Technical Note

Arthroscopic Approach to Preservation of the Hip with Avascular Necrosis

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Abstract: Avascular necrosis (AVN) of the hip is a devastating disease that affects middle-aged adults with poor outcomes if not treated in its early stages. In recent years, subchondroplasty with calcium phosphate solution has shown promising results. Concomitant intra-articular pathologies, including femoroacetabular impingement and chondral lesions, have been described in hips affected by AVN. These should be addressed at the time of surgery to lower the risk of failure. In this Technical Note, we describe an arthroscopic approach to femoral head subchondroplasty with precollapse lesion in AVN affected hip, combined with labral reconstruction and acetabular chondral treatment.

Avascular necrosis (AVN) of the femoral head is a disabling disease, as it predominantly affects people in their third and fourth decades of life and ultimately leads to secondary degeneration of the hip joint with expected functional impairment.[1-3] The end stage is osteoarthritis, so hip preservation in early stages (i.e., precollapse) of the disease is primordial.[2,4] Multiple procedures or combination of techniques have been described to address AVN hips in precollapse stages, with mixed results.[5] Femoral head subchondroplasty is a minimally invasive core decompression (CD) technique with bone substitute injection into the subchondral bone.[6] Promising results have been recently reported with the advent use of calcium phosphate ($CaPO_4$) solution in subchondral lesions around the knee.[7,8] A similar approach has been described in the hip, but clinical outcomes are less evaluated.[6,9]

Concomitant central compartment pathology, including femoroacetabular impingement (FAI) as well as chondral and labral lesions, is frequently present in the context of femoral head AVN.[10-12] There is an increasing body of evidence that FAI can lead to cartilage wear and eventual osteoarthritis.[13-15] Therefore, without the treatment of associated articular pathology, the success of femoral head subchondroplasty in AVN may be compromised. In this paper, we describe an all-arthroscopic approach to subchondroplasty of femoral head osteonecrosis with precollapse lesion, combined with pincer and cam osteoplasty, labral reconstruction and treatment of acetabular chondral lesion, as well as grafting of an acetabular cyst.

Surgical Technique (With Video Illustration)

Preoperative planning, patient positioning, and surgical technique are described in Video 1.

Preoperative Planning

Plain radiographs are used to stage the disease[16] and to rule out advanced osteoarthritis (Fig 1). Magnetic resonance imaging is performed to more accurately stage the disease and investigate for other pathologies that would be addressed at the same time during surgery (Fig 2). Magnetic resonance imaging also is used to screen for bilateral involvement in the early stage.[17] Localization of the femoral head—affected region is essential to plan the surgical approach, as intraoperative fluoroscopy is used to confirm the lesion's location. Computed tomography scan can best identify the affected area as well as identifying any subchondral cysts or FAI-related bony abnormalities (Figs 3 and 4).

Patient Positioning

Under general anesthesia, the patient is placed supine on a hip-traction operating table with legs abducted.

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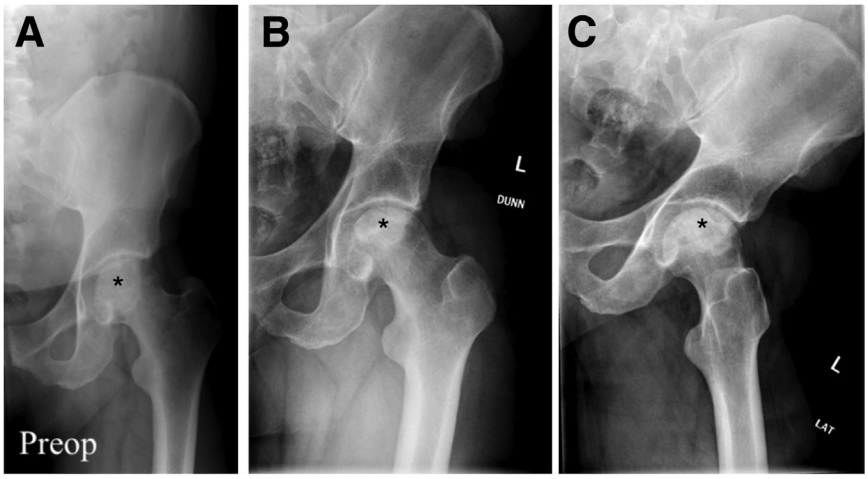

Fig 1. Diagnosis of avascular necrosis (AVN) using plain radiographs. Anteroposterior (A), Dunn (B), and frog-leg (C) views showing femoral head osteosclerotic changes (asterisk) in a left hip compatible with a stage II Ficat and Arlet[16] AVN lesion.

