Technical Note

Arthroscopic-Assisted Intraosseous Bioplasty of the Acetabulum

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Abstract: Intraosseous bioplasty (IOBP), has been previously described for arthroscopic-assisted treatment of subchondral bone cysts in the proximal tibia associated with early stages of knee osteoarthritis (OA). This technique entails combining bone marrow aspirate concentrate or concentrated platelet-rich plasma with demineralized bone matrix as a bone substitute before injecting into a subchondral bone defect under fluoroscopic guidance. The principles of IOBP as a procedure that combines core decompression with biologic bone substitute augmentation can be extended to treat subchondral bone marrow lesions such as acetabular and femoral cysts in degenerative hip OA. Intraosseous bioplasty of the hip, in particular the acetabulum, when done using this technique, is a useful alternative that can be beneficial in treating young patients with early hip arthritis to achieve successful outcomes while delaying more invasive procedures. The Technical Note described here presents a step-by-step approach, including tips and pearls for arthroscopic-assisted IOBP with decompression of the subchondral cyst in the acetabulum followed by bone substitute injection under fluoroscopic guidance. We believe this method is a safe and reproducible way to treat subchondral defects in young patients with signs of early osteoarthritis of the hip joint.

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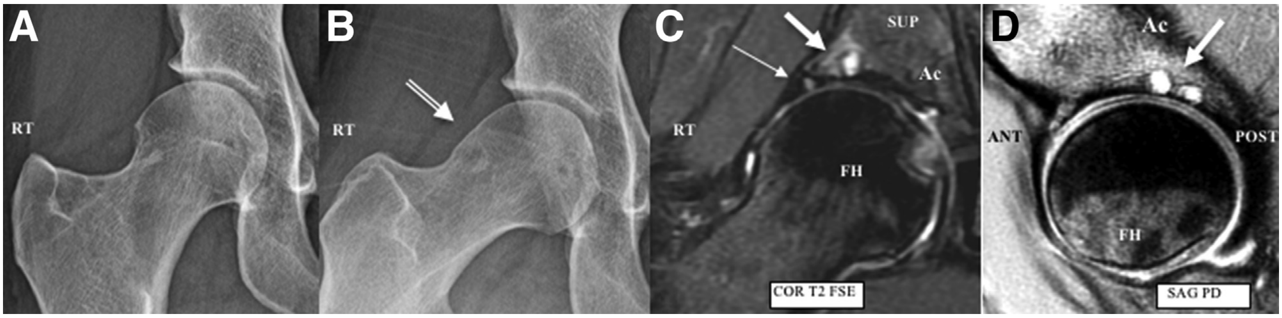

Fig 1. (A) Right hip preoperative plain radiograph anteroposterior view. (B) Dunn lateral view showing cam morphology (double line white arrow) with subtle appearing acetabular cysts. (C) Right hip magnetic resonance arthrogram (MRA) coronal T2 fast spin echo image. (D) Right hip MRA sagittal proton density weighted images depicting acetabular cysts (bold white arrow) with labral tear (narrow white arrow). (Ac, acetabulum; ANT, anterior; FH, femoral head; SUP, superior; POST, posterior.)

Subchondral bone marrow lesions (BML), which represent histologically and mechanically altered subchondral bone, have been demonstrated in the knees and hips of patients with osteoarthritis (OA).[1-3] Clinically, the presence of a BML closely correlates with pain (presence and severity) and rapid joint deterioration.[3] BML occurs in association with OA when physiologic subchondral remodeling fails because of ongoing joint forces, increased focalization of stress, and histologically represent nonhealing chronic stress fractures of subchondral bone with progressive loss of the overlying cartilage.[1,4-6] These defects may be difficult to detect on standard radiograph; however, they readily are seen on magnetic resonance imaging (MRI) as enhancing lesions on fat saturated sequences.[1]

Knee joint literature has shown that evidence of bone marrow edema or lesions is a strong predictor of future need for a total joint replacement with loss of integrity of the subchondral bone contributing to future collapse and deformity of the joint.[4,5] The resulting pain experienced by patients is debilitating and is difficult to treat conservatively. Therefore, any intervention with the capacity to relieve symptoms, repair subchondral bone, and alter the natural history of joint deterioration is intriguing.[7,8] The significance of subchondral lesions of the hip cannot be understated and a procedure to address these lesions can lead to decreased morbidity and a delay in eventual joint replacement surgery. For these reasons, less invasive, joint-preserving options are desirable, particularly for younger patients.

