Technical Note

The Femoroacetabular Impingement Resection (FAIR) Arc: An Intraoperative Aid for Assessing Bony Resection During Hip Arthroscopy

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Abstract: Symptomatic femoroacetabular impingement is one of the most common hip pathologies in young athletes. Intraoperative fluoroscopy is commonly used during hip arthroscopy to aid with portal placement and resection of the cam and pincer lesions. However, there are currently no universally agreed-on tools to allow for the assessment of adequacy of femoral and acetabular osteoplasty. Despite the general lack of consensus among hip arthroscopists, the senior author recommends using the femoroacetabular impingement resection arc to guide the adequacy of cam and pincer resection in hip arthroscopy. Using intraoperative fluoroscopy, one should aim to create a continuous "Shenton's line"-type arc along the inferior aspect of the anterior–inferior iliac spine and superolateral femoral neck base by resecting any bone that causes a break in the continuity of this arc.

Symptomatic femoroacetabular impingement (FAI) is one of the most common hip pathologies in young athletes, with a prevalence of up to 22% in soccer, hockey, and football players.[1-3] Treatment for refractory cases generally consists of hip arthroscopy with cam and/or pincer resection and labral repair or debridement. Compared with open surgical hip dislocation, hip arthroscopy allows for improved visualization of the anteroinferior, medial, posterosuperior, and lateral femoral head–neck junction.[4,5] Despite these benefits, the arthroscopic approach is technically challenging and is associated with a steep learning curve of 75 or more cases.[5-7] Furthermore, there is a lack of agreement regarding the best means of assessing the adequacy of bony resection intraoperatively. These difficulties have led to persistent symptoms, associated complications, and revision surgery secondary to over- and under-resection in some patients.[8-10]

Intraoperative fluoroscopy is commonly used during hip arthroscopy to aid with portal placement and resection of the cam and pincer lesions.[6,11,12] However, there are currently no universally agreed-on tools to allow for assessment of adequacy of femoral and acetabular osteoplasty during surgery. Therefore, the development of a simple, reproducible visual intraoperative aid is of clinical interest to orthopaedic trainees and practicing hip arthroscopists alike.

Shenton's line, first described by Edward W. H. Shenton in 1902, describes a continuous curvilinear line along the inferior aspect of the superior pubic ramus and inferomedial border of the femoral neck. In this description, any disruption of the continuity of this line suggests the presence of hip joint pathology, including developmental dysplasia of the hip and femoral neck fracture.[13] This is one of the most commonly used tools in orthopaedics due to its ease of application, and it has been adapted for use in the radiographic assessment of other joints such as the shoulder.[14] It was theorized that a similar tool could be used for hip arthroscopy.

The goal of this Technical Note is to describe the principal author's (T.Y.) technique for assessment of the adequacy of cam and pincer resection during hip arthroscopy using the femoroacetabular impingement resection (FAIR) arc.

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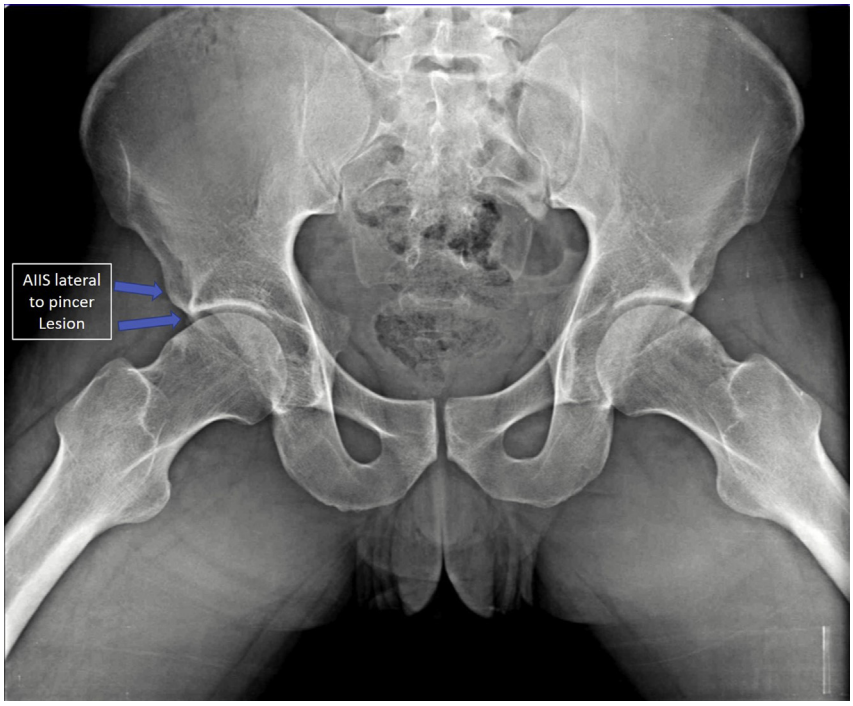

