

Intraoperative Guidance for the Surgical Correction of Cam Deformities Using Hip Arthroscopy Based on Alpha Angle Measurement



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Abstract: Residual femoroacetabular impingement syndrome due to incomplete resection of a cam deformity is the leading cause of failed hip arthroscopy. The reliability of the alpha angle has been shown for quantifying cam deformities in femoroacetabular impingement syndrome. An intraoperative navigation tool that provides the ability to compare alpha angle measurements side by side on pre- and post-resection fluoroscopic images has recently been introduced. This tool uses fluoroscopic images obtained in 6 different hip positions. The reliability of these standardized hip positions has been shown by correlation with computed tomography in localization and visualization of cam deformities. The purpose of this Technical Note is to give technical tips about the application of this tool.

Several studies have shown that residual femoroacetabular impingement syndrome (FAIS) due to incomplete resection of a cam deformity is the leading cause of a failed hip arthroscopy.¹⁻³ Studies have also shown that 5% to 10% of all hip arthroscopy patients may undergo revision surgery.⁴ Of these revision cases, 81% were found to have residual FAIS.¹ From a biomechanical perspective, it has been reported that complete cam resection leads to significantly lower intra-articular contact pressures compared with incomplete cam resection and native cam morphology.⁵ However, over-resection may increase the risk of a femoral neck fracture, although this is a rare complication.⁶ These observations reveal the importance of complete and proper cam deformity resection for patients undergoing hip arthroscopy owing to FAIS.

The alpha angle is a radiographic measurement used to evaluate both the diagnosis for surgical intervention

and the adequacy of resection in cam-type FAIS.⁷ In hips with symptomatic impingement, the femoral head-neck junction is less concave than in normal hips, leading to higher alpha angles.⁸ The reliability of the alpha angle has been validated by the adequate quantification of bone deformities at the femoral head-neck junction of the hip during FAIS procedures.⁹

Computer-assisted orthopaedic surgery approaches use monitoring systems or robotic devices to enhance the accuracy of various surgical procedures in addition to providing real-time feedback to the surgeon about the procedure performed.¹⁰ The effectiveness of computer-assisted methods has been shown during osteochondroplasty in hip arthroscopy.^{11,12}

Unlike other complex navigation systems, a user-friendly tool has recently been introduced that enables real-time control during hip arthroscopy in addition to allowing for comparison of pre- and post-resection

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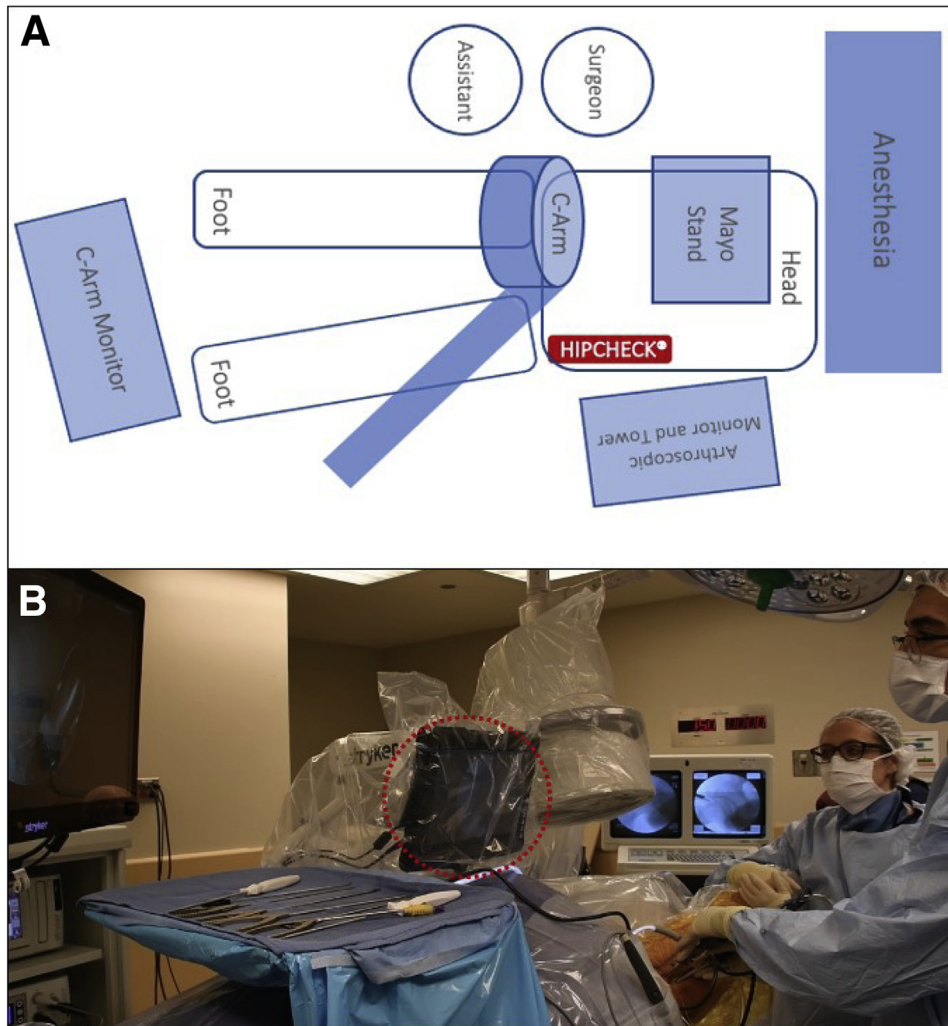


