CLINICAL ARTICLE

Subspine Hypertrophy: Higher Incidence of Symptomatic versus Asymptomatic Hips in Patients with Unilateral Femoroacetabular Impingement

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Objective: To compare the difference of anterior inferior iliac spine (AIIS) and subspine hypertrophic deformity between symptomatic and asymptomatic hips in patients traditionally diagnosed with femoroacetabular impingement (FAI), and investigate the correlation of subspine decompression with AIIS variation and subspine hypertrophic deformity.

Methods: We retrospectively reviewed 70 patients with unilateral symptomatic FAI who underwent hip arthroscopy. The operative hips and contralateral hips naturally formed the symptomatic groups and asymptomatic control groups, respectively. The morphometric comparison of the hip joint was performed between the operative and contralateral sides of each patient. Radiological assessment was performed by two observers (an experienced musculoskeletal radiologist and an experienced surgeon). Three-dimensional (3D)-CT images of each patient were blindly reviewed to determine the AIIS variation and subspine hypertrophic deformity. Reformatted two-dimensional (2D)-CT images and anterior–posterior (AP) pelvic plain radiographs were blindly reviewed to determine FAI-related morphological measurements. Moreover, the surgical assessment was reviewed by one experienced surgeon to interpret whether subspine decompression was performed. The correlation of subspine decompression with AIIS variation and subspine hypertrophy was analyzed.

Results: Out of 70 patients with unilateral symptomatic FAI, 37 were males (52.9%) and 23 (32.9%) had symptoms involving the left hip. The mean age was 39.3 ± 10.4 years and the mean BMI was 24.3 ± 3.6. The distribution of AIIS variants in symptomatic hips did not differ significantly from that in asymptomatic hips ($\chi^2 = 3.092$, $P = 0.213$). Twenty-nine hips in the symptomatic group (41.4%) and 12 hips in the asymptomatic group (17.1%) were identified as positive for subspine hypertrophy. The incidence of positive subspine hypertrophy was significantly higher in the symptomatic hips compared to the asymptomatic hips ($\chi^2 = 9.968$, $P = 0.002$). FAI-related morphological parameters including α angle, lateral center-edge angle, acetabular anteversion, crossover sign, and Tonnis grade were highly symmetrical and did not show significant differences between symptomatic and asymptomatic hips. Fifty-four of 70 hips (77.1%) had labral tears extended to the acetabular rim corresponding to the AIIS. Forty-seven hips of 70 hips (67.1%) underwent subspine decompression, which was significantly correlated with AIIS variation and subspine hypertrophic deformity ($P = 0.019$ and 0.001, respectively).

Conclusion: Subspine hypertrophic deformity was found to be more common in symptomatic side *vs* asymptomatic side in patients with unilateral symptomatic femoroacetabular impingement. Subspine hypertrophy may be considered as an underlying indication for subspine decompression besides low-lying AIIS.

Key words: Anterior inferior iliac spine; Femoroacetabular impingement; Subspine hypertrophy; Subspine impingement

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Introduction

Over the past 20 years, femoroacetabular impingement (FAI) characterized by abnormal collisions between the femoral head and acetabular rim has been recognized as the main cause of hip pain in young and active adults[1,2]. Cam and pincer deformities that can lead to hip impingement have been thoroughly evaluated radiologically and managed arthroscopically in practice. However, the incidence of radiological deformities does not always coincide with symptomatic FAI[3,4]. A common phenomenon is that most patients with FAI complain of unilateral hip pain only, and only a quarter of FAI patients have bilateral hips involved[5]. What causes the difference in symptoms of bilateral hips in patients with FAI has not been well-studied.

Recently, impingement between the anterior inferior iliac spine (AIIS) and the femoral head has been recognized as a specific hip impingement pattern that may lead to hip disability similar to FAI[6–8]. Early recognition of AIIS impingement originated from cases with previous avulsion injuries and AIIS hypertrophic deformities[9,10], which were thought to be the pathomorphological basis for true AIIS impingement. However, more recently, the so-called "subspine impingement" (SSI), which may be caused by low-lying AIIS or subspine structural abnormalities, has been considered an underlying pathological condition that co-exists with traditional FAI[11]. AIIS is an important structure near the acetabular rim that provides the insertion for the direct head of the rectus femoris. The subspine region was not a well-defined structure below AIIS, but it could anatomically involve prominent AIIS, acetabular rim, and insertion of capsule iliofemoral ligament. The pathology of the subspinal region can lead to symptoms similar to those of classic FAI. According to the published reports, the concurrent rate of SSI in the FAI patient could reach between 23.7% and 32.0%, but has been underestimated previously[12,13]. Residual AIIS impingement or subspine impingement could result in poor clinical outcomes after arthroscopy[14], suggesting that the under-recognized subspine deformity and subspine impingement may contribute to symptoms in patients with FAI.

