Technical Note

Intraoperative Use of Ultrasound for Assessing Cam Deformity and Cam Resection

Daniel J. Kaplan, M.D., Thomas W. Fenn, B.S., Jordan H. Larson, B.S., and Shane J. Nho, M.D., M.S.

Abstract: The use of intraoperative fluoroscopy is standard among hip arthroscopist to evaluate and confirm the adequacy of cam resection in patients with femoroacetabular impingement syndrome. However, given the inherent limitations of fluoroscopy, additional intraoperative imaging, such as ultrasound, should be pursued. We offer a technique to measure alpha angles intraoperatively using ultrasound to determine adequate cam resection.

Femoroacetabular impingement syndrome (FAIS) is a condition characterized by hip symptoms, clinical signs, and radiographic evidence of bony impingement, caused by either a sphericity mismatch between the femoral head and acetabulum (cam deformity) or excessive acetabular coverage of the femoral head (pincer deformity).[1,2] This osseous impingement can lead to abnormal hip joint kinematics and damage to surrounding soft-tissue structures, such as the acetabular labrum and articular cartilage.[1,3-6] Resultant labral tears and cartilage damage can contribute to early development of osteoarthritis.[7-9] Surgical management typically involves hip arthroscopy with a focus on resection of the bony deformity, restoring the femoral head-neck offset. Incomplete cam resection is the leading cause of failed hip arthroscopy, with up to 81% of revision cases found to have residual cam deformity.[10,11] This observation reveals the importance of complete cam resection in patients with FAIS, thereby showing the need for quantitative measurement of the cam deformity preoperatively to assist with surgical planning and both intraoperatively and postoperatively to evaluate the adequacy of the resection.

The alpha angle is such a measurement. It is typically measured on radiographs and used not only to diagnose and quantify cam deformities in FAIS patients prior to hip arthroscopy but also to evaluate the sufficiency of bony resection after surgery.[12] Intraoperatively, fluoroscopy is most frequently used by hip arthroscopists to evaluate and confirm the adequacy of cam resection.[13,14] Although fluoroscopy allows for real-time assessment and provides good visualization of bony deformities via good bony clarity on radiography and easy mobility of the C-arm, it comes with significant disadvantages, including ionizing radiation exposure, additional personnel in the operating room, and the need for a lead shield, which can be heavy and cumbersome. Given these limitations, there is reason to investigate other imaging modalities for intraoperative evaluation of cam resection.

Ultrasound (US) is a non-ionizing, cost-effective, accessible imaging modality that is commonly used for intra-articular hip injections and dynamic hip examinations.[15] Studies have shown that US can also be used to assess the alpha angle, showing good to excellent correlation with alpha angles measured on radiographs, as well as computed tomography (CT) and magnetic

From the Section of Young Adult Hip Surgery, Division of Sports Medicine, Department of Orthopedic Surgery, Rush Medical College of Rush University, Rush University Medical Center, Chicago, Illinois, U.S.A.

The authors report the following potential conflicts of interest or sources of funding: S.J.N. receives research support from Allosource, Arthrex, Athletico, DJ Orthopaedics, Linvatec, Miomed, Smith & Nephew, and Stryker, outside the submitted work; receives personal fees from Ossur, Springer, and Stryker, outside the submitted work; receives education payments from Elite Orthopaedics, outside the submitted work; is an editorial board member of American Journal of Orthopaedics; and is a board or committee member of American Orthopaedic Society for Sports Medicine and Arthroscopy Association of North America. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received November 15, 2022; accepted January 22, 2023.

Address correspondence to Thomas W. Fenn, B.S., Section of Young Adult Hip Surgery, Division of Sports Medicine, Department of Orthopedic Surgery, Rush Medical College of Rush University, Rush University Medical Center, 1611 W Harrison St, Ste 300, Chicago, IL 60612, U.S.A. E-mail: nho.research@rushortho.com

