Osteochondritis Dissecans Lesions of the Pediatric and Adolescent Knee

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KEYWORDS

• OCD • Pediatric • Adolescent • Cartilage • Osteochondritis dissecans • Knee

KEY POINTS

- Osteochondritis dissecans of the knee is the result of a focal idiopathic alteration of subchondral bone that may result in disruption of the articular cartilage and lead to premature osteoarthritis.
- It has a variable presentation and is mostly a juvenile disease with preadolescent and adolescent age group predilection.
- Diagnosis is based on history, physical examination, and imaging with MRI thought to be essential in diagnosing the stage and stability of the lesion.
- Goals of treatment are to promote subchondral bone healing and preservation of the overlying articular cartilage to prevent fissure, fracture, dissection, and ultimately joint arthritis.
- Treatment can vary from activity modification and observation of natural healing to arthroscopic drilling with or without fixation. Unsalvageable lesions may require arthrotomy, excision and autogenous or allograft osteochondral implantation, or chondral resurfacing techniques.

INTRODUCTION

First described by Franz König[1] in his 1886 classic German article, "Ueber freie Körper in den Gelenken," which translates in English to “On Loose Bodies in the Joint,” osteochondritis dissecans (OCD) is primarily a subchondral, subarticular bone disease that can secondarily affect the overlying chondral surface. It has more recently been defined by the ROCK study group,[2] which is composed of high-volume OCD surgeons, musculoskeletal radiologists, physical therapists, and researchers as “a focal, idiopathic alteration of subchondral bone with risk for instability and disruption of adjacent articular cartilage that may result in premature osteoarthritis.”[3] The process of disease development must be distinguished from osteochondral fractures that result secondary to a traumatic event that disrupts previously healthy bone and cartilage. Furthermore, it must be recognized that OCD lesions can be acutely disrupted, and features of OCD must be evaluated with history taking and imaging to distinguish them from osteochondral fractures.

Although many joints can be affected, it is most often monoarticular, with the knee being the most common site.

The hallmark of OCD is that symptoms do not always correlate with disease severity. It is an acquired condition with variable presentation, most in its juvenile form, ages 6 to 16 years, and can often be asymptomatic, whereas others may report focal pain or mild vague pain deep in the knee with activities, with variable degrees of joint swelling or mechanical symptoms. It is also reported to be found incidentally on radiographs in patients with knee pain related to other causes.

OCD of the knee is mostly a juvenile disease with preadolescent and adolescent age group

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predilection. Although OCD of the knee can present in an adult knee, many investigators believe it to simply be an undiagnosed case or delayed presentation of juvenile OCD.[4] Even still, de novo cases of adult OCD have been reported.[5] Although abnormal bone vascularity is a more common etiologic factor proposed, OCD is still considered by most experts an idiopathic process and likely multifactorial. Konig[1] thought the process to be related to inflammatory changes, whereas multiple other investigators proposed repetitive microtrauma as the inciting event, subsequently leading to subchondral bone contusion and abnormal blood flow and resultant osteonecrosis.[6–9] Along these lines, the theory of OCD development in its classic location in the medial femoral condyle has been reasoned to arise in part from repetitive impingement from a prominent medial tibia spine.[10,11] Other offered causes include single-event macrotrauma,[12] genetic causes,[13] and more recently, a disturbance of secondary ossification process of epiphyseal growth,[14] as evidenced in histologic studies showing formation of uncalcified cartilage within the lesion. Blanke and colleagues suggested instability of the anterior horn of the meniscus as a cause of OCD lesions, and with arthroscopic stabilization of the meniscus, 80% of patients had complete healing of the OCD on MRI at 12 months.[15] Patient-specific biomechanical factors including obesity,[16] lower extremity malalignment,[17] and soft tissue imbalances, as well as metabolic factors such as underlying vitamin D deficiencies have all been implicated by researchers.[18]

The cause of OCD is clearly incompletely understood and likely multifactorial in a rapidly growing pediatric patient.

Goals of treatment are to promote subchondral bone healing and preservation of the overlying articular cartilage and prevention of fissure or fracture, dissection, and ultimately joint arthritis.

Treatment can vary from observation of natural healing, often pursued in younger patients with stable lesions, directed by limitations on impact activities, weight-bearing, and bracing. Although older patients with more advanced lesions are often treated with arthroscopic drilling, with or without fixation and possible bone grafting. Whenever possible, retention of native chondral surface is paramount for joint preservation in salvageable lesions. Ultimately, some unstable and/or unsalvageable lesions require arthrotomy, excision and autogenous or allograft osteochondral implantation, or other chondral resurfacing techniques.

The purpose of this review is to provide a current outline of the epidemiology and anatomy, diagnosis, classification, and staging; discuss nonoperative management strategies; review operative treatment for stable and unstable as well as cartilage resurfacing and salvage procedures for failed OCD fixation and unsalvageable osteochondral defects.

EPIDEMIOLOGY AND ANATOMY

In one of the largest epidemiology studies on OCD of the knee, Kessler and colleagues, reviewing more than 1 million children, concluded the incidence of OCD of the knee in ages 6 to 19 years was 9.5 per 100,000 per year. Gender discrepancies existed, showing in boys the incidence was 15.4 per 100,000 and in girls 3.3 per 100,000.[19] The average age of OCD was 13 years with no reported cases arising in children ages 2 to 5 years. In addition, children ages 12 to 19 years had 3.3 times greater risk of developing OCD of the knee than ages 6 to 11 years. Regarding racial predilection, blacks had the highest odds ratio compared with non-Hispanic whites, Hispanics, Asian and Pacific Islanders, and other ethnicities.[19] Although men seem to have a higher incidence of OCD of the knee compared with women, some investigators have shown a trend of increasing female incidence, relating it to their increasing participation in sports.[5,7]

The knee is the most common location for OCD development, with other less common sites including the ankle and elbow, followed by shoulder and hip.[19]