Radiological evaluation of the AIIS and subspinal region in patients with FAI has been emphasized, with three-dimensional (3D) CT being one of the most common assessment tools. Hetsroni *et al.*[15] proposed a 3D-CT-based classification of AIIS in patients with symptomatic FAI and found low-lying AIIS (Types II and III) may be associated with subspinous impingement. Balazs *et al.*[16] found a similar distribution of AIIS morphology in symptomatic hips compared to asymptomatic hips, suggesting that AIIS morphology is not the only reason for SSI. Amar *et al.*[17] compared the side-to-side differences in AIIS in asymptomatic patients and found good symmetry in all measurements except for the width of the AIIS. Carton *et al.*[11] highlighted the bony morphology of the subspine region and suggested that subspine impingement should be considered to be a separate pathology to true AIIS impingement. The distribution of subspine hypertrophy in patients with symptomatic FAI has not been well-investigated. Therefore, in the present study, we proposed a hypothesis that the subspine hypertrophy could be more common in symptomatic hips than in asymptomatic hips.

The purpose of this study was to: (i) compare the AIIS variation and subspine hypertrophy between symptomatic and asymptomatic hips in patients with unilateral FAI; (ii) compare the side-to-side difference in FAI morphologic measurement; and (iii) determine the correlations of AIIS variation and subspine hypertrophy with arthroscopic subspine decompression.

Materials and Methods

Inclusion Criteria and Exclusion Criteria

Inclusion Criteria

The inclusion criteria were: (i) patients aged between 18 and 60 years; (ii) diagnosed with unilateral symptomatic FAI; (iii) underwent hip arthroscopy; (iv) have 3D-CT evaluation preoperatively; and (v) have the surgical outcome and intraoperative finding recorded.

Exclusion Criteria

Exclusion criteria were: (i) patients underwent staged or simultaneous bilateral hip arthroscopy; (ii) patients with prior trauma or surgery; (iii) hip dysplasia; (iv) inflammatory arthritis of the hip; (v) osteonecrosis of the femoral head; (vi) osteoarthritis of the hip with Tonnis grade ≥2; and (vii) cases without complete radiographic and surgical data.

Participants

This retrospective study was approved by the Institutional Review Board. A review of 183 patients who underwent arthroscopic procedures between the period of May 2017 and December 2019 was performed through the arthroscopy registry in our institute. Finally, 70 patients who underwent hip arthroscopy with unilateral symptomatic FAI were enrolled for investigation, with operative hips as the symptomatic group and contralateral hips as the asymptomatic control group (Fig. 1).

Clinical Evaluation and Management

In our institute, all patients with FAI were diagnosed by one experienced surgeon based on clinical presentation, physical examination, and radiological evaluation. The pattern of FAI was determined according to the preoperative radiological assessment following the criteria previously reported[18]. The pelvic 3D-CT image, standing anterior–posterior (AP) pelvic radiographs, Dunn view, and false profile radiographs of the symptomatic hip were routinely screened preoperatively and available for review in the Picture Archiving and Communication Systems (PACS). Hip arthroscopy is recommended for FAI patients with symptoms lasting longer than 6 months and who have failed conservative treatment. All hip arthroscopy procedures are performed by an experienced

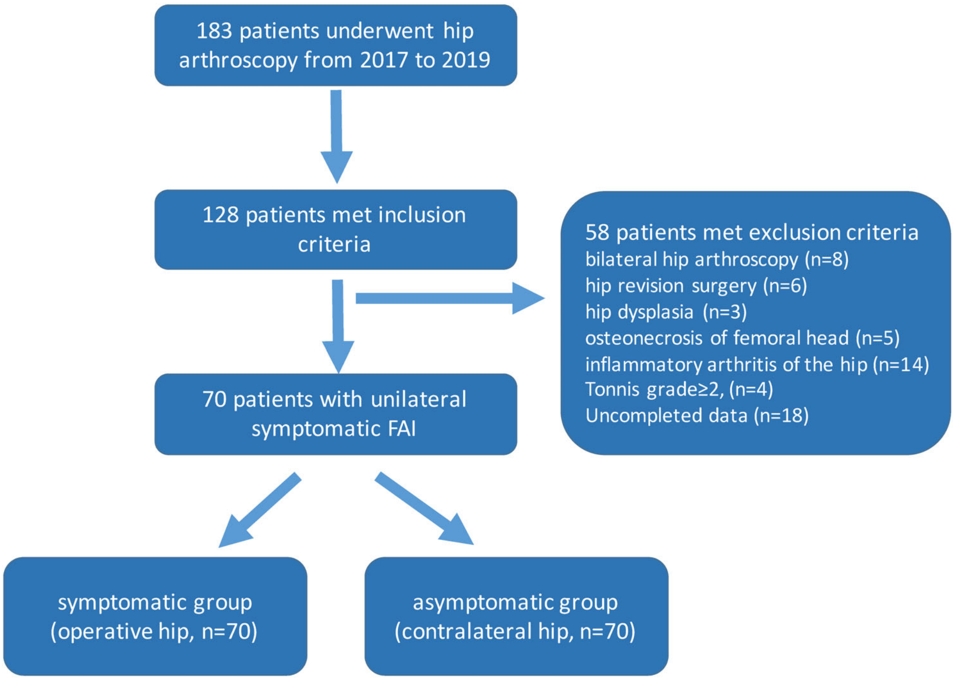

Fig. 1 Flowchart showing patient selection in the present study.

surgeon specializing in sports medicine. Osteoplasty of the acetabular rim and femoral neck junction was used to correct the pincer and cam lesions, respectively. With the advancement in recognition of subspine impingement in our institute since 2017, arthroscopic exploration of the subspinal region is routinely performed to identify pathological conditions that may lead to subspinal impingement. Subspine decompression was performed in cases of suspected subspine impingement. Arthroscopic findings and surgical procedures were recorded in a surgical database and are available for review.

