Hip Arthroscopy for Femoral Acetabular Impingement: A Bird's-Eye/En Face Perspective With Ultrasound Guidance and 3-Dimensional Hip Printing

Malik I. Ali, M.Sc.P.T.,
Anjaneyulu Purnachandra Tejaswi Ravipati, M.B.B.S., M.S. (Ortho.), D.N.B. (Ortho.), and
Ivan Wong, M.D., M.Ac.M., Dip. Sports Med.

Abstract: Femoral acetabular impingement is a common hip disorder that may prove debilitating to many patients. Surgical management is indicated by way of hip arthroscopy for impinging CAM and pincer acetabular lesions. Traditionally, fluoroscopy has been used for the intraoperative assessment of bony resection; however, many disadvantages include radiation risks, equipment demands, and more. With ultrasound-guided arthroscopy, we describe the use of 1:1 3-dimensional hip printed models through various visual perspectives of impinging lesions. Given the low cost of 3-dimensional hip printing, lack of radiation exposure, and tactile multiangular views, we propose a safer and more reproducible intraoperative technique to conventional fluoroscopy to achieve better resection and outcomes after femoral acetabular impingement surgery.

Hip arthroscopy is a minimally invasive procedure used in the treatment of hip pathology.[1,2] Femoral acetabular impingement (FAI) is a common indication that may have different biomechanical mechanisms including genetic influences.[3] Associated lesions are classified as being of a cam (i.e., femoral head abnormality) or pincer type (i.e., acetabular overcoverage), with some patients having a mixture of both.[2,3] Joint cartilage and labral damage are believed to be the result of such abnormalities with progression to articular surface arthritic changes.[2-4]

Conventionally, history and physical examination followed by imaging including radiography, computed tomography (CT) scanning, and magnetic resonance arthrography have been used for preoperative planning.[1,3] Three-dimensional (3D) printed models are becoming increasingly popular in medicine, including orthopaedic trauma, planning of osteotomies, deformity corrections, and oncology.[5] A preoperative 3D model allows for greater understanding of individual patient anatomy through tactile manipulation and dynamic assessment of the hip.[4,5] In their study on the utility of 3D models in FAI surgery, Wong et al.[4] showed that, on using a 3D-printed model, there was increased agreement among the surgeons with regard to bony resection change in 70% of femurs and 80% of acetabula. We describe our technique of arthroscopic FAI surgery, including preoperative planning, intraoperative implementation, and different visual perspectives using 3D-printed models and ultrasound-guided portal placements, without the use of fluoroscopy.

From the Faculty of Medicine (M.I.A.), Dalhousie University; and Division of Orthopaedic Surgery, Department of Surgery, Faculty of Medicine (A.P.T.R., I.W.), Dalhousie University, Halifax, Nova Scotia, Canada.

The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received April 26, 2019; accepted July 4, 2019.

Address correspondence to Ivan Wong, M.D., M.Ac.M., Dip. Sports Med., Division of Orthopaedic Surgery, Department of Surgery, Faculty of Medicine, Halifax, Nova Scotia B3H2E1, Canada. E-mail: iw@drivanwong.com

2212-6287/19561

https://doi.org/10.1016/j.eats.2019.07.004

Technique

Preoperative Planning

The process begins with a complete patient history and physical examination that leads to diagnostic evaluation of the bony impingement. Plain radiographs are ordered with standard views: weightbearing anteroposterior pelvis, false-profile, 45° Dunn, and frog-leg lateral views. Radiographic angles are then measured to