In the knee, Kessler and colleagues[19] showed 63.6% of OCD lesions develop within the medial femoral condyle, most often in the lateral aspect of the medial femoral condyle in the coronal plane and central or posterior in the sagittal plane. In 32.5%, the lesion developed in the lateral femoral condyle, with these often presenting as larger lesions, at a more advanced stage. Kessler also demonstrated 7.3% of patients from this study had bilateral knee lesions, differing from a prior report by Cooper and colleagues, who calculated 29% of 108 consecutive cases presented with bilateral lesions.[20] Other locations include the patella, lateral femoral trochlea, central femoral trochlea, and lateral tibia plateau, in decreasing order of incidence.[21] There does not seem to be a laterality dominance of OCD development, with similar numbers of left versus right lesions.[22]

DIAGNOSIS, CLASSIFICATION, AND STAGING

Diagnosis of OCD should be on the differential diagnosis in adolescents and teenagers with knee pain and should be diagnosed based on history, physical examination, and radiographs. MRI can be essential in diagnosis but is also critical in determining the stage, and therefore stability, of the lesion. It should therefore be included in the preliminary workup after diagnosis of OCD is made. A visible OCD and bony loose body on a knee radiograph represents an obviously unstable lesion; otherwise, further classification of lesion stability, such as that proposed by Guhl[23] or more recently the ROCK study group, is done at time of arthroscopy.

Cahill further delineated femoral condylar OCD classification based on lesion location on anteroposterior (AP) (medial to lateral zones) and lateral (anterior to posterior) radiographs of the knee.[5]

Clinical presentation of OCD of the knee can be variable in degree of pain or dysfunction and stage of the lesion. OCD can be discovered on radiograph incidentally after unrelated knee injury and, when asymptomatic, may require no intervention, especially if stable and in a location with low joint contact pressures. Often, stable lesions present as vague pain or limping, often free from joint swelling, whereas unstable lesions may present with pain and joint swelling or mechanical symptoms such as locking or catching of the joint with motion, especially if dissection of the progeny fragment from its origin has occurred and a loose body is present. Symptoms at any stage are often amplified by impact activities such as running, jumping, and sports participation.

Physical examination too can vary from point tenderness over the lesion with trochlear lesions palpated in knee extended and those more condylar and posterior palpated with deeper degrees of knee flexion. Pain from trochlear and patellar lesions may be elicited by compression of the patellofemoral joint. The presence of joint effusion should be examined, as this may represent an unstable OCD lesion. This effusion may be from a reactive synovitis, a dialysate of plasma in more chronically evolving lesions, and possibly frank hemarthrosis after acute shear injuries.

Imaging

Common imaging studies that are used for diagnosis and staging of OCD consist of radiographs and MRI. Bone scintigraphy and computed tomography scans are less commonly used due to exposure to radiation concerns in the pediatric population but can be useful in characterizing lesions and the healing in response to treatment. The common knee radiographic series to evaluate OCD are the AP, lateral, sunrise, and notch views, the latter being particularly helpful in viewing the more posterior femoral condyle, which is a common area for OCD in the knee. More anterior condylar lesions are seen more clearly on the AP view. Discretion must be given to distinguish anatomic normal variants including secondary ossification centers near the posterior condyles and changes seen in the normally developing epiphyseal bone in children younger than 6 years and rapidly growing adolescents, such as boys younger than 13 years and girls younger than 11 years. Often in this age group, the subchondral bone deep to the thick epiphyseal cartilage can seem corrugated with irregular borders or as islands of bone. Assessment of features seen on T2-weighted MRI such as hyperintense bone marrow edema adjacent to the area of subchondral bone in question may facilitate distinction of normal development from OCD lesions.

Although radiographic assessment of healing has been shown to be suboptimal,[24] follow-up surveillance most commonly is done with serial radiographs, whereas repeat MRI may be necessary if response to treatment suggests poor healing or progression of the lesion is evident.

After diagnosis has been made, pretreatment MRI of the lesion should be completed to most accurately characterize and appropriately stage the lesion based on the features seen within the subchondral bone and status of the adjacent cartilage. Characteristics more readily apparent on MRI are the extent of subchondral bone enhancement, architectural features such as size and depth of the lesion, and presence of cystic changes within the subchondral bone that may lend to increasing degrees of lesion instability. Although there are multiple classification systems described, the most commonly applied MRI-based classification system was developed by Hefti and colleagues in 1999[25] (Fig. 1). This system divides OCD lesions into progressive stages of severity, 1 through 5, based on features in the MRI. However, an assortment of additional criteria may be considered beyond those articulated by Hefti and colleagues For example, stable lesions (Hefti stages 1 and 2) should be distinguished from unstable lesions (Hefti 3–5) by the presence of nondisrupted lesional cartilage to the adjacent cartilage and the continuity of the subchondral

A

OCD MRI Classification

Stage	Explanation
1	Signal change in subchondral bone without clear lesion margins
2	Clear lesion margins, but without clear linear high signal (fluid-like) pattern signal between fragment and adjacent bone
3	Clear linear high signal (fluid-like) pattern signal between some areas of lesion and adjacent bone, but not surrounding entire fragment (i.e. not seen in all sequences/images involving lesion)
4	Clear linear high signal (fluid-like) pattern signal between entire in-situ fragment and adjacent bone (i.e. seen in all sequences/images involving lesion)
5	Detached fragment/loose body