2212-6287/221527

https://doi.org/10.1016/j.eats.2023.01.012

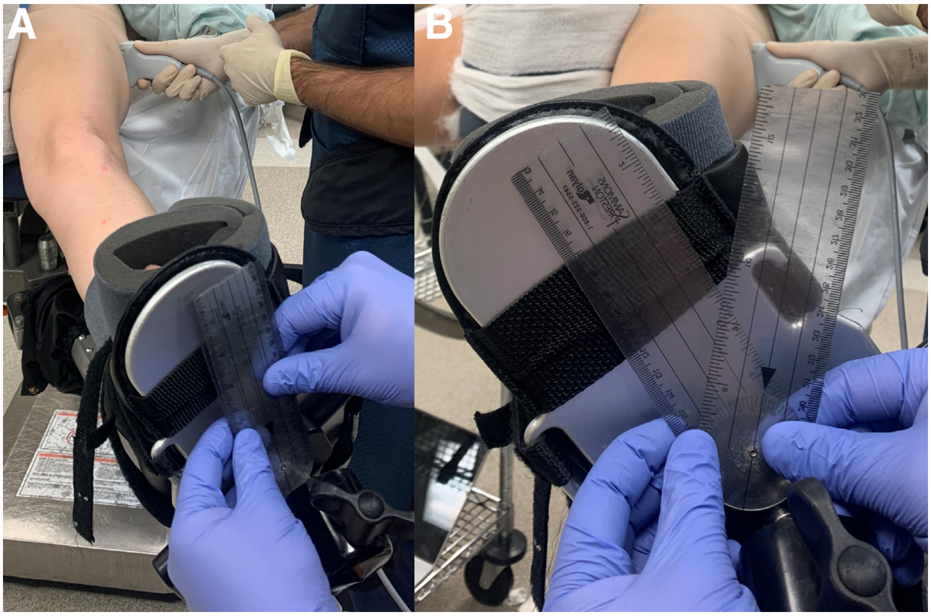

Fig 1. Left hip of operative patient with cam deformity on traction table in supine position with hip extended. With the hip in neutral rotation (A) and the hip in 30° of internal rotation (B), measurements are made with a goniometer. The ultrasound probe is placed in the transverse oblique plane, parallel to the axis of the femoral neck and perpendicular to the skin. With the hip in extension, 3 views are measured (neutral, 30° of internal rotation, and 30° of external rotation).

resonance imaging (MRI) scans.[16-18] Although US can be used to assess the alpha angle,[16-20] much of the literature regarding the use of US in hip arthroscopy has addressed arthroscopic portal placement.[21-25] Given the significant disadvantages of fluoroscopy, the use of US to assess the alpha angle intraoperatively and, thereby, the adequacy of cam resection is of substantial interest in the arthroscopic treatment of FAIS. The purpose of this technical article is to provide instruction and guidance on the use of intraoperative US to measure the alpha angle and determine the adequacy of cam resection.

Technique

Setup and Positioning

The patient is positioned supine on a flat examination table if undergoing US in an office setting or supine on a traction table if undergoing US intraoperatively (Figs 1 and 2). One advantage of US examination versus

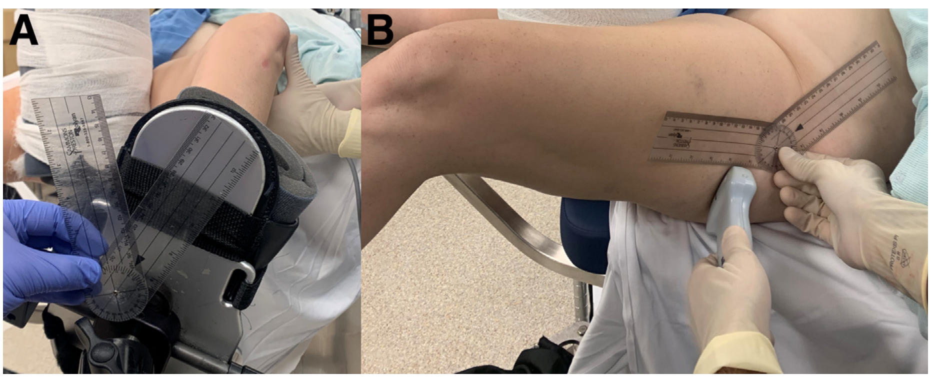

Fig 2. Left hip of operative patient with cam deformity on traction table in supine position with hip extended. With the hip in 30° of external rotation (A) and the hip flexed to 50° (B), measurements are made with a goniometer. The ultrasound probe is placed in the transverse oblique plane, parallel to the axis of the femoral neck and perpendicular to the skin. With the hip in flexion, 3 views are assessed (neutral, 40° of external rotation, and 60° of external rotation).