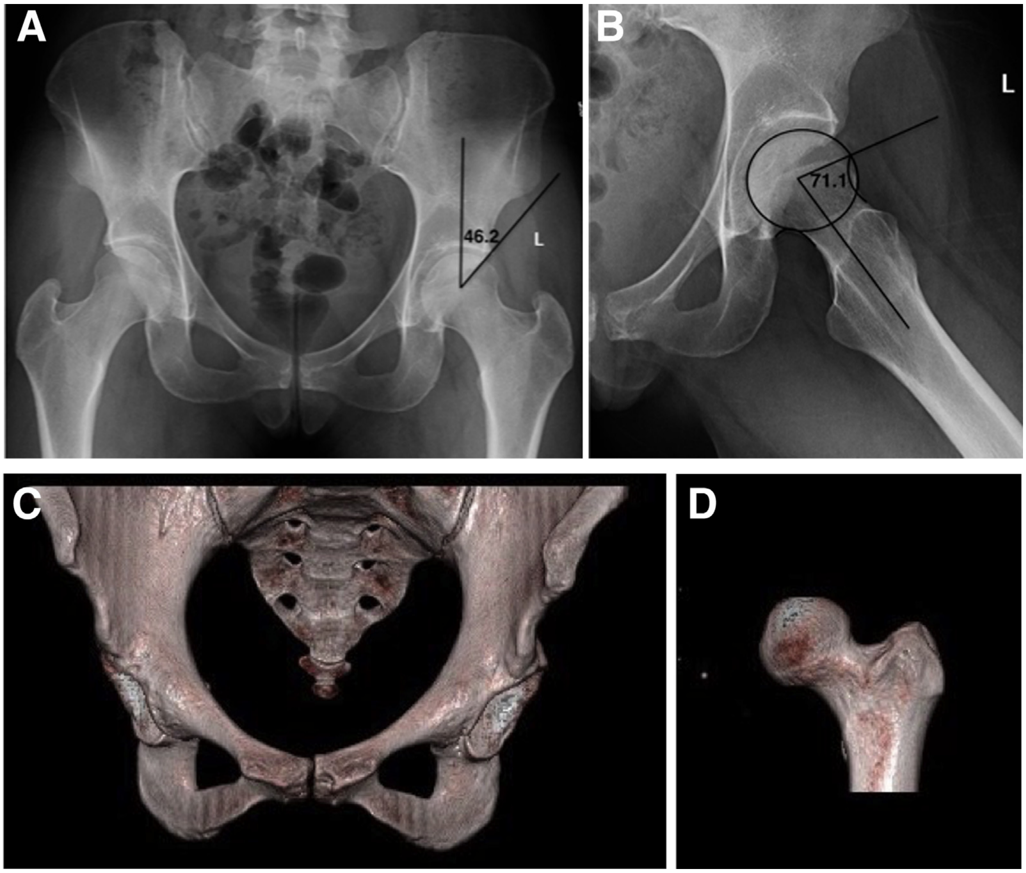

Fig 1. A weightbearing anteroposterior view of the pelvis (A) and a 45° Dunn view (B) are useful in quantifying the pincer and CAM-type lesions by measuring lateral CE angle and alpha angle, respectively. A digitally subtracted 3-dimensional computed tomography scan shows the pincer and the CAM deformities (C and D).

determine the extent of bony deformity (Fig 1). The shape of the lateral source and presence of lipping osteophytes at the head/neck junction are noted because this may alter the angle of needle entry during portal placement.

Computed-tomography scanning with 3D reconstruction is ordered for better bony evaluation. Magnetic resonance scanning is completed for neighboring soft tissue visualization and the extent of labral disease/cartilage involvement. Last, 3D polylactic acid filament models are printed using axial plane CT scanning. OSSA-3D or Osirix-MD (Osirix, Bernex, Switzerland) and MeshMixer software (Autodesk, San Raphael, CA) are used with MakerBot Replicator+ (MakerBot, New York, NY) printers for 3D hip models.

A surgical plan is created where the depth, width, and length of the resection are outlined using the described modalities. For the pincer deformity, the inferior and lateral-most extents are identified using CT scans and 3D models. The extent of the pincer and subspine impingement are outlined on the 3D model and marked as per the clock-face position. If the pincer extends beyond the psoas recess, a note is made regarding an additional medial portal to gain access inferiorly and for better angle of anchor placement. This preoperative planning prepares the surgeon to be aware of the lesion inferiorly, which otherwise would be missed because of arthroscopic access difficulty to the acetabular rim beyond the psoas recess. Similarly, the CAM deformity is identified, and the appropriate resection is outlined. The printed 3D models not only allow for accurate visualization of the acetabular femoral interface but also offer a unique tactile experience during preoperative planning. The advantages and disadvantages of this technique have been outlined in Table 1.

Intraoperative Application

The patient is given general anesthesia, and antibiotic prophylaxis is administered. With the patient in the lateral decubitus position, the Smith and Nephew Hip Positioning System and Active Heel Traction System are used, and the patient is positioned with the operative side facing up (Fig 2). The operative limb is pretensioned in the foot boot using traction and abduction over the perineal post; a joint distraction of approximately 1 cm is obtained. The distraction is confirmed with ultrasonography. Essential anatomic landmarks, including the greater trochanter and anterior superior iliac spine (Fig 3), are marked.