The feet are tightly strapped into padded boots. Balanced traction is used, and the medial thighs rest against a well-padded large perineal post. The operative lower limb is placed in 10° flexion, 15° internal rotation, 10° lateral tilt, and neutral abduction. The surgical field is prepped and draped with care to include enough skin surface along the lateral and posterolateral aspects of the thigh required for percutaneous decompression and bone substitute injection later in the procedure. Essential anatomic landmarks, including the greater trochanter and anterior superior iliac spine, are marked. Arthroscopic portals, including the standard anterolateral, mid-anterior, and anterior portals, are located (Fig 5).

Evaluation, Debridement, and Acetabular Preparation

The anterolateral portal is made in the usual manner under fluoroscopic guidance after optimal traction was applied to ensure subluxation at 1.1 cm. The mid-anterior portal is made in an outside-in fashion under direct vision. A capsulotomy, from the medial to the lateral synovial fold, which connects the 2 portals, is performed with a Samurai blade (Stryker, Kalamazoo, MI). Diagnostic arthroscopy of the central compartment is then performed. Femoral head chondral integrity is assessed based on the previously described ballottement test.[18] The labrum is assessed using a standard arthroscopic probe and, if found to be irreparable, is excised with a 4.5-mm Incisor Plus Elite blade (Smith & Nephew, Andover, MA) from the 12-o'clock to 3-o'clock position. The affected segment, measuring 75 mm, is defined with a Samurai blade (Stryker). A pincer-type FAI lesion is present and exposed after labral resection. This is removed and the acetabular boundary smoothed with a 4-mm Stonecutter burr (Smith & Nephew) in preparing a cancellous bed for the labral reconstruction.

Acetabular cartilage lesions adjacent to this area are then addressed and graded according to Kelly's classification[19] (Fig 6A). Grade 2 to 4 lesions are debrided with an angled Open Curette (Smith & Nephew) to establish a stable chondral margin. The final affected surface is approximately 7*3 cm^2 with 1 cm depth. Microfracture is performed with a 60° angled Chondral Pick (Smith & Nephew) in a circumferential, peripheral to central, manner. These are spaced 2 to 3 mm (Fig 6B).

Labral Reconstruction

The length of allograft required in this case was 75 mm, and we estimated the thickness of the native labrum to be 10 mm. An appropriate tibialis anterior

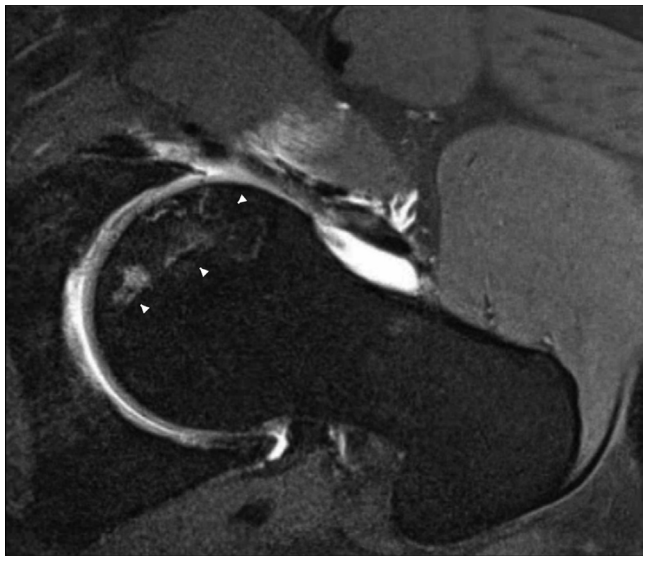

Fig 2. Axial, fat-saturated T2-weighted magnetic resonance imaging view showing the areas of the femoral head affected by avascular necrosis (white arrowheads) and absence of subchondral collapse in a left hip.