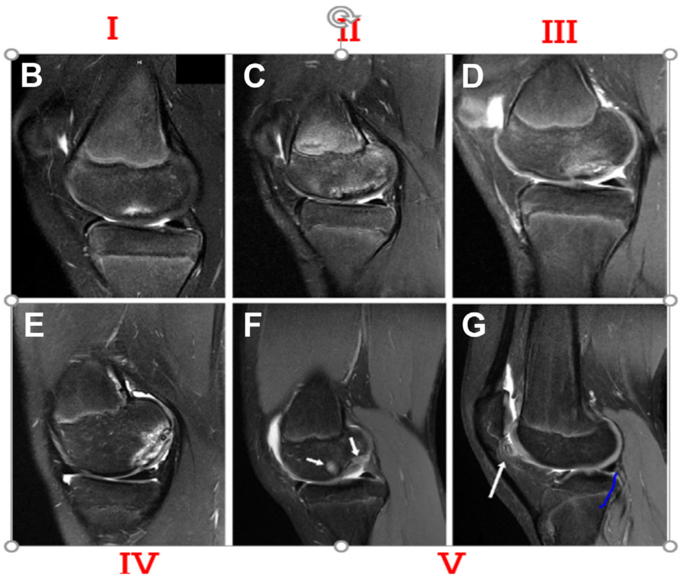

Fig. 1. Hefti classification of osteochondritis dissecans (OCD) lesions. (*A*) Describing the staging of OCD lesions based on MRI findings. (*B–F*) Sagittal T2-weighted MRI scans demonstrating the features of condylar. Hefti stage 1 (see Fig. 1B), stage 2 (*C*), stage 3 (*D*), stage 4 (*E*), and stage 5 (*F*) lesions. The stage 5 lesion in *F* is associated with an osteochondral defect (*right arrow*) and a subchondral cyst (*left arrow*). (*G*) Different sagittal T2-weighted MRI scan of the knee in the same patient shown in *F*, demonstrating a loose OCD fragment (*arrow*). ([*A*] *Adapted from* Table 1 of Hefti, F., et al., Osteochondritis dissecans: a multicenter study of the European Pediatric Orthopedic Society. Journal of Pediatric Orthopedics, 1999. 8(4):p. 231-245; and [*B*] *From* Heyworth BE, Kocher MS. Osteochondritis Dissecans of the Knee. *JBJS Rev.* Jul 2015;3(7) https://doi.org/10.2106/jbjs.Rvw.N.00095; with permission.)

bone plate. In these more stable type of in situ lesions, it should follow that there will be a paucity of high-intensity fluidlike signal behind the lesion or deep to the chondral surface, lending a lower likelihood that the cartilage has been breached. Unstable features include loss of a low signal bone plate continuity immediately below the cartilage, obvious chondral breech, and varying degrees of fluid signal deep to the lesion, deep fissuring, or delamination of overlying cartilage suggesting imminent breach of fluid deep to the lesion, if not already present. Further degrees of unstable features include elongated, linear signal surrounding the entire progeny bone fragment that are hyperintense fluidlike signal or hyper-intense cystlike lesions (CLLs).

More recently, Hussain and colleagues proposed an MRI-based, 3-group approach to staging and diagnosis of knee OCD and compared the reliability of that approach with that of the more complex (5-group) Hefti classification.[26] In doing so, they graded lesions as follows. Grade 1 is characterized by intact cartilage without a breach. Grade 2 cartilage is breech but the lesion is stable and nondisplaced. In grade 3, they included all lesions with cartilage breach and some degree of instability and deemed unstable by presence of a fluid signal between the parent and progeny bone fragment, hinged lesion with partial displacement, and lesions that are fully displaced. Their results suggested a near-perfect intrarater reliability for their novel 3-group classification system of 98% compared with Hefti intrarater reliability of 88%. By simplifying the grouping and combining the groups included in grade 3 lesions, it may be more reliable for surgeons to identify unstable lesions that require fixation versus drilling alone. They concluded that subsequent studies on validation and clinical utility are needed.

Regardless of the classifications systems, assessment for the presence of symptoms, chondral integrity and lesion stability, and degree of displacement are vital to guide treatment. These features can be ascertained on MRI alone. However, arthroscopic assessment of these factors should further guide treatment with the surgeon being prepared for multimodal strategies to obtain stability, restore biology, and promote healing.

TREATMENT

Nonoperative Treatment

Nonoperative treatment is the preferred primary approach in stable OCD lesions of the knee in skeletally immature patients.[7,27] Type of nonsurgical treatment and length of treatment have been debated but most investigators agree a period of 3 months, regardless of modality, be allowed to assess degree of and therefore potential for healing. Rates of healing vary greatly in the literature for nonsurgical treatment of juvenile osteochondritis dissecans (JOCD).

Options for treatment include immobilization, limited weight-bearing, and activity restrictions with the American Academy of Orthopaedic Surgeons guidelines in 2010 unable to recommend for or against any particular method.[28]

In 1952, van Demark reported reasonable revascularization of 2 children treated for knee OCD when restricted weight-bearing was used for a minimum of 6 months.[29] By 1985, Cahill argued that because JOCD was a fracture, any method of fracture treatment should be used, except joint immobilization.[30] Other investigators have agreed that immobilization is detrimental to chondrocyte health and contributes to quadriceps atrophy and knee stiffness.[9,31] Full immobilization seems to have fallen out of favor in more contemporary treatment algorithms. Gauzy and colleagues demonstrated healing of 30 of 31 knees in 24 children, mean age 11.4 years, with a protocol of activity modification alone, until the children were pain-free.[32] Fullick and colleagues, in a comparative study, showed more promise with the use of an unloader brace rather than crutches or activity modification alone.[27]

Although it has been shown that younger patient with stable lesions healed more frequently, there are reported higher rates of failure of JOCD lesions to heal with nonsurgical treatment.

Atypical lesion location such as those in the non–weight-bearing portion of the lateral femoral condyle are less likely to heal with nonop treatment, as they are 15 times more likely to be unstable compared with lesion on the medial femoral condyle, as shown by Samora and colleagues.[33] This evidence could serve as guidance when counseling patient and families and may be an indication for pursuing immediate or earlier surgical treatment.

In a retrospective cross-sectional study by Krause and colleagues, after 6 months of nonop treatment of stable JOCDs with activity restrictions alone and until a pain-free state was reached, 67% of 76 JOCD lesions showed no sign of progression toward healing or increased signs of instability.[34] Assessing for predictors of healing in that study, the investigators showed, in a multivariate logistic regression model used to predict healing at 12 months, that the presence of a cystlike lesion 2.6 mm provided only 39% probability of healing. If no CLL was present deep to the subchondral plate, then probability increased to 80%. After 12 months, if no healing was evident or progression observed, surgery was undertaken; this also serves to highlight the difficulty in treating JOCD, as often families do not wish to undergo 12 months of activity restrictions if an earlier surgery can return them to activities sooner.

Other studies have shown greater than or equal to 50% healing success with nonop treatment.[35–37] Wall and colleagues[29] in a study of skeletally immature patient who received 6 months of nonop treatment demonstrated 66% healing of 47 lesions. A nomogram was created from a logistic regression model suggesting larger lesion surface area and presence of mechanical symptoms such as giving-way, clicking, or locking to be predictive of poor healing rates, whereas younger age was not.