Table 1. Advantages and Disadvantages of 3D Printing

Advantages	
	No fluoroscopic risks, radiation, or equipment/personnel demands to the OR personnel
	Reproducible deformity assessment by surgeon and trainees
	Good educational tool for patients during surgery
	Only have a flat learning curve for 3D printing and is very inexpensive
Disadvantages	
	Requires surgical experience to dictate the depth of arthroscopic resection
	Ultrasound experience necessary for portal creations

3D, 3 dimensional; OR, operating room.

The anterolateral portal at the superior anterior corner of the greater trochanter is created using ultrasound guidance, keeping in mind the bony anatomy from preoperative planning (Fig 4). This portal usually corresponds to a 12:00 clock-face. The midanterior portal is then created at the midpoint between the anterolateral portal and the anterosuperior iliac spine and 2 cm inferior to the anterolateral portal. For midanterior portal creation, ultrasound-guided needle insertion is brought to the level of the hip capsule and later advanced under direct vision after the camera is inserted through the anterolateral portal. An interportal capsulotomy is completed by interchanging the camera and samurai blade from both portals. Diagnostic arthroscopy is performed to determine the extent of labral damage and bony impingement.

Pincer Resection and Labral Repair (Video 1)

Based on the preoperative evaluation, 3D models, and arthroscopic picture, the extent of the pincer lesion and subspine impingement are outlined (Fig 5). The 3D models allow us to view the acetabulum as a clock face when objectively outlining the pincer. In comparison to regular radiography or CT, the hip is visualized from different angles, providing better assessment of the impinging acetabular rim or inferior iliac spine. Thus preventing, under resection, a common occurrence with the pincer deformity.

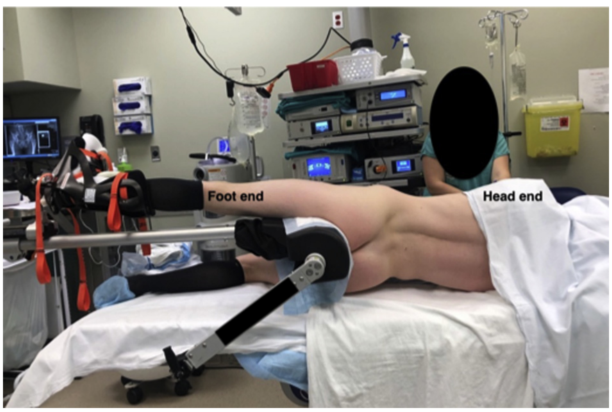

Fig 2. Positioning of left hip for hip arthroscopy in lateral decubitus.

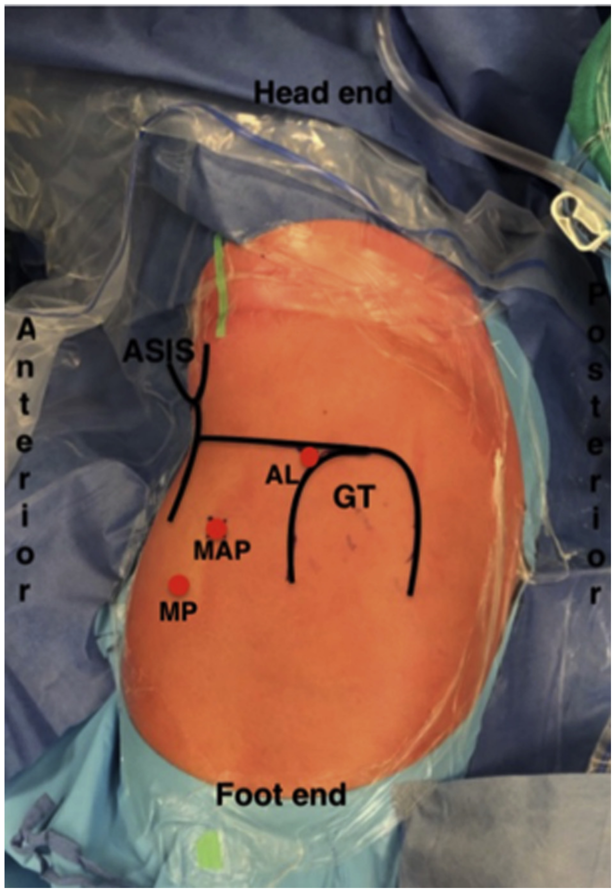

Fig 3. Position: Lateral decubitus. Side: Left hip. Skin landmarks include greater trochanter (GT) and anterior superior iliac spine (ASIS). The anterolateral portal (AL) is just anterior to the tip of the greater trochanter. The midanterior portal (MAP) is midway between the ASIS and anterolateral portal and 2 to 3 cm inferior to the anterolateral portal. An additional medial portal (Yellow dot and arrow) is used when the pincer lesion or labral tear extends beyond the 3-o'clock position or the psoas recess.

