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HIP

How frequent is absolute femoral retroversion in symptomatic patients with cam- and pincer-type femoroacetabular impingement?

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Aims

The frequency of severe femoral retroversion is unclear in patients with femoroacetabular impingement (FAI). This study aimed to investigate mean femoral version (FV), the frequency of absolute femoral retroversion, and the combination of decreased FV and acetabular retroversion (AR) in symptomatic patients with FAI subtypes.

Methods

A retrospective institutional review board-approved observational study was performed with 333 symptomatic patients (384 hips) with hip pain due to FAI evaluated for hip preservation surgery. Overall, 142 patients (165 hips) had cam-type FAI, while 118 patients (137 hips) had mixed-type FAI. The allocation to each subgroup was based on reference values calculated on anteroposterior radiographs. CT/MRI-based measurement of FV (Murphy method) and AV were retrospectively compared among five FAI subgroups. Frequency of decreased FV < 10°, severely decreased FV < 5°, and absolute femoral retroversion (FV < 0°) was analyzed.

Results

A significantly ($p < 0.001$) lower mean FV was found in patients with cam-type FAI (15° (SD 10°)), and in patients with mixed-type FAI (17° (SD 11°)) compared to severe over-coverage (20° (SD 12°). Frequency of decreased FV < 10° was significantly ($p < 0.001$) higher in patients with cam-type FAI (28%, 46 hips) and in patients with over-coverage (29%, 11 hips) compared to severe over-coverage (12%, 5 hips). Absolute femoral retroversion (FV < 0°) was found in 13% (5 hips) of patients with over-coverage, 6% (10 hips) of patients with cam-type FAI, and 5% (7 hips) of patients with mixed-type FAI. The frequency of decreased FV< 10° combined with acetabular retroversion (AV < 10°) was 6% (8 hips) in patients with mixed-type FAI and 5% (20 hips) in all FAI patients. Of patients with over-coverage, 11% (4 hips) had decreased FV < 10° combined with acetabular retroversion (AV < 10°).

Conclusion

Patients with cam-type FAI had a considerable proportion (28%) of decreased FV < 10° and 6% had absolute femoral retroversion (FV < 0°), even more for patients with pincer-type FAI due to over-coverage (29% and 13%). This could be important for patients evaluated for open hip preservation surgery or hip arthroscopy, and each patient requires careful personalized evaluation.

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Introduction

Young patients with femoral retroversion typically present with decreased internal rotation (IR) and with anterior hip pain due to femoroacetabular impingement (FAI) conflict.[1] Previous studies reported that a cam-deformity reduces IR of the hip, typically assessed in 90° of flexion.[1,2] Femoral retroversion also decreases IR,[3-5] and thus theoretically can lead to anterior FAI as well. Before the description of FAI, Tönnis et al[3] investigated abnormalities of femoral version (FV). Femoral retroversion was described by Tönnis and Heinecke[6] in 1991 as diminished femoral antetorsion syndrome, when they observed that patients with hip pain and early signs of osteoarthritis (OA) had femoral retroversion, and exhibited decreased IR of the hip joint.[3,6] However, no biomechanical explanation for this observation was given. More recently, an important contribution of FV and acetabular version (AV) on hip range of motion was reported.[5,7] Femoral retroversion can lead to an extra-articular conflict between the proximal femur and the anterior-inferior iliac spine (AIIS) in patients who have undergone total hip arthroplasty.[8] In patients with FAI, femoral retroversion was associated with combined anterior intra-articular and extra-articular subspine hip impingement.[9]

To date, the treatment of patients with FAI and femoral retroversion remains controversial, as some authors have reported that the amount of FV does not affect the clinical outcomes after hip arthroscopy for FAI.[10] On the other hand, severe femoral retroversion (previously called excessive femoral retroversion)[3] has been found to be a risk factor for poor outcomes after hip arthroscopy for FAI.[11] Surgical therapy of FAI has evolved over time, and was initially performed without consideration of FV or femoral retroversion.[2,12] In 2015, the effect of FV was investigated for patients who underwent hip arthroscopy,[11] but only a few studies investigated the effect of FV thereafter.[4,5,7] However, it could be shown that both increased and decreased FV can significantly impair the patient-related outcomes after hip arthroscopy for FAI.[11] Recently, decreased FV has been identified as a factor associated with revision surgery after hip arthroscopy at two-year follow-up.[13] Variations in FV are becoming increasingly recognized as contributing factors to the development of hip pain in patients with FAI.[14] However, two recent systematic reviews investigated the influence of FV for the outcome of hip arthroscopy,[15,16] and they reported that patients with normal FV and patients with femoral retroversion (FV < 5°) exhibited similar outcome scores, and similar failure rates at short-term follow-up.[15]