Fig 1. (A) Operating room setup for right-sided hip arthroscopy using HipCheck navigation monitor with patient in supine position. The navigation monitor (covered with a sterile sheath) can be positioned opposite the surgeon and lower than the C-arm and arthroscopy monitor during arthroscopy of the central compartment. The monitor is attached to the operating table with the support arm and has the ability to move in all axes. The monitor is moved closer to the surgeon while moving on to the peripheral compartment and starting the cam resection. (B) Position of HipCheck monitor (circle) during surgery.

fluoroscopy side by side. This navigation system (Hip-Check; Stryker, Kalamazoo, MI) enables simultaneous measurement of the alpha angle on 2-dimensional fluoroscopic images, assisting with the planning and execution of cam resection. The purpose of this article is to give technical tips on the clinical utility of the Hip-Check system.

Surgical Technique

Preoperative Planning and Operating Room Setup

No preoperative planning or imaging identification is specifically required for the HipCheck navigation system to be used during arthroscopy for symptomatic FAIS. Within the conventional operating room setup, the navigation monitor is attached to the table

contralateral to the surgical side with the aid of the support arm. This arm is specifically dedicated for use with the monitor and has the ability to move in all axes. The monitor is placed between the C-arm and arthroscopy monitor and is maintained below the level of the arthroscopy monitor. While the patient is draped, the HipCheck monitor is covered with a sterile sheath and connected to the fluoroscopic device. Operating room setup including the navigation monitor is shown in [Fig 1](#). The hip arthroscopy technique is shown in a right hip in [Video 1](#).

Arthroscopy of Central Compartment

The patient is prepared under general anesthesia in the supine position via a distractor system table (Smith &

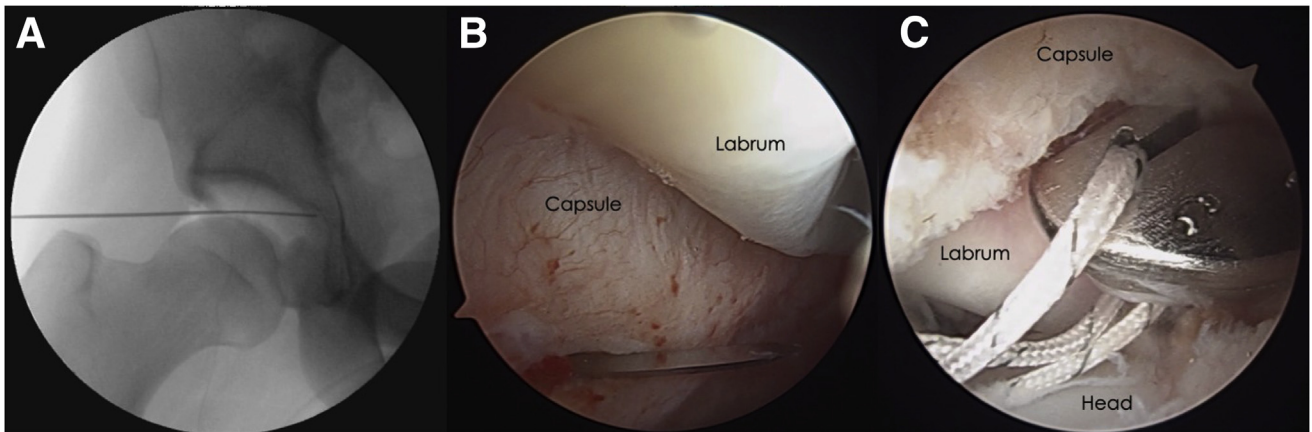


Fig 2. Interportal capsulotomy in right hip. (A) After sufficient traction, the hip joint is entered under fluoroscopic control and the anterolateral portal is created. (B) Interportal capsulotomy is performed between the modified midanterior portal and the anterolateral portal with an arthroscopic blade (Samurai). (C) Suspension suture passing is performed with the aid of a suture passer (Pivot Injector II) through the anterolateral and modified midanterior portals to the proximal side of the capsulotomy for better visualization.

