Clinically Significant Outcome Improvement After Hip Arthroscopy in Patients With Femoroacetabular Impingement Syndrome and Severe Femoral Torsion

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Background: The influence of femoral torsion on clinically significant outcome improvement after hip arthroscopy for femoroacetabular impingement syndrome (FAIS) has not been well-studied.

Purpose: To quantify femoral torsion in FAIS patients using magnetic resonance imaging (MRI) and explore the relationship between femoral torsion and clinically significant outcome improvement after hip arthroscopy.

Study Design: Cohort study; Level of evidence, 3.

Methods: Included were patients who underwent hip arthroscopy for FAIS between January 2012 and August 2018 and had 2-year follow-up and preoperative MRI scans containing transcondylar slices of the knee. Participants were categorized as having severe retrotorsion (SR; $<0^\circ$), normal torsion (NT; 0°-25°), and severe antetorsion (SA; $>25^\circ$) as measured on MRI. Patient-reported outcomes (PROs) included the Hip Outcome Score–Activities of Daily Living, Hip Outcome Score–Sports Subscale, modified Harris Hip Score, 12-item International Hip Outcome Tool (iHOT-12), and visual analog scale (VAS) for pain and satisfaction. Achievement of Patient Acceptable Symptom State (PASS) and substantial clinical benefit (SCB) were analyzed among cohorts.

Results: Included were 183 patients (SR, n = 13; NT, n = 154; SA, n = 16) with a mean age, body mass index, and femoral torsion of 30.6 ± 12.1 years, 24.0 ± 4.4 kg/m^2, and $12.55^\circ \pm 9.58^\circ$, respectively. The mean torsion was $-4.5^\circ \pm 2.6^\circ$ for the SR, $12.1^\circ \pm 6.8^\circ$ for the NT, and $31.0^\circ \pm 3.6^\circ$ for the SA group. There were between-group differences in the proportion of patients who achieved PASS and SCB on the iHOT-12, pain VAS, and any PRO ($P < .05$). Post hoc analysis indicated that the SA group achieved lower rates of PASS and SCB on the iHOT-12 and pain VAS, and lower rates of PASS on any PRO versus the SR group ($P < .05$); the SR group achieved higher rates of PASS and SCB on pain VAS scores versus the NT group ($P = .003$).

Conclusion: The orientation and severity of femoral torsion during hip arthroscopy influenced the propensity for clinically significant outcome improvement. Specifically, patients with femoral retrotorsion and femoral antetorsion had higher and lower rates of clinically significant outcome improvement, respectively.

Keywords: femoral torsion; hip arthroscopy; femoroacetabular impingement syndrome; magnetic resonance imaging; PASS; Patient Acceptable Symptom State; SCB; substantial clinical benefit

Variations in femoral torsion can have long-term implications on the development of osteoarthritis[44] as well as short-term implications on outcome after arthroscopic management of femoroacetabular impingement (FAI). Femoral retrotorsion is less commonly cited as a cause of chronic hip pain; however, it has been noted to affect gait patterns, resulting in an out-toeing gait, which may affect joints in the distal extremity.[8] It has been widely proven, however, that variations in femoral torsion can affect the motion of the hip joint and have subsequent effects on the dynamic stabilizers of the hip.[11,25] Further, it has been demonstrated that femoral torsion abnormalities outweigh the effect of cam impingement on hip internal rotation. Specifically, patients with femoral antetorsion have reduced hip internal rotation at 90° of hip flexion.[28] While torsion varies with age, it is generally accepted that the average femoral torsion is between 8° and 14° in adults, with normal ranges cited between 0° and 25°.[14] Femoral derotational osteotomy may be indicated for patients who exhibit excessive antetorsion or retrotorsion. While the indications for this

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procedure are variable, the goal is typically to create approximately 15° of antetorsion.[36]

It stands to reason that excess torsion may play a role in the development of symptomatic FAI syndrome (FAIS), given the natural progression of pathologic changes within the hip. However, this is debated, and the impact of torsion on FAIS has not been elucidated. It has been argued that excessive retrotorsion may be a contraindication to cam resection, given that this resection may not lead to much improvement in internal rotation, as the zone of conflict between the femur and acetabulum is further distal.[29] To the contrary, there is a paucity of literature examining the impact of excessive antetorsion on patient-reported outcomes (PROs) after FAIS. Furthermore, indications for femoral derotational osteotomy in the setting of FAIS with or without hip arthroscopy and its associated sequela are poorly understood.