Table 1. Pearls and Pitfalls for Ultrasonographic Measurement of Alpha Angles

Pearls	Pitfalls
Stay perpendicular to the skin with the probe to maintain accurate imaging.	Moving both probe and patient hip position
Take the hip from extension and internal rotation to flexion and external rotation to see the lateral and anterior surfaces.	Only measuring alpha angle from 1 hip position
Note that each point used to create a perfect circle around the femoral head should be on concentric bone to avoid erroneously including the deformity.	Including cam deformity in circumference of femoral head

radiography is the ability to quickly obtain imaging in several different hip positions, without any increased radiation exposure. This allows for alpha angle measurement at different points along the femoral neck, providing a better 3-dimensional understanding of the deformity. Additionally, if the examination is performed in the office, one can obtain a similar dynamic assessment of the femoral neck using US preoperatively to that obtained during surgery with fluoroscopy, providing an opportunity for a better intraoperative comparison.

Accordingly, the hip is taken through a range of positions during US examination, mimicking the positions assessed intraoperatively to evaluate residual deformity. This consists of both flexion and extension positions, with external, neutral, and internal rotation. Views with the hip in extension allow for assessment of the lateral femoral head-neck junction, whereas views obtained with hip flexion allow for anterior assessment.

US Assessment

An example of a right hip US examination, with a corresponding frog-leg lateral radiograph obtained in the office, is presented. A Sonosite C5-1 probe (Fujifilm, Tokyo, Japan) is used. A detailed description of the US assessment is described in Video 1. The US transducer is placed in the transverse oblique plane, parallel to the axis of the femoral neck and perpendicular to the skin. This transducer position creates an image similar to the transverse oblique plane obtained by an MRI scan. The hip is initially placed in extension and internal rotation, and an image capturing at least a portion of the spherical head and the distal insertion of the joint capsule is obtained to allow for standardized alpha angle measurement. This is saved for later measurement, and the limb is rotated to a neutral position. The process is repeated until all 6 positions have been imaged. Pearls and pitfalls of the technique can be found in Table 1.

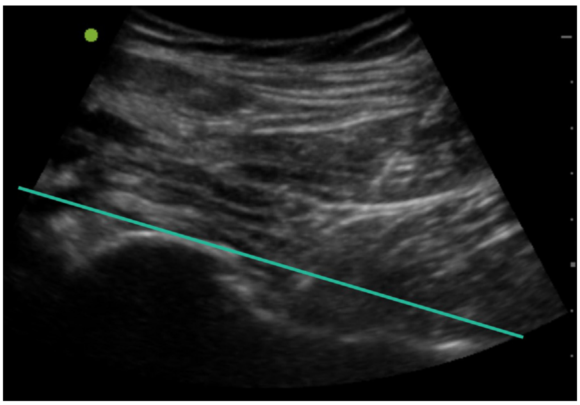

Fig 3. Ultrasound of a right hip in 50° flexion and 40° external rotation while in the supine position on the traction table. The first step to measuring the alpha angle using the ultrasound is to draw a tangential line (aqua line) next to the spherical head, identifying the distal most point of the joint capsule insertion, approximating the central axis of the femoral neck. This technique is repeated in all 6 dynamic positions of the hip. Green dot denotes the superior and superficial anatomy when utilizing the ultrasound.

On each image, the alpha angle is measured using the following technique: First, the distal-most point of the joint capsule insertion is identified, and a tangential line to the spherical femoral head is drawn (Fig 3). This line approximates the central axis of the femoral neck used in radiographic measurement.

Next, a perfect circle is drawn around the femoral head. This is created by using 3 points along the visible portion of the head, with as much spread as possible between them to improve accuracy (Figs 4 and 5). All 3 points should be placed on the concentric portion of the head to avoid erroneously including the cam deformity.

With the use of the center of the perfect circle as the hinge point, a line parallel to the tangential line, drawn earlier, is drawn down the axis of the femur. A line from this central point to the point at which the femoral head loses sphericity is then drawn. Finally, the alpha angle is calculated (Fig 6). This process is repeated for each hip position. Examples of intraoperative imaging before and after femoroplasty are shown in Figures 7-10.