The 3D model is held by operating room personnel where the hip is slightly tilted superiorly, and the anterior hip faces the surgeon. This is called the "en-face" view (Fig 5B), allowing better assessment of the inferior extent of the pincer. The second view is the "bird's-eye" view (Fig 5C), where the hip is visualized from the superior perspective. The surgeon is able to analyze the superior femoral neck (12 o'clock) and orientate using a standard clock positioning system. The bird's-eye view also helps in identifying the lateral-most extent of the pincer lesion and provides better visualization/grading of the subspine impingement.

After adequate debridement of the capsule and soft-tissue, pincer resection is done starting from the

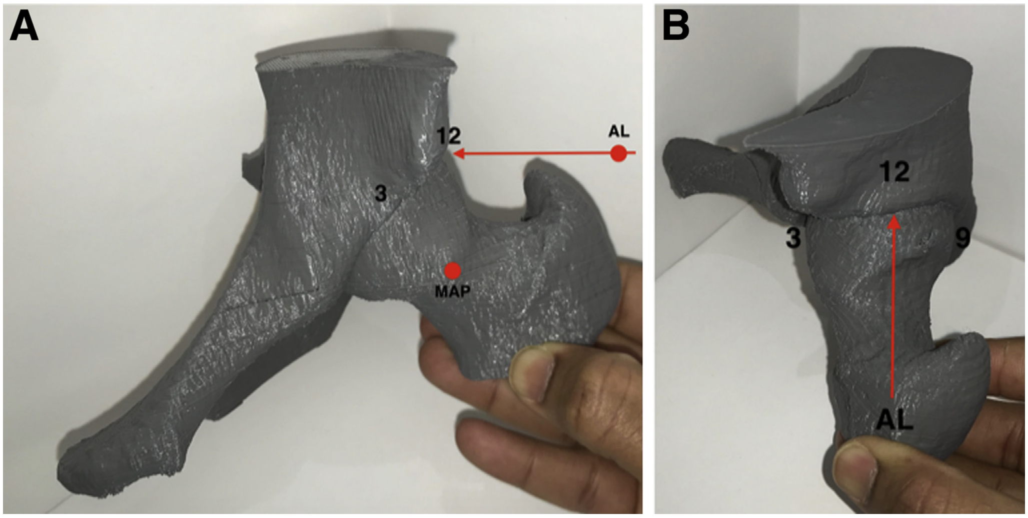

Fig 4. Three-dimensional printed model of left hip shows the location of anterolateral and midanterior portals with respect to clock face (A). Bird's-eye view of the hip shows the relation of anterolateral portal with respect to femoral neck and the greater trochanter (B).

inferior location and extending superiorly and laterally (Fig 6). The camera is usually in the anterosuperior portal and the working instrument in the midanterior portal. If the pincer extends beyond the psoas recess, an additional medial portal is made under direct vision for adequate resection and a better angle for anchor placement (Fig 6F). During surgery the chondrolabral junction is used as a guide to determine an adequate resection of the pincer lesion (Fig 6E). Once pincer resection and subspine decompression are achieved, labral repair is performed in the usual fashion (Fig 6 G-I). The hip is then reduced, and labral seal is confirmed (Fig 6J).

Cam Resection (Video 1)

As discussed during the preoperative phase, the extent of bony resection is projected from the radiographs, 3D reconstructed CTs, and 3D printed models; however, during surgery, the 3D printed hip models prove to be necessary in the absence of fluoroscopy.

