

Advances in Surgical Treatment of Osteochondritis Dissecans of the Knee

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Abstract

Osteochondritis dissections of the knee is a challenging condition to treat in both skeletally immature and mature individuals. Guiding treatment principles are the improvement of both biology and stability of the lesion. Advances in both imaging and arthroscopic assessment have aided surgeons in the assessment of these qualities of osteochondritis lesions, however level of evidence for best treatment remains overall low. Arthroscopic and open techniques may be utilized to treat these lesions. Bioabsorbable and metallic implants traversing the progeny and parent aspects of the lesion, as well as surface compressive suture fixation may be appropriate techniques for augmenting lesion stability. Subchondral drilling, injection of bone marrow aspirate concentrate, and debridement and retro-articular or open bone grafting have all been described as methods of biologic augmentation. These techniques are further described and recognition for further study regarding indications and outcomes are discussed.

Introduction

Osteochondritis dissecans (OCD) is defined as a focal idiopathic alteration of subchondral bone and/or its precursor with risk for instability and disruption of adjacent articular cartilage that may result in premature osteoarthritis.¹ While lesions may occur in multiple joints, the condylar surfaces of the knee are the most common location for osteochondritis dissecans in the human body.² The femoral trochlea and patella may also be affected.³ While idiopathic, an influence of repetitive activity in OCD is suspected. While understanding of correlates for healing are evolving, smaller lesion size and younger age at presentation remain strong predictors for lesion healing^{1,4,5,6}. Delayed healing despite appropriate non-operative management, and lesion instability remain the primary indications for operative intervention^{1,7-10}. Operative strategies are tailored dependent upon the stability status and location of the lesion, but improving lesion biology and ensuring stability are the primary goals of treatment - to provide an environment for vascularization and ultimate ossified bone formation within the progeny of the OCD lesion.

Indications for Surgical Management of OCD Lesions

Symptomatic stable osteochondritis lesions that have failed nonoperative treatment and those that have become unstable, as evidenced by a breach in the articular cartilage on the MRI and/or mechanical symptoms or effusion, are indicated for surgical intervention^{1,5,7,8, 11}. The goal

of surgical and intervention is to stimulate revascularization from the parent bone into the progeny fragment and encourage the production of ossified bone within the progeny. Additionally, any evidence of micro-instability or gross instability is an indication for stabilization^{1,9,10}. Through these methods, improved structure of the progeny leads to more normal loading of appropriately supported articular cartilage resulting in decreased bone stress, edema, and pain. In addition to these important near term symptomatic improvements, structural healing and integrity of the progeny preserves the articular cartilage and prevents osteochondral loss that may lead to osteoarthritis.

Surgical Techniques for OCD Management

Selection of surgical technique for the treatment of osteochondritis dissecans of the knee is largely dependent upon stability of the lesion^{1,12}. When the lesion is stable on MRI assessment, without evidence of a breach in the articular surface or fluid signal below the progeny fragment, fine wire drilling in a trans-articular or retro-articular fashion is the treatment of choice and is well described¹³⁻¹⁸. **(Figure 1)**

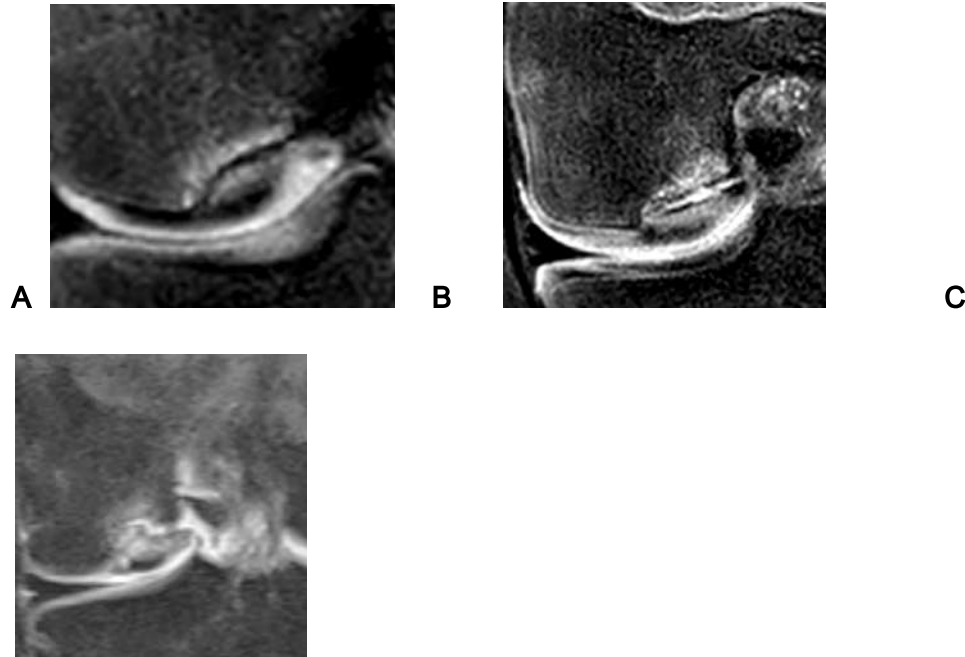


Figure 1: Magnetic Resonance (proton density, fat-saturation, coronal) Images of A. stable osteochondritis lesion, B. micro-instability lesion with intact cartilage, and C. unstable in-situ osteochondritis lesion

These lesions are often described as either cue ball lesions or shadow lesions by the research in osteochondritis dissecans of the knee (ROCK) arthroscopic classification system.(Figure 2) When¹⁹ the lesion exhibits signs of micro instability, such as a shift of the progeny on the MRI without gross breach of the articular surface, then arthroscopically the lesion may be a 'locked-door' lesion that has a visible margin but is not able to be hinged open easily. These lesions are felt to have at least some degree of micro-instability and an addition to fine wire drilling, insitu fixation may be indicated^{9,10,20,21}. More grossly unstable lesions with a definitive breach in the articular surface by MRI, may often be noted to be 'trapdoor' lesions

arthroscopically. Due to the advanced degree of fibrous interposition and avascular parent bone and progeny necrotic surface, parent bed and lesion debridement with removal of fibrous tissue is often indicated to improve the biologic environment for healing. Depending upon lesion location and the type of hinge present, this may be accomplished either by arthroscopic or open techniques²²⁻²⁵. Finally, a most advanced lesion with instability insitu or displacement of the progeny with a crater at the parent bone may be salvageable when the progeny articular cartilage is in good condition and there are minimal amounts of integrity changes to the structure of the progeny fragment. These are often best treated with an open approach and aggressive interposed tissue management and grafting prior to fixation^{21,26}. The most advanced lesions with severe comminution or degeneration of the articular cartilage of the progeny bone may not be suitable for salvage and may be indicated for osteochondral replacement strategies²⁷⁻³². Surgical techniques and augments for attempts at healing for the above salvageable lesions will be further discussed.

Drilling of Symptomatic Stable OCD Lesions with Biologic Augmentation

Both trans-articular and retro-articular drilling techniques to provide bone marrow and biologic response between the parent and progeny bone have been well described¹³. Results of these techniques are generally good, particularly in younger patients and small to moderate sized lesions. With increasing lesion size, particularly greater than 20mm in the major diameter, and with patients approaching skeletal maturity, resultant osseous formation in the progeny may be diminished. To improve results in lesions with characteristics that may be less favorable for healing, augmentation of drilling with bone marrow aspirate concentrate injection or the addition of retro-articular bone graft has been described.

Augmentation with Bone Marrow Aspirate Concentrate (BMAC) for OCD Lesions

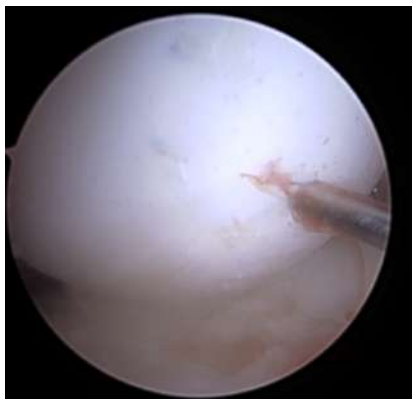
Bone marrow aspirate concentrate (BMAC) may be injected into the progeny or progeny parent bone interface in conjunction with fine wire drilling in an attempt to augment the biologic environment^{33,34}. Osteogenic precursors within bone marrow aspirate concentrate may improve the healing response compared with marrow stimulation by fine wire drilling alone. While further research surrounding the efficacy of this technique augmentation is needed, it may be utilized in this challenging condition.

