SD ± 2.31), and VAS pain scores (6.9 to 1.3; SD ± 2.16) were found to be statistically significant. Radiographs showed stable or improved lesions in all cases.

Conclusion: Retrograde extra-articular drilling provided clinical and radiographic improvement in most juveniles with OCD lesions who failed nonoperative management. This method serves to decompress the lesion and allow revascularization without disrupting the articular cartilage surface in stable OCD lesions.

Keywords: osteochondritis dissecans; juvenile OCD; retrograde drilling; extra-articular drilling

Osteochondritis dissecans (OCD) is a focal condition affecting subchondral bone, causing a spectrum of injury from softening of intact overlying articular cartilage to complete separation of osteochondral fragments and intra-articular loose bodies. Failure of revascularization leads to subchondral bone resorption and articular cartilage degeneration. König[15] first coined the term osteochondritis dissecans in 1887, and although it remains a well-known condition, the cause is still not fully known. Many attribute it to repetitive microtrauma akin to the mechanism responsible for stress fractures in other areas of the body, which has been supported by experimental models in animals.[2,3,6,7,17]

Osteochondritis dissecans is an increasingly common cause of knee pain and dysfunction among skeletally immature and young adult patients. Classification of OCD can be based on age, location, radiographic and MRI findings, and intraoperative appearance. Moreover, it is important to distinguish knee OCD in the skeletally immature versus the skeletally mature as the natural history in these 2 populations is different, with worse prognosis in patients with closed distal femoral physes. Although the majority of OCD lesions occur on the posterior lateral aspect of the medial femoral condyle, they can occur anywhere.

Juvenile OCD (JOCD) of the knee is being diagnosed at an increasing rate, likely because of the increasing number of sports participants among these populations.[5] In the

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The authors declared that they have no conflicts of interest in the authorship or publication of this contribution.

The American Journal of Sports Medicine, Vol. 39, No. 10
DOI: 10.1177/0363546511416594

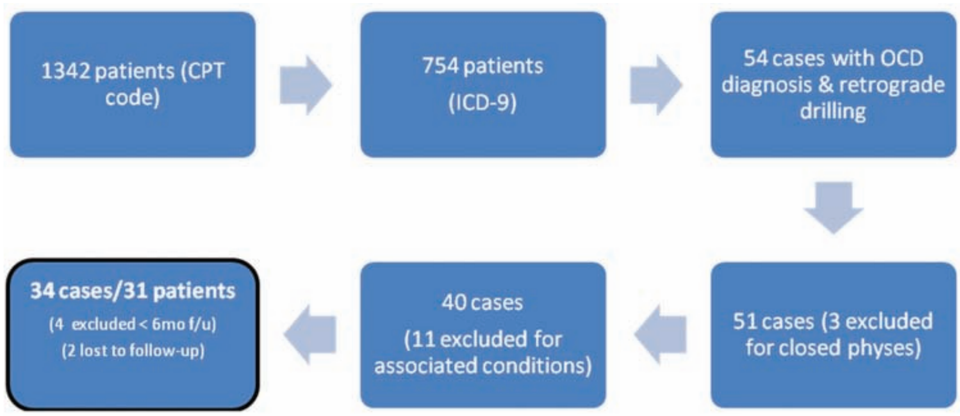

Figure 1. Patients who qualified for this review after applying inclusion and exclusion criteria.