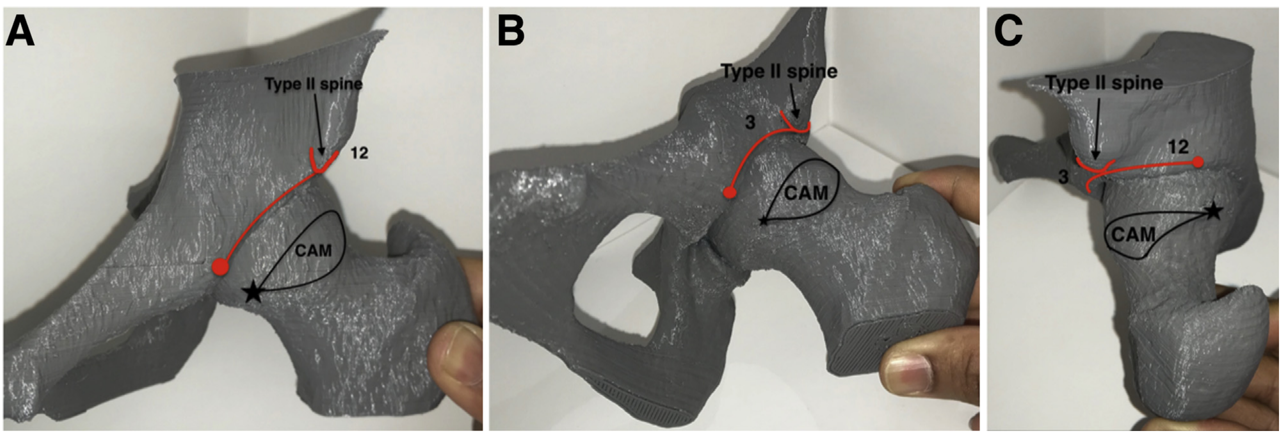

Fig 5. Preoperative planning for pincer and CAM resection on 3-dimensional printed models. En-face view (A) shows a type II subspine impingement and gives an estimate of the inferior extent of CAM (red dot) and pincer deformity (black star). (B) With the hip slightly tilted superiorly, inferior extent of the pincer and CAM lesion can be seen clearly with respect to the clock position. The "birds-eye" view of the hip (C) gives the lateral extent of pincer and CAM deformity, in this case can be seen extending almost to 12:30-o'clock position.