Radiological Assessment

3D-CT images and reformatted 2D-CT images of the pelvis were rebuilt with original CT scans by an experienced technologist. The 3D-CT images of the pelvis were rotated to acquire head-on AIIS views to determine the AIIS variation and subspine hypertrophy. Reformatted 2D-CT images and standing AP pelvic plain radiographs were used to assess FAI-related measurements. All radiographic images were randomly ordered and independently evaluated by two readers (one experienced musculoskeletal radiologist and one experienced surgeon) who were blinded to the patient's medical history. Provide the presence of disagreement in radiological evaluation, blinded adjudication will be performed by a third reader (an experienced surgeon from another institute). FAI morphometric measurements including α angle, lateral center-edge angle, acetabular anteversion, crossover sign, and Tonnis grade were side-to-side compared between symptomatic and asymptomatic hips of each patient. AIIS variation and subspinal hypertrophy were determined for both hips of each patient and their distribution was compared between symptomatic and asymptomatic hips. The measurements were defined as follows.

Anterior Inferior Iliac Spine (AIIS) Variation

Variations of AIIS were identified according to the 3D-CT-based classification previously proposed by Hetsroni *et al.*[15], with type I characterized by a high overhanging AIIS with a clear separation between the cauda of the AIIS and the acetabular rim, type II characterized by an extension of the cauda of the AIIS to the acetabular rim, and type III characterized by a distal extension of the cauda of the AIIS beyond the acetabular rim (Fig. 2).

Subspine Hypertrophy

Subspine hypertrophy has not been well-defined base on 3D-CT images previously. We adapted the arthroscopic and radiographic definition on subspine hypertrophy previously reported by Carton *et al.*[11] and applied in the present study. A flat and smooth subspine region without bony bulk and hyperplasia was determined negative for subspine hypertrophy. A positive subspine hypertrophy was determined by the presence of the following features, rugged or prominent bone surface in the subspine region, solitary or multiple os acetabuli below AIIS, and spur-like osteophyte in the subspine region (Figs 3 and 4).

α Angle

The *α* angle is measured in the plane of maximum oblique axis and is defined as the angle formed by the central axis of the femoral neck and the radial line across the femoral head,

Fig. 2 AIIS variations on head-on AIIS view of pelvic 3D-CT. Type I has a clear separation between the cauda of the AIIS and the acetabular rim (A), Type II has an extension of the cauda of the AIIS to the acetabular rim (B), and Type III has a distal extension of the cauda of the AIIS beyond the acetabular rim (C).

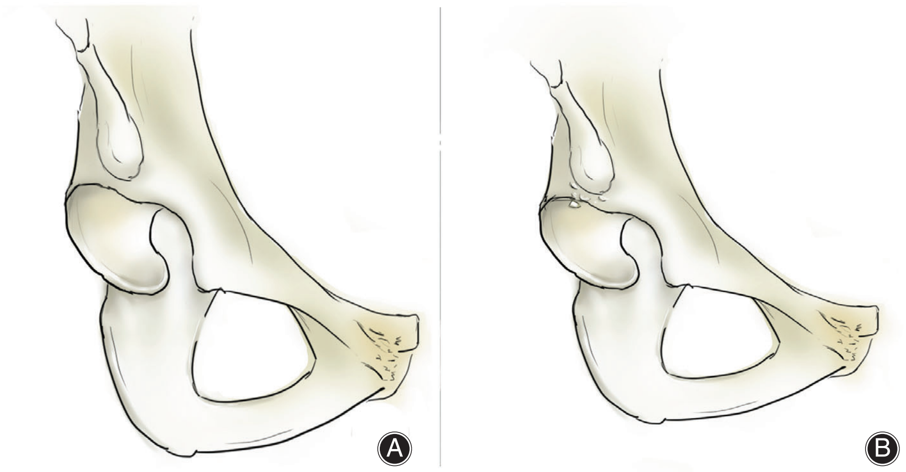

Fig. 3 Schematic diagram showing the morphological feature of a subspine hypertrophic deformity. Normal morphology of subspine region was flat and smooth (A), whereas the hypertrophic subspine region is characterized by prominent bony spurs or bonelet (B).