Fig 3. Computed tomography images showing acetabular subchondral cyst (white asterisk) and femoral head region affected by avascular necrosis (white arrowheads) in a left hip. Axial (A), coronal (B), and sagittal (C) views.

tendon allograft is selected and prepared. One end is whip-stitched with ULTRABRAID suture (Smith & Nephew) and the opposite end with a different cobraid color of ULTRABRAID suture (Smith & Nephew). The graft is shuttled into the joint through the mid-anterior portal and placed along the prepared labral bed. A Bioraptor 2.9 Knotless Suture Anchor (Smith & Nephew) is placed medially to secure the graft position. The remainder of the labral reconstruction is achieved anterior to posterior with Bioraptor 2.3 PK Suture Anchors (Smith & Nephew). Six anchors were necessary to achieve final fixation (Fig 7). Circumferential sutures are used with Revo-type knots.[20] The hip is finally reduced in its socket, and a good, watertight seal as well as a contained acetabular defect are obtained. A partial release of the psoas muscle (white portion of the musculotendinous junction) was performed in this case, as it was rubbing on the labral construct medially. Femoral neck osteoplasty was additionally required once the femoral head was reduced and assessed.

Chondral Reconstruction

The hip is redislocated. An 18G spinal needle is placed intra-capsular via a posterolateral entry. Suction is attached to the spinal needle and the hip is thoroughly irrigated and evacuated of fluid and debris. A dry joint is imperative to begin this surgical step. The prepared chondral bed is carefully dried with Surgical Strips (Codman Neuro, Raynham, MA), and the BST-Cargel (Piramal Life Sciences, Bio-Orthopaedics Division, Canada) is evenly applied to the entirety of the defect (Fig 8). We followed the technique described by Al-Qarni et al.[21]

Decompression and Grafting

Next, we address decompression of the femoral head lesion. This is also performed with a dry joint. An 18G spinal needle is placed percutaneously on the lateral cortex of the proximal femur cranial to the lesser trochanter and aligned with the femoral head lesion with fluoroscopic assistance. A stab incision is made, and the 11G AccuPort Cannula (Zimmer, Mahwah, NJ)

Fig 4. Three-dimensional reconstruction of computed tomography scan showing both cam (red arrowheads) and pincer (white arrowhead) femoroacetabular impingement lesions in a left hip.

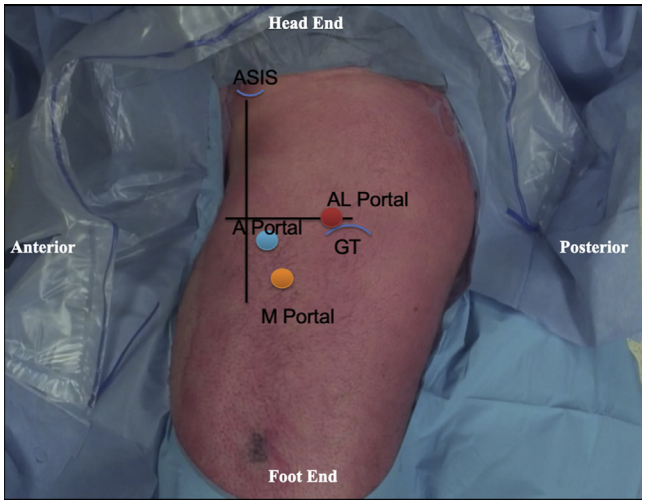

Fig 5. Skin landmarks on a left hip in supine position. (A portal: anterior portal [blue spot]; AL portal, anterolateral portal [red spot]; ASIS, anterosuperior iliac spine; GT, greater trochanter; M portal, mid-anterior portal [yellow spot].)

is drilled and placed within the femoral head lesion. Once the position in the defect area of AVN is confirmed with fluoroscopy in the anteroposterior and lateral planes, the inner drill is removed and the bone substitute (AccuFill, injectable $CaPO_4$; Zimmer) is injected. Fluoroscopic control is necessary to observe the radio-opacity filling the femoral head lesion while visualizing the hip joint with the arthroscope. Care should be taken to avoid escape of the bone substitute into the intra-articular space as well as the vastus lateralis muscle.

This patient additionally had an acetabular subchondral cyst. Bone substitute injection was also performed to fill the defect. We advise to perform this step before labral reconstruction as large subchondral cysts may impair labral anchor fixation. Under fluoroscopic guidance, an 18G spinal needle is passed percutaneously to the pelvic rim parallel to joint line and in a trajectory that avoided labral or chondral injury. The entry point was in the region of the proximal mid-anterior portal location. A small skin incision is made to permit a 4-mm dilator followed by the manufacturer's sleeve. The cortex was drilled with a 3-mm drill and the shorter bone substitute sleeve is directed into the cyst. Injection of $CaPO_4$ solution into the desired location is confirmed with the image intensifier by increased radio-opacity (Fig 9). Similarly, we should avoid intra-articular spread by direct visualization with the arthroscope. The filling was stopped once extravasation of bone substitute occurs from the cortical drill-hole.