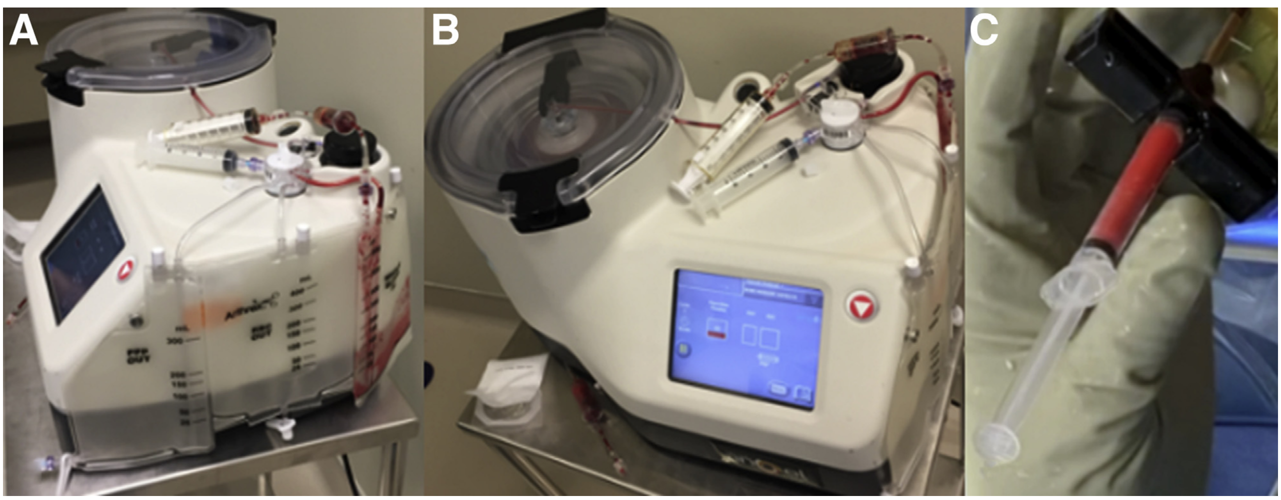

Fig 2. The Angel System (Arthrex Inc). (A) Side view; (B) front view. The bone marrow aspirate will be injected in the rightmost bag (whole blood in), and the automated process will start dividing the different blood components. First, the platelet-poor plasma (PPP) will be discarded in the leftmost bag (PPP out). Then the bone marrow aspirate concentrate (BMAC) rich in platelet-rich plasma (PRP) will be collected in the syringe on top of the system, and finally the red blood cells will be collected in the bag in the middle. The length of this process depends on the quantity of bone marrow aspirate used. In this case, it was ∼17 minutes for 60 mL of aspirate. The syringe with the harvested bone marrow is screwed in, the bone aspirate is injected in the rightmost bag, and the centrifugation process is about to start. (C) The PRP obtained from the Angel System is mixed with demineralized bone matrix, taken from a donor cadaver, until the result is a thick paste inserted in a syringe.