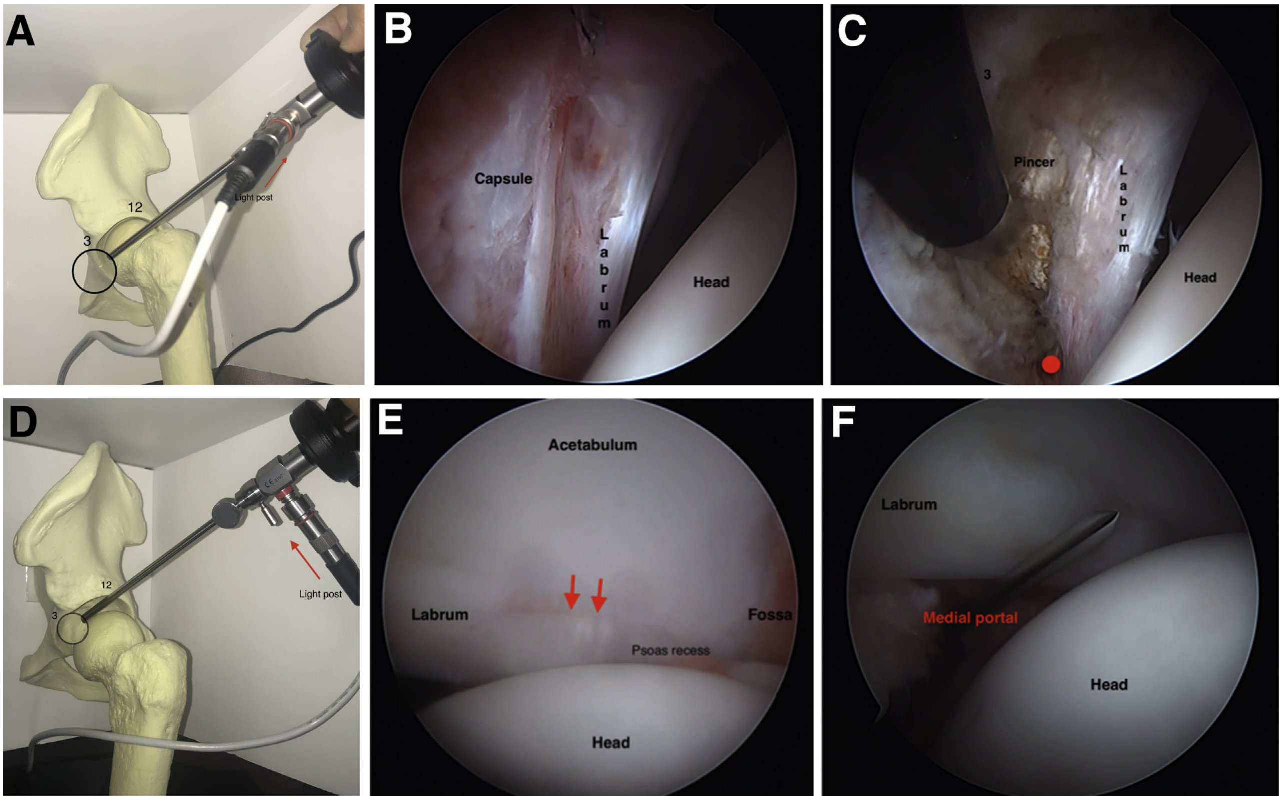

Fig 6. Position: Lateral decubitus. Side: Left hip. Viewing portal: Anterolateral portal; working portals: Mid-anterior portal and medial portal. Sequential steps of pincer resection and subspine decompression. With the 70° scope against the femur head and light post aligned toward the acetabular rim (A), the extra-articular part of the labrum is visualized (B). Sometimes, a traction stitch in the capsule adjacent to the labrum can be helpful to visualize the labral pathology. A thermal ablation device is used to carefully separate the capsule-labral junction (C). The light post is turned inward to visualize the chondrolabral junction (D and E). An additional medial portal is created under direct visualization (F) when the labral pathology or the pincer extends beyond the psoas recess. Subspine decompression and pincer resection are performed with a 5.5-mm arthroscopic burr (G and H) as per the planning on the 3-dimensional printed models (Fig 5). A labral repair is performed (I), and the hip is reduced back in the socket to confirm adequate labral seal (J).

Given that the 3D models are printed to a 1:1 ratio, the surgeon is privileged with the ability to visualize the deformity from multiple angles with no additional radiation. Similar to the pincer lesion, the "bird's-eye" view (Fig 5C) visualizes the most lateral femoral impingement at the acetabular interface and makes for a simpler identification of the cam lesion extent laterally. The OR personnel slowly rotates the 3D model from the "bird's-eye" view position so that the anterior and the inferior portions of the hip are visible (Fig 5 A and B). This gives an idea of the anteromedial extent of the cam deformity. Although arthroscopic surgical experience with bony resections is crucial for knowing the depth of excised bone, the surgeon is able to adapt their approach and have live visual prompts from the 3D hip. This planning makes the CAM identification more reproducible/visualized by the surgeon and surgical trainees.

The anterolateral and medial extents of the cam are identified; the outline of the resections is marked with thermal ablation; any soft tissue is cleared with an arthroscopic shaver (Fig 7D). The hip is abducted and slightly forward flexed to gain access to the anteromedial femur neck and head. A 5.5-mm stonecutter burr is usually used for cam resection. During this time, the camera post is extensively used to view the resection at various angles and to ensure it is smooth, uniform, and parallel to the labrum (Fig 7F).

After satisfaction with the extent of bony resection, a dynamic examination of the hip is performed as a method of evaluating hip function. If an under resection is observed, the surgeon is still able to carry on with the procedure; however, great care needs to be taken to avoid over-resection and a resultant synovial leak.

