Case Report

Femoral Neck Exostosis, a Manifestation of Cam/Pincer Combined Femoroacetabular Impingement

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Abstract: We present 2 cases of cam/pincer combined femoroacetabular impingement treated arthroscopically with labral debridement, acetabuloplasty, and femoral head recontouring. In both cases there was essentially no evidence of osteoarthritis of the hip. However, in both cases raised exostoses were evident on the anterolateral femoral neck in the region that commonly comes into contact with the acetabular rim. On the basis of 3-dimensional dynamic reconstructions, we surmise that these exostoses are a direct result of linear contact between the femoral neck and acetabular rim. We recommend that the presence of these exostoses be carefully noted by the arthroscopic hip surgeon and that they be a geographic marker of the zone of contact between the head-neck junction and the acetabular rim and a guide for the area of head osteochondroplasty in combination with appropriate treatment of the acetabular rim.

Femoroacetabular impingement (FAI) is a recently recognized clinical syndrome that results from abnormal contact between the femoral head/neck and the acetabulum. This entity has been subclassified into 2 types by Ganz et al.[1] (Table 1). Abnormal morphologies of the femoral head termed the "tilt deformity"[2] or the "pistol-grip deformity"[3] have been recognized as potential risk factors for osteoarthritis for decades, although the pathologic mechanism was not clearly known. Cam type FAI occurs from an excessively large femoral head leading to abnormal shear forces on the acetabular cartilage in positions of flexion and internal rotation. This cartilage damage is the inciting event, culminating in full-blown osteoarthritis of the hip. Pincer type FAI is caused by overcoverage of the femoral head by the acetabulum. Risk factors for pincer FAI include acetabular retroversion[4-6] or an excessively deep acetabulum (coxa profunda or protrusio). Despite this classification system, approximately 50% of patients have elements of both the cam and pincer types of FAI.[7]

Radiographic findings of pincer FAI on the acetabulum include osseous metaplasia (ossification) and tears of the labrum, labral ganglia,[8] and acetabular retroversion. On the femoral side, the herniation pits were described by Pitt et al.[9] before the recognition of FAI as cystic structures on the anterolateral femoral neck. Leunig et al.[10] have further studied the etiology of these cysts and have described them as intraosseous ganglia, using the term "fibrocystic change" of the anterior-superior femoral neck. They provided a pathomechanical explanation for these cysts as being caused by direct impaction of the femoral neck on the acetabular rim.

Recently, both femoral pathology and acetabular pathology have been addressed by use of the technique of hip arthroscopy.[11-14] Examination of the peripheral compartment of the hip along the femoral

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TABLE 1. *Radiographic Signs of Combined Cam/Pincer FAI*

	Comments
Femoral	
Herniation pit[9]/fibrocystic change[10]	These were first described by Pitt et al.[9] before the recognition of FAI. These cysts were later described by Leunig et al.[10] as "fibrocystic change" within the bone, essentially an intraosseous ganglion.
Aspherical femoral head	Initially, aspherical femoral heads were termed as having a "tilt deformity"[2] and/or "pistol-grip deformity."[3] However, the connection to FAI provided an explanation of how these deformities could lead to hip osteoarthritis.[1] Nötzli et al.[20] quantified the degree of deformity using the α angle on oblique magnetic resonance images. The α angle is calculated by placing a circle over the cartilage-covered femoral head and drawing a line from the center of the head to the center of the femoral neck. A second line is drawn from the center of the femoral head to the point where the femoral head exits the confines of the circle. In the case of an aspherical femoral head, this angle will be higher. Normal values for the α angle depend on a variety of factors including the imaging axis, the type of imaging, and the location of the head being evaluated. Typically, values $>60°$ are considered abnormal.
Femoral neck exostosis	These exostoses were noted in this case report as reactive regions of the femoral neck likely caused by direct contact on the acetabular rim. In our 2 patients the exostoses were round, raised bony lesions with a sharp demarcation from the surrounding tissue. They measured between 6 and 8 mm in diameter and were between 1 and 2 mm in height.
Acetabular	
Crossover sign[5,17]	This finding is indicative of acetabular retroversion and is noted on the anteroposterior pelvis radiograph, which must be standardized for rotation and flexion.[16] The crossover sign is positive when the anterior rim contour passes lateral to the posterior rim contour. This is most common at the superior aspect of the joint. The more distal the position of the crossover, the more severe the degree of acetabular retroversion.
Projection of ischial spine into pelvis	Kalberer et al.[18] noted that many hips with a positive crossover sign also showed projection of the ischial spine into the pelvis. They described this sign as "a new sign for acetabular retroversion." This sign has a sensitivity of 91% and a specificity of 98% for diagnosis of acetabular retroversion using the crossover sign on standardized films as the gold standard.
Labral tears[8]	Direct impaction of the femoral head-neck junction on the labrum can result in labral tears. These tears were initially believed to be the primary pathology. However, results of labral debridement alone were suboptimal in some patients. Ultimately, the work of Ganz et al.[1] linked the labral injury to direct impaction in the setting of FAI and led to the recommendation of morphologic correction in combination with labral debridement or repair.
Osseous metaplasia	In cases with an element of pincer type FAI, the femoral neck comes into direct contact with the acetabular rim and is thought to cause direct trauma to the labrum, resulting in ossification. The ossification usually starts on the rim of the bony acetabulum and progressively enters into the body of the labrum, occasionally leading to complete conversion of the labrum to bone.
Paralabral cysts and intraosseous ganglia	In some cases the direct impaction on the acetabular rim can lead to acetabular rim ganglion cysts. These cysts can be extraosseous as paralabral cysts or exist as intraosseous ganglion cysts.