Another recent systematic review reported a frequency of abnormal FV of 51% in patients with symptomatic FAI.[17] In all the evaluated studies, they found a mean FV in the normal range (10° to 25°). For patients with cam-type FAI, they reported a frequency of femoral retroversion (FV < 10°) of up to 42%.[17] However, different measurement methods of FV exist,[18] and different definitions of femoral retroversion add confusion.[10,11]

So far, the frequency of severe or absolute femoral retroversion (FV < 0°) of patients with cam-type FAI is unclear. It is also unclear if these patients are associated with combined abnormalities of FV and AV.

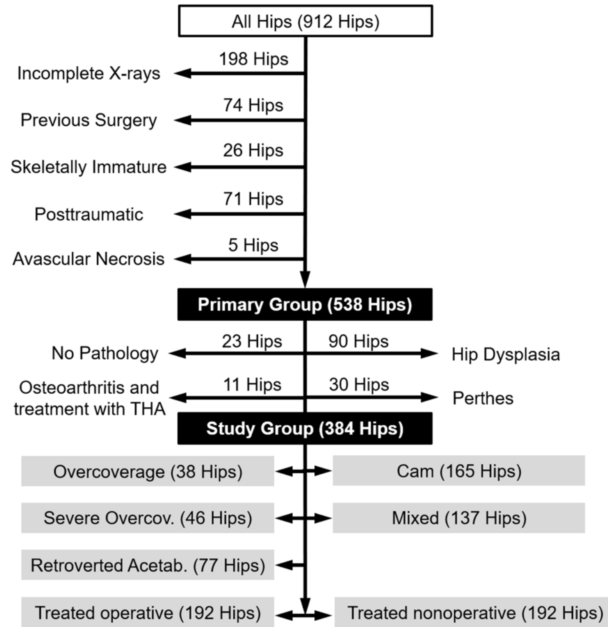

Fig. 1

Inclusion and exclusion criteria are shown. The patients (hips) in the mixed-type femoracetabular impingement group can overlap with the other subgroups. THA, total hip arthroplasty.

This study aimed to investigate mean FV, the frequency of decreased FV and absolute femoral retroversion, and the combination of femoral retroversion and acetabular retroversion in symptomatic patients with FAI subtypes. We hypothesized that the mean FV and the frequency of absolute femoral retroversion of patients with cam-type FAI is different compared to patients with pincer-type FAI.

Methods

This is an institutional review board (IRB)-approved retrospective observational study of 333 patients (384 hips) seeking to compare abnormalities of FV among different distinguished subgroups of FAI. All symptomatic patients for hip preservation surgery who had been referred to our university hospital over a five-year period (between January 2011 and December 2015) were evaluated. All patients presented with pain at the time of image acquisition. Inclusion criteria included the presence of hip pain, radiological signs of skeletal maturity, no previous surgery of hip joint altering acetabular version and/or FV, no post-traumatic condition, no avascular necrosis of the femoral head, availability of standard plain radiographs, and the availability of either CT or MRI of the pelvis/hip, including the distal femur condyles to allow for measurement of FV,[19] according to the method described by Murphy et al.[20] Out of a total of 462 patients (538 hips), 154 hips were excluded (Figure 1) for the following reasons: hip dysplasia (78 patients (90 hips)), patients with Perthes' disease (25 patients (30 hips)), patients with no obvious pathology (19 patients (23 hips)), and patients with hip OA who were treated with total hip arthroplasty (10 patients (11 hips)). This resulted in a total of 384 hips in 333 patients for inclusion in this study (Supplementary Table i; Figure 1). All patients were part of two previous studies.[14,21]

As part of the routine workup, all patients were clinically evaluated by one of our attending hip surgeons with more than ten years of experience in hip preservation surgery. This included a thorough acquisition of the patient history, a goniometric measurement of the hip range of motion, the evaluation of the anterior and posterior impingement tests,[1] the assessment of hip instability (using the apprehension/Flexion, Abduction and External Rotation tests),[22] and the assessment of abductor strength and general joint laxity. The posterior impingement test was used as a potential indicator for anterior hip instability.[1]