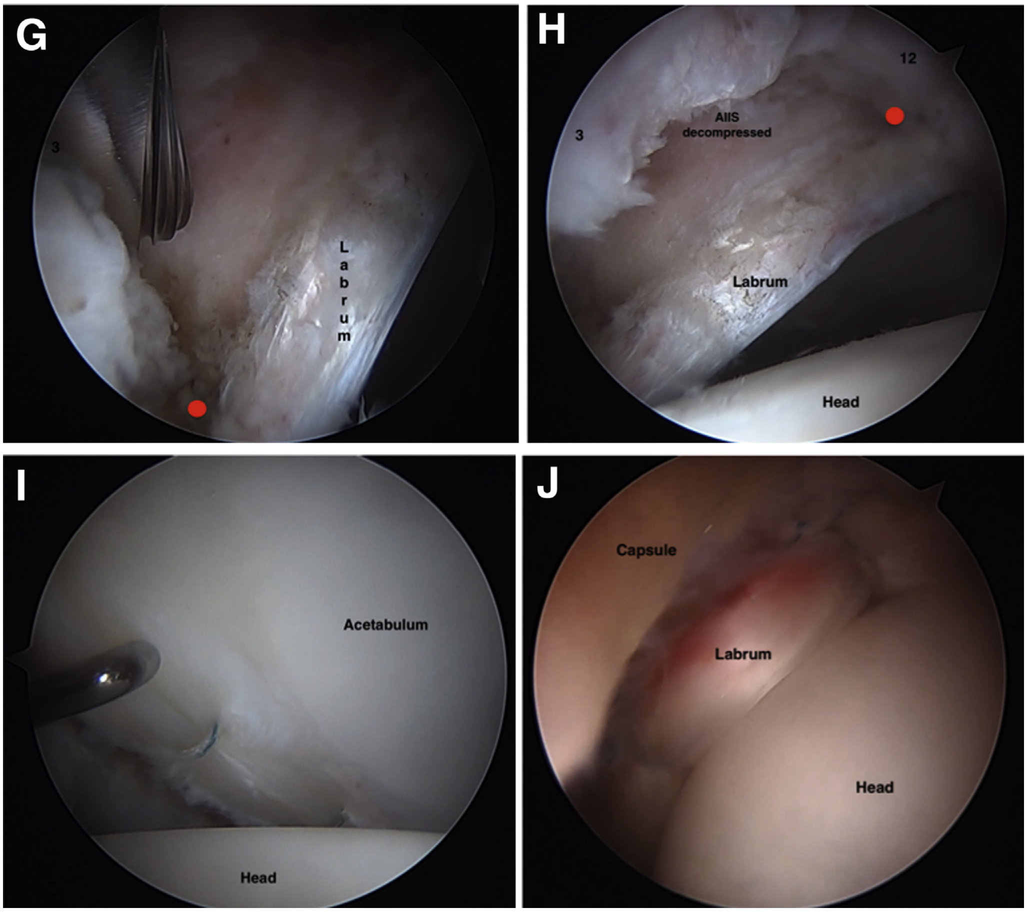

Fig 6. (*continued*).

Discussion

Hip arthroscopy is a technically demanding procedure that relies on surgical experience.[1,3] Without fluoroscopic guidance, preoperative planning requires a systematic approach for the analysis of lesion type, location, bony extent, and soft tissue involvement. Extensive preoperative imaging aids in the conceptualization and later execution of such a resection.[1-3] Fluoroscopy allows for the intraoperative imaging and direct radiographic feedback[1]; however, there is difficulty in matching the 2-dimensional fluoroscopic image and deformity with the arthroscopic image. In pincer deformities, excluding large overhanging lesions, it remains difficult to identify the lesion on X-ray films or fluoroscopic images. Another disadvantage of radiography is the risk of radiation, which extends not only to the patient but also to every member of the surgical team.[1] We believe that, with adequate preoperative planning, ultrasound-guided hip arthroscopy is a simple and reproducible technique that offers several advantages over traditional fluoroscopic use.

Over the years, 3D printing has been a growing adjunct to surgical procedures.[5] Our use of the 3D hip models proved vital during the preoperative planning process because the surgeon could instantly visualize the lesion from a tactile perspective. Likewise, the surgeon was able to reexamine the hip deformity during surgery from a 3D perspective, unlike the traditional 2-dimensional fluoroscopic images. In addition, the 3D model has been a great educational tool for patients during perioperative explanations. Given the relative ease of printing and low cost associated with each 3D hip model, it has the potential to feasibly maximize outcomes of FAI surgery. The clinical pearls of this technique have been outlined in Table 2. Accordingly, we believe an extensive preoperative plan followed by the use of ultrasound-guided portal placement, 3D-printed hip models, and an intraoperative dynamic hip examination negate the use of fluoroscopy.