neck is particularly important for eliminating impingement because this area is the point of contact of the proximal femur with the acetabular rim.[15] The abnormal morphology of the femoral head and herniation pits can be seen and addressed with peripheral compartment arthroscopy. In this article we discuss a clinical and radiographic finding associated with cam/pincer combined FAI in 2 nonarthritic arthroscopic cases. This finding consists of solitary or multiple raised osseous lesions with a circular shape and a height of between 1 and 2 mm along the anterior femoral neck. We have termed these "femoral neck exostoses" and consider them an alternative reactive response of the femoral neck to direct impaction on the acetabular rim. Recognition of this finding at the time of peripheral compartment arthroscopy can alert the surgeon that there may be direct linear contact between the femoral neck exostosis and the acetabular rim and guide the surgeon to perform an adequately distal decompression of the femoral head/neck region.

CASE 1

Patient 1 was a 52-year-old woman who presented with severe hip pain of 4 years' duration that started after she flexed her hip beyond 120° while exiting a travel trailer (Table 2). She fell and landed on her buttock and right leg. The pain was located in the anterior groin, medial and lateral thigh, and gluteal region. Hip range of motion was diminished in flex-

TABLE 2. *Comparison of Cases*

	Patient 1	Patient 2
Age (yr)/sex	52/F	18/M
Duration of hip pain (yr)	4	4
Anterior impingement sign	Positive	Positive
Posterior impingement sign	Negative	Negative
Pain location	Anterior groin, medial and lateral thigh	Anterior groin
Pain severity	8/10	7/10
Posterior wall sign	Yes	Yes
Crossover sign	Yes	Yes
Maximum α angle	67°	63°
Herniation pit	5.7 mm, anterolateral neck	6.0 mm, anterolateral neck
Ischial spine projection into pelvis	Yes	Yes
Femoral neck exostosis	Two measuring 1.5 mm high and 6 mm in diameter each	One measuring 2 mm high and 8 mm in diameter
Labral tear	Yes, 11- to 1-o'clock position	Yes, 11- to 3-o'clock position
Acetabular chondral damage	Chondromalacia of acetabular rim cartilage adjacent to labral tear	Chondromalacia of acetabular rim cartilage adjacent to labral tear

ion, external and internal rotation, and abduction. The anterior impingement test was positive.[10] The standard anteroposterior pelvic radiograph[16] (Fig 1) showed a crossover sign,[17] a posterior wall sign,[17] and ischial spine projection into the pelvis.[18] The femoral head was aspherical with reactive changes on the anterolateral neck and the presence of a herniation pit[9] (Fig 1). The patient was diagnosed with combined pincer/cam FAI. A computed tomography scan showed acetabular retroversion and labral ossification (Fig 2A) along with the herniation pit (Fig 2B). Three-dimensional reconstruction of the pelvis was performed with a commercially available software program (Mimics; Materialise, Ann Arbor, MI). This showed an abnormal focal elevation, or exostosis, of the femoral head-neck junction (Figs 3A and 3B). The proximal femur was then rotated virtually in flexion and internal rotation by use of the software program around the center of the acetabulum, simulating the "impingement sign."[19] The femoral neck exostosis came into direct contact with the acetabular rim in this position (Fig 3C). At the time of arthroscopy, extensive labral damage was noted. This was treated with labral debridement of the residual anterior labrum and acetabuloplasty with a motorized burr. As part of the peripheral compartment arthroscopy, the femoral neck was examined, showing 2 well-circumscribed, raised exostoses (Fig 4). These each measured approximately 6 mm in diameter and had a height of approximately 1.5 mm. The femoral head and neck were recontoured with a motorized burr with fluoroscopic guidance. The patient has reported a high degree of satisfaction with the procedure at early follow-up of 6 months.