JOCD age group, Lindén[17] found the prevalence to be 18 in 100 000 in females and 29 in 100 000 in males in his 10-year study in Sweden. The average age of onset ranges from 11.3 to 13.4 years, with some suggestion of a trend toward an earlier age of onset.[6,19]

Early diagnosis is important, particularly in young patients, when most lesions are stable. Provided the patient is compliant, has a stable lesion, and is not near physeal maturity, the likelihood is approximately 50% that the lesion will heal within 10 to 18 months with nonoperative treatment.[8] The modality and duration of nonoperative management reported in the literature is variable. Nonoperative treatment protocols include activity modification, weightbearing restriction, immobilization, physical therapy, and a combination of these. Failure of nonoperative treatment, usually after at least 3 to 6 months, is an indication for operative intervention. Other operative indications include detached or unstable lesions and a patient approaching physeal closure. Surgical options depend on the type of lesion and include antegrade drilling, retrograde drilling, bone grafting, internal fixation, loose body removal, osteochondral grafting, and autologous chondrocyte implantation. Subchondral drilling for creation of revascularization channels is the primary surgical procedure used for treating stable JOCD lesions. Standard drilling techniques either involve antegrade (transarticular) penetration of the intact articular cartilage or extra-articular (retrograde) approaches preserving the cartilage surface.

The efficacy of transarticular or antegrade drilling has been reported in multiple studies.[1,4,5] However, transarticular drilling has the disadvantage of causing unnecessary iatrogenic cartilage injury. Theoretically, secondary degenerative changes from articular cartilage damage have led some to recommend direct extra-articular drilling.[10] Retrograde extra-articular drilling has the advantages of creating vascular channels in subchondral bone without the associated morbidity to articular cartilage. Most studies on retrograde drilling, however, either report a small cohort or short follow-up periods.[9,16] The purpose of this report is to review an average 4-year follow-up of 34 cases of retrograde extra-articular drilling for stable JOCD of the femoral condyle of the knee.

MATERIALS AND METHODS

Patients

After approval from our institutional review board (IRB #2011-14433), the records of patients diagnosed and surgically treated for OCD of the knee at Children's Memorial Hospital between 2003 and 2008 were identified using ICD (International Classification of Diseases)–9 and CPT (Current Procedural Terminology) codes as filters. After a thorough review of all patient matches, it was determined that 54 cases fulfilled our initial search criteria. Their medical records, imaging studies, and intraoperative photographs were reviewed. Three patients were excluded because of radiographic evidence of physes closure. Eleven patients had other procedures and injuries such as concurrent anterior cruciate ligament injury, loose bodies, or microfracture/OATS (osteoarticular transfer system) procedures. Four patients did not have follow-up >6 months in the office, and the last 2 patients could not be reached for telephone interviews and reconfirmation of data (Figure 1). After applying the inclusion and exclusion criteria, a total of 34 lesions in 31 patients underwent retrograde drilling under fluoroscopic guidance and completed full postoperative follow-up, including return to clinic for clinical and radiographic examination (see below).

All included patients demonstrated radiographic evidence of OCD on plain radiographs that were confirmed with MRI. Nonoperative management included activity modification (ie, cessation of sports) for at least 6 weeks, immobilization of children in weightbearing cylinder casts for 6 weeks or non-weightbearing in adolescents for 6 weeks, followed by protected weightbearing and range of motion exercises for up to 6 months or as reossification appeared on radiographs.

The average age at the time of surgery was 12 years and 7 months (range, 8-16 years). There were 21 boys and 10 girls in the cohort. Six lesions occurred in the inferocentral areas of the lateral femoral condyle and 28 occurred, or extended into, the lateral aspect of the medial femoral condyle. All 34 lesions were clinically stable and MRI grade I or II lesions with no radiographic evidence of

TABLE 1
Magnetic Resonance Imaging Classification of Juvenile Osteochondritis Dissecans Lesions

Stage	Description
I	Small change of signal without clear margins of fragment
II	Osteochondral fragment with clear margins but without fluid between fragment and underlying bone
III	Fluid is visible partially between fragment and underlying bone
IV	Fluid is completely surrounding the fragment, but the fragment is still in situ
V	Fragment is completely detached and displaced (loose body)

separation[11,14] (Table 1). The average follow-up was 4 years (range, 1.5-7 years) (see the Appendix, available online at http://ajs.sagepub.com/supplemental/).