Fig. 4 Morphological features of subspine hypertrophic deformity on head-on AIIS view of pelvic 3D-CT. The presence of rugged or prominent bone surface in the subspine region (A), os acetabuli below AIIS (B), and spur-like osteophyte (C) in subspine region were recognized as positive with subspine hypertrophy.

where it loses sphericity. A cam lesion is defined as α angle ≥50° (Fig. 5A).

Acetabular Anteversion Angle (AAA)
The acetabular anteversion angle was measured in the plane of the maximal axis by drawing a line connecting the posterior edges of the two acetabular joints followed by a vertical line. Acetabular anteversion is defined as the angle between the line connecting the anterior and posterior edges of the acetabulum and the vertical line. *AAA* indicates the orientation of acetabulum and has association with the FAI or hip dysplasia (Fig. 5B).

Lateral Center-Edge Angle (LCEA)
The lateral center-edge angle is determined on the coronal plane where the acetabulum meets its deepest point. The LCEA is defined as the angle between the vertical line through the center of the femoral head and the line connecting the center of the femoral head to the most lateral point of the acetabulum. A pincer lesion was defined as an LCEA ≥39° (Fig. 5C).

Crossover Sign (COS)
The crossover sign was determined on the AP pelvic radiograph, with the upper part of the anterior border of the acetabulum crossing the posterior border from the lateral to the medial side to form a crossover sign. The presence of the crossover sign indicates a retroversion of the acetabulum and is related to the FAI.

Surgical Assessment
The arthroscopy videos of operative hips were retrieved from the surgical database and reviewed by a senior surgeon who is an expert in hip arthroscopy. The general arthroscopic findings and procedure of subspine decompression were determined. The correlation of subspine decompression to AIIS variations and subspine hypertrophy was analyzed.

Subspine Decompression
The acetabular rim and subspine region were exposed to discover the prominent AIIS and subspine hypertrophy. Arthroscopic subspine decompression was a procedure performed following identification of labral tear to address the subspine deformity related to subspine impingement. Subspine decompression was determined with the trimming on the acetabular rim extended to the subspine region and achieved a broad subspine space, which also provides a flat bone base for labral refixation (Fig. 6).

Statistical Analysis
All statistical analyses were performed on SPSS 22.0 (SPSS Inc., Chicago, IL, USA). Categorical variables were presented as numbers and frequencies, and the data of continuous variables presented as means ± standard deviation. Interobserver repeatability was analyzed using Cohen's Kappa, weighted Kappa, or intraclass correlation efficient (ICC). For the comparison of the radiological measurements between symptomatic hips and asymptomatic hips, paired t-test was used for continuous data including α angle, LCEA, acetabular anteversion, and chi-square test was used for categorical variables including Tonnis grade, COS, AIIS variation, and subspine hypertrophy. Correlations of subspine decompression to subspinal hypertrophy and AIIS variations were analyzed using Spearman's correlation. Statistical significance was set to $P \leq 0.05$.

Results

General Results
Out of 70 patients with unilateral symptomatic FAI who got reviewed in this study, 37 are males (52.9%) and 23 (32.9%) had symptomatic involvement of the left hip. The mean age of this group was 39.3 ± 10.4 years and the mean BMI was 24.3 ± 3.6. Seventy operative hips with symptomatic FAI contained 33 (47.1%) cam-type, 12 (17.2%) pincer-type, and 25 (35.7%) mixed-type deformities (Table 1).

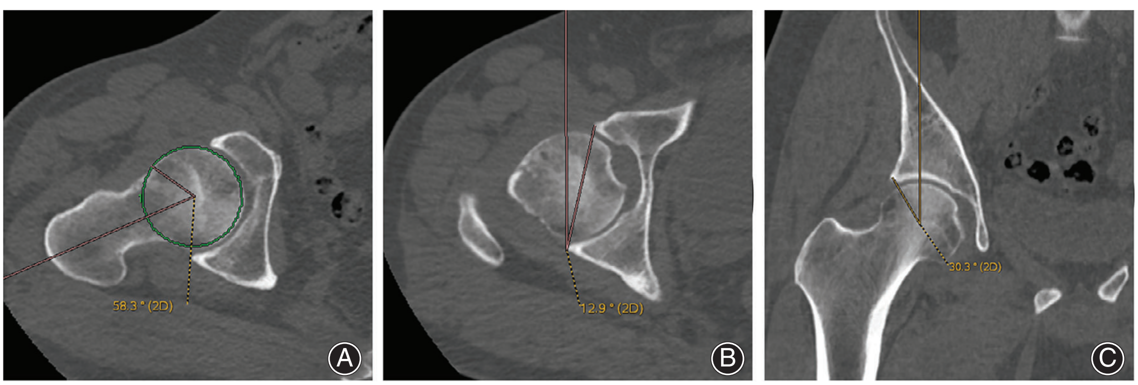

Fig. 5 FAI-related morphological measurements on reformatted 2D-CT. The α angle is measured in the plane of the maximum oblique axis (A); acetabular anteversion was measured in the plane of the maximal axis (B); the lateral central marginal angle is determined on the coronal plane where the acetabulum meets its deepest point (C).