Discussion

This article explains and demonstrates the methodology for intraoperative use of US to quantitatively assess cam resection via pre- and post-resection alpha angle measurement. Several studies and technical articles have examined intraoperative use of US during hip arthroscopy for portal placement and for diagnoses

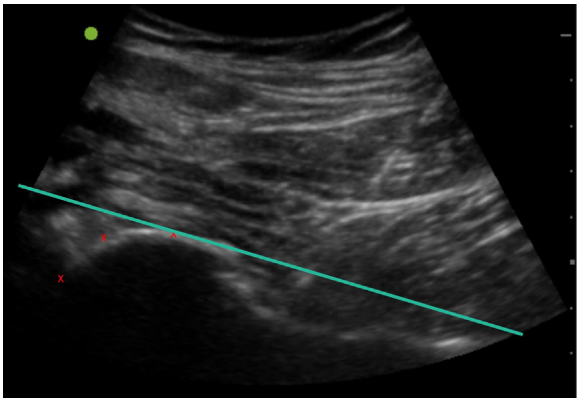

Fig 4. Ultrasound of a right hip in 50° flexion and 40° external rotation while in the supine position on the traction table. After the tangential line (aqua line) is drawn, to approximate a perfect circle around the femoral head, three points (red X's) are marked along the visible, concentric portion of the head. This technique is repeated in all 6 dynamic positions of the hip. Green dot denotes the superior and superficial anatomy when utilizing the ultrasound.

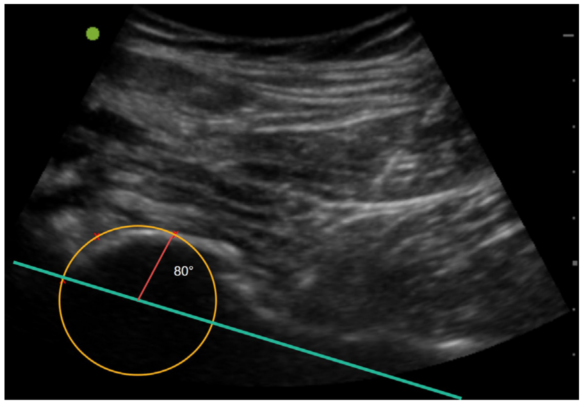

Fig 6. Ultrasound of a right hip in 50° flexion and 40° external rotation while in the supine position on the traction table. Using the center of the perfect circle (orange circle) as a hinge point, a line (aqua line) parallel to the tangential line is drawn down the axis of the femur. Another line (red line) is then drawn from the central portion of the circle to the location where the femoral head loses sphericity, and the alpha angle is calculated, which in this case was 80 degrees. This technique is repeated in all 6 dynamic positions of the hip. Green dot denotes the superior and superficial anatomy when utilizing the ultrasound.

other than FAIS.[21-24,26] Technique articles describing US-guided portal placement found it to be effective and reported low rates of chondral or labral injury; however, they did not compare US with conventional fluoroscopy.[21-24] In a recent cadaveric study in which portals were made by the same surgeon under US versus fluoroscopic guidance, Trasolini et al.[25] found rates of iatrogenic injury to be significantly greater with US guidance. In contrast, Byrd et al.[15] compared US- versus fluoroscopy-guided hip injections and found a success rate of 98% with US guidance. Moreover, patients reported greater convenience and less pain with the US-guided injections and, consequently, reported a strong preference for them.[15] These findings were consistent with the results of a study performed by Gordey and Wong[27] showing that US-guided hip arthroscopy is a safe alternative to standard fluoroscopy, with low complication rates and no significant differences in the occurrence of cartilage injury or labral puncture ($P > .05$) between the 2 techniques.

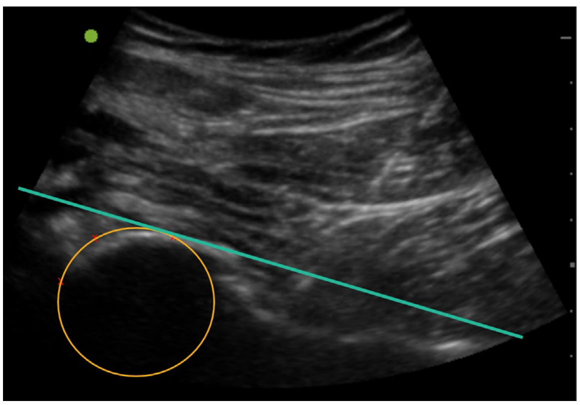

Fig 5. Ultrasound of a right hip in 50° flexion and 40° external rotation while in the supine position on the traction table. After the tangential line (aqua line) is drawn and three points (red X's) are marked along the femoral head, a perfect circle (orange circle) is then created around the femoral head. This technique is repeated in all 6 dynamic positions of the hip. Green dot denotes the superior and superficial anatomy when utilizing the ultrasound.