Surgical Technique

The knees were examined arthroscopically under general anesthesia to ensure stable OCD lesions with an intact cartilage flap. Under C-arm fluoroscopy in 3 planes, the AP, notch, and true lateral views were obtained, identifying the area of the OCD lesion. Under fluoroscopic guidance, a 0.045-in Kirschner-wire (K-wire) was placed percutaneously using free-hand technique at a level below the physis, and directed obliquely, down through the femoral condyle in a retrograde fashion (behind the lesion) (Figure 2). Specifically monitored to avoid the physis, the K-wire was directed to the middle of the OCD lesion on both AP and lateral views. Distal penetration of the K-wire was limited to the sclerotic rim seen on fluoroscopy. A hard end point at the margin of the lesion and a "breakthrough sensation" was noted in most cases at the time of drilling. Initially, the articular surface was arthroscopically examined to ensure no penetration; however, as experience accumulated, the "breakthrough sensation" was found to be a dependable surgical indicator. Multiple vascular channels were created using a multihole drill guide as needed depending on the size of the lesion, using the center K-wire as a guide ensuring penetration of subchondral bone on all attempts.

Postoperatively, the extremity was placed in a knee immobilizer and the patient maintained non-weightbearing in the ipsilateral extremity for a minimum of 2 weeks. Weightbearing and activity restrictions were lifted as early as 2 weeks postoperatively if the patient was asymptomatic and had passed an in-clinic evaluation by a certified physical therapist. Thus, pain and function served as the guide.

Postoperative Evaluation

Postoperative evaluation included clinical and radiographic examination at follow-up visits to monitor healing. Radiographs included AP, lateral, and tunnel views of the operative knee. No postoperative MRI was obtained. Lesions were categorized by the radiographic osteochondritis dissecans score of Rodegerdts and Gleissner[20] (Table 2). Each radiograph was blindly and independently reviewed by 3 of the authors. Healing was defined as disappearance of the radiolucent zone or union of the displaced fragment. We used the Lysholm score and Tegner activity level scale to assess improvement in knee functionality. In addition, clinical improvement in symptoms was measured using a visual analog pain scale (VAS). These measures were obtained from the last clinic follow-up and represent the date of follow-up in this study. Patients were contacted during the data collection period by telephone interviews and follow-up outcome measures were again collected after ensuring responses would not affect medical care in any way. During this follow-up, patients were asked to indicate if they were unsatisfied, satisfied, or very satisfied with the procedure. Lastly, to retrospectively gauge willingness to go to surgery, the patient was asked if "knowing what you know now, would you repeat the procedure?" During this follow-up call, patients were also asked to recall preoperative symptoms if needed to complete the Lysholm scale.

Statistical Analysis

Results were analyzed by the paired Student t test to determine whether the pre- and postoperative scores had achieved a statistically significant difference. A P value $<.05$ indicated statistical significance. Outcome variables were tested for normality using the Wilk-Shapiro goodness-of-fit test; only the Lysholm score showed slight departures from normality and homogeneity of variance. A binomial variable for the Lysholm pretest and posttest scores was created to make certain that this outcome was statistically significant. A paired χ^2 (McNemar statistic) was employed to correct for a potentially non-normal distribution. Data analysis was conducted using the SAS software package (SAS Institute, Cary, North Carolina).

RESULTS

No known intraoperative or perioperative complications occurred in the 34 cases of retrograde drilling. Postoperatively, there was a significant overall improvement in Lysholm scores ($P < .001$) from a mean preoperative score of 70.4 to a mean postoperative score of 95.1. Thirty-three of 34 knees (97%) showed an improvement in Lysholm scores (Table 3). The remaining knee had associated Lysholm scores of 49 and 43 pre- and postoperatively, respectively. This patient's lesion ($1.9 \times 0.9 \times 1.3$ cm) was located in the posteromedial aspect of the lateral condyle and subsequently underwent 2 microfracture procedures for refractory symptoms.

Tegner activity scores significantly increased after surgery from 4.00 to 7.21 ($P < .001$). Twenty-six knees had an improvement of at least 2 levels in this scoring system. Eight knees demonstrated no change in score.