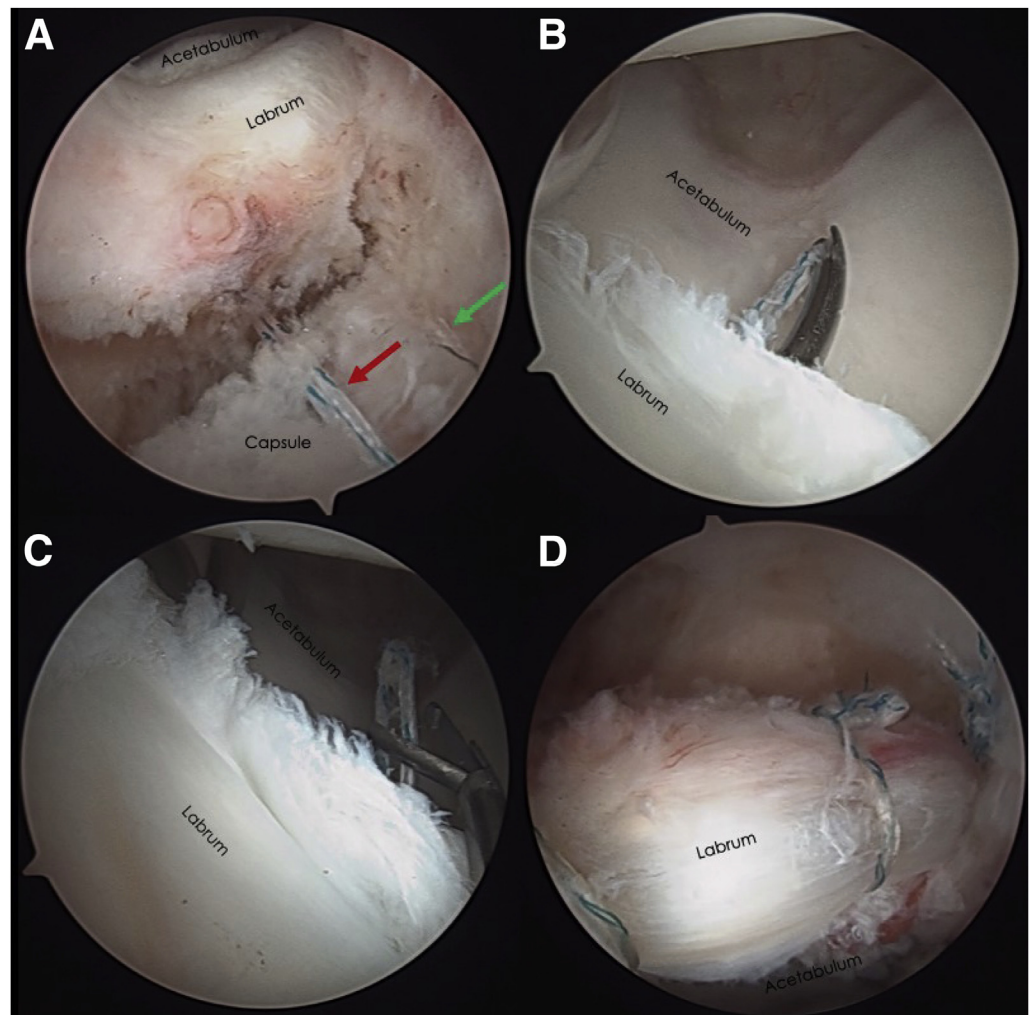


Fig 3. Labral repair in right hip through anterolateral, midanterior, and distal anterolateral portals. (A) For labral repair, the anchor is placed from the anterolateral portal at the 12-o'clock position of the acetabulum. In the midanterior portal view, the threads of the anchor are indicated with a red arrow and the suspension sutures through the capsule are indicated with a green arrow. (B, C) The suture is passed through the labrum with a suture passer (NanoPass; Stryker) via the anterolateral portal, viewing from the midanterior portal (B), and the thread from the joint is grabbed with the same tool (C). (D) View of labrum from anterolateral portal after repair with 3 anchors placed in acetabulum.