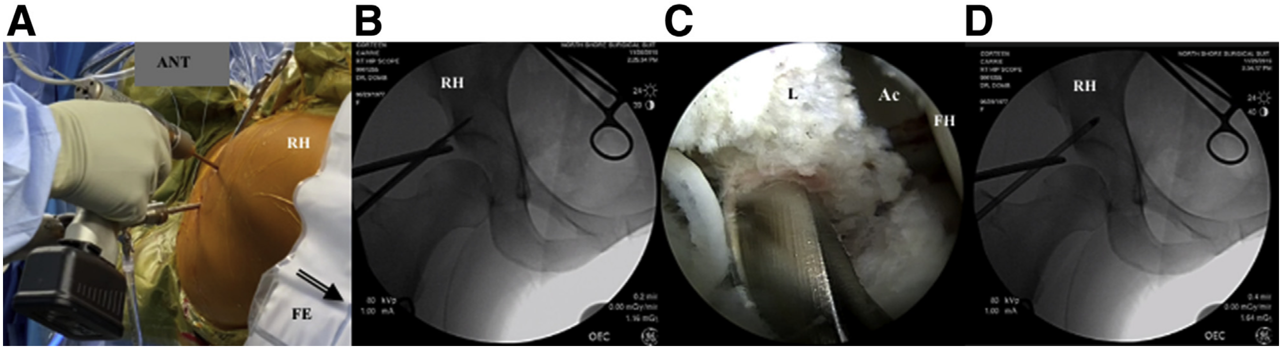

Fig 3. (A) Right hip arthroscopy external view of the right hip, patient in supine position, with arthroscope in the anterolateral portal (AL) for viewing and power drill and guide wire through the distal anterolateral accessory portal for working. (B) Fluoroscope image of the right hip showing guidewire in position decompressing subchondral cysts. (C) Intraoperative image of right hip arthroscopy intra-articular view confirming starting a 5.5-mm reamer tip over guide wire. (D) Fluoroscope image of the right hip confirming final reamer position in the cyst location. (Ac, acetabulum; ANT, anterior; FE, foot end; FH, femoral head; L, labrum; RH, right hip.)

The earliest described procedure to treat bone marrow lesions of the hip was core decompression. It demonstrated reasonable short-term outcomes; however, the long-term results were similar to those of nonoperative groups.[9] Larger acetabular intraosseous cysts (>1 cm^3) have been addressed in the past by additional breach in the cyst wall with "outside-in" drilling using open[10] and arthroscopic techniques,[11] or a curved delivery device through the articular side[12] penetrating into the cyst cavity to deliver bone graft material. Arthroscopic-assisted subchondroplasty, involving orthobiologic treatment with percutaneous calcium phosphate injections into BML, showed improved pain and functionality in patients with early OA.[7,8,13] However, this intervention was found to be ineffective for treating bone marrow edema lesions in adults with advanced osteoarthritis.[14]

Intraosseous bioplasty (IOBP), was first described for arthroscopic-assisted treatment of subchondral bone cysts in the proximal tibia for the early stages of knee OA.[15,16] This technique entails combining bone marrow aspirate concentrate (BMAC) or concentrated platelet-rich plasma (cPRP) with demineralized bone matrix (DBM) as a bone substitute before injecting it into subchondral bone defects under fluoroscopic guidance. IOBP of the hip, in particular the acetabulum, when done using this technique is a useful alternative that can be beneficial in treating young patients with early hip arthritis to achieve successful outcomes while delaying more invasive procedures. The Technical Note described here presents a step-by-step approach, including tips and pearls for arthroscopic-assisted IOBP with decompression of the subchondral cyst in the acetabulum followed by bone substitute injection under fluoroscopic guidance. We believe this method is a safe and reproducible way to treat subchondral defects in young patients with signs of early osteoarthritis of the hip joint.

This study was performed in accordance with the ethical standards in the 1964 Declaration of Helsinki and with relevant regulations of the US Health