There was a statistically significant improvement of 1.73 (range, 0-3) in the Rodegerdts and Gleissner radiographic scores ($P < .001$) (Figure 3). In our cohort of 34

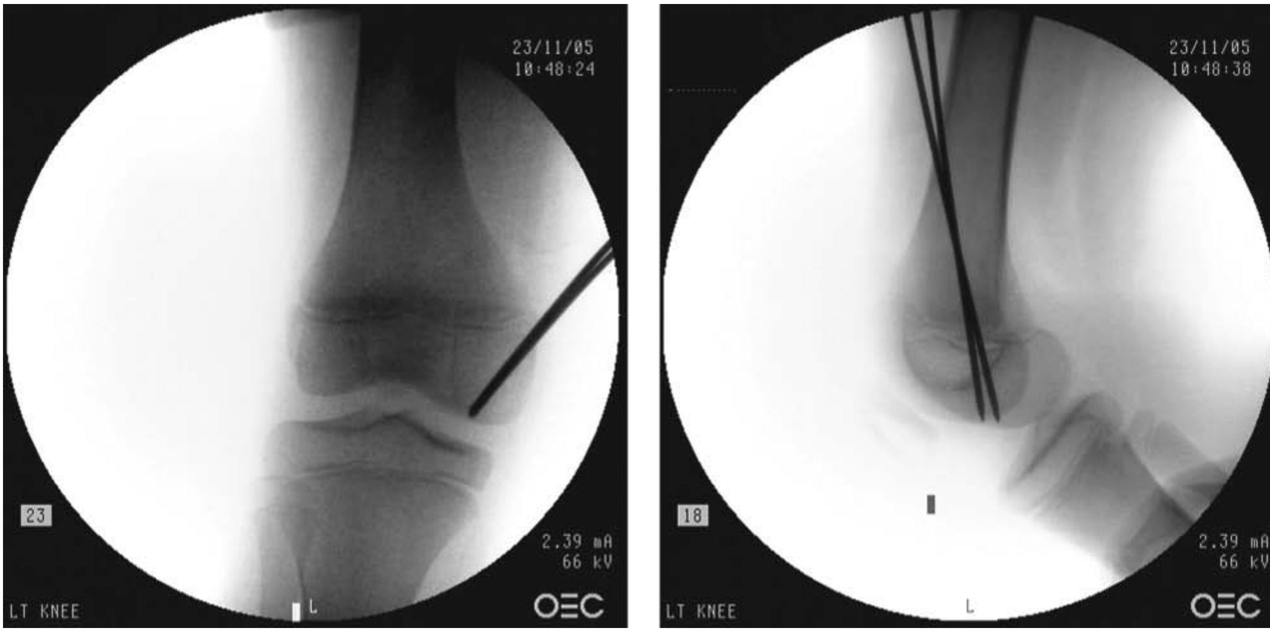

Figure 2. Intraoperative AP and lateral fluoroscopy images of the retrograde drilling procedure.

TABLE 2
Radiographic Osteochondritis Dissecans Scores According to Rodegerdts and Gleissner[20]

Grade	Radiographic Appearance
I	Potentially depressed osteochondral fragment
II	Demarcation without sclerotic rim
III	Demarcation with sclerotic rim
IV	Nondisplaced partially detached fragment
V	Displaced fragment (loose body)

lesions, 32 (94%) demonstrated an improvement in final follow-up radiographic scores, and 2 knees (6%) demonstrated no change. Despite showing no radiographic improvement, both of these patients had improvements in VAS, Lysholm, and Tegner scores.

The visual analog pain scale (0-10, 10 being worst) was used to measure the subjective improvement in symptoms. There was a significant decrease in pain levels from 6.91 preoperatively to 1.35 postoperatively (P <.001). Only 1 patient described no improvement in pain after the procedure. Eighteen patients (53%) reported zero pain during follow-up visits. The majority of the remaining patients showed an improvement by at least 3 levels on the VAS (see Appendix, available online).