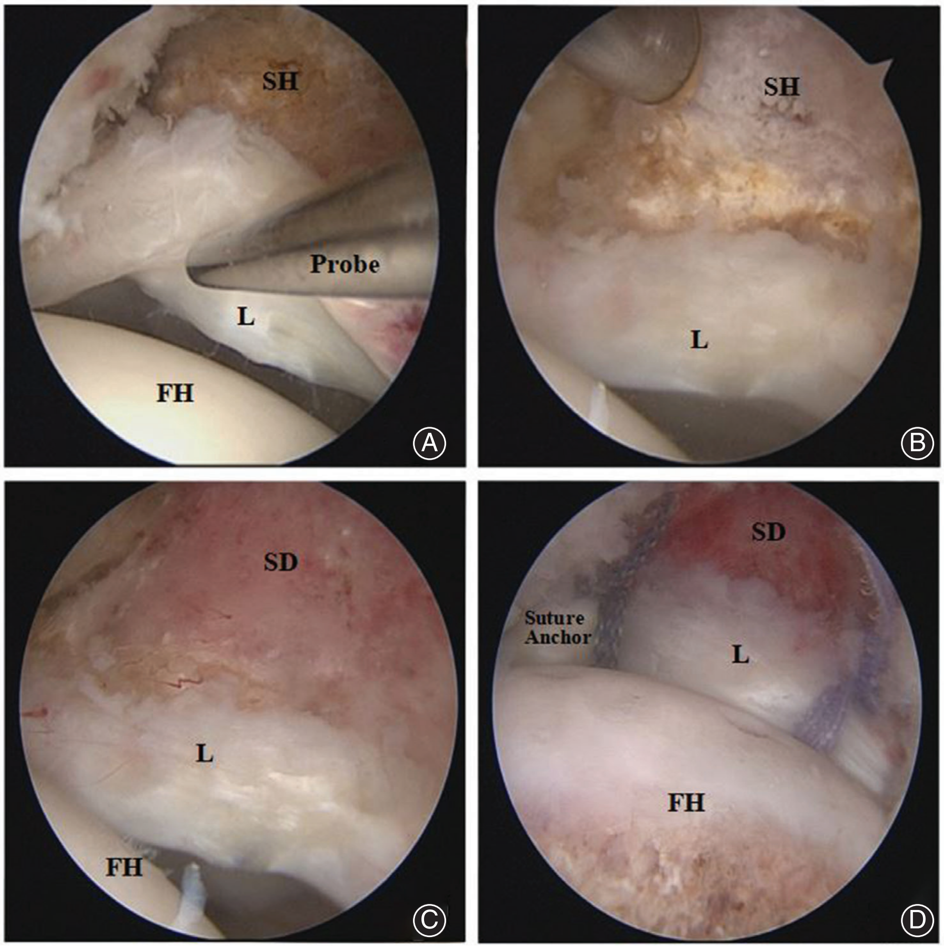

Fig. 6 Arthroscopic findings and procedures of management for subspine impingement. (L = labrum; FH = femoral head; SH = subspine hypertrophy; SD = subspine decompression). (A) Prolapsed labrum was found in the corresponding segment below AIIS. (B) Subspine hypertrophic deformity was identified after exploration in the subspine region. (C) Subspine decompression was performed to get a flat and broad subspine space. (D) Torn labrum was reattached with suture anchors.

TABLE 1 Patient demographics

Demographics	Number (%)/mean ± SD
Age at surgery (years)	39.3 ± 10.4
BMI (kg/m^2)	24.3 ± 3.6
Sex	
Male	37 (52.9)
Female	33 (47.1)
Side of surgery	
Left	23 (32.9)
Right	47 (67.1)
FAI pattern of operative hip	
Cam type	33 (47.1)
Pincer type	12 (17.2)
Mixed type	25 (35.7)

Data are expressed as mean ± SD and number (percentage).

The interobserver agreement for the assessment of FAI morphometric measurement was almost perfect with ICC ranging from 0.91 (95% *CI* = [0.87; 0.93]) to 0.98 (95% *CI* = [0.976; 0.988]). The interobserver agreement for the assessment of subspine hypertrophy and AIIS variations were almost perfect, with Kappa = 0.88 (95% *CI* = [0.79; 0.96]) and 0.86 (95% *CI* = [0.78; 0.94]) respectively.

Radiological Results

Anterior Inferior Iliac Spine (AIIS) Variation

According to the classification of AIIS variants based on 3D-CT, type I AIIS was present in 20 (28.6%) and 29 hips (41.4%) in the symptomatic and asymptomatic groups, respectively, type II AIIS was present in 44 (62.9%) symptomatic and 38 (54.3%) asymptomatic hips, and type III AIIS was present in six (8.5%) symptomatic and three (4.3%) asymptomatic hips. The distribution of AIIS variants in symptomatic hips did not differ significantly from that in asymptomatic hips ($\chi^2 = 3.092$, $P = 0.213$) (Table 2).