Routine radiological evaluation generally consisted of an anteroposterior (AP) pelvic radiograph taken with a standardized technique,[1] and a cross-table lateral radiograph of the hip. Additional projections or functional views were acquired if needed for diagnosis or surgical planning. The AP pelvic radiograph was then assessed with a previously described and validated computer software (Hip2Norm, University of Bern, Switzerland). This software allows accurate and reliable measurement of eight radiological parameters of the hip, including the assessment of femoral coverage. The α angle was measured as a measure of femoral asphericity on the axial cross-table radiograph. All radiological measurements were performed by two independent observers (TDL and IAST).

Based on the analysis of the conventional radiographs, the patient cohort was subdivided into five different subgroups (Supplementary Table i): 1) cam-type FAI, 2) pincer-type FAI due to over-coverage (lateral centre-edge angle (LCEA) 35° to 39°), 3) pincer-type FAI due to severe over-coverage (LCEA > 39°), 4) pincer FAI due to acetabular retroversion, and 5) mixed-type FAI. The allocation to each group was based on previously published reference values for acetabular and femoral morphology (Supplementary Table i).[3,23,24] A cam-type deformity was defined as an α angle > 50° (Supplementary Table i). Mixed-type FAI was defined as the combination of an α angle > 50° and LCEA between 34° and 39°. Over-coverage was defined as a LCEA between 34° and 39° with an α angle below 50° (Supplementary Table 1). Diagnosis of acetabular retroversion was based on three radiological signs: positive crossover sign[25] and retroversion index > 30%,[26] positive ischial spine sign,[27] and positive posterior wall sign,[25,26] independent from α angle. Half of the 333 patients with FAI underwent surgical treatment (50%) and mean age was 33 years (standard deviation (SD) 12) (Supplementary Table i). Overall, hip arthroscopy and open surgical hip dislocation were most often performed for treatment of these patients. Hip arthroscopy and surgical hip dislocation for cam resection were performed for patients with cam-type FAI, while surgical hip dislocation was mainly performed for patients with severe over-coverage and mixed-type FAI (Supplementary Table ii). Some of the patients with acetabular retroversion underwent anteverting periacetabular osteotomy (PAO, Supplementary Table i). Femoral derotation osteotomy was performed in a minority of patients.

In order to calculate FV and AV, all symptomatic patients either underwent standardized protocol-specific MRI and/or CT of the hip. The use of each of these imaging methods for this purpose has been validated by previous studies that compared the measurement of FV[28] and AV[29] on MRI, and on CT showed comparable results. MR arthrography was obtained according to a standardized technique.[26,30] In brief, the scans were performed using a Siemens TRIO 3.0 T high field scanner (Erlangen, Germany). The patients were positioned supine, and the feet were fixed in a neutral position to prevent motion during scanning. A radial proton density sequence was acquired for evaluation of chondrolabral lesions. Sagittal and coronal proton density-weighted and axial T1-weighted images were acquired, of which the axial slices were used for measurements of FV and AV. A second axial T1-weighted sequence of the femoral condyles was used for measurements of FV.[14,18] These sequences were taken immediately after the original axial T1-weighted sequences, and the patient was instructed not to move the leg to ensure accurate measurement. If needed, CT was acquired according to a previously validated protocol.[9,31] A slice thickness of 2 mm and an interval of reconstruction of 1.7 mm were chosen.

FV was measured according to Murphy et al[20] (Figure 2) by two different independent observers (TDL and FS) using three reference points on transverse slices at different femoral locations: the femoral head centre, the centre of the base of the femoral neck, and the condylar axis. No summation image was used. The method described by Murphy et al[20] is performed by superimposing the centre of the femoral head on the CT section through the base of the femoral neck and showed good interobserver reliability.[14,18] Because of the good reproducibility,[18] and the similarity to the summation image method described by Tönnis and Heinecke,[3] this method was used. Normal FV was 10° to 25° according to Tönnis et al.[3] Definitions used for decreased FV were FV < 10° and FV < 5°, and absolute femoral retroversion was defined as FV < 0°. Other reported normal values for FV ranged from 8° to 18° using various measurement methods.[32–34] Definitions and categories for femoral retroversion or femoral anteversion vary in the orthopaedic literature. Reported thresholds for categorizing