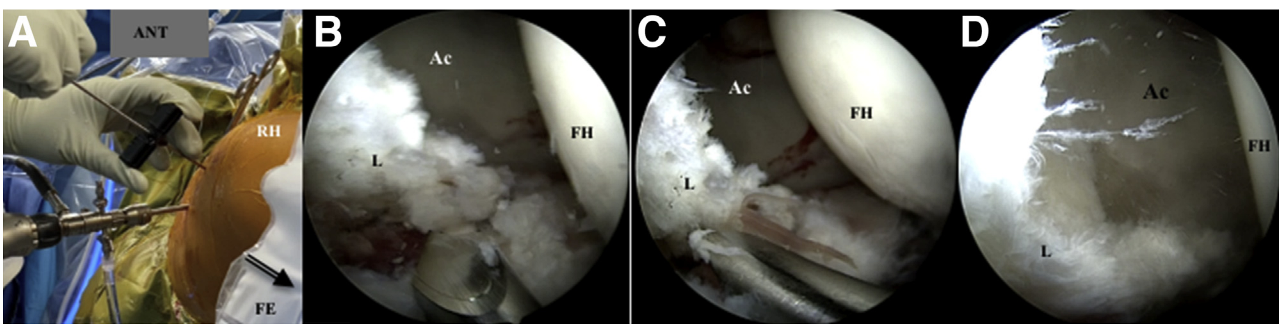

Fig 4. (A) Intraoperative image of right hip arthroscopy external view of the right hip, patient in supine position, with arthroscope in the anterolateral portal (AL) for viewing and open-ended delivery cannula fed over guide wire through the distal anterolateral accessory portal for working. (B) Arthroscopic intra-articular picture confirming open-ended delivery cannula tip over guidewire near cyst decompression entry port; (C) intra-articular picture confirming final delivery cannula position wire. (D) Arthroscopic intra-articular view verifying integrity of joint surface (focal chondral defect in the center of image can be seen). (Ac, acetabulum; ANT, anterior; FE, foot end; FH, femoral head; L, labrum; RH, right hip.)

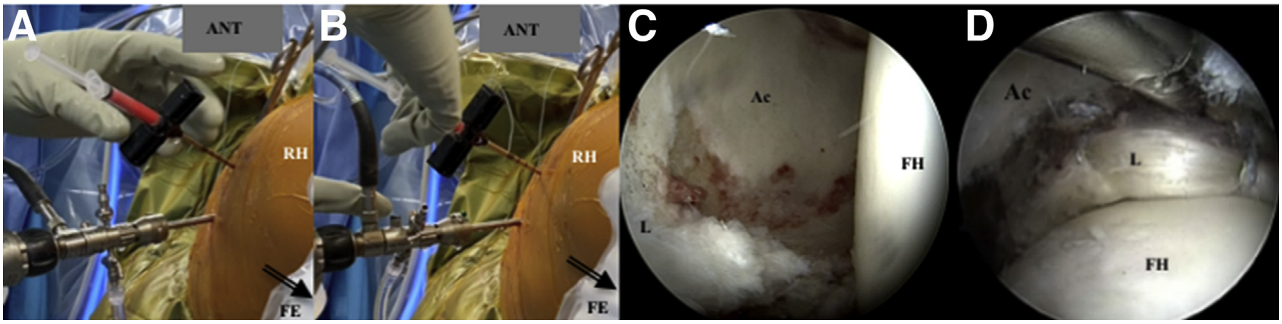

Fig 5. (A) Right hip arthroscopy external view of the right hip, patient in supine position, with arthroscope in the anterolateral portal (AL), with open-ended delivery cannula in desired position through the distal anterolateral accessory portal and inside 2.4-mm guide pin removed and the syringe, previously loaded with the bone marrow aspirate concentrate-demineralized bone matrix mixture, is screwed in on the top of the cannula, ready to inject. (B) Bone substitute delivery completion with syringe/delivery cannula in precise position. (C) Right hip arthroscopy intra-articular view confirming cleared joint space of residual debris. (D) Final intraoperative image of arthroscopic intra-articular view of the right hip joint (off traction) with effective suction seal following labral repair. (Ac, acetabulum; ANT, anterior; FE, foot end; FH, femoral head; L, labrum; RH, right hip.)

Insurance Portability and Accountability Act. Details that might disclose the identity of the subjects under study have been omitted. This study was approved by the institutional review board (ID: 5276). This study was performed at the American Hip Institute Research Foundation.