Subspine Hypertrophy

Twenty-nine hips in the symptomatic group (41.4%) and 12 hips in the asymptomatic group (17.1%) were identified as positive for subspinal hypertrophy. The incidence of positive subspinal hypertrophy in the symptomatic hips was 2.4

TABLE 2 Comparison of distribution of AIIS variations

	AIIS variations				
Hips	Type I	Type II	Type III	χ^2	*P*
Symptomatic	20 (28.6)	44 (62.9)	6 (8.5)	3.092	0.213
Asymptomatic	29 (41.4)	38 (54.3)	3 (4.3)		

Data are expressed as number (percentage).

TABLE 3 Comparison of the incidence of subspine hypertrophy

	Subspine hypertrophy			
Hips	Positive	Negative	χ^2	*P*
Symptomatic	29 (41.4)	41 (58.6)	9.968	0.002
Asymptomatic	12 (17.1)	58 (82.9)		

Data are expressed as number (percentage).

time higher compared to the asymptomatic hips ($\chi^2 = 9.968$, $P = 0.002$). (Table 3).

α Angle

The mean alpha angles were 57.3° ± 9.4° and 55.5° ± 6.0° for symptomatic and asymptomatic hips, respectively ($P = 0.120$).

Acetabular Anteversion Angle (AAA)

The mean acetabular anteversion angles for symptomatic and asymptomatic hips were 16.9° ± 3.8° and 16.3° ± 5.6°, respectively ($P = 0.380$).

Lateral Center-Edge Angle (LCEA)

The mean lateral center-edge angle for symptomatic and asymptomatic hips were 34.8° ± 6.5° and 34.0° ± 7.4°, respectively ($P = 0.268$).

Crossover Sign (COS)

There are 19 hips and 13 hips with a positive crossover sign in the symptomatic and asymptomatic groups, respectively. There was no significant difference in the incidence of positive crossover sign between the two groups ($\chi^2 = 1.458$, $P = 0.227$).

Tonnis Grade

There were no hips with Tonnis grade ≥2 in this cohort, and 21 (30.0%) symptomatic and 15 (21.4%) asymptomatic hips were identified as Tonnis grade 1. There was no significant difference in Tonnis grade of osteoarthritis between the two groups ($\chi^2 = 1.346$, $P = 0.246$).

The results of FAI-related morphologic measurements were shown in Table 4.

Surgical Result

General Arthroscopic Findings

Labral tears were found in all hips that underwent hip arthroscopy, and in 54 of 70 hips (77.1%) the labral tears extended to the acetabular rim corresponding to the AIIS. Labral debridement was performed in 16 cases, and labral refixation and reconstruction were performed in 52 and two cases, respectively.

Subspine Decompression

There were 47 hips (67.1%) with subspinal decompressions identified. The procedure of subspinal decompression was significantly correlated with AIIS variation and subspinal hypertrophy. Spearman correlation coefficients were 0.280 and 0.393, respectively ($P = 0.019$ and 0.001, respectively) (Table 5).

Discussion

The main findings of this study in patients with unilateral symptomatic FAI are as follows: (i) symptomatic hips had a higher incidence of subspinal hypertrophy compared with asymptomatic hips; (ii) FAI morphometric measurements did not show a significant difference between symptomatic hips and contralateral asymptomatic hips, and (iii) arthroscopic subspinal decompression may be associated with AIIS variation and subspinal hypertrophy.

"Side-to-Side" FAI Morphometric Measurements

The appearance of symptomatic FAI is thought to be a multifactorial outcome based on congenital bone abnormalities, and abnormal bone morphology may be the main cause of symptomatic differences[18]. The α angle, LCEA, crossover sign, and acetabular anteversion have been considered as the well-recognized and most commonly used radiological parameters for the evaluation of FAI. In the present study, we found a high symmetry of FAI-related morphological parameters in patients with FAI, which is consistent with previous reports[19,20]. The presence of bilateral symmetrical hip deformities was rational because FAI was considered to be a congenital and developmental pathological condition.

The bilateral hip joints of one patient develop with the same genetic factors and in a similar mechanical environment (e.g. body weight and sports). Although no statistical difference in FAI morphometric measurements was found, we could not ignore the trend that symptomatic hips have a larger mean of α angle and higher incidence of COS than asymptomatic hips. The kinematics of the pelvic-hip complex could have an influence on the development of symptomatic FAI. Fader *et al.*[21] found that pelvic and lumbar deformities may contribute to symptomatic differences between symptomatic FAI and asymptomatic FAI. In the current study, the side-to-side comparison in the same patient between symptomatic and asymptomatic hip eliminated the influence of pelvic kinematics on hip symptoms to some extent. The result of the current study implies that latent morphological deformity addition to the FAI deformity could participate in the development of symptoms in patients with FAI.