A number of studies have explored the efficacy of US for the evaluation of cam-type FAIS, with variable results.[16-19] An early study by Buck et al.[16] found highly variable sensitivity and specificity of the qualitative sonographic signs they assessed as compared with MRI, which served as the gold standard, and receiver operating characteristic curve analysis of alpha angle measurements made using US showed a low area under the curve. Moreover, interobserver agreement was low for qualitative sonographic signs and moderate for alpha angle measurements.[16] In contrast, Lerch et al.[18] found no significant differences in alpha angles measured using US versus MRI, with strong correlations between US and MRI measurements in all hip positions. Robinson et al.[17] found significant discrepancies between alpha angles measured using US and CT, serving as the gold standard, with a mean absolute difference between the measurements of 10.5° despite mean values of 64.5° and 62.5°, respectively. Nevertheless, the US measurements showed a high sensitivity and negative predictive value for detecting cam deformity, albeit with low specificity.[17]

Lerch et al.[19] also explored the utility of US for measuring alpha angles after resection, finding

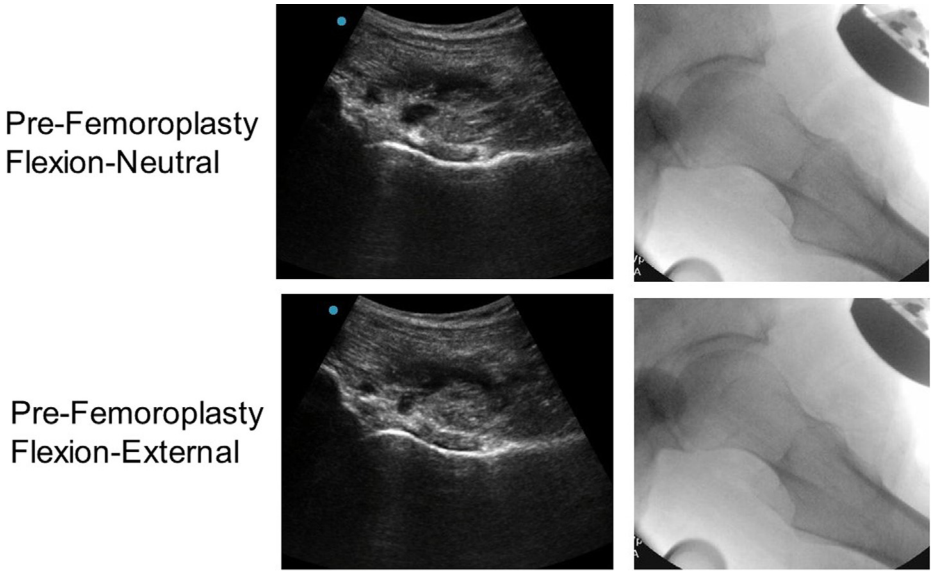

Fig 7. Ultrasound (left) and fluoroscopic (right) images of left hip of operative patient on traction table in supine position prior to femoroplasty. The different views of the femoral neck pathology with different rotations (flexion-neutral and flexion—external rotation) can be appreciated, as can the similarity between ultrasound and fluoroscopy. Blue dot denotes superior anatomic position.

postoperative measurements to be significantly smaller than preoperative measurements in all hip positions and 95% of postoperative measurements to be below the typical cutoff value of 50°. However, there was no comparison with a gold-standard alternative methodology.[19] A recent cadaveric study by Clapp et al.[20] was the first to investigate the use of intraoperative US to assess the adequacy of cam resection via pre- and post-resection alpha angle measurements. These measurements were compared with measurements made using contemporaneous fluoroscopy; no significant differences were found in any of 6 hip positions except flexion with neutral rotation.