Postoperative Care

The patient is placed in a hinged-hip brace, with restricted range of motion of 0 to 90° of flexion. Toe-touch weight-bearing is advised. Progressive range of motion exercises are initiated early. The brace is discontinued at 6 weeks and gradual progression to weight-bearing as tolerated over the next 6 weeks is instructed.

Discussion

This paper describes a technique of arthroscopic hip preservation surgery, which addressed a variety of central and peripheral compartment pathologies coexisting

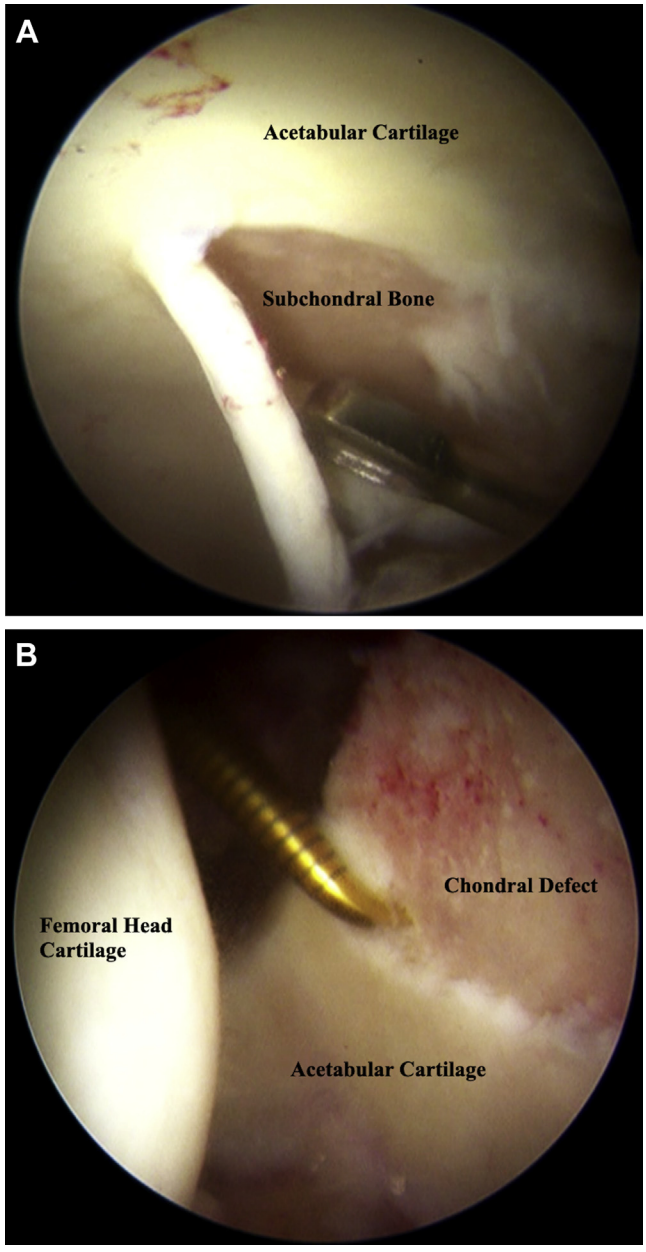

Fig 6. Acetabular chondral lesion preparation in a left hip in supine position. (A) View from the mid-anterior portal showing an acetabular full-thickness chondral flap. (B) View from the anterolateral portal showing microfracture performed with a 60° angled chondral pick in a circumferential, peripheral to central, manner. The labrum was irreparable and excised in this case.

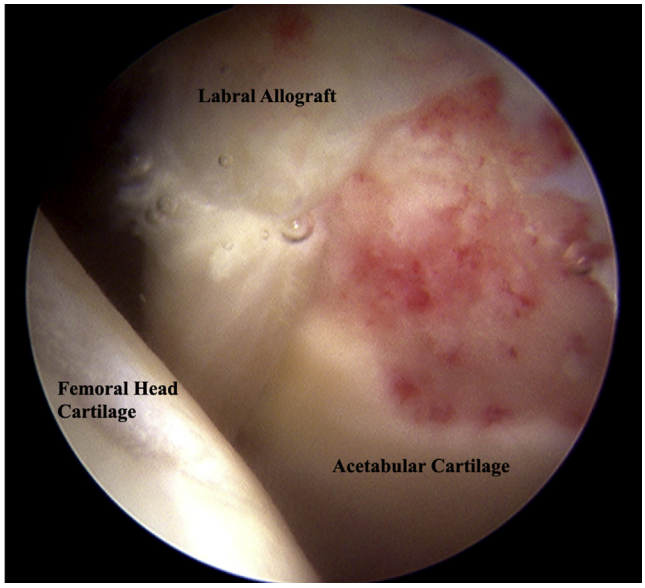

Fig 7. Intra-articular visualization of the acetabulum after chondral preparation and labral reconstruction in a left hip in supine position, viewing from the anterolateral portal.