Bone marrow aspirate concentrate is harvested from the anterior iliac crest via a limited approach. Commercially available equipment and standard technique is employed³⁵⁻³⁷. A modified Jamshidi needle is introduced through the iliac crest to a depth of approximately 10mm. Aspiration and rotation of the needle allows the harvest of marrow blood from the iliac crest from multiple regions surrounding the needle in a uniform fashion. After three 90° rotations at any given level, the needle is advanced an additional 5mm and the procedure is repeated. Once 60ccs of blood is collected within the anticoagulant-filled syringe, this blood is then placed in a centrifuge to produce approximately 5ccs of BMAC.

Bone marrow aspirate concentrate may then be delivered into the lesion via a trans-articular or retro-articular approach. **(Figure 2)**

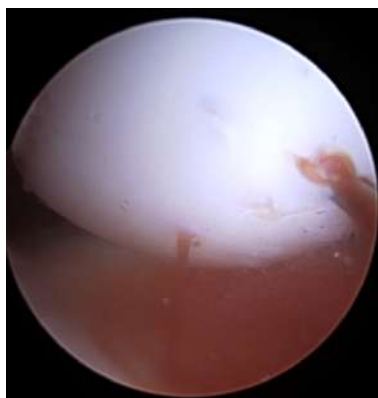


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C



D



E



Figure 2: A. Harvest of iliac crest bone marrow blood for centrifuge preparation into Bone Marrow Aspirate Concentrate (BMAC). B and C. Injection of BMAC via trans-articular 18 gauge needle following trans-articular fine-wire drilling of stable medial femoral condyle OCD. D. Retro-articular, fine-wire drilling of stable medial femoral condyle OCD (with additional distal femoral trans-physeal screw utilized for hemi-epiphysiodesis guided growth for genu varum correction. E. Introduction of Jamshidi needle over a central retro-articular wire to guide needle for injection of retro-articular BMAC.

A small to medium-gauge Jamshidi needle, either under direct visualization and a trans-articular approach, or under fluoroscopic control in a retro-articular fashion is used to deliver the BMAC. The Jamshidi needle may be advanced over a suitable size K-wire centered within the lesion to aid in initial localization with later confirmation of location and depth by fluoroscopic control. The BMAC is then injected slowly, either in a center location of the progeny and progeny parent interface or may be injected in two to three regions within the lesion. In a trans-articular delivery method, a small amount of bone marrow aspirate concentrate may be noted extravasating from the multiple fine wire drill holes, confirming proper distribution of the BMAC throughout the subchondral lesion. Postoperatively the patient remains non-weight bearing for six weeks, as in standard trans-articular drilling protocols. As mentioned above, further research regarding the efficacy of this technique is needed.

Augmentation with Retro-articular Bone Grafting for OCD Lesions

Femoral condylar OCD lesions with an intact articular surface but significant fibrous interposition between the parent and progeny, or the presence of large subchondral cysts may present significant challenges to fine wire drilling alone. In such cases, additional biologic osteoinductive

and conductive tissue may be desired. Following fine wire drilling at 2 to 3mm, retro-articular cancellous autograft may be added^{38,39}. A small incision over the Ipsilateral anterior iliac crest is used for manual curettage and cancellous bone harvest, or either a 6mm autograft osteochondral harvester or a commercially available cylindrical tap-harvester on a cordless drill may be employed. Three to five ccs of cancellous bone, or a 6mm core may be harvested for use for retro-articular bone grafting.

A 2.4mm guide pin is positioned within the lesion using multiplanar fluoroscopic control. A surgical triangle to position the knee in a flexed position, clear of the contralateral extremity, is useful for stable positioning and access during drilling. Following placement of the 2.4 guide pin, a 6 or 7mm reamer may be used to enter the lesion from the medial or lateral margin of the involved condyle, staying distal to the epiphysis in immature patients. Once the core track is established, curettage and suction debridement may be carried out within the fibrous tissue or cyst deep to the progeny fragment. Following preparation of the lesion, the harvested iliac crest bone graft is introduced into the core tract. Utilizing a half-cannula through the soft tissues placed at the aperture of the reamer tract may facilitate introduction of the bone graft with smooth forceps or an arthroscopic grasper. Once the bone graft is within the tunnel, a small surgical tamp may be used to compress the bone graft into the lesion with fluoroscopic confirmation of tamp and graft delivery position. **(Figure 3)**

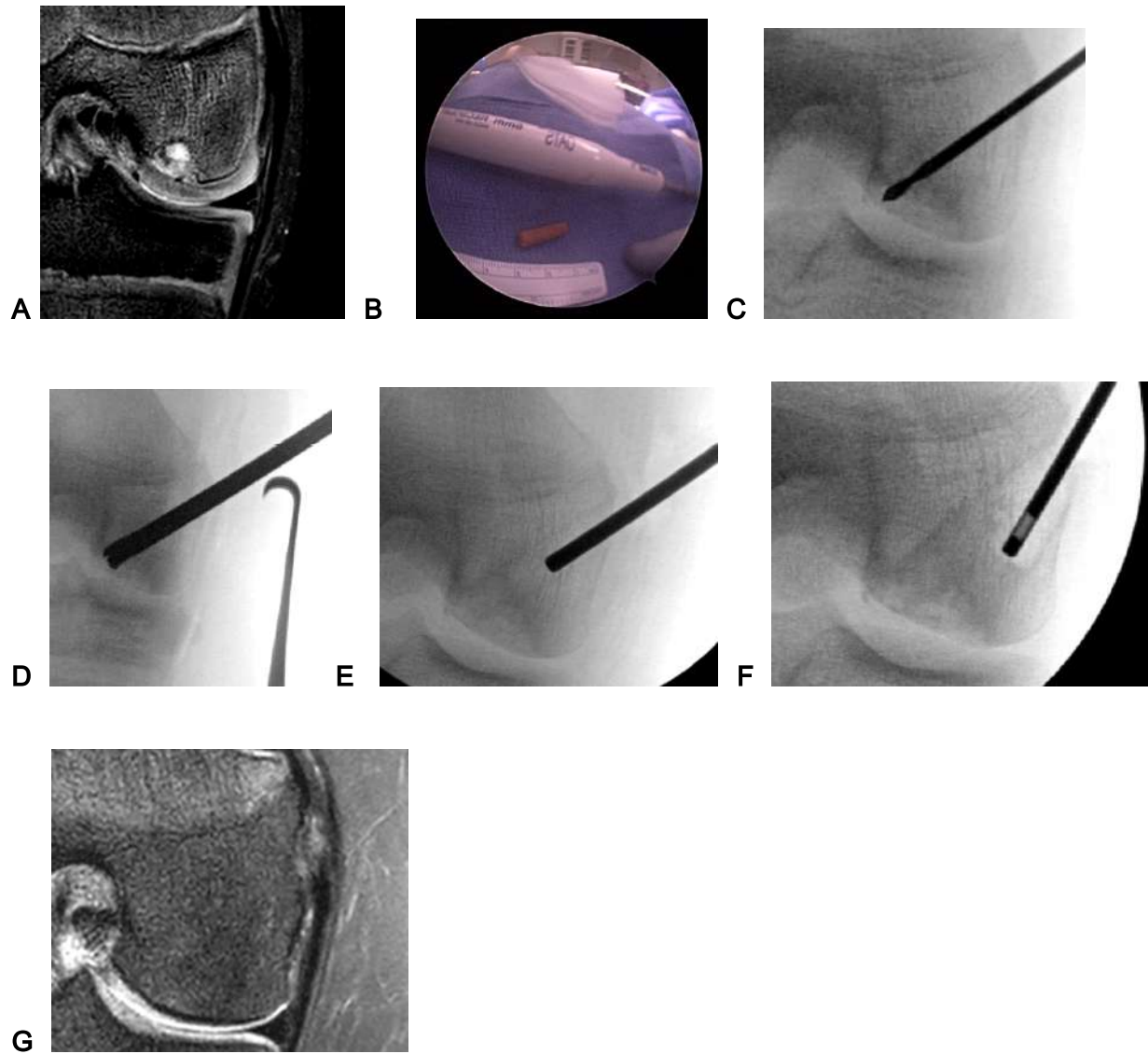


Figure 3: A. A proton density fat-saturated coronal slice MRI of medial femoral OCD with cystic lesions and fibrous tissue below the articular cartilage. B. A commercially available autograft cylindrical core harvester that may be used to harvest bone from the iliac crest for retro-articular bone grafting. C. 2.4mm guide wire placement below the distal femoral physis into the medial femoral OCD lesion. D. A 6mm reamer directed into the retro-articular aspect of the OCD lesion

over the guide wire. E. Bone graft tamped into position in the retro-articular space of the OCD. F. Additional bone graft tamped into a second core placed into the retro-articular OCD. G. A proton density fat-saturated coronal slice MRI of the healed medial femoral OCD 2 years following retro-articular bone grafting.