Indications, Evaluation and Preoperative Imaging

This patient has significant right hip pain limiting her activities of daily living and is unresponsive to conservative treatment. Clinical examination is positive for impingement sign and hip instability. Radiographically, there is cam morphology in the hip with alpha angle of ∼67° with no evidence of advanced arthritis (Fig 1 A and B). The hip is graded as Tönnis 1 because of evidence of subchondral cysts. However, advanced OA was not evident and the patient had >2 mm of joint space. MRI scans demonstrated a labral tear with 2 acetabular cysts, each measuring up to 0.5 cm in diameter. The adjacent cortical bone appeared to be intact with no evidence of subchondral collapse (Fig 1 C and D). The patient is consented for arthroscopic hip surgery with labral repair versus debridement versus reconstruction, femoroplasty, and arthroscopic-assisted IOBP for subchondral acetabular cysts.

Surgical Technique

Patient Preparation and Positioning

After induction of general anesthesia, the patient is placed in the supine position on the traction extension table (Smith & Nephew, Andover, MA) with a well-padded peroneal post, the genitalia protected, and the feet well secured. The right hip is prepped and draped in usual sterile fashion. Traction is applied to the hip under fluoroscopy.

Fluoroscopy Technique

The C-arm is positioned on the nonoperative side and draped in sterile fashion. A true anteroposterior radiograph of the pelvis is obtained by tilting the C-arm to compensate for the Trendelenburg inclination.[17] Under fluoroscopy, the joint seal is broken, and traction is applied.

Portals Placement

The anterolateral portal is created with an 11-blade. A spinal needle is introduced into the joint under fluoroscopy and the joint is vented, achieving further distention. The spinal needle is reinserted to ensure avoidance of the labrum and femoral head. An over-the-guidewire technique is used to place a 70° arthroscope through the 4.5-mm cannula. This same technique is repeated to place a 5-mm cannula through the mid-anterior portal. The Beaver blade is used to perform a capsulotomy, incising the capsule parallel to the acetabular rim to connect the 2 portals. An additional distal anterolateral accessory portal is made to provide a better angle for capsule elevation and during capsular closure.

Diagnostic Arthroscopy of the Hip

The diagnostic arthroscopy of the right hip is then performed, which confirmed the presence of a labral tear as well as small regions of chondral damage on the acetabulum, adjacent to areas of known subchondral cysts.

Arthroscopic Labral Repair, Acetabuloplasty, Femoroplasty

After the capsule is elevated using the ablator radiofrequency wand, the acetabuloplasty is undertaken using the 5.5-mm bur to perform the acetabular rim

Table 1. 4-Phase Rehabilitation Protocol Followed After Arthroscopic Hip Preservation

Phase 1: Immediate rehabilitation (1-3 weeks)	Goals of phase 1 are to diminish pain, protect the repaired tissues, and prevent muscle inhibition as well as the development of anterior hip contractures. The postoperative brace and crutches were used for 2 weeks immediately after surgery. After 2 weeks, the patient progressed to weightbearing as tolerated. Passive range of motion restrictions for weeks 1-3 are as follows: • Flexion up to 90° • Extension to 0° • Abduction up to 25 to 30° • Internal rotation (IR) at 90° of hip flexion to 0° • IR in prone limited by comfort • External rotation (ER) at 90° of hip flexion up to 30° • ER in prone position up to 20° Prerequisite to advance to next phase: Full, nonpainful weightbearing of involved extremity must be achieved.
Phase 2: Intermediate rehabilitation (4-8 weeks)	Goals of phase 2 is to continue protection of the repaired tissue, restoration of full hip range of motion (ROM) and normal gait patterns, and strengthening of the hip, pelvis, and both lower extremities with emphasis on the gluteus medius, improving core strength and stability. Prerequisite to advance to next phase: • Full and pain-free hip active range of motion in all planes • Pain-free normalized gait • Hip flexor strength of 4 (of 5) on manual muscle testing • Hip abduction, adduction, extension, and IR/ER strength of 4 (of 5) on manual muscle testing of involved extremity.
Phase 3: Advanced rehabilitation (9-12 weeks)	Goals of phase 3 are the restoration of hip flexor muscle strength to 4 and 4+ (of 5) for all other hip motions, as well as improving balance, proprioception, and cardiovascular endurance. Precautions include avoidance of contact activities, aggressive hip flexor strengthening, as well as forced or aggressive stretching that elicits pain. Criteria for progression to sport-specific training includes hip flexor muscle strength of 4+ and 5 (of 5) in all other lower extremity musculature.
Phase 4: Sport-specific training (>12 weeks)	Includes jogging progression program along with hopping and agility drills - return to run protocol Prerequisite for return to play: Full ROM to all planes of the hip and cardiovascular endurance, normal strength and flexibility throughout the core and lower extremities Return-to-play video testing involving: • Single hop for distance, triple hop for distance, and triple crossover hop for distance with at least 90% limb symmetry. • Double-leg squat followed by single-leg squat off of an 18-inch box. • 15-foot lateral cone shuffles