Larger scale, comparative, controlled trials would be needed to better elucidate best nonoperative strategies for the treatment of JOCD of the knee.

OPERATIVE TREATMENT OF STABLE OSTEOCHONDRITIS DISSECANS

Failed nonop treatment (3–6 months) or lesions with poor healing potential such as those with closed peri-genu physes in the skeletally mature adolescents and teens are indications for surgical treatment. Failed nonop treatment can be defined as persistent symptoms (pain, effusion, or mechanical symptoms) or failure of the OCD lesion to show progression toward healing on serial radiographs or MRI scans. Masquijo and Kothari[22] proposed an algorithm for treatment based on stability of the lesion and integrity of the articular surface (Fig. 2). The first line of surgical treatment of stable OCD lesions is drilling of the lesion. The 2 principal techniques for condylar drilling include transarticular drilling and retroarticular drilling. Transarticular drilling is performed across the articular surface in a retrograde fashion with arthroscopic guidance, whereas retroarticular drilling is drilling through nonarticular epiphyseal bone in an antegrade

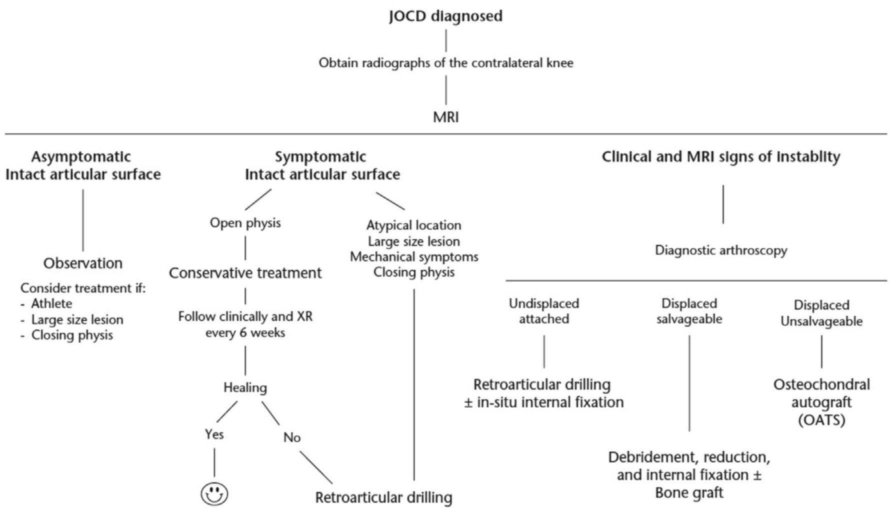

Fig. 2. Algorithm for treatment of juvenile osteochondritis dissecans (JOCD). (*From* Masquijo J, Kothari A. Juvenile osteochondritis dissecans (JOCD) of the knee: current concepts review. *EFORT Open Rev*. May 2019;4(5):201–212. https://doi.org/10.1302/2058-5241.4.180079; with permission.)

fashion into the lesion and uses fluoroscopic, electromagnetic,[38] or open MRI[38] guidance. Other techniques have been offered such as intercondylar notch drilling[39] as to minimize disruption of intact articular surface. All share a common principal of using a Kirschner wire (K wire) to penetrate and disrupt the sclerotic margins of the OCD lesion to establish tunnels between the healthy, adjacent cancellous bone and the diseased subchondral bone of the lesion. The intention is to establish a conduit for bleeding and thus healing factors and ossification of the lesion. Healing with this treatment on average takes 4 to 6 months in most series.[36,40–44] All drilling techniques are combined with diagnostic arthroscopy to evaluate the lesion and palpate its degree of stability, inspecting for gross fragment motion or chondral fissures at its margin. Varying degrees of stability may be encountered with this assessment and can further guide decision-making if fixation of the lesion may also be needed.

Multiple studies have demonstrated excellent healing rates with drilling for stable lesions. Earlier reports by Bradley and Dandy, using the transarticular technique, reported healing in 9 of 11 children within 12 months postoperatively.[45] Other investigators have reported excellent healing rates with this technique, with poorer results occurring in patients with chondral fissuring and closed distal femur physes, advancing the concept that additional fixation should be considered when evidence of lesion instability is present, particularly for more skeletally mature patients.[40,46,47]

Kocher and colleagues, in a large series of transarticular OCD drilling of 30 knees in patients 8.5 years to 16.1 years (average 12.3 years) who had failed nonop treatment for at least 6 months, showed healing of all lesions at an average of 4.4 months, with improvement of Lysholm score from 58 to 93.[41]

Lee and Mercurio[48] in a report on 5 lesions, one of which was in the lateral femoral condyle and another in the talus, provided the first description of outcomes using the retroarticular technique and included bone grafting of the lesion. All lesions healed by 6 months, with one patient remaining partially symptomatic at 6 months but with significant improvement.

Larger series in skeletally immature patients have shown a majority healing response of OCD lesions with resolution of symptoms by Donaldson and Wojtys,[49] Adachi and colleagues,[50] and Ojala and colleagues.[51]

Edmonds and colleagues showed a return to activities at 2.8 months after retroarticular drilling in all 59 children treated with this technique for JOCD of the knee.[42] Seventy percent of the lesions in this study showed radiographic healing at average time of 11.9 months.

Relative advantages of transarticular drilling are that it is technically simpler with no need for fluoroscopy and allows for direct visualization of the drilling passes and their spacing relative the size and margins of the lesion. There are some unknown concerns, however, as to the long-term implications of disrupting the articular chondral surface, which can be lessened by a degree by first pressing the tip of the wire through the chondral surface to underlying bone before drilling, which is anticipated to leave more linear rather than circular distortion of the articular continuity. With this technique, the chondral surface would heal with fibrocartilage, rather than hyaline cartilage. Advantages of the retroarticular technique are that it avoids disruption of intact articular cartilage, thereby allowing for greater number of passes with a larger wire and also the potential for cannulated bone grafting. In a systematic review, Gunton and colleagues[44] showed no statistically significant difference in the 2 techniques in terms of patient outcomes. Retroarticular drilling led to radiographic healing of 86% of 111 lesions at a mean time of 5.6 months, whereas transarticular drilling resulted in healing of 91% of 94 lesions at 4.5 months.