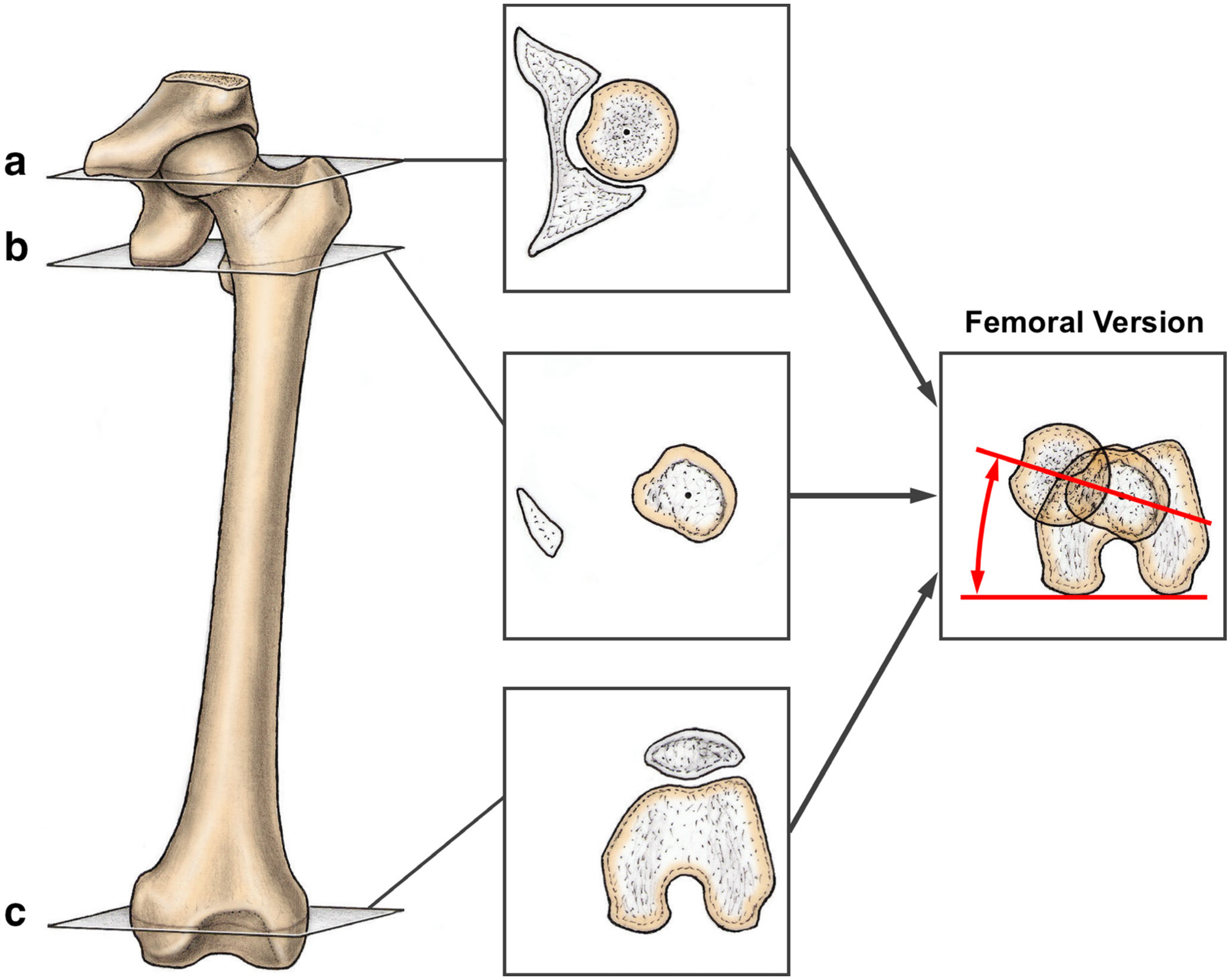

Fig. 2

Measurement of femoral version using the method described by Murphy et al[20] is shown using three axial (transverse) CT or MR images. Femoral version is calculated using a line connecting a) the femoral head centre, b) the base of the femoral neck, and c) the posterior condylar axis of the distal femur. Figure reprinted with permission from Lerch et al.[14]

FV in femoral retroversion were below 25°,[35] below 10°,[3] below 5°,[36] and below 0°.[32]

Central AV was measured on three o'clock (equator level) according to Hetsroni et al[37] and was defined as the angle between a sagittal line and a line connecting the anterior and posterior acetabular rim. A normal central AV and FV was defined from 10 to 25°. Acetabular retroversion was defined as AV < 10°. Increased AV was characterized as AV > 25° and the frequency of subgroups was calculated. Abnormal AV was defined as AV < 10° or > 25°.