Postoperatively, six weeks of non-weight bearing is employed as with other techniques involving fine wire drilling of intact lesions. Avoidance of impact activity is recommended until improved bone within the progeny is visualized on imaging. While anecdotal and case reports are encouraging, indications and improved evidence for utilization of this technique is pending.

Advanced Techniques and Augmentation with Internal Fixation of Unstable OCD Lesions

Stabilization and compression of OCD lesions is indicated when signs of instability exist²⁰. Healing requires a stable environment for revascularization of the progeny and progeny bone formation. MRI assessment and arthroscopic assessment suggesting any shift in the progeny position relative to the parent bone is a sign that this instability exists¹⁰. Arthroscopic examination with findings of a margin of cartilage that has become divided from the surrounding tissue (such as those represented by locked-door or trapdoor findings by the rock arthroscopic stability classification), or when the cartilage has minimal changes but the lesion is able to be moved or blotted by an arthroscopic probe, are the best standards for estimating stability. The surgeon may elect to add stabilization and compression in any of these lesions. Metallic or bio-absorbable screws provide both stability and compression; while bioabsorbable pins may add stability, they provide compression to a lesser degree⁴⁰. These implants have all been used in settings of both ossified and unoccupied progeny lesions⁴¹⁻⁴³. Suture bridge fixation, in which tensioned sutures bridge across the surface of the progeny between suture anchors placed to a

subchondral depth through the articular or periarticular surface, is another described method for providing stability and compression^{25,44-47}. Choice of fixation method is dependent upon surgical assessment of the lesion and evidence for best techniques is evolving.

Open and Arthroscopic Lesion Fixation with Screws

Compressive screw fixation, whether metallic or bio absorbable, may be used to treat OCD lesions insitu when micro instability without gross displacement is present⁴⁸. These lesions may be represented by a slight shift of the progeny position noted by MRI or when arthroscopic evaluation confirms a discernible cartilage margin or denatured cartilage edge of the lesion (locked door lesion). Or when the entirety of the lesion is subtly mobile to ballottement with an arthroscopic probe. The relative benefits and risks of metallic versus bio absorbable screw fixation have been evaluated retrospectively and either may be a reasonable option for the treating surgeon^{21,49-53}. Metallic screws may offer compression without risk of material related synovitis or implant breakage, but like bio-absorbable screws, may loosen and become prominent causing secondary body wear. Metallic screws may also be indicated for removal when they are at the immediate subchondral margin. Implant loosening or surrounding cartilage degeneration leading to an exposed implant may be risks that are decreased by using screws within progeny lesions that have ossified bone within the progeny, or epiphyseal cartilage within the progeny that is still firm and has not become softened with secondary necrosis.

Insitu screw fixation may be used in conjunction with fine wire drilling in either an arthroscopic or open fashion to stabilize and compress lesions exhibiting micro-instability. In this setting, surgeons may often choose to place screws arthroscopically with a headless, cannulated screw system. Following arthroscopic lesion assessment and fine wire drilling, these screws may be

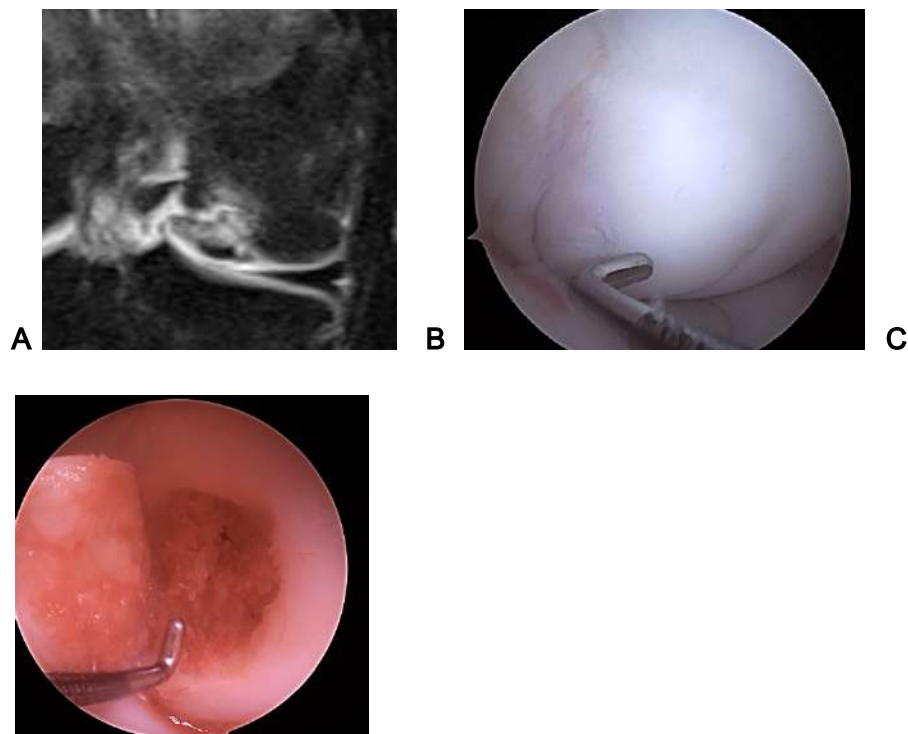
placed into the femoral condyle or trochlear surface in a standard arthroscopic position with varying degrees of knee flexion to provide perpendicular access to the lesion. The surgeon may improve visualization by using accessory portals and visualizing the lesion from the opposite side of the knee while using cannulated guide wires or small steinman pins to assess the best trajectory of approach to enter the lesion in a perpendicular fashion. In the femoral trochlea or more anterior positions of the femoral condyle, access over a surgical knee positioning triangle may add limb-stability and improve access and fluoroscopic visualization as needed. In the posterior aspects of the femoral condyle, more flexion is required for proper screw trajectory into the lesion.

When placing cannulated screws arthroscopically, portal and fat pad management is important for both visualization and efficiency of cannulated drilling and screw delivery. In addition to accessory portals for viewing, at times an arthroscopic probe in an accessory portal to retract the fat pad and capsule anteriorly away from the condylar structures may assist with visualization and screw delivery into the knee. In practice, guidewire placement percutaneously with secondary portal creation around the guide wire is often most efficient. Screws may be placed in a trajectory through the patellar tendon at times with minimal damage or risk to the tendon if a longitudinal division in line with the fibers is utilized. In deeper degrees of flexion, care should be taken to avoid division through the anterior horn of the medial or lateral meniscus. Once the guidewire is positioned, drilling may be conducted through the created portal established with a 11 blade around the guidewire pin. Further dilation prior to screw placement may be accomplished with the empty screwdriver to further establish the portal prior to screw placement. In general, a screw depth twice the depth of the progeny depth is recommended for stability. Whether metallic or bioabsorbable, screws should be placed

approximately 1mm below the depth of the deep margin of the articular cartilage. When ossified progeny is not present, screws should be placed a minimum of 4mm below the articular surface. Screw depth can be estimated by direct visual inspection by moving the arthroscope below the screw tract and looking through the articular defect at the screw interface, or a guide pin may be used to visually probe and estimate the depth from the articular cartilage to the screw head. Fluoroscopy may be used and is recommended to ensure the screws are positioned at an appropriate depth. Leaving the guidewire in place during these maneuvers can aid in efficiency for fine adjustment. Throughout cannulated screw placement, care must be taken to avoid flexion and extension of the knee following guidewire placement that may result in binding of the guidewire risking wire breakage. Positioning of the knee with an assistant in a comfortable position to hold the knee during placement or placement over a surgical triangle as above is recommended. While there is little evidence guiding the number of screws needed for adequate lesion stabilization and compression, one screw for every 10mm Diameter region throughout the lesion is recommended.