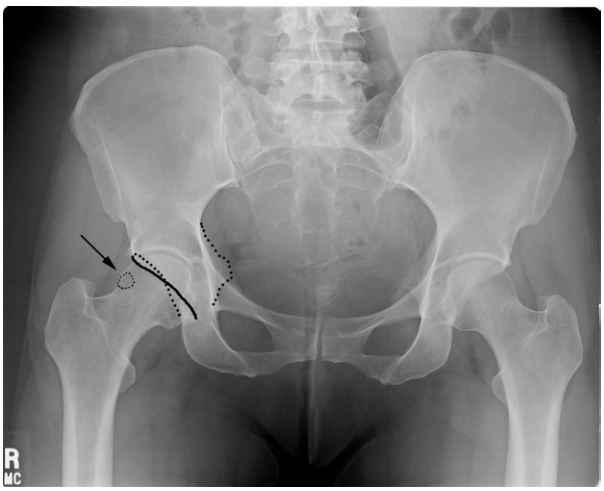

FIGURE 1. Anteroposterior pelvis radiograph of patient 1 showing anterior acetabular wall (solid line), posterior acetabular wall (dotted line on acetabular rim), herniation pit (arrow), and projection of ischial spine into pelvis. The configuration of the anterior and posterior acetabular walls shows a crossover sign and posterior wall sign (posterior wall medial to center of femoral head). Data from reference 17.

CASE 2

Patient 2 was an 18-year-old man with bilateral hip pain first felt in the right hip after performing a roundhouse kick during martial arts training (Table 2). He felt a pop in his hip, followed by increasing pain. Hip range of motion was diminished in internal and external rotation. There was a positive anterior impingement test.[10] The standard anteroposterior pel-

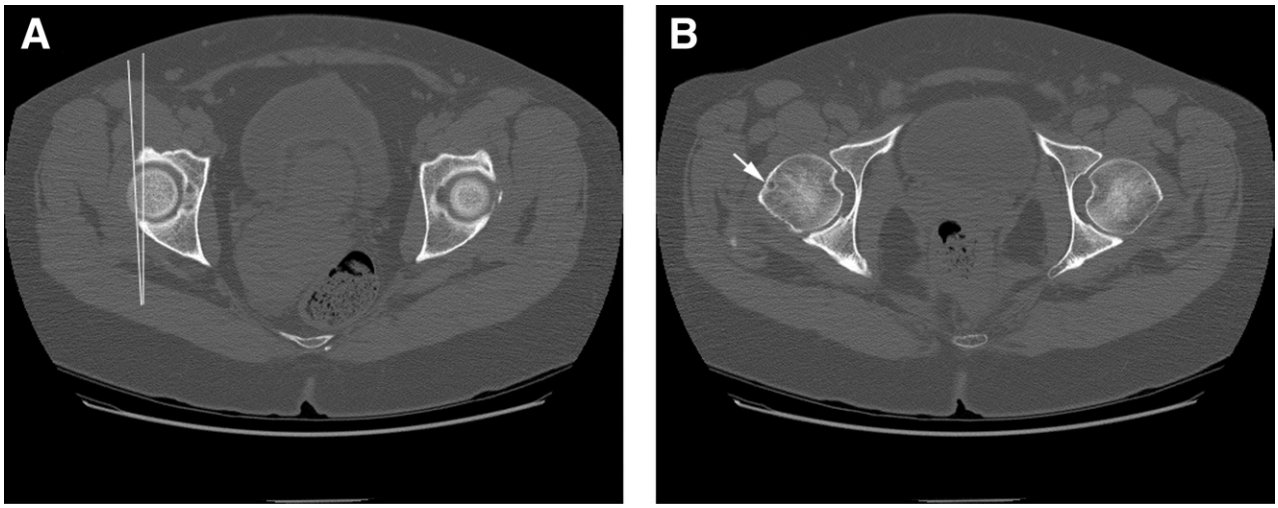

Figure 2. (A) Axial computed tomography section through superior aspect of the hip showing acetabular retroversion in the cranial acetabulum. The angle between the white lines represents the angle between the sagittal plane and the line connecting the anterior and posterior rims of the acetabulum. (B) The axial computed tomography section through the inferior aspect of the hip shows a herniation pit (arrow).