Two different observers (TDL and FS) with three years of experience in musculoskeletal radiology measured FV and AV independently at two different timepoints on a random sample of 50 hips taken from our patient cohort. A good agreement (defined as interclass correlation coefficient (ICC) > 0.8 was found for both reproducibility and reliability of FV (intraobserver ICC of Observer 1 of 0.93, ranging from 0.87 to 0.96 and intraobserver ICC of Observer 2 of 0.97, ranging from 0.95 to 0.98).[38] A substantial agreement (defined as ICC > 0.6)[38] was found for reproducibility and reliability of central AV (ICC of Observer 1 0.8 ranging from 0.65 to 0.89 and ICC of Observer 2 of 0.78 ranging from 0.61 to 0.87). Interobserver agreement for FV was 0.96 (0.94 to 0.97) and for AV was 0.75 (0.620.83).

Statistical analysis. A power analysis and sample size calculation for FV in a fixed effect, one-way analysis of variance (ANOVA) design with a level of significance of 1%, β error of 5%, given previously reported mean values of femoral version of 13° in volunteers, 10° in 33 cam-type hips, 18° in ten pincer hips, and a published standard

Table I. Results of mean femoral version and acetabular version for subgroups and sex differences.

Parameter	Overall study group	Over-coverage	Severe over-coverage	Acetabular retroversion	Cam-type FAI	Mixed-type FAI
Number of hips (patients)	384 (333)	38 (33)	46 (41)	77 (65)	165 (142)	137 (118)
Mean femoral version, ° (SD; range)	16 (11; -16 to 58)	17 (14; -16 to 58)	20 (12; -12 to 47)	16 (11; -4 to 48)*	15 (10; -15 to 55)*	17 (11; -13 to 46)*
Mean femoral version females, ° (SD; range)	20 (12; -16 to 58)	18 (16; -16 to 58)	22 (11; -2 to 47)	19 (12; -3 to 48)	20 (10; -4 to 55)	18 (12; -8 to 46)
Mean femoral version males, ° (SD; range)	13 (9; -15 to 35)	14 (10; -1 to 29)	15 (11; -12 to 29)	13 (8; -4 to 35)	12 (9; -15 to 34)	15 (10; -13 to 35)
Mean central acetabular version, three o'clock version, ° (SD; range)	18 (7; -1 to 38)	20 (5; 5 to 29)	19 (7; 6 to 35)	13 (6; -1 to 26)*	19 (6; 2 to 33)	16 (7; -1 to 33)

Level of significance was adjusted with a Bonferroni correction for five groups (0.05/5 = 0.01).
*Significant difference compared to severe over-coverage ($p < 0.001$).
FAI, femoroacetabular impingement; SD, standard deviation.

Table II. Results of the prevalence analysis for normal (10 to 25°) and abnormal (< 10° or > 25°) femoral version, and femoral retroversion < 10° and < 5° and absolute femoral retroversion (FV < 0°).

Prevalence analysis	Overall study group	Over-coverage	Severe over-coverage	Acetabular retroversion	Cam-type FAI	Mixed-type FAI
Decreased FV < 10°	26%	29%*	12%	32%*	28%*	23%*
Decreased FV < 5°	15%	21%	9%	13%	16%	13%
Absolute femoral retroversion (FV < 0°)	6%	13%	5%	3%	6%	5%
Abnormal FV (< 10° or > 25°)	45%	58%*	35%	46%	43%	44%
Normal FV (10 to 25°)	55%	42%*	65%	54%	57%	56%

Level of significance was adjusted with a Bonferroni correction for five groups (0.05/5 = 0.01).
*Significant difference compared to severe overcoverage ($p < 0.001$).
FAI, femoroacetabular impingement; FV, femoral version.

deviation (SD) of 10° was performed.[39] With five groups, this resulted in a total number of 200 patients (40 patients per group). A post-hoc power analysis using the results of FV of the group with cam-type FAI and α of 1% (0.01) showed a power of 97%.[40]

Statistical analysis was performed using Winstat software (R. Fitch Software; Bad Krozingen, Germany). A normal distribution was present for all continuous parameters, which were confirmed using the Kolmogorov-Smirnov test. Continuous variables among the study groups were compared using the univariate ANOVA. Adjustment for multiple comparisons was done with the Bonferroni correction for five groups (0.05/5 = 0.01). A p-value below 0.01 was considered significant. Continuous values for each study group were compared to the normal group using the independent-samples *t*-test. Categorical variables were compared among the study groups and relative to the normal group using the chi-squared test.