Fig 1. Anteroposterior pelvic radiograph demonstrating excessive pelvic tilt. As can be seen, this results in a lateralized appearance of the anteroinferior iliac spine, and an underappreciation of the pincer lesion. For this reason, the femoroacetabular impingement resection arc technique should not be used based on a radiograph with excessive tilt.

Preoperative Planning

This study was approved by the Institutional Review Board Operations at NYU Langone Health. A complete history and physical examination form the foundation of the clinical encounter. Clinical assessment suggestive of FAI includes a reported history of groin or hip pain exacerbated by hip flexion or mechanical symptoms such as clicking and locking, and physical examination signs including a positive flexion, adduction, internal rotation test and anterior pain with resisted hip flexion. The former is suggestive of classic impingement, whereas the latter suggests subspine impingement. In addition, pain provoked by hip extension and external rotation suggests posterior impingement, whereas pain with hip extension and internal rotation suggests ischiofemoral impingement. An assessment of the dynamic structures around the hip is also performed to rule out extra-articular causes of hip pain, including palpation and strength assessment of the abdominal, hip flexor, adductor, and abductor muscle groups. Imaging studies complete the clinical assessment, including radiographs (4 views—anteroposterior pelvis, 45° and 90° Dunn, and cross-table lateral) and magnetic resonance imaging to assess for labral pathology. Typical radiographic indices of combined FAI are an α angle >55° and a lateral center-edge angle >35.°[15,16] In addition to the presence of these physical examination findings and radiographic indices, the patient must have not responded to an appropriate course of nonsurgical treatment to be indicated for hip arthroscopy. This article will highlight the technique of assessment of the adequacy of cam and pincer resection during hip arthroscopy using the FAIR arc.

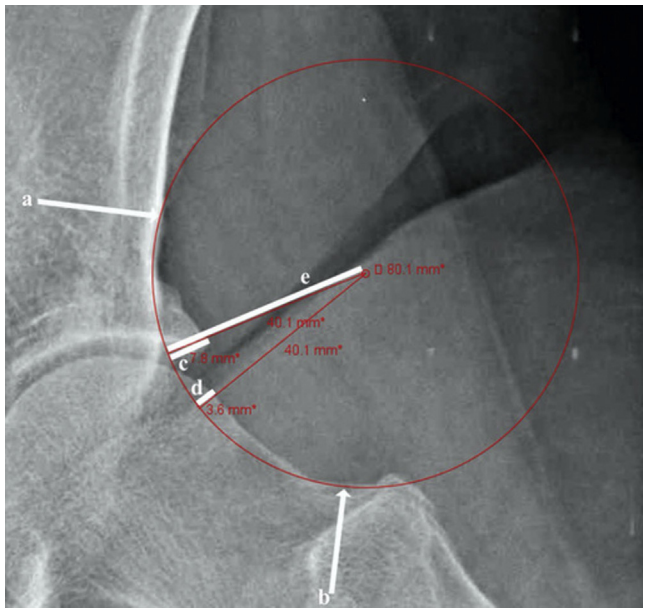

Fig 2. 45° Dunn view of a left hip. The femoroacetabular impingement resection arc (red circle) is subtended by the inferior aspect of the anteroinferior iliac spine (A) and superolateral femoral neck base (B), with measurements of the maximal radial height maximal radial height of the pincer (C) and cam (D) lesions. Measurements are drawn in a centripetal manner, or along the circle's radius (E).