with AVN of the femoral head (Tables 1 and 2). A combination of mini-invasive gestures often is required in precollapse stages of AVN, as chondral surface integrity is primordial to joint survival.[4,22]

Nonoperative treatment of AVN of the femoral head is associated with poor outcomes compared with CD in early stages of the disease.[23-25] The best outcomes can be expected from core decompression in patients with necrotic lesions involving less than 50% of the femoral head.[26] Minimally invasive arthroscopy-assisted techniques have been described.[6,27] Recent trends in treating early AVN are toward the combination of CD with biomaterials.[28] Subchondroplasty, which includes the injection of $CaPO_4$ material in addition to CD, is an emerging surgical technique with good outcomes in subchondral lesions around the knee.[7,8] Data regarding clinical outcomes in the hip are still lacking, but a few studies showed promising results in the short and mid-term follow-up.[29-31] Subchondroplasty also seems effective in preventing further collapse of the femoral head.[29,32] Civinini et al.[29] reported on 37 hips with precollapse and early precollapse (Steinberg stage I-IIIA[33]). In total, 78.4% had no further collapse at a mean follow-up of 20.6 months, and only 3 hips were converted to total hip arthroplasty. There were also no complications, which demonstrates the safety of this procedure. In fact, the aim of subchondroplasty is to prevent collapse of the femoral head and to delay osteoarthritic changes.[3] Subchondroplasty is increasingly adopted in treating cystic lesions in the femoral head and acetabulum during hip arthroscopy, which shows the importance of combining fluoroscopy with arthroscopy for the successful treatment of intra-articular hip pathologies.[6,9] $CaPO_4$ substitute has shown better biomechanical behavior in maintaining articular congruency in tibial plateau fractures compared with autologous bone.[34] Moreover, AccuFill (Zimmer), which was used in this

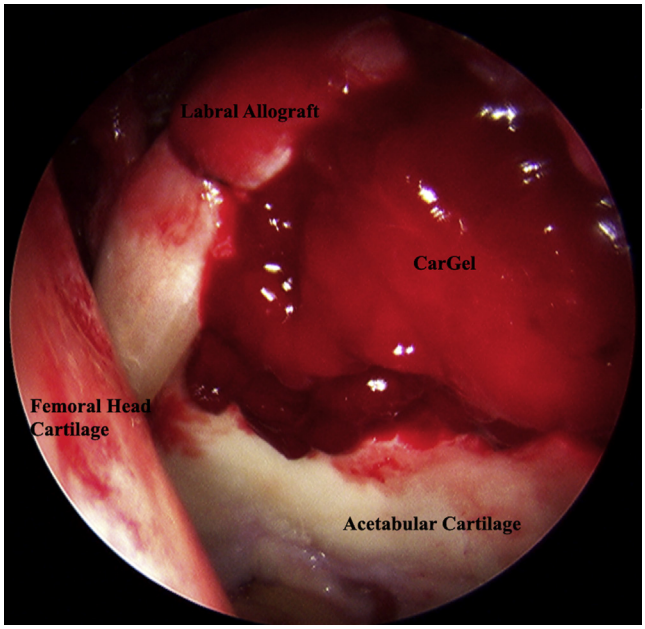

Fig 8. Final view of the acetabular rim after labral and chondral reconstructions in a dry left hip in supine position, viewing from the anterolateral portal.