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trimming of ~1-mm rim between 11 o'clock and 3 o'clock, using fluoroscopic visualization to trim the pretemplated amount of bone from the impingement part of the rim. Next, in the known area of subchondral cystic degeneration, abrasion arthroplasty is performed on the acetabular margin creating bleeding subchondral bone. This is followed by labral repair using the looped stitch technique. A total of 4 stitches and anchors (1.8-mm knotless FiberTak, Arthrex, Naples, FL) are placed. Excellent refixation of labrum is achieved in this fashion. The arthroscope and the curved shaver are then moved into the peripheral compartment as the traction is released and the hip is flexed to 45° and femoroplasty was performed using a 5.5-mm burr with extensive fluoroscopic visualization.

Table 2. Advantages and Disadvantages for Arthroscopic Intraosseous Bioplasty

Advantages	Disadvantages
• Direct arthroscopic visualization of chondral defects • Complete joint assessment and management with minimally invasive joint preservation technique • Precision-driven cyst decompression under fluoroscopic guidance	• Increased operative time • Technically demanding procedure with steep learning curve • Potential for complications inherent to hip arthroscopy

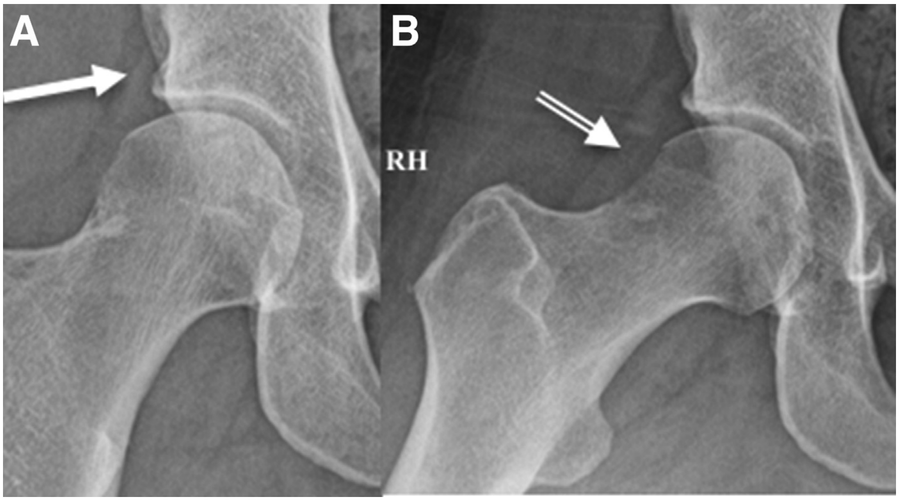

Fig 6. (A) Right hip (RH) postoperative plain radiograph anteroposterior view. (B) Dunn lateral view showing cam resection (femoroplasty) cam morphology correction (double line white arrow), with subtle signs of acetabular drilling for cyst decompression (bold white arrow).

Bone Marrow Harvest and Bone Substitute Material Preparation

Using the Arthrex Angel BMAC System (Arthrex), the adjacent iliac crest region within the sterile surgical field is accessed for bone marrow harvest. The harvesting cannula is impacted between the inner and outer tables of iliac crest, and the inner stylus of the cannula is removed. Two 30-mL syringes, pretreated with 5 mL of acid-citrate-dextrose formula A, are secured to the cannula, and bone marrow harvest aspiration is performed to fill both syringes (Fig 2A). Once the harvest is complete, both syringes are connected to the Angel System (Fig 2B). The processing time to obtain the concentrate from 60 mL of aspirate is approximately 17 minutes. Next, BMAC and bone substitute compound is prepared on back side table by combining cell concentrate and the DBM until the mixture has the consistency of a thick paste (Fig 2C) and kept ready in a prefilled syringe to be injected.