Measurements of patient lower extremity torsion can take place as part of the routine workup of hip pain. Magnetic resonance imaging (MRI) is the gold standard in the evaluation of labral tears of the hip when indicating patients with FAIS for surgery. Additionally, MRI has been found to be reliable and reproducible when compared with computed tomography (CT) in assessing femoral torsion.[43] Given that MRI is obtained as part of the routine workup of patients with FAIS who may require surgery, MRI can provide assessment of torsion in this setting without added cost to the patients.

The purpose of this study was to utilize a large cohort of prospectively collected patient-reported data to retrospectively review the effects of femoral torsion on 2-year PROs after arthroscopic surgery for FAIS to determine the propensity for clinically significant improvement stratified by femoral torsion. We hypothesized that a large proportion of our cohort would have a normal femoral torsion and that patients with excessive antetorsion or excessive retrotorsion would have similar outcomes with regard to achievement of Patient Acceptable Symptom State (PASS) and substantial clinical benefit (SCB).[23]

METHODS

Patient Selection

Institutional review board approval was granted to prospectively collect and retrospectively analyze clinical outcomes and imaging of patients who underwent hip arthroscopy for FAIS by the senior author (S.J.N.) between January 2012 and August 2018. Inclusion criteria were all patients with a clinical and radiographic diagnosis of symptomatic FAIS, failure of nonoperative management (physical therapy, oral anti-inflammatories, and/or intra-articular steroid injection), minimum 2-year follow-up, and MRI containing the pelvis and transcondylar slices of the knee. Exclusion criteria were as follows: patients undergoing revision hip surgery; those with Tönnis grade >1 osteoarthritis, developmental hip disorders (Legg-Calvé-Perthes disease or slipped capital femoral epiphysis), or moderate/severe hip dysplasia (lateral center-edge angle, <20°); and those undergoing concomitant gluteus medius or minimus repair. Patients with mild/borderline hip dysplasia (lateral center-edge angle, 20°-25°) were included.

Of the 2638 consecutive patients who underwent hip arthroscopy during the study period, 241 patients had MRI scans that allowed for measurement of femoral torsion. There are multiple reasons that a minority of potentially eligible patients had adequate MRI to assess femoral torsion. First, the senior author has traditionally used CT to assess femoral torsion. With recent advances in MRI, in combination with an effort to minimize additional radiation exposure in a young patient cohort, the senior author has gradually transitioned to MRI scans to assess hip morphologic characteristics. While many patients had CT imaging that would allow for measurement of femoral torsion, the literature has demonstrated that there may be differences in torsion measured on MRI and CT.[2] Therefore, only patients with MRI scans were included in this study. In addition, the senior author specializes in the treatment of FAIS, and many patients are referred to the clinic for evaluation with prior imaging obtained from an outside facility. The relationship between femoral torsion and outcomes after hip arthroscopy is an emerging topic. Although the senior author now includes knee imaging for all patients undergoing hip arthroscopy, many referring physicians have not adopted this practice.

Surgical Technique

All hip arthroscopies were performed as previously described.[16,18] Briefly, an interportal capsulotomy was created to establish access to the central compartment. Once established, procedures included acetabuloplasty as indicated, labral repair as indicated, and chondral lesion debridement to stable margins. A vertical T-capsulotomy was performed for visualization of the cam deformity. A comprehensive cam resection was performed to address any

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Ethical approval for this study was obtained from Rush University Medical Center (ORA No: 12022108-IRB01-CR07).

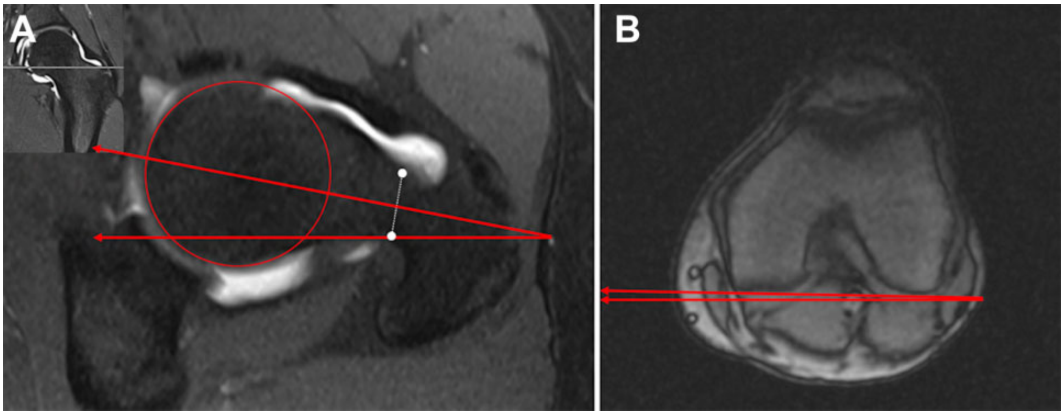

Figure 1. Axial femoral torsion was based on the angle between (A) a line connecting the center of the femoral head to the center of the femoral neck and (B) a line connecting the posterior condyles of the knee. A horizontal line was used on each axial slice as a reference line for measurement purposes.