The use of US for intraoperative assessment of cam resection would be an ideal solution to many of the inherent disadvantages of fluoroscopy, but it faces

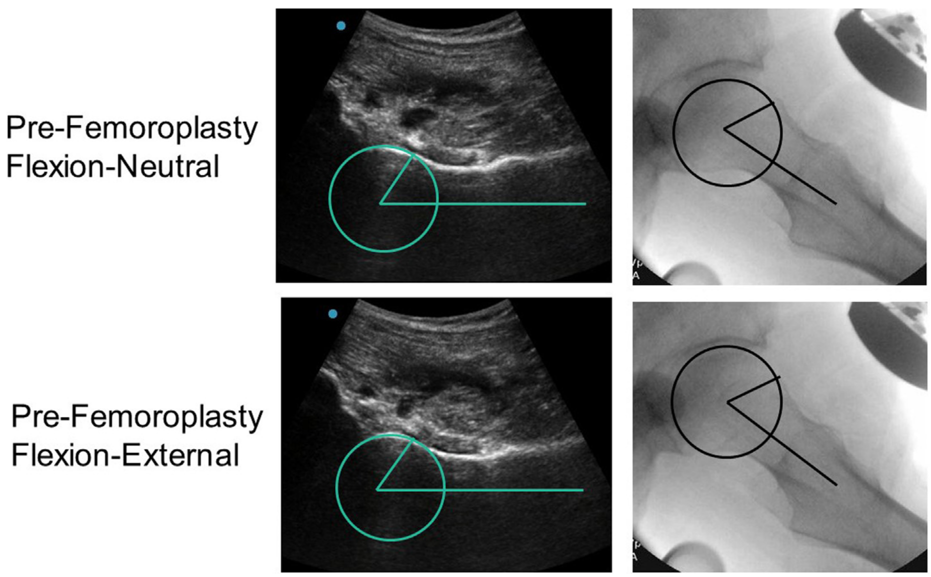

Fig 8. Ultrasound (left) and fluoroscopic (right) images of left hip of operative patient on traction table in supine position prior to femoroplasty. Different views of the femoral neck pathology with different rotations (flexion-neutral and flexion—external rotation) on both ultrasound and fluoroscopy are shown with alpha angles (blue circles and angle lines) drawn, demonstrating the technique and showing the similarity in measurements. Blue dot denotes superior anatomic position.

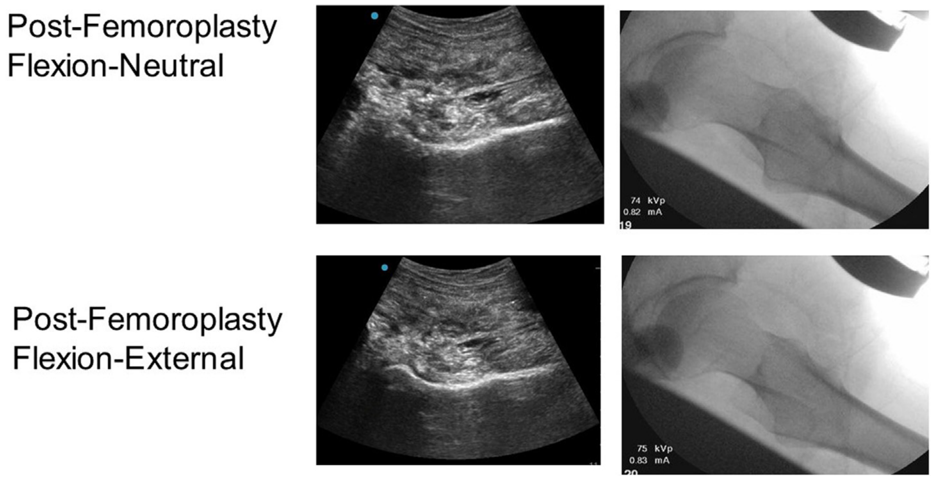

Fig 9. Ultrasound (left) and fluoroscopic (right) images of left hip of operative patient on traction table in supine position after femoroplasty. The different views of resolution of the femoral neck pathology with different rotations (flexion-neutral and flexion−external rotation) can be appreciated, as can the similarity between ultrasound and fluoroscopy. Blue dot denotes superior anatomic position.