Identification and Decompression of the Subchondral Cyst

The subchondral cysts are decompressed under fluoroscopic guidance with simultaneous arthroscopic viewing of the joint surfaces while the bone substitute compound is being prepared (Fig 3 A and D). The location of the subchondral acetabular fracture is first identified with MRI scans. Through the mid-anterior portal, the guidewire is inserted, and adequate position of the pin is verified with the help of fluoroscopy, confirming the location of the cyst in the acetabular roof (Fig 3B). Then, the subchondral bone cyst decompression is performed with a 2.4-mm wire pin drilled in the location of the cyst. The spinal needle and the fluoroscope are useful to localize the lesion (Fig 3 B and D). In cases where the cyst is far enough from the joint, it is possible to carefully ream over the guide wire and decompress the lesion even further (Fig 3D). With the help of the intraoperative radiographs to check the distance from the sourcil, a cannulated reamer is used (Video 1). In addition, arthroscopic visualization is necessary to monitor the integrity of the acetabular articular surface during the reaming process. Once reaming was complete, the 2.4-mm guidewire pin is placed in situ (Fig 4A). The Arthrex Angel cannulated system for delivery of the BMAC-DBM mixture is placed into the region of the decompressed cyst by direct arthroscopic visualization combined with fluoroscopic guidance. Both viewing methods are vital to ensure precise delivery of bone substitute (Fig 4 B and C).

BMAC-DBM Inoculation (Intraosseous Bioplasty)

The syringe with the concentrated BMAC/PRP-DBM is secured to the delivery cannula and then injected. Injection proceeded from the deepest part of the lesion to the most superficial area, slowly withdrawing the delivery cannula out while injecting the mixture. It is important to periodically take intraoperative radiographs to document the placement of the cannula tip and to ensure the void in the acetabulum is filled (Fig 5 A and B). Arthroscopic viewing of the hip joint while completing the procedure is done to ensure no bone substitute material is eluted into the joint space (Fig 5C).

Table 3. Indications and Contraindications for Arthroscopic Acetabular Intraosseous Bioplasty

Indications	Contraindications
• Contained subchondral degenerate cysts in the acetabular weightbearing dome • Tönnis grade 0 -1 • Avascular necrosis	• Severe hip osteoarthritis • Open/uncontained subchondral cysts • Obvious subchondral fracture/bone collapse

Table 4. Arthroscopic Intraosseous Bioplasty Pearls and Pitfalls

Pearls	Pitfalls
• Subchondral cysts can be comprehensively assessed by simultaneous fluoroscopy and arthroscopy • Definition and treatment of chondral lesions • Ability to address coexisting labral pathology and impingement lesions • Potential leak of biomaterial/bone substitute into the joint can be extricated safely and completely under vision • Guidewire triangulation	• Subchondral fracture • Inadequate cyst decompression • Incomplete bioplasty resulting from cortical breach between cyst and joint space • Potential variability of bone substitute consistency • Missed guide pin entry location

Closure

The capsulorrhaphy is then undertaken using No. 1 Vicryl sutures to produce appropriate anatomic tension on the capsule. The joint is lavaged and sucked dry of fluid. All instruments are withdrawn from the joint. The portals are closed using 3-0 nylon sutures. Steri-Strips and sterile dressings are applied, and the hip is placed in the hip brace, locked 0 to 90° of flexion. The patient is safely awakened and extubated and taken to the recovery room in stable condition.