Results

A significantly ($p < 0.001$, ANOVA) lower mean FV was found for patients with cam-type FAI (15° (SD 10°) and for patients with mixed-type FAI (17° (SD 11°)) compared to patients with severe over-coverage (20° (SD 12°); Table I). Mean FV of all 333 patients was 16° (SD 11°) (Table I). Mean central AV of all 333 patients was 18° (SD 7°), and patients with acetabular retroversion had a significantly ($p < 0.001$, ANOVA) lower mean central AV of 13° (SD 6°) compared to patients with over-coverage (AV of 20° (SD 5°)).

Frequency of decreased FV < 10° was significantly ($p < 0.001$, chi-squared test) higher in patients with cam-type FAI (28%; Table II), and patients with over-coverage (29%) compared to severe over-coverage group (12%; Figure 3). Patients with over-coverage had slightly higher frequency (13%) of absolute femoral retroversion (FV < 0°) compared to severe over-coverage (5%). Absolute femoral retroversion (FV < 0°) was found in 13% of patients with over-coverage, 6% of patients with cam-type FAI, and 5% of patients with mixed-type FAI (Table II). Frequency of decreased FV < 5° was slightly lower for patients with cam-type FAI (16%) compared to patients with over-coverage (21%; Table II).

The frequency of decreased FV < 10° combined with normal AV was significantly ($p < 0.001$, independent-samples *t*-test) higher in patients with cam-type FAI (21%) compared to severe over-coverage group (9%; Table III). Of the patients with over-coverage, 11% had decreased FV < 10° combined with acetabular retroversion (AV < 10°; Table III). The prevalence of normal FV combined with normal AV was lower of the patients