In some positions throughout the knee, arthrotomy may be needed to access best screw placement for OCD lesions. Compressive fixation in the patella may often require a moderate sized para-patellar arthrotomy to evert the patella to at least a 90° position for appropriate access to the lesion. Medial and lateral femoral trochlear lesions may often be accessed arthroscopically in a shallower degree of knee flexion with translation of the Patella medially and laterally to allow guide wire and screw placement. In some lesions, particularly those that are more central, arthrotomy may be needed for appropriate access. Mid-condylar and posterior condyle lesions, particularly in the lateral femoral condyle where the infrapatellar fat pad and capsule limits access and flexion, may be best accessed by limited infra-patellar arthrotomy.

Following steps for screw placement as described above, when using either arthroscopic or open screw placement techniques the surgeon should record the details of knee positioning and screw trajectory within the operative report. Screws may often be indicated for implant removal and a detailed description of positioning during screw placement will aid in implant removal should this be required. **(Figure 4)**



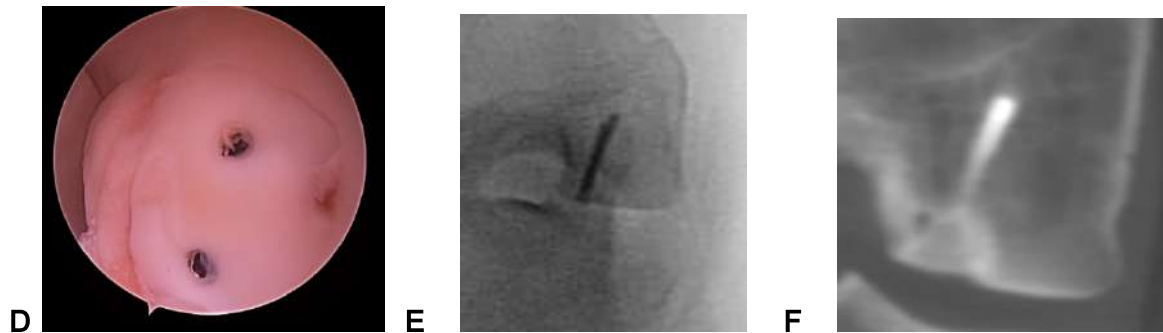


Figure4: A. A proton density fat-saturated coronal slice MRI of medial femoral OCD with in-situ instability and a break in the articular cartilage. B. Arthroscopic view of medial femoral condyle unstable OCD 'trap-door' lesion. C. View following curettage and autologous bone grafting of the parent bed with the progeny fragment hinged open and ready for replacement. D. Two 2.3mm headless titanium compression screws positioned across the lesion and seated just below the deep articular cartilage surface of the progeny fragment. E. Fluoroscopic anterior-posterior notch view of the screws in appropriate depth position within the reduced OCD. F. Computed Tomography scan coronal image of osseous union of medial femoral condyle OCD with screws in position.

Open and Arthroscopic Lesion Fixation with Suture Bridge

Unstable OCD lesions, whether micro-instability in situ or when grossly unstable, may have minimal or fragmented bone within the progeny and be less amenable to screw fixation. The articular cartilage on such lesions may be in excellent condition overall and indicated for salvage, but placement of screws within an all-cartilage progeny, or within a progeny with fragmented bone may be less desirable. In these lesions the screws may have lesser purchase due to the soft all-chondral nature of the progeny, or the progeny may have risk of softening or

structural deterioration leading to screw exposure and mechanical complication. These less ossified lesions may be indicated for suture bridge fixation. Suture bridge fixation has been described and larger series have been recently published with excellent results in osteochondral and chondral fractures, and with results similar to screw fixation for larger challenging osteochondritis dissecans lesions^{25,44-47}.

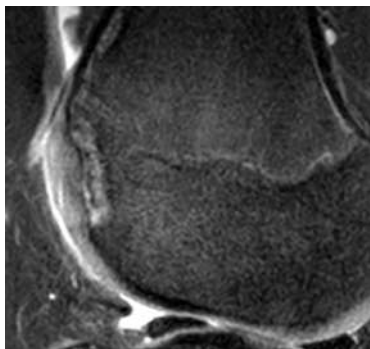
Suture bridge fixation is accomplished by placing either a sliding suture anchor or a knotless anchor device at the margin of the osteochondral lesion. Sutures then span across the surface of the lesion and are fixed with subsequent knotless suture anchors to create several strands of tensioned bridging suture across the surface, applying compression and stability from a compressive surface effect as opposed to point compression with screws. The suture anchors may be placed in a periarticular position in the trochlea or spanning the articular surface and into the notch but often lesions may be best treated by placing the anchors approximately 2 to 3mm into the healthy margin surrounding a lesion. This allows the suture to span the lesion crossing a margin of healthy cartilage and minimizes cavitation of the tensioned suture limb into the margin of the lesion. When anchors are placed through the articular surface, 3mm or smaller resultant defects in the surface fill predictably with fibrocartilage in the post treatment setting. For acute osteochondral lesions, #1 or #2 vicryl suture has been used successfully and has the advantage of dissolving over three to six weeks. This obviates the need for secondary surgery. However, when used for OCD lesions, longer duration of stability and compression may be required for healing and therefore 1.3mm polyester tape has been utilized more frequently in this setting. This requires a secondary surgery for suture removal, similar to the second surgery many surgeons employ to remove metallic screw implants. Protocols for optimal implant type,

suture type, suture number, tension force, direction of suture strands, and duration of suture implantation are all under study and require further level of evidence for best recommendations.

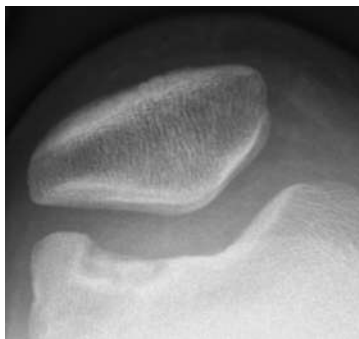
Suture bridge fixation may be used with either arthrotomy or with an arthroscopic technique.

Suture bridge may be employed following arthrotomy for an all-cartilage progeny fragment that has been treated with debridement and bone grafting. Following preparation and final reduction of the lesion, the lesion is provisionally held with a trans-articular .045 K wire. For fixation, 2.9 knotless suture anchors with 1.3-millimeter polyester tape sutures are commonly utilized. In the trochlea, a primary anchor with two to four strands may be placed on the posterior central aspect of the lesion 2 to 5mm from the lesion margin. The strands may then be brought to individual knotless anchors that may be placed in the supra-trochlear non-articular distal femur. This can result in two to four bridging sutures that are in line with the flexion arc of the knee. These are placed with manual tensioning and a mallet is used to finally engage the anchor with resultant tension across the lesion. When the lesion is fixed the sutures may be examined using an arthroscopic probe to confirm proper tension, the K-wire is removed, and the suture is cut flush with the proximal anchors. **(Figure 5)**