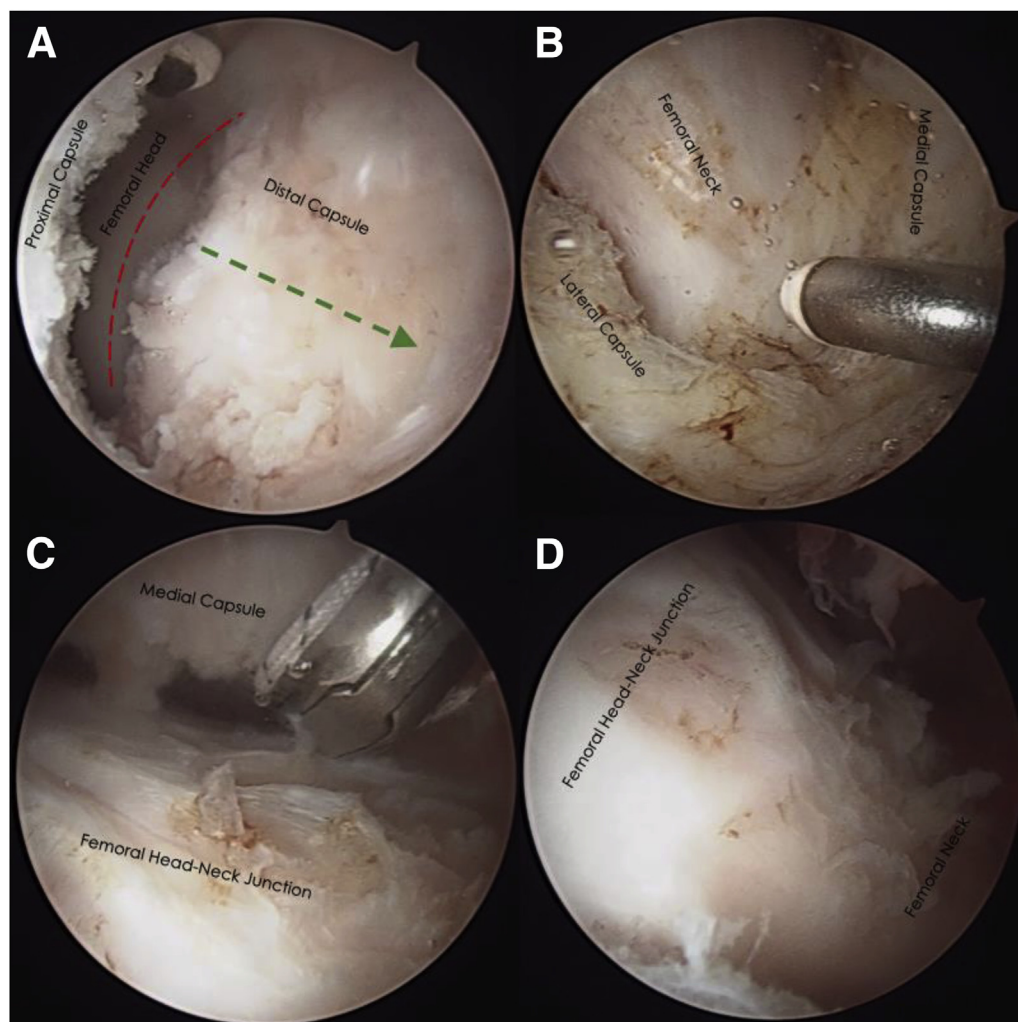


Fig 4. T-capsulotomy during arthroscopy of peripheral compartment in right hip. (A) The red line indicates the previous interportal capsulotomy, and the green arrow indicates the direction of the T-capsulotomy after debridement of the capsule in the peripheral compartment in the midanterior portal view. (B, C) After completion of the T-capsulotomy from the medial to lateral aspect of the femoral neck axis using a radiofrequency probe through the distal anterolateral portal (B), the view is improved by suspension sutures passed through the medial and lateral ends of the capsulotomy using a suture passer (Pivot Injector II) (C). (D) Arthroscopic view of cam deformity at femoral head-neck junction from midanterior portal.

Nephew Endoscopy, Andover, MA). After joint distraction of approximately 1 cm (confirmed with fluoroscopy), the anterolateral and modified midanterior portals are created. An interportal capsulotomy is performed between these portals with an arthroscopic blade (Samurai; Stryker). This is followed by applying retraction via suspension sutures that are passed with the aid of a suture passer (Pivot SlingShot; Stryker) through the anterolateral and modified midanterior portals to the proximal side of the capsulotomy for better visualization (Fig 2). Diagnostic evaluation of the central compartment is performed using a 70° arthroscope (Arthrex, Naples, FL). The distal anterolateral portal is then created. Arthroscopy of the central compartment is completed after any other indicated procedures are conducted, such as anchor placement, labral repair, or synovial debridement (Fig 3).

Cam Resection and HipCheck Application

The procedure continues with the peripheral compartment after traction is released. A T-capsulotomy is performed parallel to the femoral neck using a radiofrequency probe (Dyonics RF System; Smith & Nephew Endoscopy) and/or arthroscopic blade (Samurai) while the hip is in flexion (FL). The view is improved by applying retraction through suspension sutures passed through the medial and lateral ends of the capsulotomy using a suture passer (Pivot Injector II; Stryker) (Fig 4).

Each fluoroscopic image obtained is instantly transferred to the HipCheck monitor connected to the fluoroscopic device. The HipCheck monitor is moved closer to the surgeon to obtain pre-resection measurements before resection is started. Prior to the first measurement, the surgeon uses the touchscreen to identify the midpoint of the femoral neck and head on a