An informal survey, collected during follow-up, showed that in 32 (94%) of the 34 cases, the patient would repeat the surgery if given the option again. Three patients underwent the procedure bilaterally and thus repeated the surgery on the contralateral extremity at a different time. Twenty-two patients (65%) stated they were very satisfied with the outcome, 9 (26%) were satisfied, and 3 (8%) were not satisfied. These 3 patients also answered that they would not recommend the surgery to other patients with similar clinical presentations; the remaining 31 (91%) would recommend the procedure to other patients.

DISCUSSION

Osteochondritis dissecans of the knee is a well-described condition that can cause significant morbidity in children and adolescents. The typical OCD lesion involves the posterior and lateral aspect of the medial femoral condyle in active adolescents. Previous history of trauma is not uncommon. Those patients with stable lesions who fail nonoperative treatment are candidates for surgical drilling of these lesions. Transarticular drilling causes iatrogenic articular cartilage damage, leading to fibrocartilage healing and potential degenerative arthritis.[5] A recent extra-articular intercondylar approach described by Kawasaki et al[12] offers the benefits of avoiding penetration of the articular cartilage; however, given the approach, the area of access, and thus treatment, is limited. They reported excellent outcomes in the 16 patients treated with this method, but in a patient in whom the lesion was in the inferocentral portion of the lateral femoral condyle, the surgeon had to revert to a retrograde approach because of difficulty positioning the K-wire.

Our study demonstrated significant improvement in Lysholm, Tegner, VAS, and radiographic scores 4 years after physeal-sparing, extra-articular antegrade drilling in 34 cases consistent with satisfactory results. To our knowledge, this represents the largest reported series using this technique. Retrograde drilling, when applied to stable lesions, has the revascularization benefits of transarticular drilling, but avoids morbidity to the

TABLE 3
Outcome Measures

Outcome Measure	Preoperative[a]	Postoperative[a]	Change[a]	P Value[b]
Lysholm score	70.35 ± 15.88	95.12 ± 10.43	24.77 ± 14.95	1.05E-11
Tegner activity	4.00 ± 2.20	7.21 ± 1.67	3.21 ± 2.31	1.26E-9
Visual analog scale pain score	6.91 ± 1.75	1.35 ± 2.01	5.56 ± 2.16	5.19E-17

[a]Values are mean ± standard deviation.
[b]All P values statistically significant with $P < .001$.

Figure 3. Pre- and postoperative radiographs of an 11-year-old girl with right medial femoral condylar osteochondritis dissecans.

TABLE 4
Comparison of Outcomes Based on Patient Satisfaction and Outcome Measures

Parameter, Mean	Satisfied and Very Satisfied Patients With Positive Outcome Measures	Unsatisfied Patients With Negative Outcome Measures
Age, y	12.5	15
Preoperative lesion size, cm^3	1.3	4.1
Time between symptom onset and surgery, mo	17	28

TABLE 5
Outcome Measure Changes Based on Location of Lesion

Outcome, Mean Improvement	Medial Femoral Condyle	Lateral Femoral Condyle
Lysholm	27.1	13.5
Tegner activity	3.3	3.0
Visual analog scale	6.1	2.83
Radiographic score	2.1	2.0

articular cartilage. Anderson et al[5] had healing in 20 of 24 OCD lesions treated with "retrograde" drilling, with poorer results in those who were skeletally mature. Kocher et al[13] performed a transarticular antegrade drilling in 30 knees with a mean age of 12.3 years. They reported an average postoperative Lysholm score of 92.8 (compared with 95.1 in this study) and an average radiographic score improvement of 1.1 (compared with 1.73). Furthermore, these patients were kept non-weightbearing for 4 weeks and allowed to return to activity at a minimum 12 weeks. Donaldson and Wojtys[9] reported excellent outcomes with full return to activities and radiographic evidence of healing in 12 of 15 patients (3 lost to follow-up) treated with transarticular retrograde drilling with average follow-up of 21 months. Our report provides longer term follow-up in addition to quantifiable data regarding clinical and radiographic scores. Louisia et al[18] performed transarticular drilling of medial femoral condylar OCD lesions and found excellent results in 12 (71%) of 17 skeletally immature patients with an average follow-up of 11.8 years. While this represents a small cohort in a specific OCD lesion type, the long-term follow-up promotes the idea of greater long-term data on OCD drilling to determine if articular cartilage penetration is harmful.