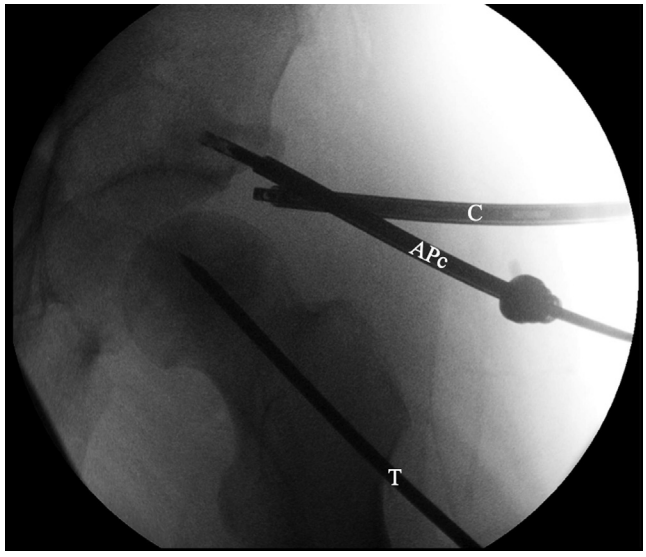

Fig 9. Intra-operative fluoroscopic image showing radio-opacities of bone substitute within the femoral head and subchondral area of the acetabulum in a left hip in supine position. The arthroscopic camera (C) is inserted through the anterolateral portal. The AccuPort cannula (APc) is used to inject 2 mL of AccuFill inside the acetabular cyst. In total, 5 mL of AccuFill solution was used in the femoral head avascular necrosis affected area, overlapping on this view with the tip of trocar (T) advanced through the femoral neck.

Table 1. Pearls and Pitfalls of the Surgical Technique

Pearls	Pitfalls
Maintain sufficient sterile surgical field for the anticipated entry point of the percutaneous decompression	Attention should be paid to concomitant pathology in central compartment
Debride the acetabular chondral lesion before labral reconstruction in preparation for BST-CarGel	Pay attention to the presence of acetabular cyst, as these can impair labral anchor fixation
Use a 18G spinal needle attached to suction via a posterolateral approach to evacuate the joint prior to chondral reconstruction time	BST-CarGel must only be applied on a subchondral dry surface
Use of intraoperative fluoroscopy in both planes is essential to localize bone defects and guide the pins	Subchondral $CaPO_4$ injection should be performed under arthroscopic control to avoid extravasation inside the joint
Place a 18G spinal needle percutaneously under fluoroscopic assistance to ensure drilling is cranial to lesser trochanter	
Decompression of the femoral head is performed under direct vision within a dry joint	

Table 2. Advantages and Disadvantages of Arthroscopic Hip Subchondroplasty

Advantages	Disadvantages
Minimally invasive procedure with good outcomes in the hip and knee	Most effective in precollapse AVN lesions; results with early collapse lesions are variable.
Good safety profile with no major complications	Lack of long-term outcomes
Address intra-articular pathologies at the same time	Requires fluoroscopic assistance to localize subchondral defects
Direct visualization inside the joint during decompression and bone substitute material injection ensures respect of the articular surface	
Use of $CaPO_4$ substitute is effective in preventing further femoral head articular surface collapse	

AVN, avascular necrosis.

case, is a nanocrystalline $CaPO_4$ injectable solution that has proven its efficacy and demonstrated adequate implantation into the trabecular bone among different bone substitute materials.[35]

Concomitant intra-articular pathologies are underestimated in the context of AVN. These should be addressed as well to prevent clinical failure. Special attention should be paid to chondral lesions, as these are major prognostic factors in osteoarthritis development.[5] Surgical options include microfracture (MF), mosaicplasty, autologous chondrocyte implantation, and osteochondral allograft transplantation, ,with MF being the most commonly used.[36] The use of a gel-forming, chitosan-based biopolymer BST-CarGel (Piramal Life Sciences, Bio-Orthopaedics Division), in the reconstruction of chondral lesions is a recent modality,[37,38] and it works by stabilizing the blood clot by dispersing a soluble polymer scaffold containing chitosan.[39] CarGel was first safely reported in femoral condyle lesions in a well-designed, multicenter, randomized controlled trial.[37] At short- to mid-term follow-up, CarGel generated significantly greater lesion filling and superior repair tissue quality compared with MF treatment alone in short- to mid-term follow-up.[40] Recent reports showed similar promising outcomes in treating acetabular defects.[38,41] John et al.,[38] in their cohort of 80 patients, demonstrated a significant decrease in progressive joint space narrowing and conversion to total hip arthroplasty with the use of CarGel in adjunct to MF compared with MF alone (34.6% vs 5.9% of cases converted to hip arthroplasty, respectively; $P = .001$).

Attempts at hip preservation in the young population are emerging, given the ongoing advancements in hip arthroscopic techniques. AVN of the femoral head is one the challenging pathologies as it is frequently associated with intra-articular lesions. A fluoroscopic-assisted hip arthroscopy is often necessary to address all pathologies for better outcomes after femoral subchondroplasty. This surgical technique successfully addressed treatment of a mixed-type FAI lesion, labral reconstruction with allograft, and acetabular chondral reconstruction in addition to subchondroplasty of both the femoral head and the acetabular rim.