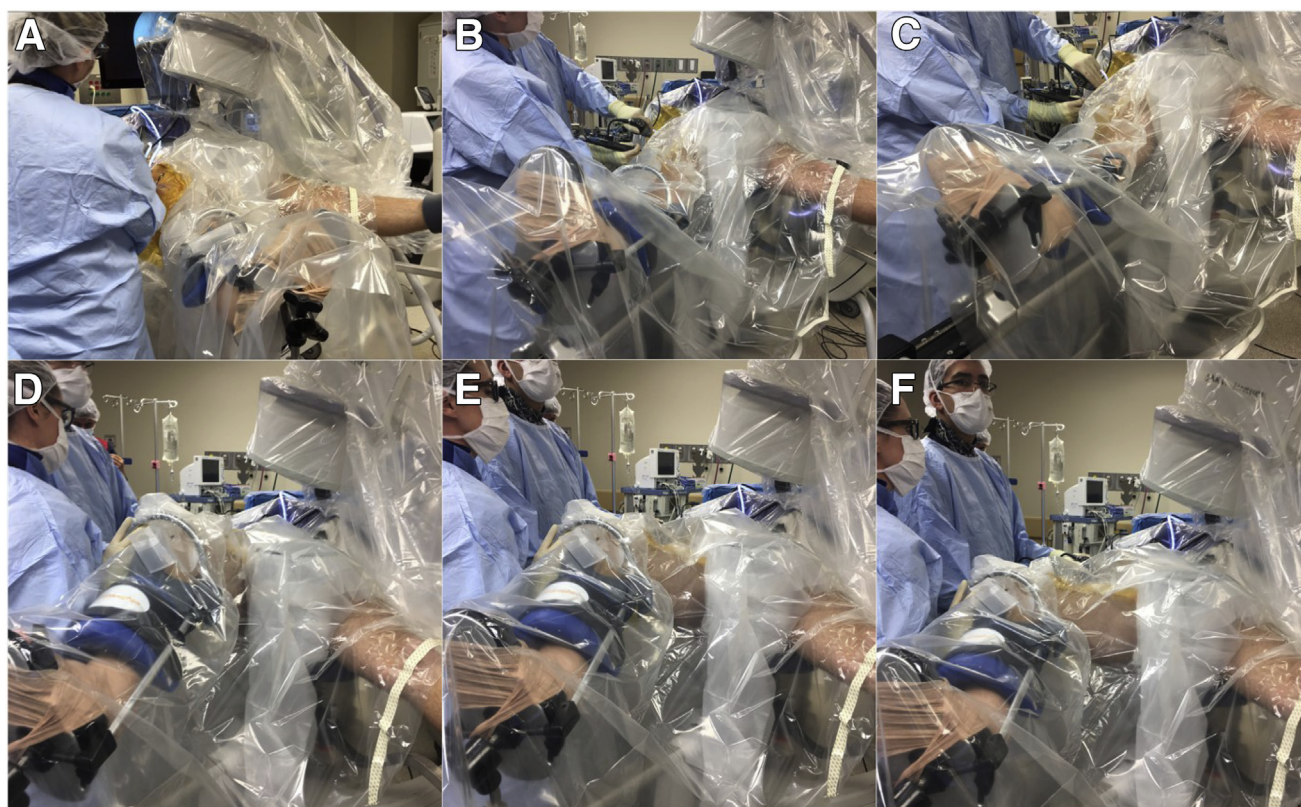


Fig 5. Hip positions for HipCheck application in right hip with patient in supine position. The 6 hip positions in which to obtain the fluoroscopic images required for the HipCheck system before and after resection are as follows: 30° of internal rotation with 0° of flexion (FL) (A); 0° of rotation with 0° of FL (B); 30° of external rotation (ER) with 0° of FL (C); 0° of rotation with 50° of FL (D); 40° of ER with 50° of FL (E); and finally, 60° of ER with 50° of FL (F).

fluoroscopic image obtained while the hip is in neutral position with the C-arm placed at a 15° cephalic tilt and 15° oblique position. This is followed by fluoroscopic imaging obtained in the following positions of the hip: 30° of internal rotation with 0° of FL; 0° of rotation with 0° of FL; 30° of external rotation (ER) with 0° of FL; 0° of rotation with 50° of FL; 40° of ER with 50° of FL; and finally, 60° of ER with 50° of FL (Fig 5).

The navigation system automatically measures the alpha angle on each image and reports the measurement by a schematic display of the radiograph on the navigation screen. The measured values are recorded as pre-resection values by the system. Osteochondroplasty is then started to recontour the femoral neck by gentle movements using a 5.5-mm arthroscopic burr (Arthrex) (Fig 6). At any time during the osteochondroplasty procedure, radiographic images can be obtained and evaluated with the navigation system to ensure instant assessment of the current extent of resection (Table 1, Fig 7).

Post-resection measurements can be conducted after confirmation that the performed resection is adequate, which is determined by lack of impingement in a dynamic hip examination. The fluoroscopic images taken before resection are obtained again in the same 6 hip positions in the same order (Table 1). The navigation system measures post-resection alpha angles on fluoroscopic images, thereby providing the opportunity to make an intraoperative radiologic evaluation of the resection performed (Fig 8). The steps followed during cam resection and HipCheck application are summarized in Table 2.

Capsule Closure and Postoperative Management

After confirmation of adequate cam resection through the HipCheck system, primary closure of the T-capsulotomy is performed by tying No. 1 Vicryl sutures (Ethicon, Somerville, NJ) passed using a suture-shuttling device (Pivot SlingShot) (Fig 9). The operation is terminated by closing the portals. Intra-articular and