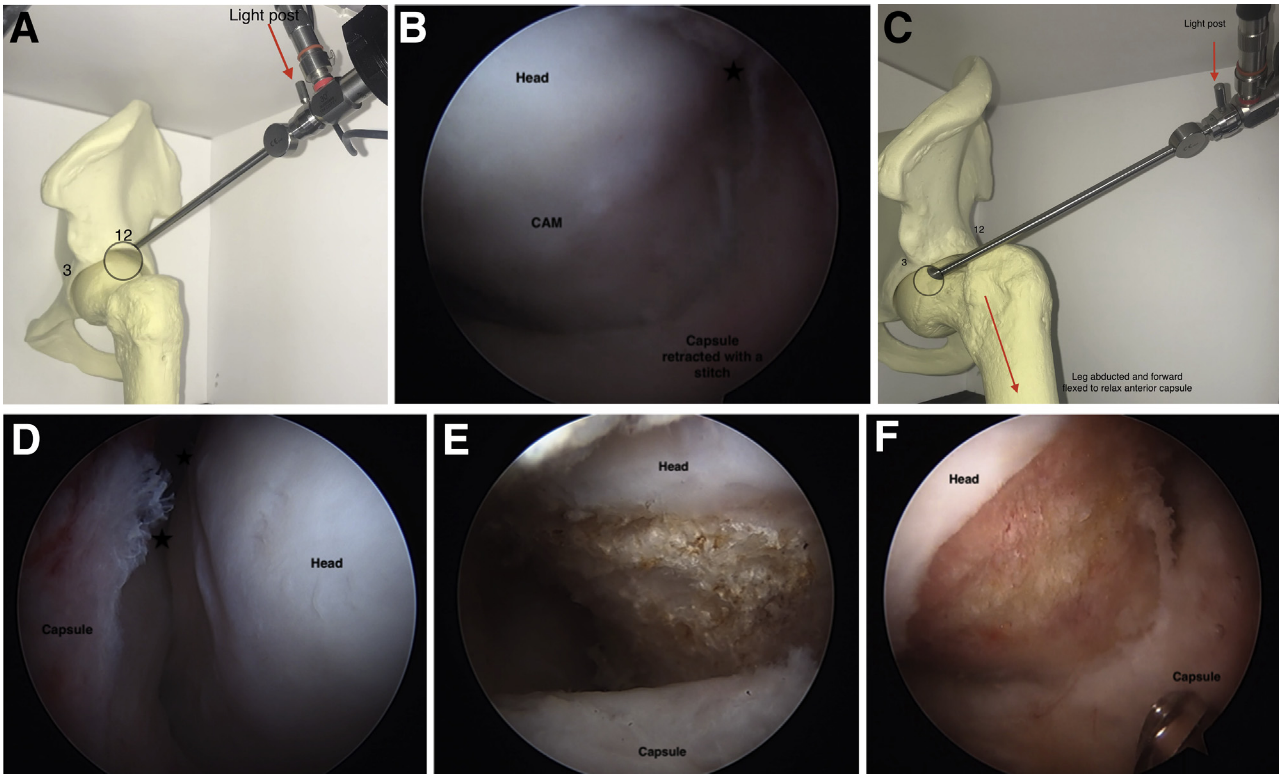

Fig 7. Position: Lateral decubitus. Side: Left hip. Viewing portal: Anterolateral portal; working portals: mid-anterior portal. Sequential steps of cam resection. By driving the camera and the 70° scope slightly beyond the capsule and the light post directed toward the femur head (A), the anterolateral extent of the cam lesion is determined (B, lateral margin cam is marked with a black star). Then the hip is abducted and forward flexed to access the anteromedial head and neck. The scope is moved anteriorly, and the light post is turned (C and D) to visualize the anterior and medial extent of the cam deformity as outlined in the 3D models. A thermal ablation device is used to debride and outline the resection (E). A 5.5-mm arthroscopic burr is used to smoothen the cam deformity in relation to the adjacent femur neck (F).

Table 2. Clinical Pearls With the Utility of US and 3D Hip Models

3D printed hip models should be assessed at the standard hip views of "bird's-eye" and "en face."
Preoperative planning using 3D-models should be completed before surgical scrubbing for tactile visualization.
One should be familiar with the use of US for adequate portal creation and placement.
Bony resection should be assessed periodically to avoid under-resection/over-resection, and this can be achieved by viewing with the arthroscope from multiple angles.
Dynamic hip examination should be completed before closure to ensure adequate seal and cam resection.
There is a short learning period required for 3D printing.

3D, 3-dimensional; US, ultrasonography.

References

1. Keough T, Wilson D, Wong I. Ultrasound-guided portal placement for hip arthroscopy. *Arthrosc Tech* 2016;5:e851-e856.
2. Plastow R, Hakim Z, Fehily M, Wall A. The simplest method to classify CAM lesions. *J Hip Preserv Surg* 2016;3:288-294.
3. Nasser R, Domb B. Hip arthroscopy for femoroacetabular impingement. *EFORT Open Rev* 2018;3:121-129.
4. Wong TT, Lynch TS, Popkin CA, Kazam JK. Preoperative use of a 3D printed model for femoroacetabular impingement surgery and its effect on planned osteoplasty. *AJR Am J Roentgenol* 2018;211:W116-W121.
5. Hoang D, Perrault D, Stevanovic M, Ghiassi A. Surgical applications of three-dimensional printing: A review of the current literature & how to get started. *Ann Transl Med* 2016;4:456.