References

1. Van Der Jagt D, Mokete L, Pietrzak J, Zalavras CG, Lieberman JR. Osteonecrosis of the femoral head: Evaluation and treatment. *J Am Acad Orthop Surg* 2015;23:69-70.
2. Moya-Angeler J, Gianakos AL, Villa JC, Ni A, Lane JM. Current concepts on osteonecrosis of the femoral head. *World J Orthop* 2015;6:590-601.
3. Atilla B, Bakircioğlu S, Shope AJ, Parvizi J. Joint-preserving procedures for osteonecrosis of the femoral head. *EFORT Open Rev* 2019;4:647-658.
4. Zhang QY, Li ZR, Gao FQ, Sun W. Pericollapse stage of osteonecrosis of the femoral head: A last chance for joint preservation. *Chin Med J (Engl)* 2018;131:2589-2598.

5. Larson E, Jones LC, Goodman SB, Koo K-H, Cui Q. Early-stage osteonecrosis of the femoral head: Where are we and where are we going in year 2018? *Int Orthop* 2018;42:1723-1728.
6. Kapil N, Samuel LT, Kamath AF. Management of bone marrow lesions of the hip with subchondral calcium phosphate injection: Surgical technique and tips. *Arthrosc Tech* 2020;9:e863-e875.
7. Chua K, Kang JYB, Ng FDJ, et al. Subchondroplasty for bone marrow lesions in the arthritic knee results in pain relief and improvement in function. *J Knee Surg* 2021;34:665-671.
8. Cohen SB, Sharkey PF. Subchondroplasty for treating bone marrow lesions. *J Knee Surg* 2016;29:555-563.
9. Bessa F, Rasio J, Newhouse A, Nwachukwu BU, Nho S. Surgical treatment of subchondral bone cysts of the acetabulum with calcium phosphate bone substitute material in patients without advanced arthritic hips. *Arthrosc Tech* 2020;9:e1375-e1379.
10. Nazal MR, Parsa A, Martin SD. Mid-term outcomes of arthroscopic-assisted Core decompression of Precollapse osteonecrosis of femoral head-minimum of 5 year follow-up. *BMC Musculoskelet Disord* 2019;20:1-10.
11. McCarthy J, Puri L, Barsoum W, Lee J ann, Laker M, Cooke P. Articular cartilage changes in avascular necrosis: An arthroscopic evaluation. *Clin Orthop Relat Res* 2003;(406):64-70.
12. Izumida H, Kanaji A, Nishiwaki T, et al. Acetabular labral tear complicating idiopathic osteonecrosis of the femoral head treated by labral repair with hip arthroscopy: A case report. *J Med Case Rep* 2014;8:1-4.
13. Amanatullah DF, Antkowiak T, Pillay K, et al. Femoroacetabular impingement: Current concepts in diagnosis and treatment. *Orthopedics* 2015;38:185-199.
14. Ceylan HH, Vahedi H, Azboy I, Rezaie AA, Parvizi J. Mini-open femoroacetabular osteoplasty risk factors for failure and conversion to hip arthroplasty. *J Bone Joint Surg Am* 2020;102:e59.
15. Wylie JD, Kim YJ. The natural history of femoroacetabular impingement. *J Pediatr Orthop* 2019;39:S28-S32.
16. Ficat R, Arlet J. Forage-biopsie de la tete femorale dans l'osteonecrose primative. Observations histo-pathologiques portant sur huit forages. *Rev Rhum* 1964;31:257-264 [in French].
17. Cohen-Rosenblum A, Cui Q. Osteonecrosis of the femoral head. *Orthop Clin North Am* 2019;50:139-149.
18. Ruch DS, Sekiya J, Dickson Schaefer W, Koman LA, Pope TL, Poehling GG. The role of hip arthroscopy in the evaluation of avascular necrosis. *Orthopedics* 2001;24:339-343.
19. Ranawat A, Kelly B. Function of the labrum and management of labral pathology. *Oper Tech Orthop* 2005;15:239-246.
20. Kim J. Significance of the Internal Locking Mechanism for Loop Security Enhancement in the Arthroscopic Knot. *Arthroscopy* 2001;17:850-855.
21. Al-qarni A, Orth SB, Lewington MR, Wong IH, Sc M, Medicine DS. Reconstruction of focal femoral head cartilage defects with a chitin-based scaffold. *Arthrosc Tech* 2016;5:e257-e262.
22. Mont MA, Cherian JJ, Sierra RJ, Jones LC, Lieberman JR. Nontraumatic osteonecrosis of the femoral head: Where do we stand today? A ten-year update. *J Bone Joint Surg Am* 2015:1604-1627.