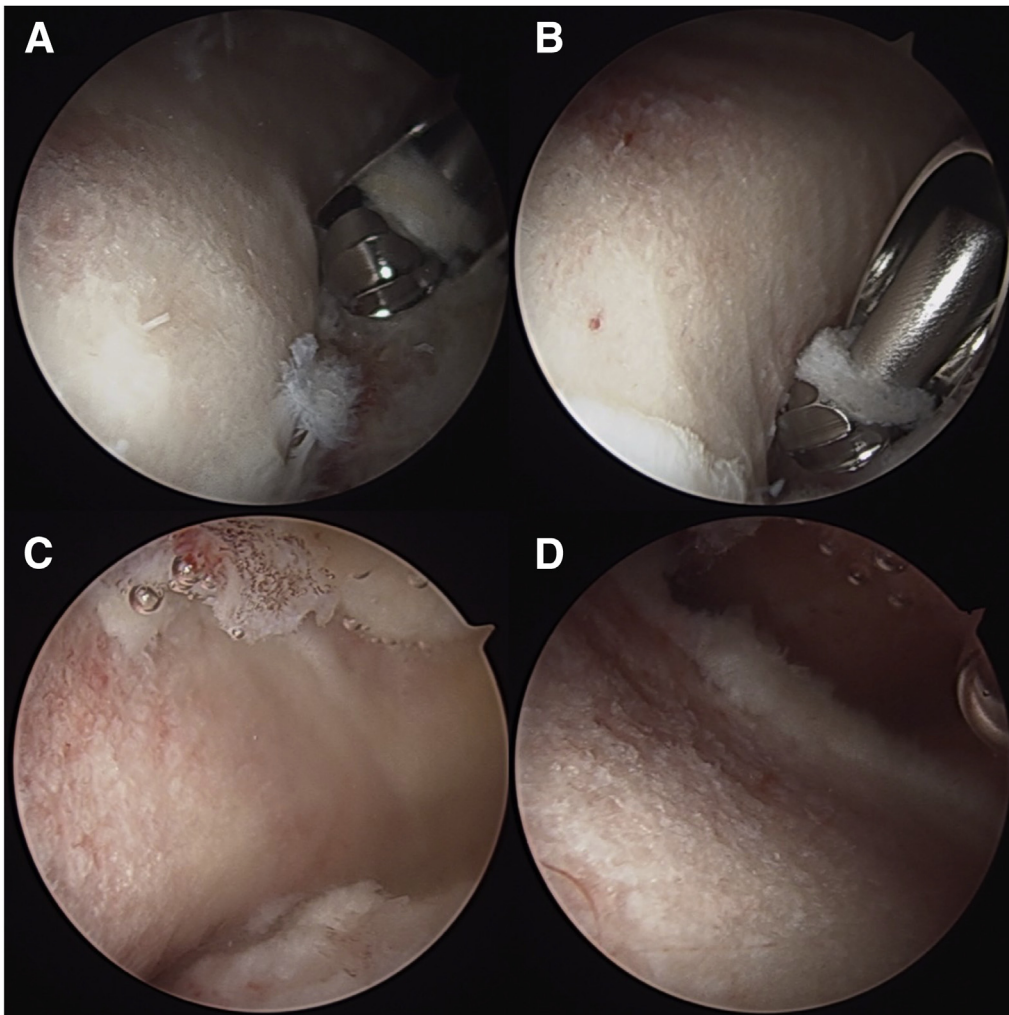


Fig 6. Osteochondroplasty performed through distal anterolateral portal with arthroscopic burr in right hip: views of superolateral aspect of cam deformity before (A) and after (B) resection with arthroscopic burr from midanterior portal and arthroscopic views of superolateral (C) and anterior (D) aspects of cam deformity after resection.

Table 1. Pearls and Pitfalls

Pearls

For a more controlled resection, fluoroscopy can be used in certain intervals to monitor the course of the procedure by alpha angles measured with the navigation system.

To conduct proper measurements for the pre- versus post-resection comparison, the pre-resection fluoroscopic images obtained in the specified hip positions should be possible to repeat after resection in the exact same manner.

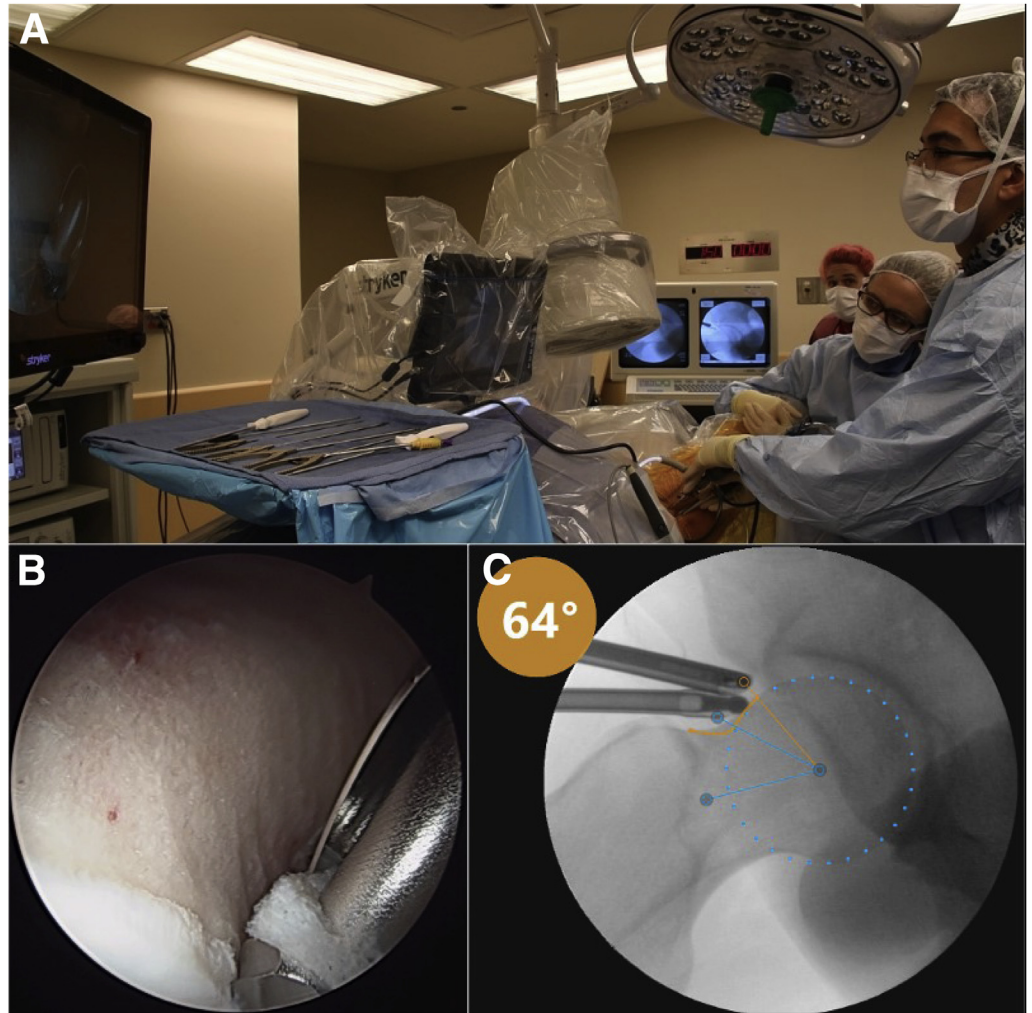
Pitfalls

While one is obtaining fluoroscopic images, surgical instruments superimposed onto the femoral neck or head on the image may have a negative impact on measurements.

The fluoroscopic field should be checked to ensure good visualization of the cam deformity at different hip positions because this can affect proper measurement.