OPERATIVE TREATMENT OF UNSTABLE OSTEOCHONDRITIS DISSECANS

For stable lesions that have failed drilling procedures and for unstable lesions that remain in situ, fixation of the lesions is generally the next step in treatment. Instability of the lesion can range from in situ lesions with micro- or macro-instability and gross instability with dissection and loose body. Adjuvant techniques often included with fixation are drilling of the lesion and bone grafting deep to the progeny fragment; this might be done arthroscopically or via parapatellar arthrotomy, with autogenous or allograft bone, and with variable types of fixation implants.[52] All techniques use the concepts of restoring the articular surface, use of rigid fixation, enhancement of the vascularity to the osseous portions of the lesion, and early joint mobilization.[30]

If subchondral bone access can be obtained, for example, in a trap door lesions, the fibrous or necrotic bone deep to the lesion can be excised and bone graft material can fill the void, providing structure and biology critical to healing.

There are a variety of fixation implants available (Table 1). In 1990, in a series of 17 skeletally immature patients, Anderson and colleagues described fixation with one or multiple K wires combined with debridement and bone grafting.[4] Sixteen of the seventeen lesions were healed at an average of 8 months. The use of K wires,

Table 1
Surgical methods for the treatment of unstable knee osteochondritis dissecans

	Methods of Internal Fixation for Useable OCD of the Knee	
Method	**Advantages**	**Disadvantages**
Metallic devices		
Kirschner wire	Cost, availability, ease of placement	Exit site morbidity, lack of compression, need for removal, bending
Cannulated screws	Good fixation, multiple size options	Increase damage to articular surface from screw head, need for removal, backing out
Variable-pitch screws	Good fixation, "headless" countersinking	Possible need for removal
Bioabsorbable devices		
Pins/rods/pins	Size, planes of fixation, less stress shielding	Breakage, loss of fixation, foreign body immune response
Screws	Good fixation, obviate hardware removal	Breakage, loss of fixation, foreign-body immune
Biological devices		
Mosaicplasty	Native tissue, graft across interface, obviate hardware removal	Possible donor site fracture, bone peg loosening, technically more challenging
Bone sticks	Native tissue, graft across interface, obviate hardware removal	Donor site morbidity, loss of fixation, technique in its infancy technically more challenging

Nathan L. Grimm, Christopher K. Ewing, Theodore J. Ganley, The Knee: Internal Fixation Techniques for Osteochondritis Dissecans, Clinics in Sports Medicine, 33(2), 2014, 313–319, https://doi.org/10.1016/j.csm.2013.12.001.

however, has fallen out of favor due to their lack of compressive forces, tendency to bend, and possibility of migration. As an alternative, the use of screw fixation has become more popular, given the lower profile, rigid fixation with compressive forces provided. Different screw options have evolved including small, solid, flat-head screws (often countersunk deep to the chondral surface), variable pitch screws,[53–55] and cannulated, partially threaded screws.[56] The goal of solid fixation and minimizing implant-related complications, such as potential for loosening and migration, prominence to the chondral surface and the chondral wear that can then ensue, should be considered when choosing fixation of OCD lesions.

Healing rates with variable pitch and cannulated screws have been reported to be 90% with near-normal functional knee scores.[53–56]

Most metallic screws have the potential to become prominent if lesion healing leads to chondral settling or if lesions fail to heal and progress. Smaller or fragmented progeny bone fragments make the use of metallic screws less desirable, as it is difficult to bury the implant and achieve intended compression and rigid fixation. It remains somewhat controversial whether such implants require routine removal, unless abrasion on the opposing surface becomes apparent, in which case it is required. Because of this concern and the desire to avoid further surgery after fixation of OCD lesions, recently, implants made from bioabsorbable materials, such a polylactide (PLA) and polyglycolide (PGA), are being used with greater frequency. Variable descriptive terms have been assigned to these types of implants, including pins, rods, tacks, nails, darts, and screws.

Another advantage of nonmetal, bioabsorbable implants are that they generate less implant-related artifact if repeat MRI is needed after fixation.

Disadvantages documented in case reports of bioabsorbable implants are sterile abscess formation, synovitic reactions to the foreign material, implant breakage during or after insertion, and migration.[57–60] PGA has been reported to degrade by 3 months after implantation potentially rendering the lesion unstable if not healed by that time, which we know it often to be 6 months or greater. PLA degrades as much as 6 years after implantation and may pose a threat to the opposing chondral surface if lesion settling or implant migration were to occur. More recent advances combine the 2 substances to maximize benefits of fixation while minimizing each implant's risk of complications.[61]

Other reports have shown high healing rates, low implant-related complications, and improved knee functional scores with the use of bioabsorbable implants.[61,62]

Kocher and colleagues reported on 26 skeletally immature knee OCD lesions that underwent fixation of instability with one or more of 4 different fixation methods: variable pitch screws (n = 11); bioabsorbable tacks (n = 10); partially threaded, cannulated screws (n = 3); or bioabsorbable pins (n = 3). Healing occurred in 84.6% (22 lesions) at an average of 6 months and mean functional knee scores of 80% to 85% with no significant difference according to lesion location, stage, and fixation method.[63] Tabaddor and colleagues reported no implant-related complication using bioabsorbable implants used for fixation of 24 unstable OCD lesions with healing rates in 16 or 17 lesions based on postoperative MRI and in 22 of 24 based on postoperative radiographs.[61]

Both metal and bioabsorbable implant length must be accounted for during implantation to avoid injury to the distal femur physis, which can be as shallow as 20 to 25 mm from the articular surface in some locations.[64]

Autogenous purely osseous or osteochondral bone pegs or bone sticks is a category of stabilization techniques that has also been performed as an alternative to implant fixation with good results. Navarro and colleagues[65] and Slough and colleagues[66] in retrospective series using bone stick fixation reported satisfactory results in 91% of 11 patients at 4-year follow-up and 80% of 10 patients at 2.9-year follow-up, respectively.