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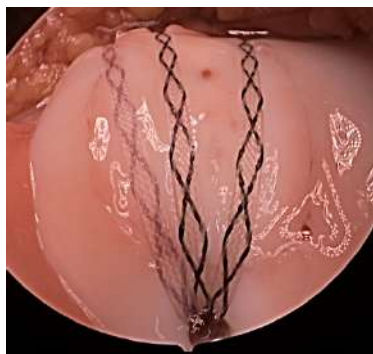
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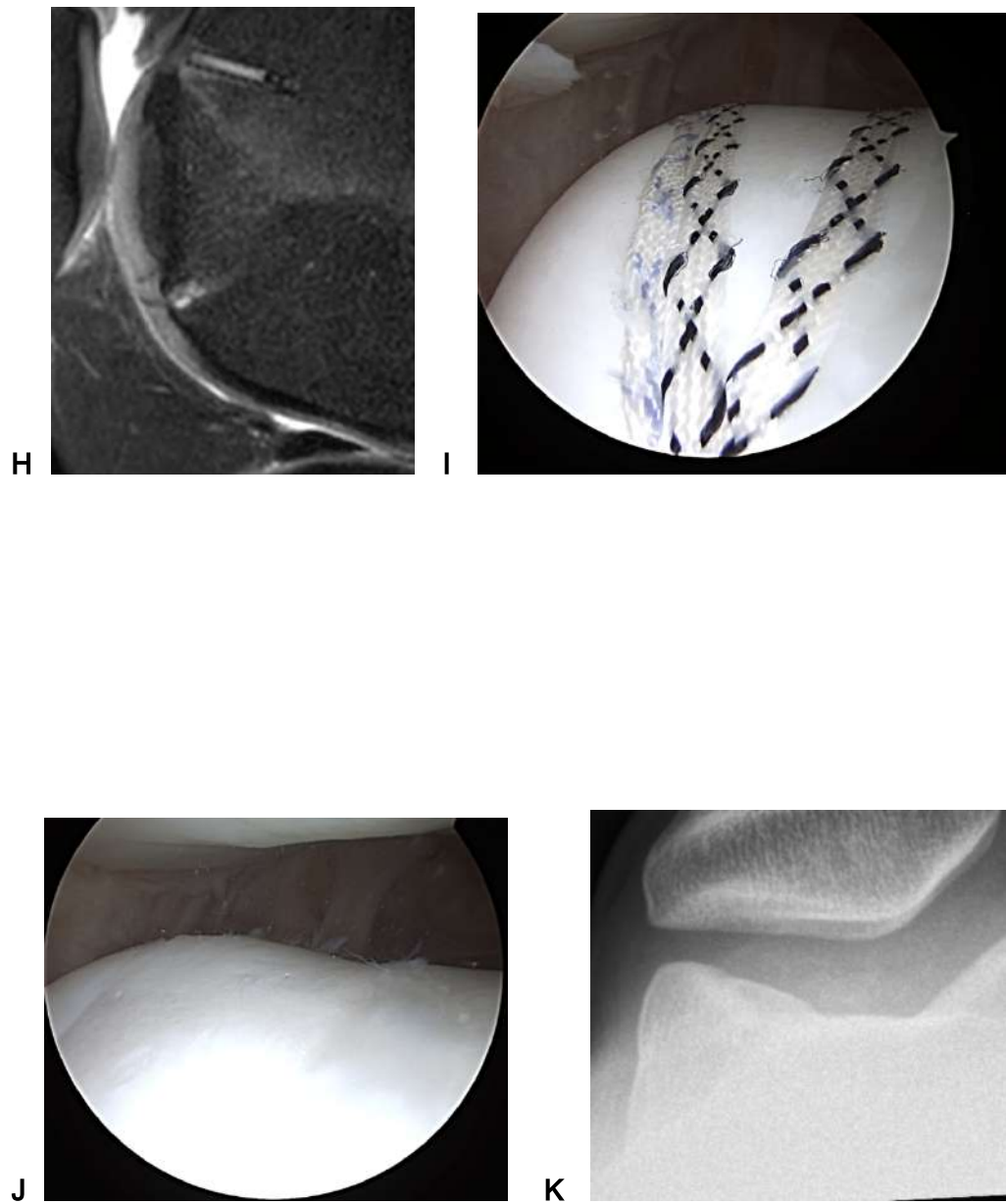
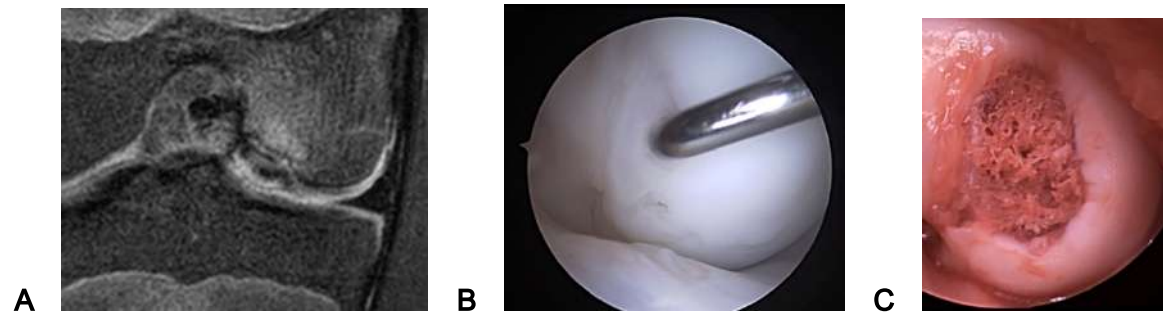


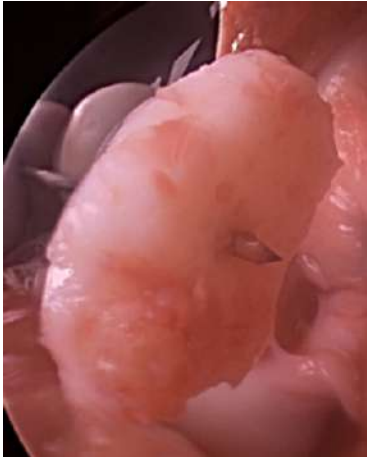
Figure 5: A. A sagittal proton density fat saturation MRI of an unstable lateral femoral trochlear OCD. B. Merchant axial radiograph of trochlear OCD. C. Arthroscopic image of probe displacement of unstable lateral trochlear OCD. D. Debridement of fibrous tissue from parent bed of OCD following arthrotomy. E. Undersurface of trochlear OCD progeny fragment prior to

debridement and refixation. F. Autologous bone graft in prepared parent bed of OCD. G. Suture bridge fixation of trochlear OCD utilizing knotless anchors and 1.3mm polyester tape suture. H. A sagittal proton density fat saturation MRI of united lateral femoral trochlear OCD 5 months following treatment. I and J. Suture and lesion appearance at arthroscopic suture removal 5 months following suture bridge fixation of OCD. K. Merchant axial radiograph of united trochlear OCD 14 months following treatment.

A similar technique may be used for condylar lesions with the primary anchor with multiple strands positioned most posterior with the individual strands bridging to anchors anterior to the lesion. In these lesions the anterior anchors may also be trans-articular and 2- 5mm from the anterior margin of the lesion. Further study of secondary body wear effects is indicated, but sutures in line with the arc of motion have been used preferentially over transverse sutures and very minimal articular surface changes are noted at arthroscopic suture removal. The post operative protocol is six weeks of non-weight bearing with early motion followed by six weeks of activity of exercise bike and swimming with no impact activity or prolonged walking distances. Advanced imaging is obtained at three months to evaluate healing and planning for arthroscopic suture removal. At this time standard arthroscopic evaluation of the lesion can be carried out and the sutures may be elevated with an arthroscopic probe or freer and an arthroscopic grasper may be used with tension and rotation and the suture can be removed by sliding the suture through the subchondral anchor. At second look arthroscopy a small depression on the progeny lesion from the suture tract is commonly noted. Fissuring or cracking of the cartilage is not commonly seen. Fibrocartilage is often appropriate in appearance at the suture anchor positions and second-body wear on the tibial, meniscal, or patellar surfaces has been noted to

be minimal and often grade one in nature - similar to other second look arthroscopies, following non-suture related salvage techniques. **(Figure 6)**