abnormal femoral bony morphology. A dynamic examination was performed to confirm complete resection of bony impingement. The T-capsulotomy was repaired using a suture shuttling device starting at the base of the vertical portion, followed by the interportal segment. Rehabilitation was performed as previously described.[31]

Quantification and Classification of Femoral Torsion

MRI-based femoral torsion measurements were performed by an orthopaedic surgeon (F.S.B.) and a trained biomedical engineer (A.C.N.) under the senior author's supervision. All MRIs were performed using a 1.5-T MAGNETOM Espree system (Siemens Healthcare) scanner in the supine position. The axial T2 MRI parameters were as follows: relaxation time, 4000 to 6000 milliseconds; time to excitation, 70 milliseconds; slice thickness/gap, 4/1 mm; field of view, 350 to 380 mm; matrix, 238 × 320. All MRI scans were exported as Digital Imaging and Communication in Medicine (DICOM) files and stored in our institutional picture archiving and communication system (PACS).

MRI-based axial measurements were made on a single transverse slice using a previously described and validated method by Hernandez et al.[21,24,42,44] A single slice best visualizing the femoral head, femoral neck, and greater trochanter was selected. The first line was drawn from the femoral head centroid through the midpoint of the femoral neck and the second line was drawn connecting the posterior aspect of the femoral condyles. The angle between the 2 lines was used to measure femoral torsion (Figure 1). Torsion classifications were defined as severe retrotorsion (SR; $<0^\circ$ of antetorsion), normal torsion (NT; 0°-25° of antetorsion), and severe antetorsion (SA; $>25^\circ$ of antetorsion). This stratification was chosen (1) based on previous literature classifications[9,12,26,27,44] and (2) after review of the torsion measurement technique and imaging used in comparison with those of prior literature.[24]

For intrarater reliability, femoral torsion was measured by an orthopaedic surgeon (F.S.B.) on 2 separate occasions with >1 month between measurements. For interrater reliability, a trained biomedical engineer (A.C.N.) also measured femoral torsion on all 241 scans. For the purpose of blinding, the 2 reviewers did not have access to the patients' outcome scores. The inter- and intrarater reliability of the measurements was assessed using a 2-way mixed-effects model for absolute agreement.

Evaluation of Functional Outcomes

PROs were collected at the preoperative visit and at a minimum of 2 years postoperatively. PROs included the Hip Outcome Score–Activities of Daily Living (HOS-ADL),[32] Hip Outcome Score–Sports Subscale (HOS-SS),[33] modified Harris Hip Score (mHHS),[3] 12-item International Hip Outcome Tool (iHOT-12),[17] and 100-point visual analog scale (VAS) for hip pain and overall satisfaction. The 2-year scores required to achieve the PASS was based on previous literature and were as follows: mHHS (threshold = 74)[5]; HOS-ADL (threshold = 87)[5]; HOS-SS (threshold = 75)[5]; iHOT-12 (threshold = 63)[37]; and pain VAS (threshold = 21.6).[1] The 2-year scores required to achieve the SCB were based on previous literature and were as follows: mHHS (threshold = 82.5)[38]; HOS-ADL (threshold = 93.3)[38]; HOS-SS (threshold = 84.4)[38]; iHOT-12 (threshold = 63.5)[38]; and VAS pain (threshold = 15.4).[1]

Statistical Analysis

Continuous variables are presented as means and standard deviations, and categorical variables are presented as percentages. The Shapiro-Wilk test of normality was used to determine whether data were normally distributed. The Levene statistic was used to determine homogeneity of variances. Parametric continuous variables were analyzed by paired t test or analysis of variance, while nonparametric data were analyzed by Mann-Whitney U or Kruskal-Wallis test. Chi-square analysis was used to analyze categorical variables. An a priori α level was set at .05 to indicate statistical significance. All statistical analysis was performed using SPSS Version 26 (IBM).