CARTILAGE RESURFACING AND SALVAGE TECHNIQUES

Chondral resurfacing and salvage procedures are most commonly done after failed fixation surgery of unstable OCD lesions or residual defects from dissection of OCD lesions with loose fragments that are unsalvageable. Because this is often encountered after attempted fixation of OCD fragments, the chondral surface or underlying bone fragment often is degenerated, macerated, fragmented, or otherwise in such poor condition that fixation is not possible or healing rate is expected to be very low (**Fig. 3**). Such procedures often are considered as an index procedure for chronically dissected OCD lesions with a residual defect.

Although reports exist showing good healing of Hefti stage V lesions after fixation,[63] lesions that dissect greater than 6 to 12 weeks from attempted

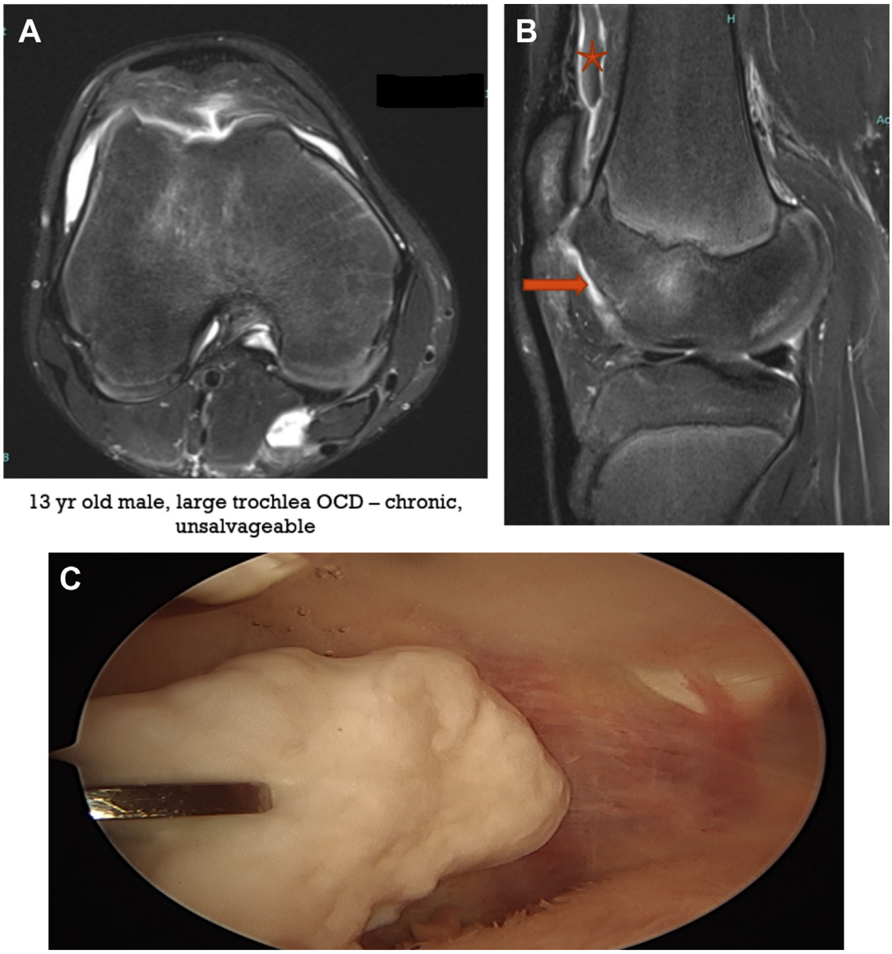

Fig. 3. Example of chronic loose body from a trochlear OCD that had no bone on the undersurface, irregular borders, and macerated edges and had enlarged due to synovial fluid intravasation (*A–C*). Red star indicates a large osteochondral loose body in the suprapatellar pouch and the red arrow indicates the origin of the loose body and residual defect on the lateral trochlea of the femur.

fixation may have detrimentally necrotic or sclerotic changes to the progeny bone and/or there has been an increase in size of the progeny fragment due to synovial fluid intravasation that may substantially decrease the chances of successful fixation. In these circumstances or those after failed fixation or intralesional degeneration such that the fragment is incongruous, more advanced cartilage salvage techniques are often used (Fig. 4). These techniques include single autogenous osteochondral plug transfer or multiple plugs (mosaicplasty), osteochondral allograft transplantation, or autogenous cultured chondrocyte implantation. The timing and the degree to which a young patient must be symptomatic before undergoing these more involved techniques is variable and controversial. In a long-term follow-up study by Anderson and colleagues[67] poor results were seen in patients who underwent OCD fragment excision alone, highlighting the importance of more aggressive resurfacing procedures for unsalvageable lesions before the onset of degenerative changes. It has also been noted in multiple studies that younger patients who undergo these salvage procedures for unsalvageable OCD lesions have better outcomes than their older counterparts.[68,69] Moreover, unaddressed OCD defects can be associated with meniscus tears, especially those lesions located on the tibia plateau.[70]

AUTOLOGOUS CHONDROCYTE IMPLANTATION

Autogenous chondrocyte transplantation (ACI) is a 2-stage technique where a cartilage biopsy is obtained from nonarticulating area often