Subspine Impingement and Femoroacetabular Impingement

Subspine impingement was an under-recognized pathologic condition that could contribute to the development of symptoms in FAI patients. Nwachukwu[22] found isolated subspine impingement could result in labral injury and hip disability, even in the absence of known FAI morphology. SSI has been recognized as one of the potential causes for poor outcomes after primary hip arthroscopy[14,19]. The revision hip arthroscopy with subspine decompression has been considered as an effective procedure for symptomatic improvement[20]. The high incidence of SSI coexisting in patients with FAI has been previously underestimated due to the relatively new definition of SSI and the high similarity between SSI and focal pincer FAI in terms of pathological mechanisms and clinical symptoms[12,13]. Therefore, the preoperative recognition and diagnosis of SSI were important to perform hip arthroscopy for FAI. However, it is challenged for the surgeons because the clinical manifestations of SSI have a high degree of similarity to those of traditional FAI and overlap with them. Recently, the variation of the morphology of AIIS has been considered as the related factor of SSI, and the radiological assessment has been highlighted in the preoperative evaluation of AIIS morphology.

TABLE 4 Comparison of FAI-related morphologic measurements

Parameters	Symptomatic hip	Asymptomatic hip	*P*
α angle (°)	57.3 ± 9.4	55.5 ± 6.0	0.120
AAA (°)	16.9 ± 3.8	16.3 ± 5.5	0.380
LCEA (°)	34.8 ± 6.5	34.0 ± 7.4	0.268
COS	19 (27.1)*	13 (18.6)*	0.227
Tonnis grade	21 (30.0)†	15 (21.4)†	0.246

Data are expressed as mean ± SD and number (percentage). AAA, acetabular anteversion angle; COS, crossover sign; LCEA, lateral center-edge angle. * The value shows the number and percentage of cases with positive crossover sign. † The value shows the number and percentage of cases with Tonnis grade 1.

Subspine Impingement and Subspine Hypertrophy

The classical AIIS variations was 3D-CT-based and proposed by Hetsroni[15], which depends on the determination of the relative location of AIIS to the acetabular rim. However, in many cases, it is hard to outline the caudal of AIIS and clearly separate it from the acetabular rim. As a result, only fair to moderate interobserver agreements could be achieved in the previous reports[16,21]. Although Hetsroni considered low-lying AIIS has a high relation to SSI, the pathomechanism of SSI was still controversial. Wong *et al.*[23] found no difference in AIIS morphology with symptomatic hips *vs* asymptomatic hip, which indicates that the low-lying AIIS is not the only risk factor for subspine impingement. Carton[11] has noticed the morphology of the subspine region and proposed an arthroscopic classification of subspine hypertrophy. In the current study, we found a higher occurrence of subspine hypertrophy in symptomatic FAI hips compared to the asymptomatic FAI hips, which provided a new perspective to understand the divergence of symptoms in patients with FAI. One typical case showed symmetrical FAI deformity on bilateral hips and the difference in morphology of AIIS and subspine region (Fig. 7). Subspine region has not been well-described and is usually ignored, but it is an important anatomical structure. The AIIS and subspine region provide attachment for the direct head of the rectus femoris and the iliofemoral ligament. A broad subspine space could provide a buffering space to avoid the squeezing of the labrum. On the contrary, subspine hypertrophy could aggravate the crowding of subspine space and subsequently make the impingement

TABLE 5 Correlation of subspine decompression with AIIS variation and subspinal hypertrophy

	AIIS variation				Subspine hypertrophy		
Subspine decompression	Type I	Type II	Type III	*r*	Positive	Negative	*r*
Yes	8	33	6	0.280*	24	23	0.393*
No	12	11	0		5	18	

Data are expressed as number. * $P < 0.05$.

Fig. 7 Pelvic 3D-CT image of a 43-year-old male patient with symptomatic FAI-involved left hip. Symmetrical cam deformity (narrow arrow) and acetabular coverage could be seen on bilateral hips (A), but the morphology of AIIS and subspine region was different, with head-on AIIS view of the right hip (B) showing a type II AIIS without subspine hypertrophy (white bolded arrow), and head-on AIIS view of the left hip (C) showing a type I AIIS with subspine hypertrophy (red bolded arrow).