Table 1. Pearls and Pitfalls of the FAIR ArcPearls and Pitfalls of the FAIR Arc Pearls and Pitfalls of the FAIR Arc

Pearls	Pitfalls
The ROI circle tool should be placed so that it is in contact with the inferior aspect of the AIIS and base of the lateral femoral neck	Applying the FAIR arc in an image with unacceptable pelvic tilt may result in the ASIS projecting lateral to the pincer lesion
45° Dunn views should be obtained pre-, intra-, and postoperatively	Applying the FAIR arc in a patient with femoral retroversion may result in an obscured femoral head–neck junction by superimposition of the greater trochanter
MRH should be measured at the apices of the pincer and cam lesions	

AIIS, anteroinferior iliac spine; ASIS, anterosuperior iliac spine; FAIR, femoroacetabular impingement resection; MRH, maximal radial height; ROI, region of interest.

Surgical Technique (With Video Illustration)

FAIR Arc Calculation

The FAIR arc measurement is performed using the 45° Dunn view radiograph. Of note, excessive pelvic tilt will result in an apparent lateralized anteroinferior iliac spine and underestimation of the pincer (Fig 1). A region of interest tool is used to draw a best-fit circle that incorporates the inferior aspect of the anteroinferior iliac spine and superolateral femoral neck base. The maximal radial height is then measured from the circumference of this circle to the apex of the cam lesion and the apex of the pincer lesion. The direction of the measurement is centripetal, toward the center of the FAIR arc (Fig 2). This measurement is obtained pre- and postoperatively, and visualized intraoperatively using fluoroscopy (Video 1). Pearls and pitfalls of the technique can be found in Table 1.

Diagnostic Arthroscopy

The patient is positioned in the supine position on the traction table with and the feet are secured in padded boots. The C-arm is positioned between the patient's legs, parallel to the nonoperative extremity, and the cassette is aimed perpendicular to the ipsilateral femoral neck. Traction is first applied to the contralateral abducted leg to center the patient on the table, then to the ipsilateral leg until the hip is appropriately distracted, as confirmed by intraoperative fluoroscopy. The complete surgical technique is depicted in Video 1. First, a vertical line is drawn from the anterosuperior iliac spine (ASIS) to serve as a visual reminder of the approximate location of the lateral femoral cutaneous nerve. With the use of a Seldinger technique and fluoroscopic guidance, a standard anterolateral viewing portal is created 3 cm anterior to the tip of the greater trochanter, followed by a mid-anterior portal. When correctly positioned, the 2 portals should roughly form an isosceles triangle with the ASIS (Fig 3). After confirming the correct intra-articular placement of the 2 portals, an interportal capsulotomy is performed distal to the labrum and a diagnostic arthroscopy is completed to evaluate for concomitant pathology, including labral tears, ligamentum teres tears, and osteochondral lesions such as chondrolabral delamination and cartilage defects.

Acetabular Rim Exposure and Pincer Resection

During the acetabuloplasty portion of the procedure, the C-arm is tilted back by 20° to obtain a profile view of the anterior rim. To adequately access the acetabular rim and subspine region for bony resection and anchor placement, the capsulolabral junction needs to be exposed. Using a 50° radiofrequency ablator (Arthrex, Naples, FL), this plane is developed proximally for up to 15 mm[17] and until the psoas tendon and reflected head