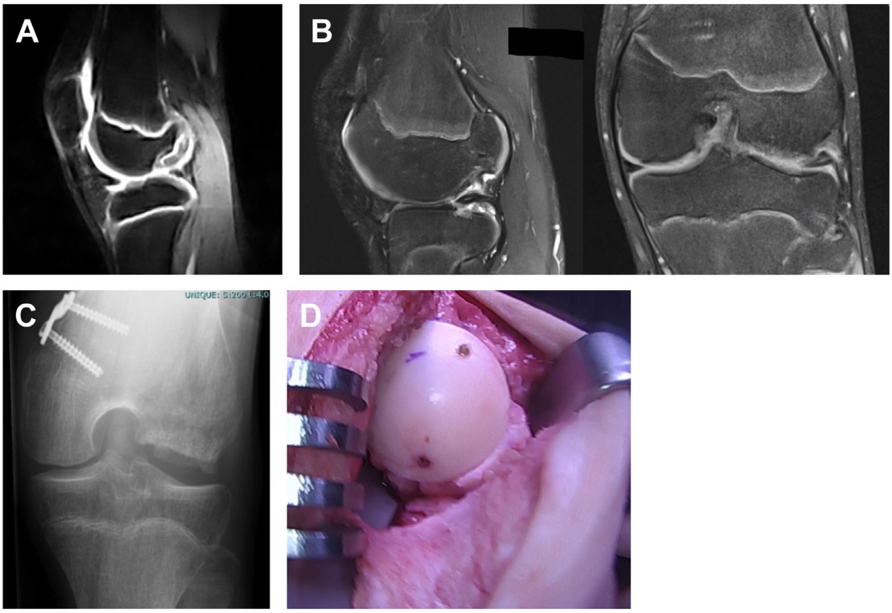

Fig. 4. A 15-year-old boy who had failed prior operative attempts such as drilling, autogenous bone grafting, and fixation. He was indicated for an osteochondral allograft due to the size of the lesion and poor containment. (*A*) Initial sagittal plane MRI with high signal intensity deep to the progeny fragment indicating lesion instability. Initial treatment was autogenous bone grafting, drilling, and internal fixation. (*B*) Coronal and sagittal MRI before osteochondral allograft implantation. (*C*) AP radiograph demonstrating the lateral femoral condyle lesion and previously placed guided growth implant. (*D*) Osteochondral allograft implant after fixation.

within the notch or superior, peripheral condyles of the femur, which is then grown ex vivo and implanted at an interval of growth no sooner than 6 weeks later into the defect. First- and second-generation ACO is done by placing a patch (periosteal—Gen I, or bovine—Gen II) over the lesion and injecting culture chondrocytes deep to this graft. Third-generation technique involves matrix-induced culture growth of the chondrocytes (MACI), in which the chondrocytes are grown on a collagen matrix and implanted in this manner, obviating graft suture and injection (Fig. 5). At implantation, the lesion to receive the implant is debrided sharply at its periphery and deep to the calcified cartilage layer, hemostasis is achieved, and the MACI implant is placed into the defect and then glued (fibrin) in place. In Gen I technique, a periosteum patch is used, and it is important to ensure the cambium layer of the patch is placed on the deep surface. Suture fixation should ensure a water-tight seal, which can be tested with saline injection before chondrocyte culture injection.

Multiple studies looking at the outcomes of ACI in adolescent patients exist. Most recently, Carey and colleagues[71] in a 10- to 25-year follow-up study with a mean follow-up of 19 years and average follow-up age of 43 years, of ACI done for unsalvageable OCD lesions done between 1990 and 2005, showed that although most of the patients underwent a second surgery (many done as "second look" procedures as part of study protocol), when defining failure as revision of the ACI graft or joint arthroplasty, the survivorship of ACI for OCD was 87% at 10 years, 85% at 15 years, 82% at 20 years. Years prior, Macmull and colleagues[72] demonstrated 84% good or excellent results at 5.5 years in 31 adolescent patients with a mean age of 16.3 years. Although some feel ACI is limited to purely chondral lesions with minimal bone loss, it has been applied with good results in OCD lesions with depths greater than or equal to 8 mm, using a bilayer collagen membrane technique (sandwich technique).[73,74] This technique involves placing morselized cancellous bone graft to fill the defect that is covered with a collagen membrane, superficial to which the cultured chondrocytes are placed and in turn covered with a second collagen membrane, creating the ACI sandwich. Minas and colleagues[75] evaluated the outcomes of this sandwich technique of ACI combined with autogenous bone grafting in 24 patients from 2001 to 2013 to a historical control group that underwent autogenous bone grafting alone

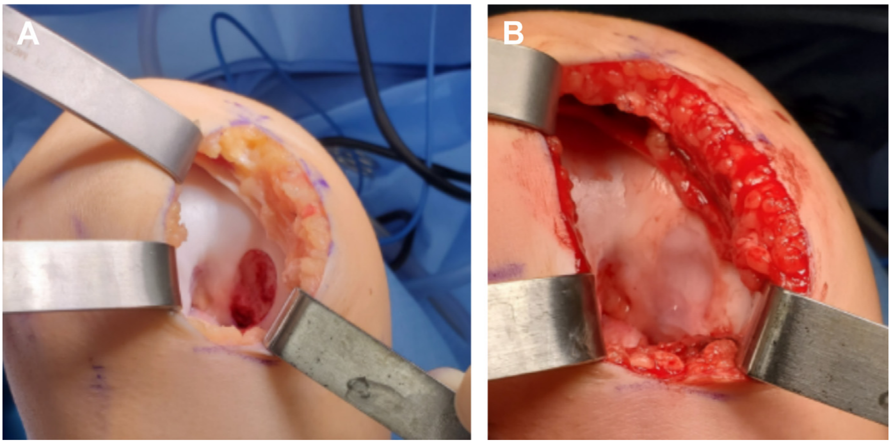

Fig. 5. A 14-year-old girl with a prior loose body removal, drilling procedure of a medial femoral condylar OCD, and cartilage biopsy. She was indicated for matrix-induced autogenous chondrocyte implantation. (*A*) After templated resection of the lesion. (*B*) After tourniquet deflation to ensure subchondral hemostasis and MACI implantation.

from 1995 to 2002. The procedure was done by a single surgeon for symptomatic lesions greater than 8 mm. The groups were matched in terms of age, sex, side of the operated knee, body mass index, lesion type, lesion size, lesion depth, lesion location, or the need for realignment osteotomy. They showed a 62% failure rate in the ABG alone group versus 13% in the ACI sandwich group.