vis radiograph[16] (Fig 5) showed a crossover sign,[17] a posterior wall sign,[17] ischial spine projection into the pelvis,[18] a herniation pit, and an aspherical femoral head-neck junction. The patient was diagnosed with cam/pincer FAI. On magnetic resonance arthrography, there was an area of acute prominence on the anterolateral femoral head-neck junction that appeared as sclerotic bone on the T1 axial oblique images (Fig 6). At hip arthroscopy, the patient was noted to have an exostosis in the region of the anterolateral femoral neck with a height of approximately 2 mm and a diameter of approximately 8 mm (Fig 7). He also had ossification of the anterior-superior acetabular labrum. He underwent femoral head recontouring and labral debridement at arthroscopy. He has continued to have moderate pain since the procedure and is being considered for an open surgical hip dislocation.

DISCUSSION

On the basis of a detailed study of pincer impingement, 4 factors appear to be extremely common, if not pathognomonic, of this condition. These are the herniation pit,[9] crossover sign,[17] projection of the ischial spine into the pelvis,[18] and the posterior wall sign.[17] The critical finding in cam type FAI is an aspherical femoral head.[20] The purpose of this report is to discuss a new manifestation of cam/pincer type FAI—an exostosis located on the anterolateral femoral neck—that has received little previous attention in the literature. These exostoses are distinct from the cystic herniation pits in that they are raised circular structures composed of cortical bone. They may share their pathogenesis with the entity referred to by Pitt et al.[9] as the "reaction zone." However, the reaction zone, as described by Pitt et al., did not have any elements characteristic of an exostosis, which is a spur or outgrowth from a bone.

Leunig et al.[10] compared the incidence of fibrocystic change in hips with radiographic findings of FAI with the incidence in hips with developmental dysplasia (DDH). They found these cysts in 39 of 117 hips with FAI and none of the 132 hips with DDH. They thus challenged the previous contention that these cysts were due to contact and abrasion of the iliofemoral ligament or iliopsoas that might be associated with hip instability in an extended position as might be seen in DDH. Rather, their findings suggested that these cysts were directly related to contact of this region of the femoral neck with the acetabular rim in deep flexion. The potential enlargement of herniation pits or fibrocystic change was shown by Günther et al.,[21] who discussed 3 very large cysts in patients with radiographic findings of FAI. Two of their patients received decompression of the cyst, bone grafting, and secondary stabilization with a screw and side plate device. They suggested that the large cysts originated from small fibrocysts that form from mechanical impingement and then enlarge because of hydrodynamic expansion of the cysts due to repetitive contact be-