Failure to check the fluoroscopy and HipCheck monitor connection before surgery may result in connection problems that are more difficult and time-consuming to resolve during surgery.

Fig 7. Instant assessment of cam resection performed in right hip. (A) During resection of the cam deformity, the surgeon observes the measurement of the alpha angle on the fluoroscopic image using the HipCheck monitor. (B, C) Simultaneous views of arthroscopic image from midanterior portal (B) and alpha angle measurement on HipCheck monitor (C).



periarticular local anesthetic injections are given for postoperative pain management. Pre- and post-resection measurements recorded in the navigation database can be exported as a portable document format report.

Discussion

The HipCheck navigation system provides the opportunity to check the adequacy of cam resection during surgery with an objective radiologic measurement on fluoroscopic images. In addition to enabling control during surgery both before and after cam resection, the HipCheck system provides the opportunity to instantly check the adequacy of the resection performed via fluoroscopic images obtained at any desired position of the hip.

Fluoroscopy performed at a single hip position fails to provide adequate information on the 3-dimensional (3D) extent of the cam resection because it offers a 2-dimensional assessment. Ross et al.¹³ showed that alpha angles measured on fluoroscopic images obtained in 6 different hip positions constitute a reliable reference for assessment of a cam deformity by confirming the fluoroscopic alpha angle measurements with those made on 3D computed tomography (CT) images. They also stated that these images may be more important when preoperative 3D imaging is not available. The series of 6 views confirmed by Ross et al. were as follows: 30° of internal rotation with 0° of FL, 0° of rotation with 0° of FL, 30° of ER with 0° of FL, 0° of rotation with 50° of FL, 40° of ER with 50° of FL, and 60° of ER with 50° of FL. These views are also

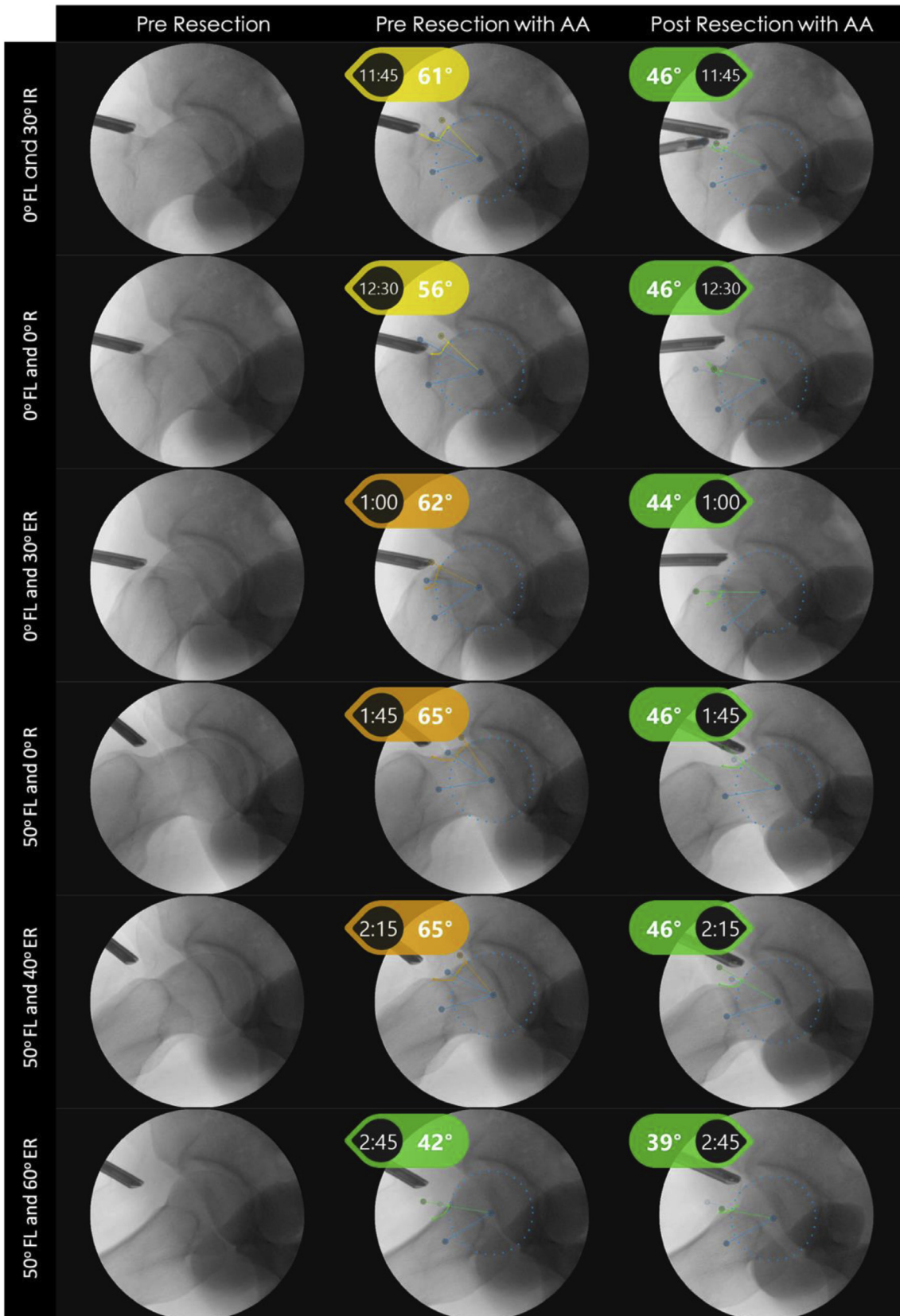


Fig 8. Pre- and post-resection measurements in right hip. Measurements made by the HipCheck system on images obtained from repeated fluoroscopies in 6 different hip positions before and after resection are shown. The radiographs obtained at different hip positions, as specified at the beginning of the lines, are shown in each column to juxtapose the pre-resection and post-resection alpha angle values at those positions from left to right. (AA, alpha angle; ER, external rotation; FL, flexion; IR, internal rotation; R, rotation.).