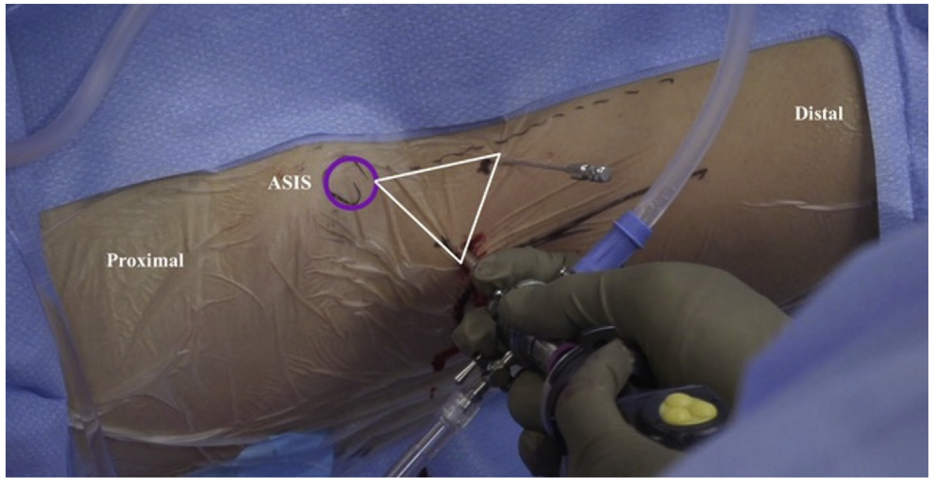

Fig 3. Clinical image of a right hip demonstrating arthroscopy landmarks. Correct placement of the anterolateral and mid-anterior portals, with the arthroscope positioned in the former and the spinal needle in the latter. These should roughly form an isosceles triangle (white triangle) with the ASIS (purple circle). ASIS, anterosuperior iliac spine.

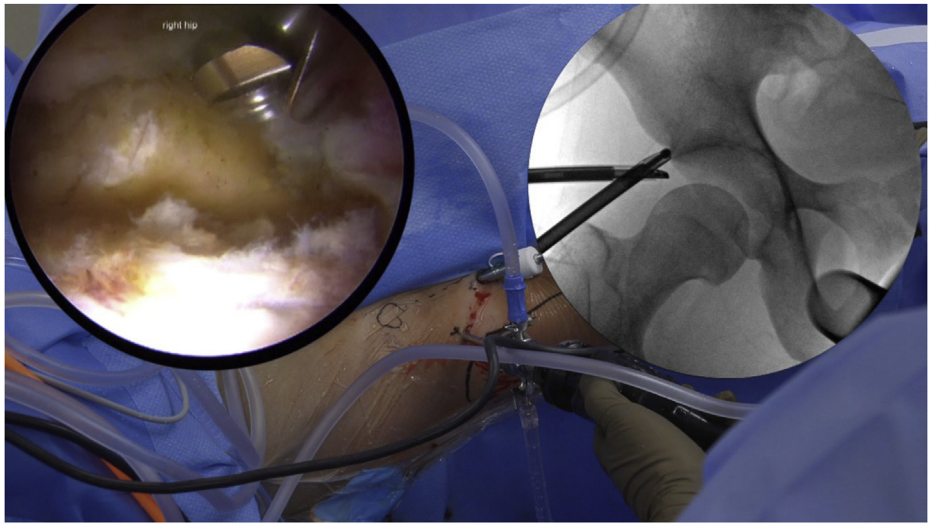

Fig 4. Clinical image of a right hip, with arthroscopic inlet in the upper left, and corresponding fluoroscopic image in inlet in upper right. Working in the central compartment, the burr is placed on the subspine (anteroinferior iliac spine), which will subsequently be resected.