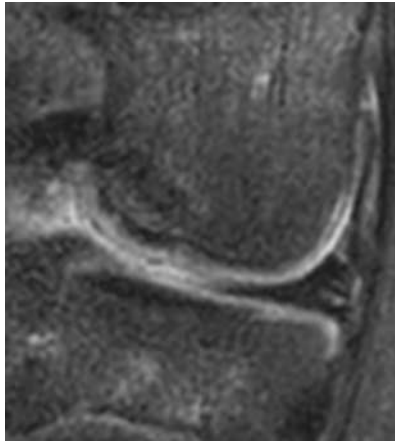


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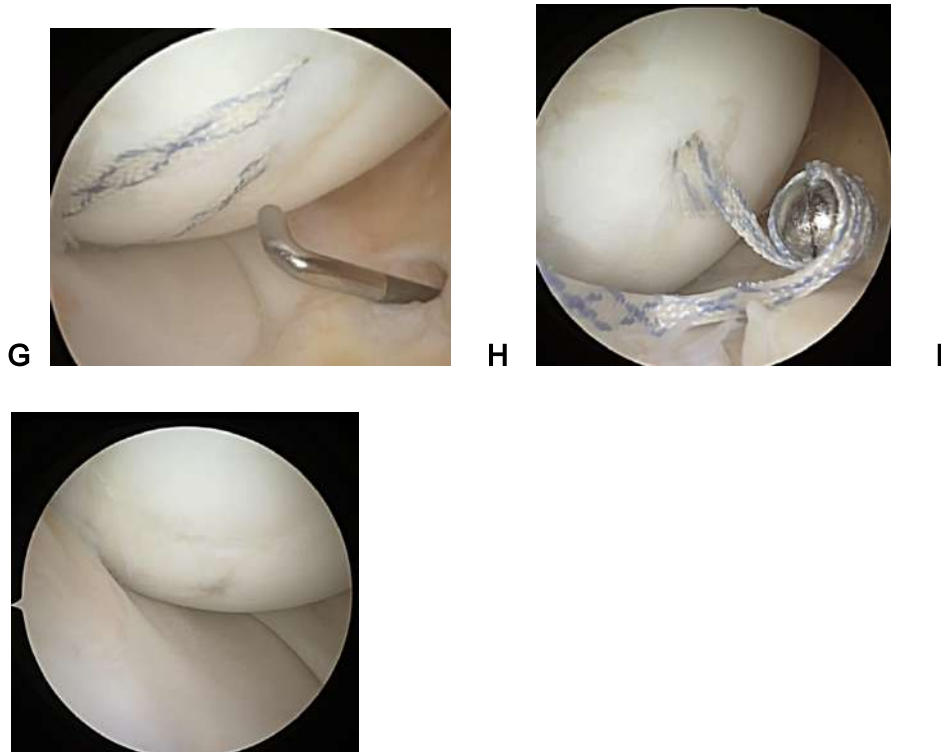
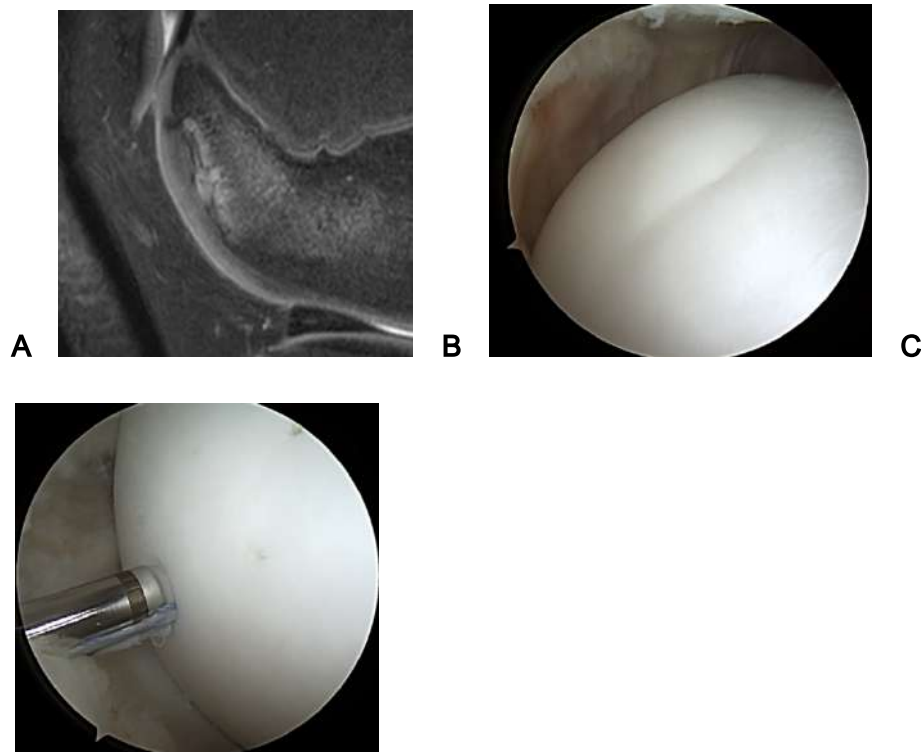


Figure 6: A. A coronal proton density fat saturation MRI of an unstable medial femoral condyle OCD. B. Arthroscopic image of probe displacement of unstable medial condylar OCD. C. Autologous bone graft in prepared parent bed of OCD. D. Progeny fragment pinned with 0.045 K-wire for preparation of provisional refixation. E. Suture bridge fixation of medial condylar OCD utilizing knotless anchors and 1.3mm polyester tape suture. F. A coronal proton density fat saturation MRI of united medial femoral condyle OCD 4 months following treatment. G. Suture and lesion appearance at arthroscopic suture removal 4 months following suture bridge fixation of OCD. H. Arthroscopic suture removal with grasping of suture following elevation with probe and rotating grasper to pull suture from knotless anchor embedded in subchondral bone. I.

Arthroscopic view following suture removal demonstrating lesion union with anchor location fibrocartilage and minimal condylar or tibial secondary body wear.

Suture anchor fixation may be used arthroscopically for OCD lesions with suspected micro-instability. Lesions that are ballotable or a locked door lesion may be good candidates for the addition of compression. Arthroscopic screw placement may be an option for selected lesions, but lesions with little to no bone in the progeny may benefit from suture bridge fixation. Implant and suture selection is as described above with non-absorbable suture preferred for OCD lesions in most cases. Following retro-articular or trans articular drilling and consideration of other biologic augmentation as discussed above, a suture bridge technique may be conducted arthroscopically. Implant placement is carried out through accessory portals as described above for drilling to allow perpendicular approach to the condylar surface. Flexion and extension of the knee over the edge of the bed or within a leg holder with an assistant controlling leg position is useful. The primary anchor is most often placed posterior to the lesion as described above. Following placement of the primary anchor the sutures are retrieved through a new accessory portal that has been localized with needle or fine wire localization and created in the best position for the more anterior suture anchor placement. Once these sutures have been retrieved with a ring grasper through the new portal, they may be loaded into the knotless anchor. A drill cannula through the same portal is used to create the drill tract and the anchor is then placed under arthroscopic visualization. This can then be carried out for the subsequent sutures and anchors in a stepwise fashion. Utilization of the anchor within the joint and tension on the suture allows suture management to ensure that the suture can be manipulated to lay flat on the articular surface prior to final implantation. When a knotless anchor is used, the drill cannula and drill are removed, and the anchor is then placed within the

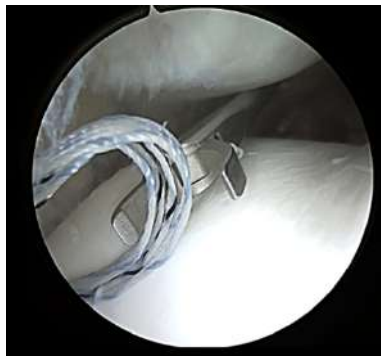
drill tract. In the arthroscopic setting, using a commercially available rigid plastic sleeve that is supplied with a waxed suture implant may serve to identify the position and trajectory of the drill tract. This plastic sleeve may be placed down the drill cannula after the drill has been removed and the sleeve is held in place within the drill hole while the suture and suture anchor are manipulated into position and tension is placed within the suture in preparation for placement. At this point, the rigid plastic sleeve may be removed from the drill hole and the anchor placed and impacted into position in the usual fashion. As in the open technique, the anchor should be impacted to 1mm below the deep articular cartilage margin. The remaining suture following anchor placement may be clipped with a flush cutting arthroscopic knot cutter. The lesion is then inspected for stability and the sutures may be inspected for proper tension. **(Figure 7)**