When dividing the cohort into 2 subgroups based on patient satisfaction and outcome quality, age was found to be an independent, multivariate predictor of positive outcome (Table 4). The average age of patients with positive outcomes was 12.5, versus 15 for patients with less favorable outcomes; however, the trend did not achieve statistical significance. This is consistent with previous reports in the literature that indicate poorer outcomes in older patients and patients with closed physes.[13] This may be secondary to decompression of the subchondral bone without traumatic disruption of the cartilage, which may not heal as readily in older patients. The location of the lesion appears to be a predictor of outcome as well, with typical lesions on the posterolateral medial condyle faring better than lesions in other locations (Table 5). Again, this trend did not achieve statistical significance.

This study has the inherent weaknesses of a case series, including selection bias. The postoperative follow-up Lysholm, Tegner activity, and VAS score measures were collected during the last clinical follow-up. The preoperative Lysholm scores were collected from chart review, and retrospectively completed as needed, during follow-up calls, which subjects the data to recall bias; however, the preprocedure values for Tegner activity and VAS scores were collected via chart review alone. The examiner-administered informal survey introduces bias, but had no clinical sequelae and was for research purposes only. Of note, the Lysholm functional scale is well-validated for knee injuries in adults, but has not been validated in the pediatric population. Nonetheless, we found it to be a useful outcome measure and a measure that has been used in similar studies that allowed for comparison.

Moreover, the study lacked a control group of patients who continued nonoperative treatment or underwent another approach such as transarticular drilling; rather, a literature control was used. Concern is expressed by some authors that retrograde drilling may fail to penetrate the subchondral bone and thus create effective vascular channels that promote healing.[13] Our technique with the aid of fluoroscopy demonstrates that retrograde drilling can provide adequate revascularization with both successful clinical and radiographic outcomes. A potential downside of this surgical technique is unintentional penetration of the articular surface while only monitoring via fluoroscopy, not arthroscopy. This technique may require greater technical skill or accuracy compared with transarticular drilling; however, it is the surgeons' experience that there is a shallow learning curve.[13] Disadvantages of increased fluoroscopic usage and soft tissue injury with this retrograde approach must be weighed against articular surface damage in transarticular approaches.[12]

Patient satisfaction is a critical, but not often reported, outcome measure in OCD surgical intervention. Patient perception is crucial to the long-term success of any treatment, especially surgery, given the need for rehabilitation and recovery that requires patient compliance. Our informal survey qualitatively showed successful patient satisfaction measures in the majority of the patients. This could lead to continued satisfaction during longer follow-up and, theoretically, less morbidity. Furthermore, 94% of our patients showed improvement in radiographic scores, 97% showed improvement in clinical Lysholm scores, and 89% would recommend the surgery. This improvement in symptoms and function is greater than the 50% likelihood of healing with nonoperative treatment.

In conclusion, adolescents and young adults suffering from OCD lesions of the knee have a higher healing potential than skeletally mature patients. However, a significant percentage of these patients fail non-operative therapy and require surgical intervention. Retrograde extra-articular subchondral drilling recreates vascular channels for neovascularization without damaging articular cartilage and extensively restricting postoperative activity and weight-bearing.

ACKNOWLEDGMENT

We thank and acknowledge John Grayhack, MD, Joseph Janicki, MD, and Brittany Patrick, MPH, for their contributions to this project.

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