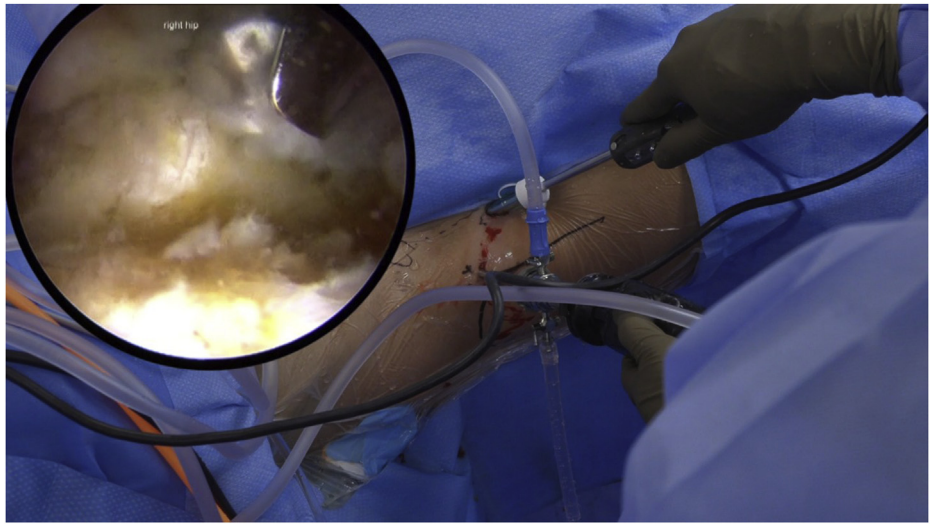

Fig 5. Clinical image of a right hip, with arthroscopic inlet in the upper left. Working in the central compartment, the burr is used to resect the subspine.

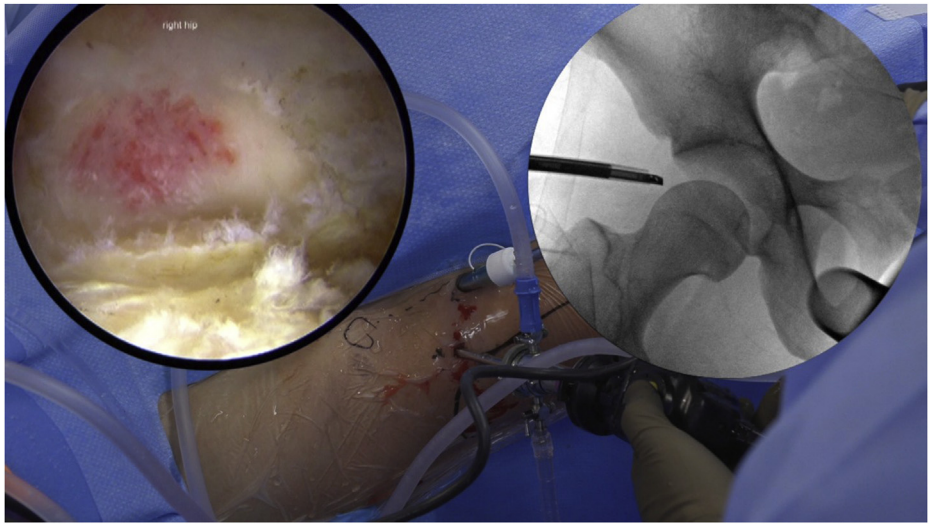

Fig 6. Clinical image of a right hip, with arthroscopic inlet in the upper left, and corresponding fluoroscopic image in inlet in upper right. The resection of the subspine lesion can be appreciated both arthroscopically and radiographically.

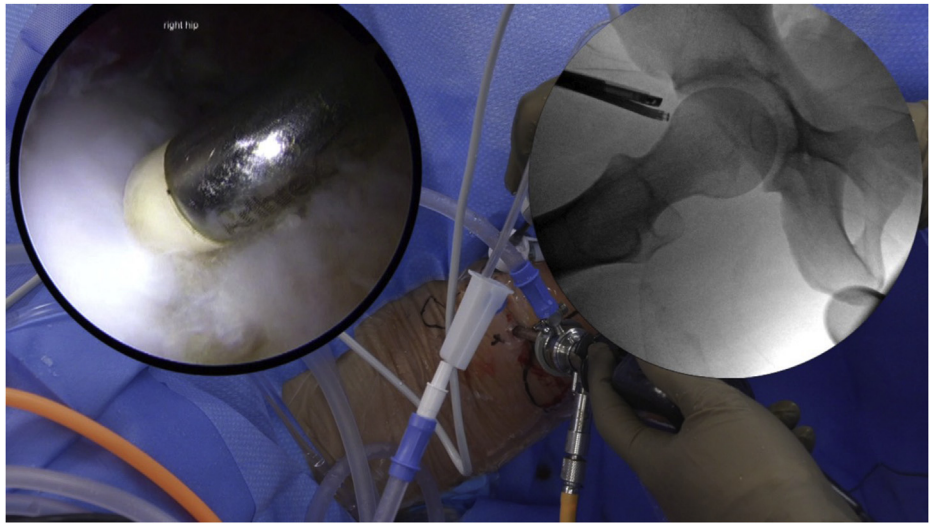

Fig 7. Clinical image of a right hip, with arthroscopic inlet in the upper left, and corresponding fluoroscopic image in inlet in upper right. Working in the peripheral compartment, the burr is placed on the cam lesion, in anticipation of later resection.

of the rectus femoris are visualized anteriorly and posteriorly, respectively (Fig 4). A high-speed burr (Arthrex) is then used to resect the pincer and subspine overhang until the FAIR arc has been reconstituted (Figs 5 and 6).