23. Mont MA, Carbone JJ, Fairbank AC. Core decompression versus nonoperative management for osteonecrosis of the hip. *Clin Orthop Relat Res* 1996;324:169-178.
24. Marker DR, Seyler TM, Ulrich SD, Srivastava S, Mont MA. Do modern techniques improve core decompression outcomes for hip osteonecrosis? *Clin Orthop Relat Res* 2008;466:1093-1103.
25. Mukisi-Mukaza M, Manicom O, Alexis C, Bashoun K, Donkerwolcke M, Burny F. Treatment of Sickle cell disease's hip necrosis by core decompression: A prospective case-control study. *Orthop Traumatol Surg Res* 2009;95:498-504.
26. Rajagopa M, Samora JB, Ellis TJ. Efficacy of core decompression as treatment for osteonecrosis of the hip: A systematic review. *HIP Int* 2012;22:489-493.
27. Pierannunzii L. Endoscopic and arthroscopic assistance in femoral head core decompression. *Arthrosc Tech* 2012;1:e225-e230.
28. Calori GM, Mazza E, Colombo A, Mazzola S, Colombo M. Core decompression and biotechnologies in the treatment of avascular necrosis of the femoral head. *EFORT Open Rev* 2017;2:41-50.
29. Civinini R, De Biase P, Carulli C, et al. The use of an injectable calcium sulphate/calcium phosphate bioceramic in the treatment of osteonecrosis of the femoral head. *Int Orthop* 2012;36:1583-1588.
30. Jiang HJ, Huang XJ, Tan YC, Liu DZ, Wang L. Core decompression and implantation of calcium phosphate cement/Danshen drug delivery system for treating ischemic necrosis of femoral head at Stages I, II and III of antigen reactive cell opsonization. *Chin J Traumatol* 2009;12:285-290.
31. Sionek A, Czwojdziński A, Kowalczewski J, et al. Hip osteonecroses treated with calcium sulfate-calcium phosphate bone graft substitute have different results according to the cause of osteonecrosis: Alcohol abuse or corticosteroid-induced. *Int Orthop* 2018;42:1491-1498.
32. Ng VY, Granger JF, Ellis TJ. Calcium phosphate cement to prevent collapse in avascular necrosis of the femoral head. *Med Hypotheses* 2010;74:725-726.
33. Steinberg DR, Hayken D, Steinberg ME. A quantitative system for staging. *J Bone Joint Surg Br* 1995;77:34-41.
34. Welch RD, Zhang H, Bronson DG. Experimental tibial plateau fractures augmented with calcium phosphate cement or autologous bone graft. *J Bone Joint Surg Am* 2003;85:222-231.
35. Colon DA, Yoon BJV, Russell TA, Cammisa FP, Abjornson C. Assessment of the injection behavior of commercially available bone BSMs for Subchondroplasty® procedures. *Knee* 2015;22:597-603.
36. El Bitar YF, Lindner D, Jackson TJ, Domb BG. Joint-preserving surgical options for management of chondral injuries of the hip. *J Am Acad Orthop Surg* 2014;22:46-56.
37. Stanish WD, McCormack R, Forriol F, et al. Novel scaffold-based bst-cargel treatment results in superior cartilage repair compared with microfracture in a randomized controlled trial. *J Bone Joint Surg Am* 2013;95:1640-1650.
38. John R, Ma J, Wong I. Better Clinicoradiological results of BST-CarGel treatment in cartilage repair compared with

microfracture in acetabular chondral defects at 2 years. *Am J Sports Med* 2020;48:1961-1966.
39. Kumar MNVR, Muzzarelli RAA, Muzzarelli C, Sashiwa H, Domb AJ. Chitosan chemistry and pharmaceutical perspectives. *Chem Rev* 2004;104:6017-6084.
40. Shive MS, Stanish WD, McCormack R, et al. BST-CarGel® Treatment Maintains Cartilage Repair Superiority over Microfracture at 5 Years in a Multicenter Randomized Controlled Trial. *Cartilage* 2015;6:62-72.
41. Tahoun M, Shehata TA, Ormazabal I, Mas J, Sanz J, Tey Pons M. Results of arthroscopic treatment of chondral delamination in femoroacetabular impingement with bone marrow stimulation and BST-CarGel ®. *SICOT J* 2017;3:51.