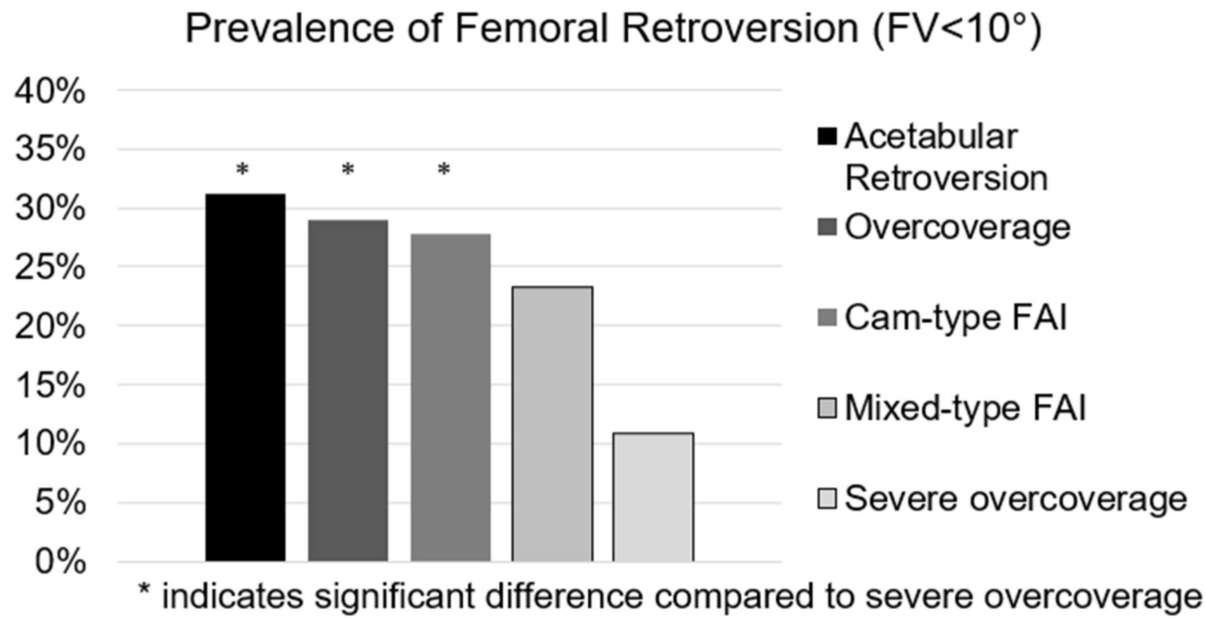

Fig. 3

Frequency of decreased femoral retroversion (FV) < 10° is shown for the five groups of patients with subtypes of femoroacetabular impingement (FAI). A significantly ($p < 0.001$, chi-squared test) higher frequency of decreased FV < 10° was detected for patients with cam-type FAI (28%), and for patients with over-coverage (29%) compared to patients with severe over-coverage (12%).

Table III. Prevalence of combinations of femoral retroversion and acetabular retroversion are displayed.

Combination	Overall prevalence	Over-coverage	Severe over-coverage	Acetabular retroversion	Cam-type FAI	Mixed-type FAI
Normal FV with normal AV	37%	34%	37%	34%	41%	37%
Decreased FV < 10° combined with increased AV	2%	3%	2%	0%	4%	1%
Decreased FV < 10° combined with normal AV	18%	16%	9%	19%*	21%*	17%
Decreased FV < 10° combined with acetabular retroversion	5%	11%	0%	12%	3%	6%

*Significant difference ($p < 0.001$) compared to severe over-coverage group (chi-squared test). Level of significance was adjusted with a Bonferroni correction for five groups (0.05/5 = 0.01).
AV, acetabular version; FAI, femoroacetabular impingement; FV, femoral version.

with over-coverage (34%) and acetabular retroversion (34%), compared to mixed-type FAI (37%; Table III).

Discussion

Most importantly, frequency of decreased FV < 10° was significantly ($p < 0.001$, chi-squared test) higher in patients with cam-type FAI and in patients with over-coverage compared to severe over-coverage (Figure 3). Overall, almost one-third of the FAI patients had decreased FV < 10°, but several combinations were found, and each patient requires a careful personalized evaluation. In addition, a significantly ($p < 0.001$, ANOVA) lower mean FV of the patients with cam-type FAI and mixed-type FAI was found compared to patients with severe over-coverage (Table I). Analyzing combined abnormalities of FV and AV, it was noted that 11% of the patients with over-coverage had decreased FV < 10° combined with acetabular retroversion. Theoretically, these patients could be at risk for anterior intra- and extra-articular hip impingement.[9,41]

FAI is a known cause for hip pain and precursor to hip OA in young patients.[2] Hip arthroscopy is increasingly being used for treatment of FAI, a tremendous increase in hip arthroscopy to treat FAI was reported between 2005 and 2013.[42] While use of hip arthroscopy for treatment of FAI continues to rise, the effect of FV and femoral retroversion is a controversial subject of discussion. Severe femoral retroversion was discussed as a potential contraindication for hip arthroscopy for some hip surgeons,[11] while others reported good patient-reported outcomes after hip arthroscopy for patients with femoral retroversion,[10] and found no difference compared to patients with normal FV.[43] To date, the treatment of patients with FAI and femoral retroversion remains controversial because there is conflicting evidence regarding whether or not the amount of FV affects the clinical outcomes after hip arthroscopy for FAI.[10,11] Absolute femoral retroversion (FV < 0°) was associated with inferior outcomes after periacetabular osteotomy for the treatment of acetabular retroversion.[44] Femoral retroversion was associated with out-toeing of the foot,[45] and with extra-articular subspine hip impingement.[9] Extra-articular subspine impingement was also described for patients with pincer-type FAI due to acetabular retroversion.[41]

Comparing our results with the literature, similar measurements of mean FV in symptomatic FAI patients were found, emphasizing the validity of our results.[39,46–48] These reports are characterized by different definitions for the normal values of FV and a large heterogeneity of measurement techniques and imaging methods. For most of the methods, FV was measured on transverse images,[14] but others used oblique axial images,[10,11] which impairs comparison of their results. The reported frequency of patients with abnormal FV in FAI ranged from 13%[49] to 24%[50] for FV < 5°, and from 15%[50] to 34%[4] for FV > 20°. In comparison to a recent systematic review reporting abnormal FV of up to 51%,[17] a lower prevalence of patients with abnormal FV (45%; Table II) was found. The reason for this discrepancy could be a selection bias of patients evaluated in an university hospital, or different measurement methods used in other studies. The orthopaedic literature remains sparse regarding FAI patients with femoral retroversion,[15] and different definitions of femoral retroversion exist; some authors defined it using FV < 10°,[14] FV < 5°,[11,36] FV < 0°[44] or FV< -2°.[10] Some authors reported a slightly higher frequency of decreased FV < 10° of 27% for patients with mixed-type FAI (compared to 23%; Table II)[36] and others reported a lower prevalence of femoral retroversion of 15%[11] and 9%.[10] Another study found a similar rate of severely decreased FV < 0° (absolute femoral retroversion) of 5% of patients with acetabular retroversion.[44]