Labral Repair

Although not yet well defined in the literature, the senior author prefers to repair rather than resect the labrum if it is of sufficient quality for repair. This is achieved using a curved passing instrument (NanoPass; Stryker, Kalamazoo, MI), No. 2 SutureTape (Arthrex), and 2.9-mm knotless PEEK (polyether ether ketone) anchors (PushLock; Arthrex) placed 1 to 1.5 mm proximal to the labral edge to ensure no intra-articular penetration during drilling. In this case, 2 anchors were placed, one at the 12-o'clock and one at the 1:30-o'clock position (Fig 3).

Cam Resection

Once work in the central compartment is complete, both legs are taken out of traction and the surgical hip is flexed to 45° and abducted 20° to obtain an intraoperative Dunn view (Fig 7). The FAIR arc-based cam

Fig 8. Intraoperative fluoroscopic image of a 45° Dunn view of a right hip during arthroscopic resection of a cam lesion. Using the femoroacetabular impingement resection arc, it can be seen that the lesion measures approximately 4.5 mm.

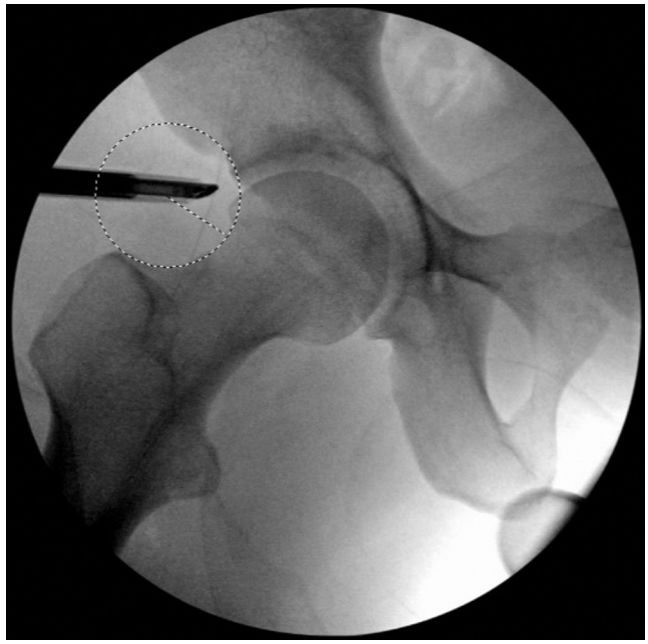

Fig 9. Intraoperative fluoroscopic image of a 45° Dunn view of a right hip during arthroscopic resection of a cam lesion. Using the femoroacetabular impingement resection arc, the previous 4.5-mm cam lesion is now resected.