Postoperative Rehabilitation

The patient is advised to remain partial weightbearing (20 pounds) on the operated extremity with crutches for 2 weeks while continuing the hip brace for postoperative stability. Physical therapy began the day after surgery, following all 4 phases of the protocol (Table 1).[18]

Discussion

The IOBP has been shown to provide pain relief in the short term by using BMAC and DBM as an adjunct to arthroscopy for treating BML associated with degenerative conditions of the knee.[16] The IOBP procedure is the biologic treatment of bone marrow lesions with techniques that encourage physiologic remodeling and repair of the subchondral bone defects by performing a core decompression of the lesion and a direct application of BMAC mixed with DBM into the defect under fluoroscopic guidance.[15,16] This procedure targets and fills subchondral bone defects in patients who have not responded to conservative treatment. The PRP-DBM injection has osteogenic potential to promote bone production and fill the void left from decompression.[19] Given the prevalence of similar bone marrow lesions in the hip, it is reasonable to also assume that IOBP can be a useful treatment in hip osteoarthritis as well.

Subchondral cysts may be a precursor to arthritic change in the joint.[1,2] Without obvious macroscopic Outerbridge grade III and IV damage, a significant percentage of patients remain asymptomatic before having a painful decline in joint function.[20]

Patients typically present with presence of a bone defect that can be seen on fat-suppressed MRI (e.g., T2-weighted fat-saturated, proton density fat-suppressed, short tau inversion recovery sequences) and no resolution of pain with conservative care or other nonsurgical interventions.[1,6] Among different treatment options that were used to treat bone marrow lesions in the hip, earlier described procedures such as core decompression had long-term outcomes that did not differ significantly from nonoperative groups.[9] Larger acetabular intraosseous cysts (>1 cm^3) have been addressed in the past by additional breach in the external cyst wall with "outside-in" drilling using open[10] and arthroscopic techniques,[11] or a curved delivery device through the articular side[12] penetrating into the cyst cavity to deliver bone graft material. These techniques are at a disadvantage because the potentially closed subchondral cyst is made open by taking down the outer wall or penetrating the floor of the cyst, thus further weakening the subchondral bone. Arthroscopic-assisted subchondroplasty with percutaneous injection of calcium phosphate into the BML showed decreased pain and improved functionality in patients with early OA.[7,8,13,21] However, this intervention was found to be ineffective for treating bone marrow edema lesions in adults with advanced osteoarthritis.[14]

Recently, Krych et al.[22] showed that these cysts can be associated with high-grade chondral defects in patients with either marrow edema and/or subchondral cysts who had worse patient-reported outcomes at final follow-up than a matched cohort without subchondral cysts or edema. Hartigan et al.[23] reported on the 2-year follow-up results of arthroscopic management of patients with labral pathology who have preoperative MRI scans demonstrating subchondral cysts. The patients with femoral cysts had a 36% conversion rate to total hip arthroplasty compared with 17% in the acetabular cyst group in that study.

Table 5. Intraosseous Bioplasty Risk and Limitations

Risk	Limitations
• Risks inherent to hip arthroscopy such as iatrogenic chondral damage	• Large and multiloculated cysts with obvious acetabular compromise in structural integrity • Cyst with intra-articular communication

IOBP of the hip, in particular the acetabulum, is a useful alternative with definitive advantages (Table 2) that can be extremely beneficial for patient outcomes and delay of more invasive procedures when done using the proper technique described here. This Technical Note describes arthroscopic-assisted percutaneous decompression of subchondral cysts in the acetabulum with application of autologous BMAC mixed with DBM injected into the defect space under fluoroscopic guidance. Additionally, arthroscopic labral repair, acetabuloplasty, femoroplasty, and capsulorraphy were performed, addressing the coexisting pathologies in this patient's hip (Fig 6 A and B). There are some contraindications (Table 3) for this technique as well as a few disadvantages, pitfalls (Tables 2 and 4), risks, and limitations (Table 5) that have been addressed here.

Conclusions

Intraosseous bioplasty of the acetabulum is a useful technique meant to decompress subchondral bony lesions, aimed to provide structural support to a mechanically compromised joint by providing the necessary biologic healing. This procedure has potential to be used as an adjunct during arthroscopic hip preservation, potentially delaying more invasive procedures to relieve hip pain, such as joint arthroplasty.

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