Table 2. Steps of Navigated Peripheral-Compartment Hip Arthroscopy

Traction release, T-capsulotomy, and capsule retraction with suspension sutures are performed. The C-arm is placed at a 15° cephalic tilt and 15° oblique position. The navigation monitor is moved closer to the surgeon. The surgeon marks the femoral head and neck on the first fluoroscopy image obtained in neutral position using a touchscreen. Fluoroscopic images are obtained in the following hip positions: 30° of IR with 0° of FL; 0° of rotation with 0° of FL; 30° of ER with 0° of FL; 0° of rotation with 50° of FL; 40° of ER with 50° of FL; and finally, 60° of ER with 50° of FL. On obtaining each image, the system calculates the alpha angle. The next image is obtained after selecting “save” for the previously calculated alpha angle. Cam resection is performed with a 5.5-mm arthroscopic burr. Images are obtained at the desired hip positions during resection to instantly check the amount of resection. After it is concluded that the performed resection is adequate according to the dynamic hip examination, the fluoroscopic images are obtained in the same 6 hip positions in the same order as before with automatic measurement of alpha angles. Capsule closure is performed.

ER, external rotation; F, flexion; IR, internal rotation.

recommended and used by the current navigation system in intraoperative evaluation. Of the 6 views obtained in these hip positions, the 3 views obtained at different degrees of rotation at 0° of FL are particularly useful in the evaluation of the superolateral aspect of the femoral head-neck junction whereas the other 3 views obtained at 50° of FL are useful in the evaluation of the anterior aspect.

The current navigation system does not significantly reduce the dependence on surgical experience as compared with other CT-based navigation systems that offer 3D evaluation for the assessment of the arthroscopic extension and 3D localization of the cam deformity at the head-neck junction as seen on fluoroscopic images during arthroscopy. However, it has important advantages, such as ease

of use, noninvasiveness, and lack of the need for CT evaluation or additional instrumentation on the patient (Table 3). In this respect, the HipCheck system does not prolong, and may even shorten, the operative time, unlike other CT-based 3D navigation systems that require a time-consuming perioperative setup. Besides, possible challenges in the cost and supply of this newly introduced system can be considered a limitation. In addition, there is a risk that the head and neck will not be manually defined properly before the measurements or the surgeon will not control how the alpha angle measurements are measured by the system, leading to incorrect data. The pearls and pitfalls as well as the advantages and disadvantages are described in Tables 1 and 3.

Fig 9. Capsule closure in right hip. The part of the T-capsulotomy parallel to the femoral neck is closed first, followed by the interportal part. In the midanterior portal view, passing the suture through the capsule with the aid of a suture passer (Pivot SlingShot) is indicated by the red arrow (A) and tying the sutures passed by both capsulotomy sides is indicated by the green arrow (B).

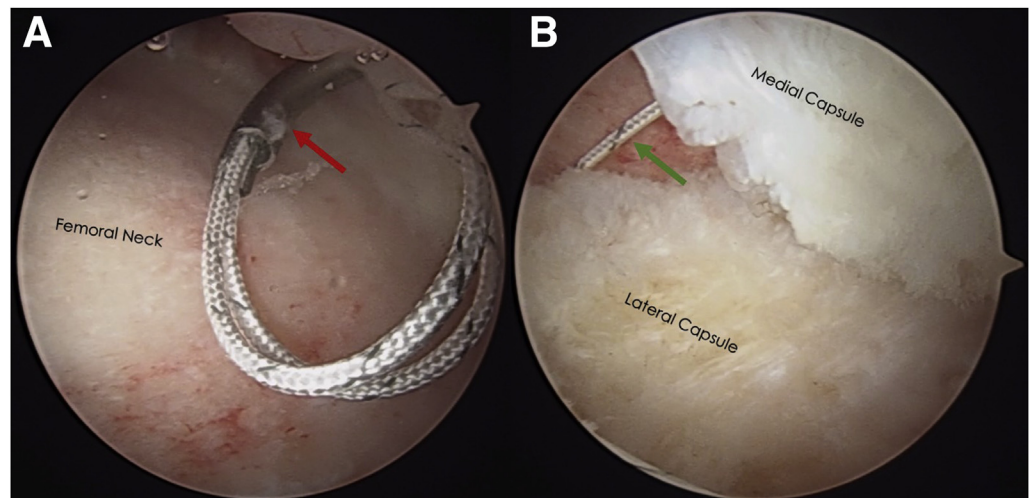


Table 3. Advantages and Disadvantages

Advantages
Reduces risk of inadequate resection or over-resection
Shortens operative time
Accelerates learning curve in hip arthroscopy
Increases satisfaction of surgeon and patient
Noninvasive and does not require additional instrument implantation on patient
No requirement of CT imaging and is compatible with fluoroscopic images
Disadvantages
After the surgeon starts to use the system, a non-operating system or the absence of the system may lead to a feeling of blindness.

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