several limitations. Its potential inferiority for arthroscopic portal placement may still necessitate fluoroscopy at the beginning of the procedure. Given the pre-eminent importance of complete cam resection, the heterogeneous results of studies comparing alpha angle measurements using US versus gold-standard modalities such as MRI, CT, and fluoroscopy, and the steep learning curve associated with performing and interpreting US measurements,[20-23] surgeons may be hesitant to rely on US for intraoperative assessment of cam resection. Moreover, the intraoperative use of US can be logistically challenging, requiring an assistant to hold the arthroscopic instruments while the surgeon handles the transducer. For these reasons, US may be more effective for preoperative screening and assessment of cam deformity—particularly given its high sensitivity and potential equivalence with gold-standard alpha angle measurement techniques—and

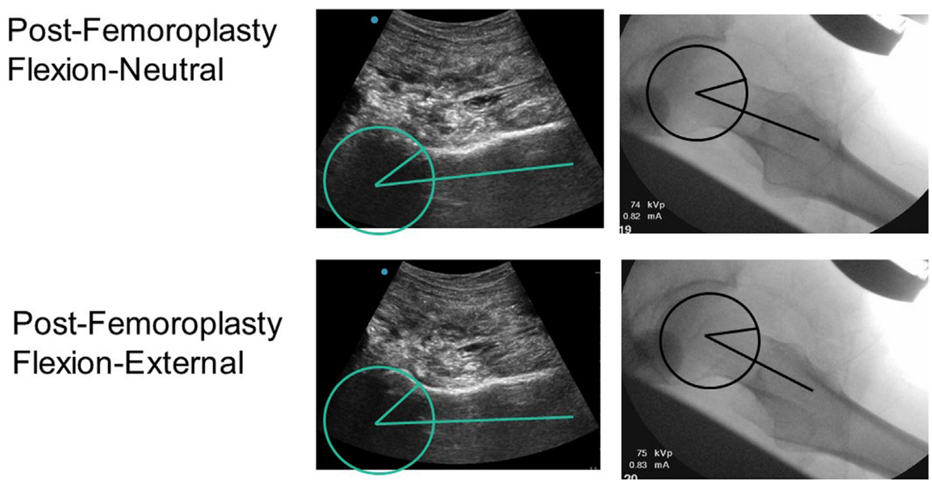

Fig 10. Ultrasound (left) and fluoroscopic (right) images of left hip of operative patient on traction table in supine position after femoroplasty with alpha angles (blue circles and angle lines) drawn using described technique. Similarities between ultrasound and fluoroscopy can be noted in the different rotations (flexion-neutral and flexion−external rotation). Blue dot denotes superior anatomic position.

postoperative assessment of cam resection. Its use could help reduce ionizing radiation exposure during these less critical time points.