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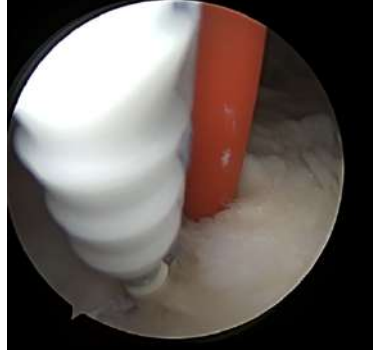
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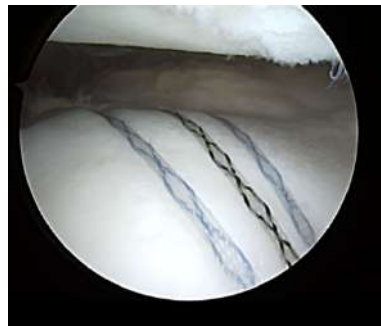
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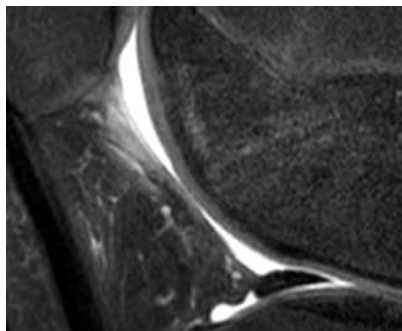
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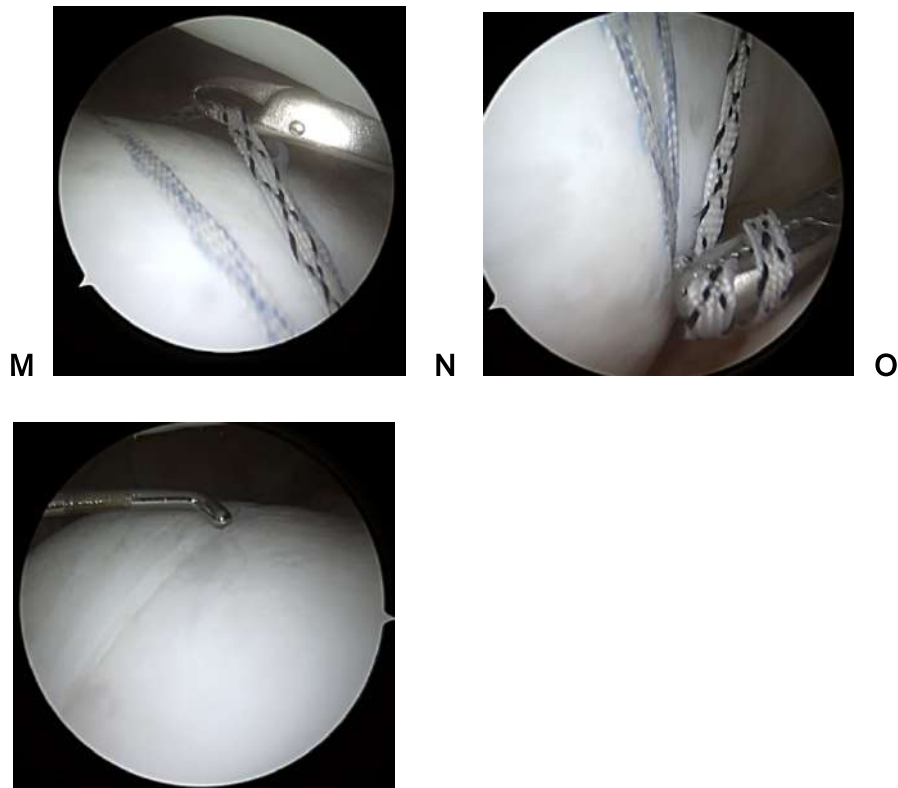


Figure 7: A. A sagittal proton density fat saturation MRI of an lateral femoral trochlear OCD with micro-instability. B. Arthroscopic image of 'locked-door' lateral trochlear OCD. C. Arthroscopic placement of knotless suture anchor loaded with two strands of 1.3mm polyester tape distal to trochlear OCD following trans-articular drilling. D and E. Arthroscopic shuttle of sutures to supra-patellar portal with ring-grasper. F. Drilling for first anchor location for spanning suture bridge just proximal to trochlear articular cartilage and distal femoral physis. G, H, and I. Utilization of red plastic suture sleeve as placeholder to mark drill hole location to facilitate arthroscopic placement of loaded anchor to be placed under suture tension. J. Suture management to repeat process of sequential arthroscopic anchor placement to adequately span lesion. K. Completed arthroscopic suture bridge fixation of trochlear OCD utilizing knotless anchors and three strands of 1.3mm polyester tape suture.

L. A sagittal proton density fat saturation MRI of united lateral femoral trochlear OCD 3 months following treatment. M and N. Suture removal at 4 months following arthroscopic trans-articular drilling and suture bridge fixation of OCD. O. Trochlear articular surface appearance following arthroscopic suture removal from united OCD.

Post operative protocol is as described above and reoperation for suture removal for polyester suture implants would be recommended at three to four months. Again, further level of evidence regarding implant choice, the timing of suture removal, efficacy of the technique, and complication rates are all pending.

Open and Arthroscopic Interposition Cancellous Bone Grafting for OCD Lesions

Unstable OCD lesions with significant fibrous interposition between the progeny and parent bone may be indicated for debridement and bone grafting prior to fixation^{21,23,54-57}. Improving the biologic environment for osseous healing and then eventual ossification of the progeny should be paramount when planning surgical treatment. In addition to removing fibrous tissue between the parent and progeny fragment, removing the sclerotic margin of the parent's bone to expose healthier bleeding cancellous bone may aid in lesion healing. Additional light superficial debridement on the under surface of the progeny fragment to remove superficial necrotic margins may also be beneficial. The debridement of the lesion and placement of interposition cancellous autograft bone may be accomplished either by arthroscopic or open technique. A limited arthrotomy may allow best access for most lesions but select lesions with a hinge in a zone of the trochlear or condyle that is accessible arthroscopically may lend themselves to appropriate visualization and access^{22,58}. The surgeon should ensure that the goals of debridement to healthy tissue, adequate bone graft delivery and visualization for final fixation

are all optimal and not compromised by arthroscopic technique, otherwise an open technique should be selected.

The lesion is hinged open on any remaining appropriate cartilage margin, tissues adjacent to the posterior cruciate ligament, or in some cases the progeny may be removed for best access and preparation of the parent bed and progeny prior to refixation. A combination of motorized chondrotome and curettage to remove fibrous tissue and bony margins to expose healthy cancellous bone is recommended. At times, a water-cooled high-speed Burr may be employed within the parent bed. The goal of parent bone debridement is to visualize normal cancellous interstices following the removal of dense sclerotic bone. On the under surface of the progeny light debridement with a curette or a 15 blade at a right angle to the surface to superficially debride the progeny may be indicated. Following gross debridement of each surface, a water-cooled .045 K wire drilling at 2-millimeter intervals may be used to aid in improving surface bleeding and preparation for ingrowth within both the parent and progeny fragment.

Following aggressive debridement back to healthy cancellous bone there is most often a defect remaining between the progeny and parent bone. Cancellous autograft bone may be harvested from the distal femur or proximal tibia, or the ipsilateral anterior iliac crest. When harvested from the iliac crest, a small incision and manual bone graft extraction with osteotomes and curettes may be employed. A commercially available bone graft harvesting cylinder using a high-speed drill may also allow for bone graft harvest with minimal incision or access required. Local bone graft harvest may be accomplished through an arthrotomy from the supratrochlear distal femur or from the proximal tibia. Care should be taken to be either proximal or distal to the respective

physis if the patient is immature. A small cortical window is created and hinged or preserved for later replacement following bone graft harvest. The bone graft is harvested in a similar fashion to the iliac crest, either manually or with a commercially available power harvester. For defects larger than two to 3mm when harvesting from the distal femur or proximal tibia, bone grafting the defect with cancellous allograft chips may be used to aid defect healing and decrease the risk of postoperative fracture.

Once a suitable amount of bone graft is harvested, in an open technique this can be placed within the parent bed and thumb compression followed by a tamp can be utilized to compress the bone within the lesion. Trial placement of the progeny back across the lesion to estimate proper filling and restoration of contour may be required. Once the appropriate bone graft is placed, the progeny is held stable with a .045 K wire in preparation for either screw or suture bridge fixation. **(Figure 8)**