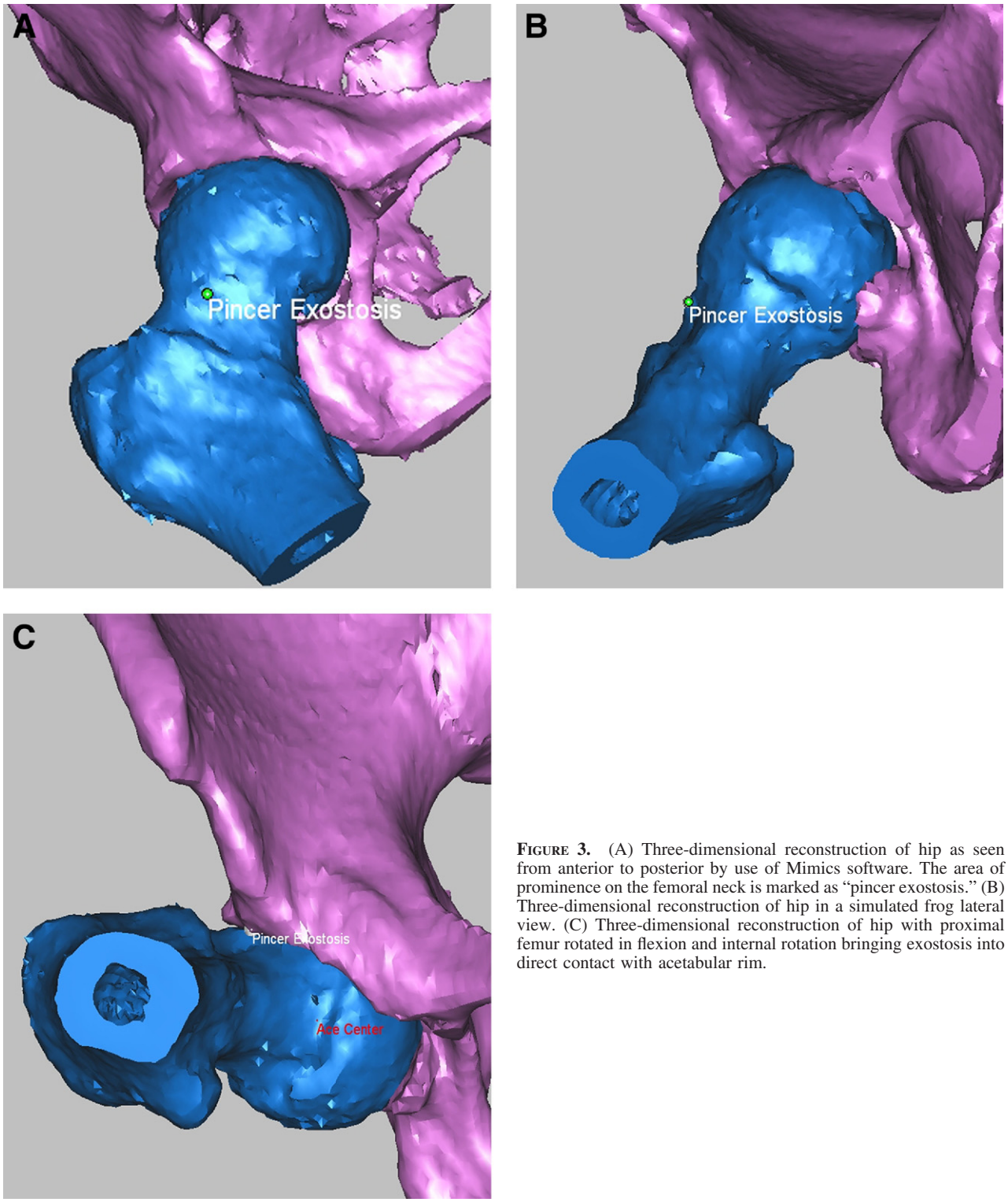

Figure 3. (A) Three-dimensional reconstruction of hip as seen from anterior to posterior by use of Mimics software. The area of prominence on the femoral neck is marked as "pincer exostosis." (B) Three-dimensional reconstruction of hip in a simulated frog lateral view. (C) Three-dimensional reconstruction of hip with proximal femur rotated in flexion and internal rotation bringing exostosis into direct contact with acetabular rim.

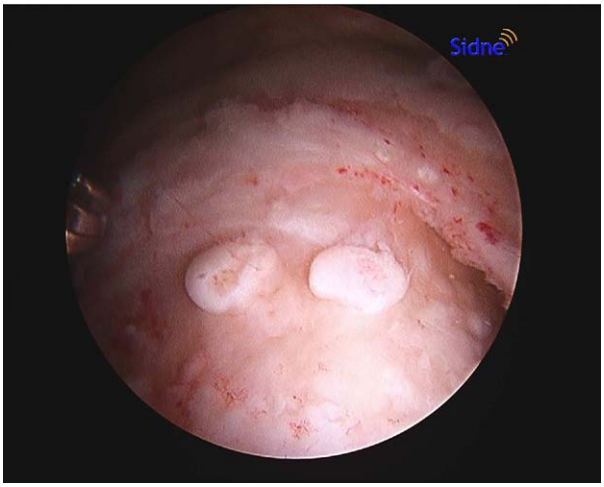

Figure 4. Arthroscopic photograph of right anterolateral femoral neck of patient 1 obtained in supine position, with hip flexed 45° with neutral ankle rotation, and viewing anterolateral femoral neck through direct anterior portal. Two elevated exostoses are noted in the field of view corresponding to the exostosis in Fig 3.

Figure 6. Oblique axial T1 magnetic resonance arthrogram image of patient 2 showing an anterior femoral neck bump and underlying area of bone sclerosis (arrow).

tween the femoral head-neck junction and the acetabular rim.