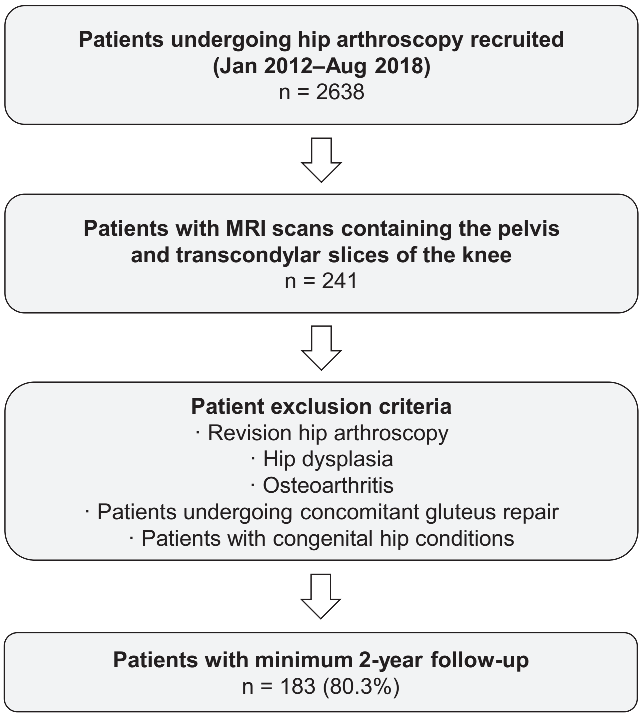

Figure 2. Flowchart of patient selection. MRI, magnetic resonance imaging.

TABLE 1
Baseline Patient Characteristics Compared by Femoral Torsion Stratification[a]

Variable	SR (<0°; n = 13)	NT (0°-25°; n = 154)	SA (>25°; n = 16)	*P* Value[b]
Age, y	26.5 ± 11.6	31.4 ± 12.2	25.6 ± 10.4	.070
BMI, kg/m^2	23.2 ± 3.3	24 ± 4.5	24.3 ± 4	.568
Female sex	53.8	72.1	75	.355
Smoker	7.7	8.2	0.0	.537
Workers' compensation	0.0	3.2	0.0	.661

[a]Data are reported as percentage or mean ± SD unless otherwise indicated. BMI, body mass index; NT, normal torsion; SA, severe antetorsion; SR, severe retrotorsion.
[b]Analysis of variance (Kruskal-Wallis) or chi-square test.

An a priori power analysis indicated that with an alpha error probability of .05 and a medium effect size ($\eta^2 = 0.06$; Cohen $F = 0.25$), a total of 159 patients were required to achieve a statistical power of 80%.

RESULTS

Patient Characteristics

A total of 241 patients had MRI scans that allowed for measurement of femoral torsion. A total of 13 patients were excluded for having undergone revision surgery (n = 4) or concomitant gluteus medius/minimus repair (n = 3) or having moderate or severe hip dysplasia (n = 6) (Figure 2). Of the 228 patients, 183 (80.3%) completed PROs at minimum 2-year follow-up and were included in the study. The mean age and body mass index (BMI) of the study cohort were 30.6 ± 12.1 years and 24.0 ± 4.4 kg/m^2, respectively, and 71.0% were female (Table 1). The mean follow-up time was 27.1 months. The procedures performed for the cohort are summarized in Table 2.

TABLE 2
Frequency of Procedures Performed for the Study Population[a]

Procedure	Frequency
Femoroplasty	100.0
Capsular repair or plication	100.0
Labral repair	99.5
Acetabular rim trimming	93.4
Trochanteric bursectomy	7.1
ITB release	1.6
Microfracture	1.1
Excision HO	1.1
Psoas release	0.0

[a]HO, heterotopic ossification; ITB, iliotibial band.

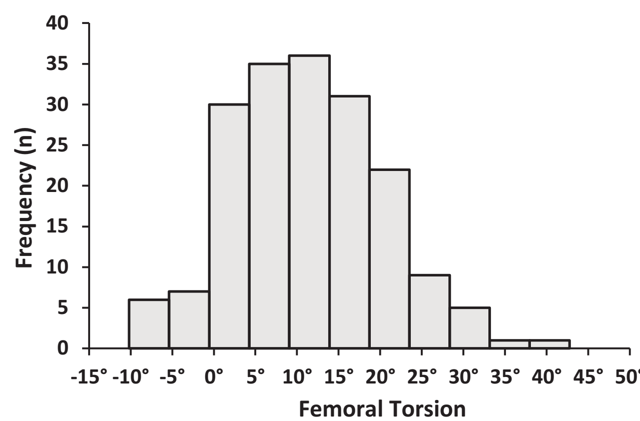

Figure 3. Histogram of femoral torsion frequency by 5° increments.