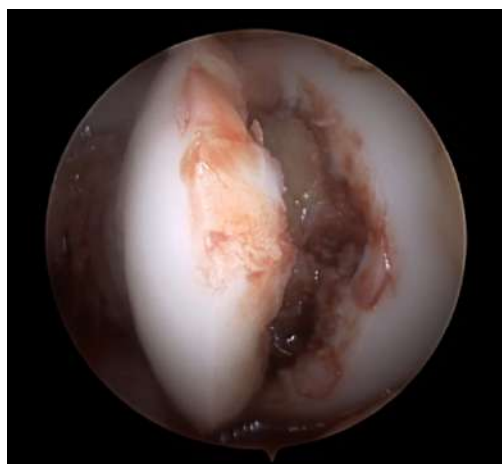
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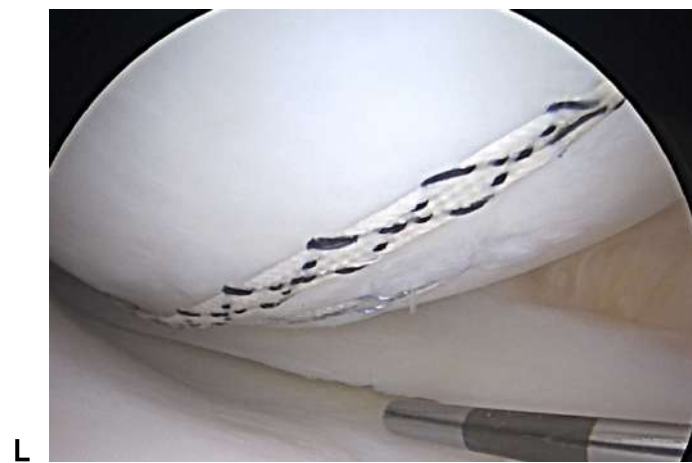
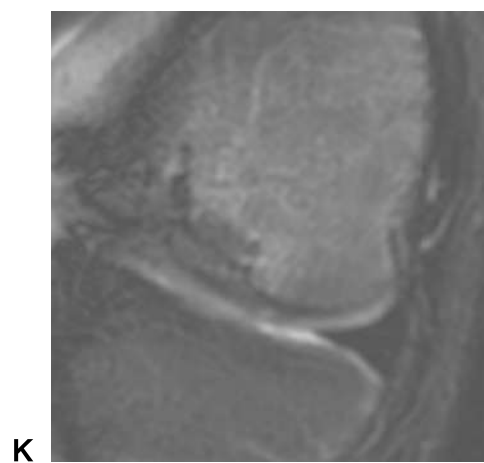
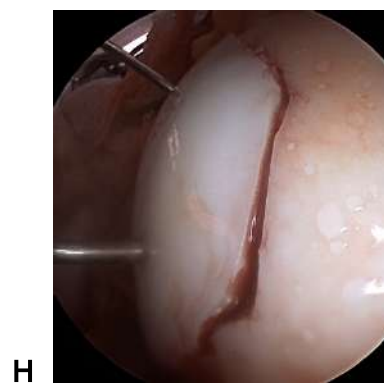
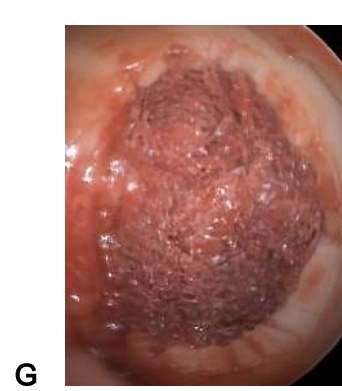
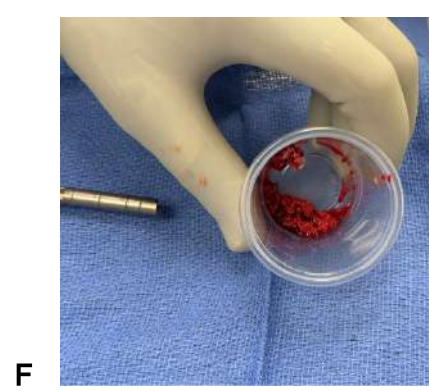
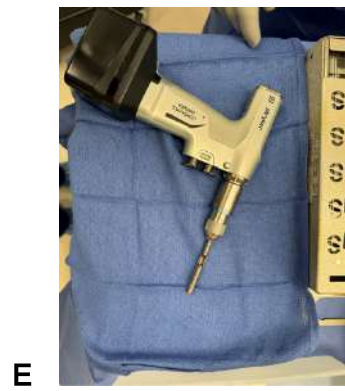


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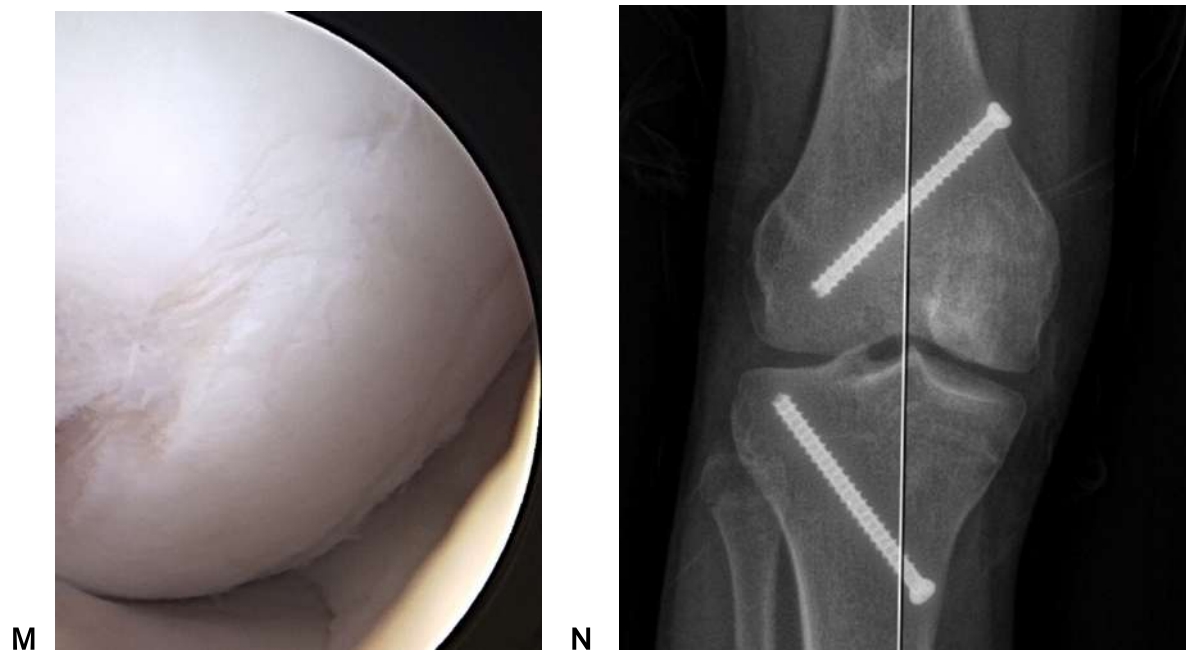


Figure 8: A. A standing alignment radiograph window demonstrating zone I varus alignment and a concurrent medial femoral condyle OCD. B. A coronal proton density fat saturation MRI of an unstable medial femoral condyle OCD. C. Unstable progeny OCD fragment hinged and rotated on PCL tissue following arthrotomy. D. Parent bed following debridement of fibrous tissue from OCD following arthrotomy. E and F. Commercially available power bone graft harvester and cancellous autograft from distal femur and proximal tibia harvested through the proximal and distal extent of the arthrotomy wound. G. Autologous bone graft in prepared parent bed of OCD. H. Temporary K-wire fixation of progeny fragment reduced over bone graft within parent bed of OCD. I. Suture bridge fixation of condylar OCD utilizing knotless anchors and 1.3mm polyester tape suture. J. Fluoroscopic image showing reduced medial femoral OCD lesion, allograft cancellous morselized graft backfilling femoral and tibial autograft bone harvest sites, and distal femoral and proximal tibial trans-physeal guided growth hemi-epiphysiodesis to

treat genu varum. K. A coronal proton density fat saturation MRI of united medial femoral OCD 6 months following treatment. L and M. Suture and lesion appearance at arthroscopic suture removal 6 months following suture bridge fixation of medial femoral condylar OCD. N. A standing alignment radiograph window of united medial femoral condyle OCD and corrected mechanical axis 19 months following treatment.

In the arthroscopic setting, morselized cancellous autograft may be delivered through a slightly enlarged arthroscopic portal using a modified tuberculin syringe to deliver the bone graft into the parent bed and below the progeny fragment.²² Once the adequate bone graft is delivered a probe and other arthroscopic instruments may be used to temporarily stabilize the progeny in a reduced position and a .045 K wire can be utilized to stabilize the progeny in preparation for either arthroscopic screw or suture bridge final fixation. Following stabilization of the progeny, a motorized chondrotome is employed for lavage and loose body removal to ensure that there is no bone graft remains within the intra articular space prior to the completion of the surgery.

Conclusion

Osteochondritis dissecans is the failure of endochondral ossification within the subchondral bone of the knee with resultant fibrous interposed tissues between the parent and progeny bone and surrounding sclerotic cancellous bone. The biology of this lesion presents significant challenges for healing and the development of a united subchondral bone that can support stable hyaline cartilage. Strategies to improve both the biology and stability of osteochondritis dissecans lesions are required to accomplish satisfactory results. Whether approached arthroscopically or open, surgeons should carefully consider the status of the parent bone margin, parent and progeny fragment interface, and progeny fragment tissue. Each of these

regions may require careful attention to improve the biology of the lesion. Similarly, lesion stability requires critical assessment. Any degree of instability may lead to incomplete vascularization and ossification of the progeny fragment. Stabilizing and compressive forces may augment bone healing. To achieve the above goals, delivery of osteoinductive and osteoconductive autogenous bone graft or bone marrow aspirate concentrate and stabilization with screw or suture constructs may be utilized. These techniques warrant continued research to identify appropriate indications and correlations for improved outcomes in these challenging osteochondritis lesions.

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