It has been reported that quantification of FV depends on the measurement method,[18] rather than on modality (CT or MRI). Differences in FV measurements up to 20° between measurement methods were described.[18] For better generalizability of the results found in the current study, an example was made using a different measurement method for FV: the Reikeras method.[18] For instance, if FV below -9° is measured with the Reikeras method, this corresponds to FV of 0° measured with the method used in our study, the Murphy method (Figure 2), assuming a difference of 9° according to a recent study.[18] Therefore, a threshold of below -9° or -10° of FV (to avoid false positive results) could be used for absolute femoral retroversion when using the Reikeras method (and 0° of FV for decreased FV or femoral retroversion using this method).[18,51] Interpretation of the results in the current study is based on the Murphy method, and the applied method should be considered when reporting FV. Based on the results of this study, routine measurement of FV and AV could be recommended, in accordance with a previous study analyzing combined abnormalities of FV and AV.[21] Another recent study reported equivalent usage of CT and MRI for measurement of FV,[29] and so these measurements could be made without potential additional radiation exposure.[52]

This study differs from previous reports. Some authors only report the mean values for FV instead of the frequency of abnormal FV,[37,39,53] or report on 3D modelling,[54] which can be misleading. Others do not distinguish among the distinct subgroups of impingement,[37,53] or report on cadaveric femurs.[55] Furthemore, the reports before the year 2000 typically do not involve an assessment of particular features related to FAI such as cam-type deformities.[3] In contrast, the current analysis of FV and AV evaluated five subgroups of symptomatic FAI patients.

This study does, however, have limitations. First, it does not represent a cross-sectional analysis despite the large number of patients. Although this is a consecutive patient series, it rather should be interpreted as a selective patient group from a European university hospital, which could include a higher percentage of abnormal values compared to the general population. There could be a potential selection bias of complex patients with limited generalizability. Second, no investigation of detailed patient-specific outcomes or clinical follow-up was performed, because this was not the aim of our study. Therefore, no conclusion regarding clinical outcome should be drawn. However, all patients were symptomatic at the time of imaging. Of the 333 patients with symptomatic FAI, 50% underwent surgical treatment. The results of this study apply to patients with FAI only, and not to patients with hip dysplasia or hip instability,[56] because patients with hip dysplasia were excluded (Figure 1). Another limitation is that spinopelvic parameters were not evaluated,[57] and no 3D or 4D information was available for these patients.[52]

In addition, the age of the FAI patients ranged from 14 to 71 years (Supplementary Table i). This might be problematic because FV reportedly decreases in the first two decades of life before closure of the growth plates.[3,6,58] In accordance with previous reports,[59,60] there are no substantial age-dependent changes of FV after skeletal maturity is reached.[58] Patients with skeletal immaturity were excluded (Figure 1), and this should not affect the results of this study.

In conclusion, patients with cam-type FAI had a considerable frequency (28%) of decreased FV < 10°, and 6% had absolute femoral retroversion (FV < 0°), even more for patients with pincer-type FAI due to overcoverage (29% and 13%). This could be important for patients evaluated for open hip preservation surgery or hip arthroscopy, and each patient requires careful personalized evaluation.

Take home message

- Decreased femoral version < 10° is prevalent in almost one-third of the patients with cam-type femoroacetabular impingement (FAI) and pincer-type FAI caused by over-coverage.
- A higher prevalence of absolute femoral retroversion was found in patients with pincer-type FAI due to over-coverage compared to patients with cam-type FAI.
- Decreased femoral version < 10° combined with acetabular retroversion was prevalent in 11% of patients with over-coverage and 6% of patients with mixed-type FAI.

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Supplementary material

Tables containing definition of the study groups and detailed radiological parameters.

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