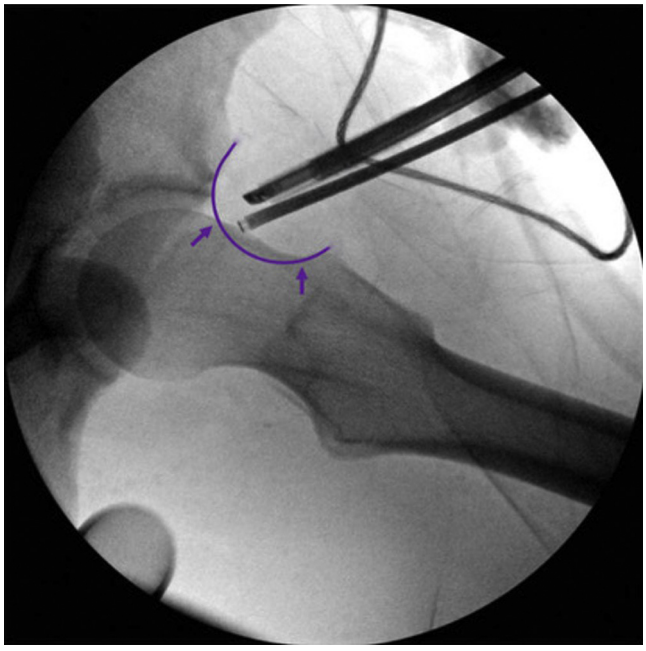

Fig 10. Another example of a different patient. Left hip intraoperative 45° Dunn view demonstrating cam lesion osteochondroplasty pre-resection relative to the FAIR arc (purple semi-circle) as a template.

resection is then completed in a step-wise fashion, moving from medial to lateral as the leg is progressively extended, ensuring FAIR arc reconstitution in all positions of hip flexion (Figs 8-10). If any further rim or subspine resection is required, traction can be reapplied and the central compartment can be reentered.

Capsular Closure

Capsular repair is achieved with a curved passing instrument (SlingShot; Stryker) and interrupted or figure-of-8 No. 2 sutures. Care is taken to ensure the labral repair isn't compromised with proximal passage of the capsular suture(s). The portals are then irrigated and closed in a layered fashion.

Postoperative Rehabilitation

The surgical extremity is protected with a hip abduction brace for 1 week and 50% foot-flat weight-bearing with crutches for 4 weeks. A structured physiotherapy protocol is begun 1 week after surgery. Strengthening is introduced at 6 weeks, and a return to unrestricted activity is permitted no earlier than 3 months postoperatively.

Discussion

Outcomes after hip arthroscopy for FAI have been shown to be excellent at mid-term follow-up in appropriately selected patients.[18-20] Unfortunately, there is a well-known steep learning curve associated with this procedure. Part of the challenge relates to the difficulty in assessing the adequacy of bony resection intraoperatively, given the wide variability in fluoroscopic protocols between surgeons and a general lack of consensus regarding the optimal technique. However, a number of intraoperative tools have been described to help with intraoperative assessment of the extent of bony resection.[21-23] Matsuda[21] described a fluoroscopic templating technique for acetabuloplasty that consisted of obtaining an anteroposterior view of the distracted hip, outlining the pincer lesion with an erasable marker directly onto the intraoperative imaging monitor, and resecting away the rim within the confines of the marking.

Mofidi et al.[23] used intraoperative 3-dimensional (3D) computed tomography performed at 2 separate intervals, before arthroscopy and after osteoplasty, to assess adequacy of cam and pincer resection. The authors reported good success with this technique, albeit at the expense of a high associated operational cost and technician-dependent variability in image quality. Audenaert et al.[22] subsequently demonstrated improved accuracy of surface registration using 3D-fluoroscopy compared with imageless computer navigation, which was felt to be due to the limited amount bony architecture that can be digitized during hip arthroscopy. Despite the promising results shown with the use of intraoperative 3D computed tomography for hip arthroscopy, this technique is currently unrefined and most centers still rely on plain fluoroscopy to aid with osteoplasty due to the limitations described above.

The FAIR arc described in this Technical Note is an easy, reproducible visual cue that can be used to assess the adequacy of bony resection that is akin to Shenton's line of the hip. Advantages and disadvantages of this technique can be found in Table 2. A break in this FAIR

Table 2. Advantages and Disadvantages of the FAIR Arc Technique

Advantages	Disadvantages/Limitations
Easy, reproducible visual cue	Maximum safe amount of bony resection undefined (risk of hip instability)
Helps avoid under-resection, one of the most common causes for revision	Has not been tested in patients with abnormal femoral version (i.e., retroversion)
Does not require specialized intraoperative equipment (standard fluoroscopy only)	Has only been tested using the 45° Dunn view
Part of normal workflow (does not add substantial time to the case)	One-dimensional assessment of a 3-dimensional problem

FAIR, femoroacetabular impingement resection.

arc is seen in the setting of a cam or pincer lesion, and the goal of surgery is to restore the continuity of this line.

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