An ossified bar extending from the femoral head to the trochanteric region of the femur has been well described for more than a century.[22,23] More recently, a femoral head "bump," often termed a "pistol-grip deformity" or a "tilt deformity" in this location, has been associated with the development of osteoarthritis. The shape of the bump can be variable but is typically described as a broad region of excess bone along the anterosuperior or anterolateral femoral head with a smooth transition to the weight-bearing zone of the femoral head.[24] The femoral head deformity has

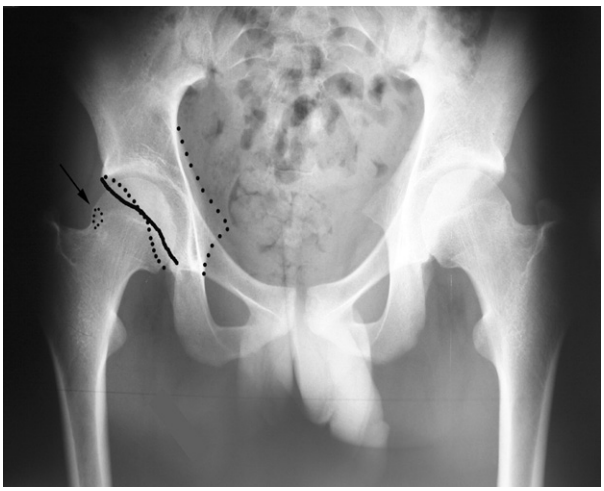

Figure 5. Anteroposterior pelvis radiograph of patient 2 showing anterior acetabular wall (solid line), posterior acetabular wall (dotted line on acetabular rim), herniation pit (arrow), and projection of ischial spine into pelvis. The configuration of the anterior and posterior acetabular walls shows a crossover sign and posterior wall sign (posterior wall medial to center of femoral head). Data from reference 17.

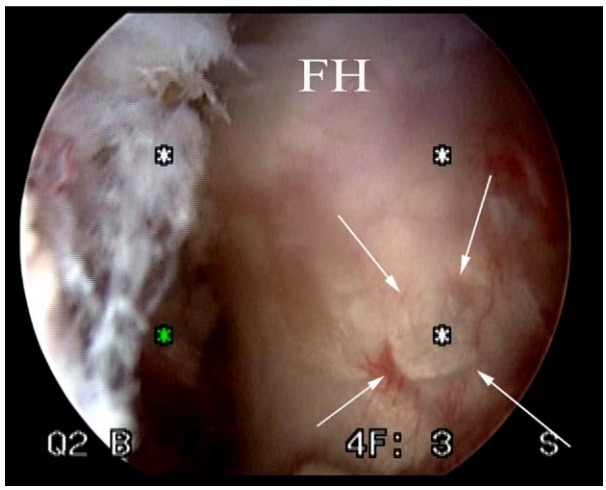

Figure 7. Arthroscopic image of right anterolateral femoral neck of patient 2 obtained in supine position, with hip flexed 45° with neutral ankle rotation, and viewing the anterolateral femoral neck through direct anterior portal. An exostosis (white arrows) is shown corresponding to the region seen on the magnetic resonance arthrogram image in Fig 6. (FH, femoral head.)

been attributed to a subtle slipped capital femoral epiphysis,[25] a congenital extension of the epiphysis, and reactive change from repetitive trauma. The cartilage histology of this segment of abnormal femoral head has also been studied, and hyaline cartilage has been noted. However, there has been evidence of cartilage degeneration in this region as well based on histologic scoring and upregulation of collagen type I and type II messenger ribonucleic acid.[26] Thus the broad-based femoral head bump found in FAI is clearly distinct from the focal exostosis described in the cases we present. An osteophyte is defined as a bony outgrowth. According to this definition, the femoral neck exostosis can be characterized as an osteophyte. However, it has a number of unique characteristics including its presence in otherwise healthy joints without end-stage osteoarthritis. In addition, the exostosis is in a region of the femoral neck that characteristically contacts the acetabular rim based on our 3-dimensional computed tomography reconstructions, indicating a possible reactive etiology.

In conclusion, femoral neck exostosis as described in this report is a clinical finding that can be noted at arthroscopy or during open impingement surgery. It is an exceedingly subtle radiographic finding based on the small size of the exostosis and the need for a perfectly tangential femoral radiograph to visualize the exostosis.

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