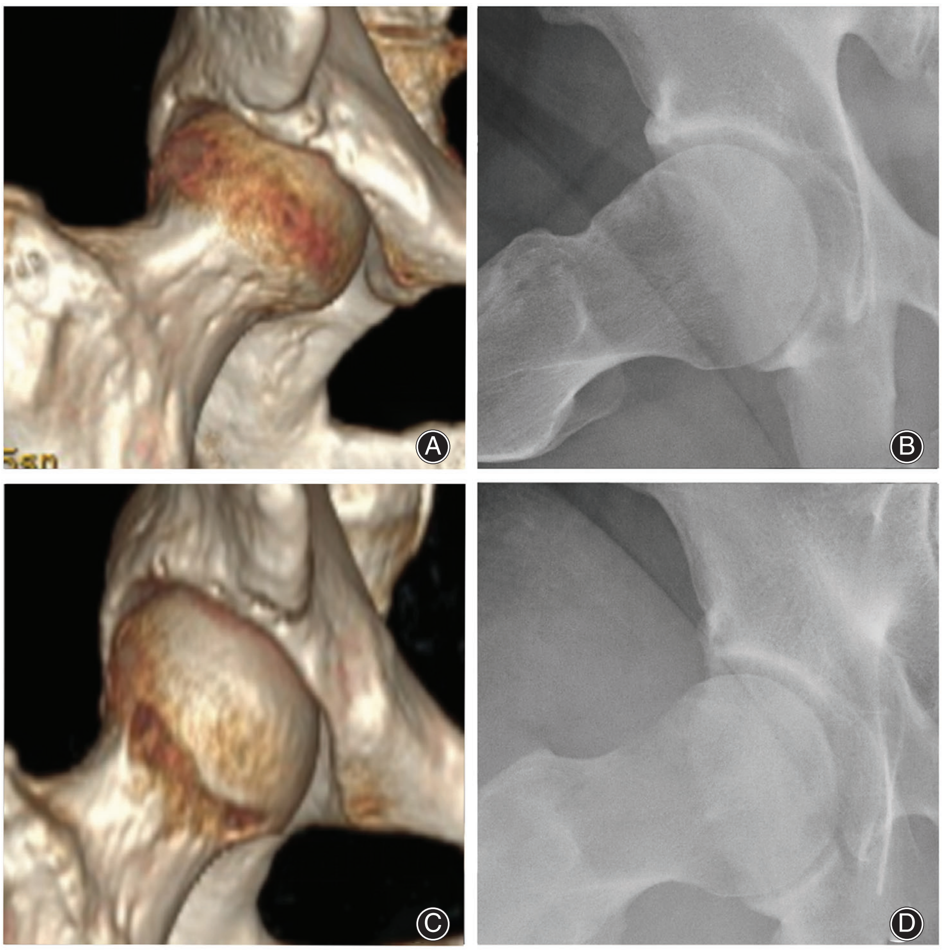

Fig. 8 Radiographic images of a typical case, including preoperative 3D-CT showing a subspinous hypertrophic deformity (A), preoperative plain film showing a cam lesion and subspinous hypertrophy (B), and postoperative 3D-CT (C) and plain film (D) after subspinous decompression and cam-plasty.

more serious. What causes the subspine hypertrophy has not been investigated clearly and it may be initiated by repeated strain placed across the attachment of the anterior hip capsule and/or the ossification following chondrolabral pathology[11].

Subspine Decompression and Subspine Hypertrophy

Hip arthroscopy could provide a definitive diagnosis for patients suspected of having SSI. Arthroscopic subspine exploration usually starts from the capsular attachment of the labrum and extends to the origin of the iliofemoral ligament. We found that 52 of the 70 patients had labral tears in the segment of the acetabulum corresponding to the AIIS. A protruding bony structure in the subspinal region extruding the prolapsed labrum can usually be found, which can be identified as an arthroscopic finding of subspinal impingement. Arthroscopic subspinal decompression has been proven to be a safe and effective treatment for SSI[20,24–26]. However, there is no consensus on the indications for subspinal decompression. Hetsroni[15] suggested that low-lying (type II and III) AIIS should be considered as an indicator for subspine decompression. Nawabi[24] suggested that the subspine morphology should be taken into consideration before making a decision to perform AIIS decompression. Aguilera-Bohórquez[12] suggested 3D motion analysis might be an aid to the dynamical understanding of AIIS impingement and determine the procedure. In the current study, out of 47 patients who underwent subspine decompression, 29 cases had subspine hypertrophy, and 39 had low-lying AIIS (type II and III). The correlation analysis shows both subspine hypertrophy and AIIS variation were associated with subspinal decompression, and the correlation coefficients of subspine hypertrophy are higher. It indicates that the SSI could be a common condition that coexists with FAI, and subspine hypertrophy should be recognized as a feature of SSI besides low-lying AIIS. Although the morphologic feature of AIIS and subspine region was recognized, we still insist that the diagnosis and management of subspine impingement should be based on physical examination, radiological assessments, and arthroscopic examination exploring of the subspine region. In a typical case of FAI, preoperative radiographs revealed a subspinal hypertrophic deformity and cam lesion, which was addressed by arthroscopic subspinal decompression and cam-plasty (Fig. 8).

Limitation

There are limitations to this study. First, although FAI morphometric measurements have been assessed in this study, the parameters were not comprehensive, e.g. the FAI pattern in asymptomatic hips was not determined, and the femoral anteversion was absent because our CT data only contains the pelvic scan. Therefore, we could not conclude that the morphology of FAI is totally symmetrical. Second, although the experienced surgeon who reviewed surgical videos was invited from another institute and blinded to the medical information of patients, we cannot completely avoid subjective factors involved. Third, subspine hypertrophy is a relatively new definition, and we just state its morphological feature but do not make a systematic investigation in its relation to the classical AIIS classification. Further research on AIIS and the subspine region could improve the limitations of the current research.

Conclusion

Subspine hypertrophic deformity was found to be more common in symptomatic side *vs* asymptomatic side in patients with unilateral symptomatic femoroacetabular impingement. Subspine hypertrophy may be considered as an underlying indication for subspine decompression besides low-lying AIIS.

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