OSTEOCHONDRAL AUTOGRAFT TRANSFER SYSTEM

Mosaicplasty techniques, including the osteochondral autograft transfer system (OATS; Arthrex, Naples, Florida), are often used for contained, smaller (2.5 cm sq or smaller) lesions. This system provides transfer of both cartilage and subchondral bone from areas of the knee that do not articulate, often from the lateral femoral condyle lateral to the trochlea and anterior to the articulation with the tibia at its meniscal margin. Lesions are indicated for this if they are not so large that 1 or 2 autogenous plugs are adequate to fill the lesion without compromising the donor site and infringing on its articulating boundaries, although the contralateral knee can provide additional graft options. It has been shown that mosaicplasty may be a better long-term solution for such lesions compared with microfracture alone. Gudas and colleagues[76] demonstrated this in a study of 50 adolescent and teenage JOCD lesions of the femoral condyle treated in a randomized method to either microfracture or OATS. They found good or excellent results in both groups at 1 year in terms of subjective and objective outcomes but reassessment at beyond 4 years showed the OATS group to maintain 83% excellent results, whereas the microfracture group declined to 63%. In addition, there were 41% failures in the microfracture group and none in the OATS group, with a direct correlation between defect size and poor outcome in the microfracture group that was not observed in the OATS group, showing that even with larger lesions, OATS provided better outcomes. Furthermore, the patients in the microfracture group returned to their preinjury level 14% of the time at 4.2 years, whereas those in the OATS group did so at 81%.

FRESH CADAVERIC OSTEOCHONDRAL ALLOGRAFT

An alternative to mosaicplasty, for larger, uncontained lesions, is the use of osteochondral allograft transplantation that has been developed with promising success; this involves the procurement of fresh (nonfrozen) allograft bulk tissue donors, such as an entire femoral condyle from which a custom-sized graft can be obtained and implantation into a defect, providing both the chondral resurface and the supportive subchondral bone (see Fig. 4). The advantages of this approach avoid the donor site morbidity seen with mosaicplasty and the ability to address larger lesions with a single operation. There remains, however, a concern regarding long-term maintenance of graft incorporation and the phenomenon of creep substitution with the use of these graft options.

Lyon and colleagues[77] reported on the use of fresh osteochondral allograft transplantations in 11 children, average age 15.2 years, with a mean follow-up of 2 years, in which all grafts achieved radiographic incorporation with a return to sport activities between 9 and 12 months postoperatively. Murphy and colleagues[78] reported in a larger series of 43 pediatric and adolescent knees that underwent this procedure, average age 16 years, that graft survivorship was 90% at 10 years with good functional scores. In that study, however, only 60% of all procedures were done for OCD, and of those patients, 35% underwent secondary surgery with patients with OCD representing 4 of the 5 allograft revision procedures done. These revisions were done at an average of 2.7 years after the index procedure.

More recently, in perhaps one of the largest studies to date, Daud and colleagues[68] reported on 244 patients between 1972 and 2018 who underwent fresh cadaveric osteochondral allograft (FOCA) for unsalvageable knee OCDs. Mean patient age was 37.8 years (range 10–75 years) and mean follow-up was 9 years (range 1.0–29.8 years). With survivorship as the primary outcome, failure was defined as conversion to total knee arthroplasty, revision allograft or graft removal, knee fusion, and amputation. Measured secondary outcomes were the functional modified Hospital for Special Surgery Score (mHSS) and radiographic assessment of arthritis using the Kellgren-Lawrence grading scale. Graft survivorship was evaluated at 5-year intervals from 5 to 30 years, and a stepwise decline was noted (insert graph with results). Thirty-eight percent (93 grafts) resulted in failure at an average of 11 years (0.5–38 years), and the mean mHSS score improved significantly, from 68.7 (range, 19–91) preoperatively to 80.3 (range, 52–100) at the time of the latest follow-up. Multivariate analysis revealed that graft location (ie, medial-sided or multiple grafts) and increased age were significantly negatively associated with survival. Ten-year survival was greater than 80% in patients younger than 50 years but less than 40% in patients older than 60 years.

Leon and colleagues[69] also showed promising results of FOCA in a similar patient population (average age 28 years) when combined with realignment osteotomy and found that persistent postoperative malalignment occurred more frequently in failed grafts (28.6% vs 4.3%; $P = .023$) and was a risk factor for graft failure, highlighting the need to identify and treat malalignment if FOCA is being considered.

Although several techniques seem to be feasible as salvage options for unsalvageable OCD lesions, one theoretic advantage of ACI as an index procedure is that OATS and osteochondral allograft transplants still remain a viable secondary option in the setting of failed ACI, whereas the reverse is less likely to be true.

SUMMARY

Symptomatic knee OCD lesions in the pediatric and adolescent population are an increasingly common presentation and should be considered when a young patient presents with knee pain. Treatment varies depending on the history, examination, and lesion type (size, site, stability). Nonoperative management is the first line of treatment of stable OCD lesions. For unstable OCD lesions operative management in the form of fixation is indicated. Should fixation fail salvage treatment options such as ACI or OATS are available but further multicenter research in these techniques are needed to determine the preferred treatment option.

CLINICS CARE POINTS

- It is important to assess for features of OCD in history taking, such as a previous pain deep in the knee with activities or joint swelling and mechanical symptoms, to distinguish them from osteochondral fractures.
- Physical examination in symptomatic patient reveals point tenderness at point of lesion with pain from trochlear and patellar lesions elicited by compression of the patellofemoral joint. The presence of a joint effusion may represent an unstable OCD lesion.
- MRI in addition to knee radiographs is an important aspect of imaging workup and helps determine stage and stability. Notch view knee radiographs are particularly helpful in viewing the posterior femoral condyle, which is a common area for OCD in the knee.
- Nonoperative treatment, such as partial weight-bearing and activity modification, is the primary approach in stable OCD lesions of the knee in skeletally immature patients, with a minimum of 3 months of observation of healing required before deciding on any further intervention.
- Failure of nonoperative treatment is defined as persistent symptoms (pain, effusion, or mechanical symptoms) or failure of the OCD lesion to progress toward healing on imaging.
- Failed nonoperative treatment or lesions with poor healing potential in skeletally mature

adolescents and teens are indications for surgical treatment. The first line of treatment is drilling with a K wire to disrupt the margins of the OCD lesion and establish tunnels with healthy, adjacent cancellous bone. Healing takes on average 4 to 6 months.

- For stable lesions that have failed drilling procedures and for unstable lesions, operative fixation of the lesions is generally the next step in treatment.
- Should fixation fail then chondral resurfacing and salvage procedures such as osteochondral allograph transplantation are considered.

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