References

1. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: Femoroacetabular impingement as a cause of early osteoarthritis of the hip. *J Bone Joint Surg Br* 2005;87:1012-1018.
2. Rhee C, Le Francois T, Byrd JWT, Glazebrook M, Wong I. Radiographic diagnosis of pincer-type femoroacetabular impingement: A systematic review. *Orthop J Sports Med* 2017;5:2325967117708307.
3. Grace T, Samaan MA, Souza RB, Link TM, Majumdar S, Zhang AL. Correlation of patient symptoms with labral and articular cartilage damage in femoroacetabular impingement. *Orthop J Sports Med* 2018;6:2325967118778785.
4. Dwyer MK, Tumpowsky C, Boone A, Lee J, McCarthy JC. What is the association between articular cartilage damage and subsequent THA 20 years after hip arthroscopy for labral tears? *Clin Orthop Relat Res* 2019;477:1211-1220.
5. Henak CR, Ateshian GA, Weiss JA. Finite element prediction of transchondral stress and strain in the human hip. *J Biomech Eng* 2014;136, 021021.
6. Más Martínez J, Sanz-Reig J, Verdú Román CM, Bustamante Suárez de Puga D, Morales Santías M, Martínez Giménez E. Tönnis stage 0 and 1 acetabular rim cartilage injuries: Incidence, grade, location and associated presurgical factors. *Rev Esp Cir Ortop Traumatol* 2017;61:154-161.
7. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: A cause for osteoarthritis of the hip. *Clin Orthop Relat Res* 2003;417:112-120.
8. Hoch A, Schenk P, Jentzsch T, Rahm S, Zingg PO. FAI morphology increases the risk for osteoarthritis in young people with a minimum follow-up of 25 years. *Arch Orthop Trauma Surg* 2021;141:1175-1181.
9. Ng KCG, Mantovani G, Modenese L, Beaule PE, Lamontagne M. Altered walking and muscle patterns reduce hip contact forces in individuals with symptomatic cam femoroacetabular impingement. *Am J Sports Med* 2018;46:2615-2623.
10. Cvetanovich GL, Harris JD, Erickson BJ, Bach BR, Bush-Joseph CA, Nho SJ. Revision hip arthroscopy: A systematic review of diagnoses, operative findings, and outcomes. *Arthroscopy* 2015;31:1382-1390.
11. Clohisy JC, Nepple JJ, Larson CM, Zaltz I, Millis M. Academic Network of Conservation Hip Outcome Research (ANCHOR) Members. Persistent structural disease is the most common cause of repeat hip preservation surgery. *Clin Orthop Relat Res* 2013;471:3788-3794.
12. Kang ACL, Gooding AJ, Coates MH, Goh TD, Armour P, Rietveld J. Computed tomography assessment of hip joints in asymptomatic individuals in relation to femoroacetabular impingement. *Am J Sports Med* 2010;38:1160-1165.
13. Smart LR, Oetgen M, Noonan B, Medvecky M. Beginning hip arthroscopy: Indications, positioning, portals, basic techniques, and complications. *Arthroscopy* 2007;23:1348-1353.
14. Kelly BT, Weiland DE, Schenker ML, Philippon MJ. Arthroscopic labral repair in the hip: Surgical technique and review of the literature. *Arthroscopy* 2005;21:1496-1504.
15. Byrd JWT, Potts EA, Allison RK, Jones KS. Ultrasound-guided hip injections: A comparative study with fluoroscopy-guided injections. *Arthroscopy* 2014;30:42-46.
16. Buck FM, Hodler J, Zanetti M, Dora C, Pfirrmann CWA. Ultrasound for the evaluation of femoroacetabular impingement of the cam type. Diagnostic performance of qualitative criteria and alpha angle measurements. *Eur Radiol* 2011;21:167-175.
17. Robinson DJ, Lee S, Marks P, Schneider ME. Ultrasound determination of the femoral head-neck alpha angle. *Ultrasound Med Biol* 2018;44:495-501.
18. Lerch S, Kasperczyk A, Warnecke J, Berndt T, Rühmann O. Evaluation of cam-type femoroacetabular impingement by ultrasound. *Int Orthop* 2013;37:783-788.
19. Lerch S, Kasperczyk A, Berndt T, Rühmann O. Ultrasonography can quantify the extent of osteochondroplasty after treatment of cam-type femoroacetabular impingement. *Int Orthop* 2015;39:853-858.
20. Clapp IM, Alter TD, Sivasundaram L, Gursoy S, Perry AK, Nho SJ. Ultrasound demonstrates potential in identify proximal femoral morphology before and after cam resection: A cadaveric study. *Arthroscopy* 2023;39:751-757.e2.
21. Hua Y, Yang Y, Chen S, et al. Ultrasound-guided establishment of hip arthroscopy portals. *Arthroscopy* 2009;25:1491-1495.
22. Weinrauch P, Kermeci S. Ultrasound-assisted hip arthroscopy. *Arthrosc Tech* 2014;3:e255-e259.
23. Keough T, Wilson D, Wong I. Ultrasound-guided portal placement for hip arthroscopy. *Arthrosc Tech* 2016;5:e851-e856.
24. Williams BT, Vadhera A, Maheshwer B, et al. Is there a role for ultrasound in hip arthroscopy? A systematic review. *Arthrosc Sports Med Rehabil* 2020;2:e655-e660.
25. Trasolini NA, Sivasundaram L, Rice MW, et al. Ultrasound can determine joint distraction during hip arthroscopy but fluoroscopic-guided portal placement is superior. *Arthrosc Sports Med Rehabil* 2022;4:e1083-e1089.
26. Weinrauch P, Kermeci S. Ultrasonography-assisted arthroscopic proximal iliotibial band release and trochanteric bursectomy. *Arthrosc Tech* 2013;2:e433-e435.
27. Gordey E, Wong I. Comparison of complications in X-ray versus ultrasound-guided hip arthroscopy. *Arthroscopy* 2022;38:802-807.