The inter- and intrarater intraclass correlation coefficients for the femoral torsion measurements were 0.986 (95% CI, 0.981-0.990) and 0.965 (95% CI, 0.953-0.974), respectively, indicating excellent reliability. The mean amount of femoral torsion for the entire study population was 12.55° ± 9.58° (Figure 3). After stratification based on magnitude and orientation of femoral torsion, the sample sizes and mean torsion values within each group were as follows: SR (n = 13), –4.5° ± 2.6°; NT (n = 154), 12.1° ± 6.8°; and SA (n = 16), 31.0° ± 3.6°. There were no significant differences in age, BMI, sex, tobacco

TABLE 3
Radiographic Parameters Compared by Femoral Torsion Stratification[a]

	SR (<0°)	NT (0°-25°)	SA (>25°)	*P* Value
Preoperative				
Alpha angle - AP, deg	60.1 ± 19.2	60.9 ± 18.5	55.5 ± 16.6	.578
Alpha angle - Dunn, deg	62 ± 10.3	59.1 ± 13.3	58.4 ± 14.5	.760
ACEA, deg	27.3 ± 6.1	32.5 ± 6.7	29.2 ± 8.2	.144
LCEA, deg	29.8 ± 5.1	31.0 ± 5.4	30.1 ± 5.9	.489
Tönnis angle, deg	8.2 ± 3.4	6.1 ± 4.2	7.6 ± 5.8	.212
Posterior wall sign	41.7	36.4	33.3	.903
Coxa profunda	50.0	60.6	60.0	.773
Protrusion acetabuli	0.0	1.4	0.0	.826
Tönnis grade 1 OA	8.3	1.4	0.0	.188
Ischial spine sign	50.0	28.7	26.7	.289
Crossover sign	25.0	20.3	33.3	.487
Postoperative				
Alpha angle - AP, deg	44.1 ± 4.0	44 ± 7.9	43.9 ± 5.2	.778
Alpha angle - Dunn, deg	38.7 ± 3.1	37.3 ± 5.0	38.9 ± 5.9	.124
LCEA, deg	28.7 ± 6.3	28.8 ± 5.4	28.9 ± 5.4	.894
Tönnis angle, deg	9.1 ± 3.3	6.9 ± 8.4	8.4 ± 12.1	.084

[a]Data are reported as mean ± SD or percentage. ACEA, anterior center-edge angle; AP, anteroposterior; LCEA, lateral center-edge angle; NT, normal torsion; OA, osteoarthritis; SA, severe antetorsion; SR, severe retrotorsion.

use, or workers' compensation status between the study groups.

Baseline Imaging Characteristics

Preoperative radiographic imaging parameters are described in Table 3. There were no significant differences in the preoperative or postoperative radiographic parameters between the study groups.

Clinical Outcomes Analysis

Analysis of PROs revealed no significant difference between groups in mHHS, HOS-ADL, HOS-SS, iHOT-12, VAS pain, or VAS satisfaction at baseline or latest follow-up (Table 4).

The proportion of patients who achieved PASS and SCB at the latest follow-up was also analyzed. Between-group differences were seen on the iHOT-12, pain VAS, and any PRO ($P < .05$). Post hoc analysis with Bonferroni correction comparing the SR and SA groups indicated that the SR group achieved higher rates of PASS and SCB on the iHOT-12 and pain VAS, and higher rates of PASS on any PRO ($P < .0167$) (Table 5). In addition, when comparing the SR and NT groups, higher rates of PASS and SCB on pain VAS were achieved in the SR group in comparison with the NT group ($P < .0167$). There were no other differences on post hoc comparison.

We sought to evaluate the influence of the specific femoral torsion classification on the study results. Patients were therefore also classified based on the following groupings: femoral retrotorsion (<5° of antetorsion)[13,25,40]; NT (5°-20° of antetorsion); and femoral antetorsion (>20° of antetorsion).[4,25,40] After narrowing the definition of NT, the number of patients in each group were as follows: retrotorsion (n = 43); NT (n = 102); and antetorsion (n = 38). Analysis of the proportion of patients who achieved the PASS and SCB for each outcome measure revealed between-group differences in pain VAS (PASS and SCB) as well as mHHS (PASS) ($P < .05$). Post hoc analysis with Bonferroni correction comparing the retrotorsion and antetorsion groups revealed that patients with femoral retrotorsion had greater rates of achievement of PASS and SCB in pain VAS ($P < .0167$) (Table 6). When comparing patients with normal femoral torsion and antetorsion,

TABLE 4
Preoperative and 2-Year Patient-Reported Outcomes Compared by Femoral Torsion Stratification[a]

	SR (<0°)	NT (0°-25°)	SA (>25°)	*P* Value
Preoperative				
mHHS	62.0 ± 11.0	57.3 ± 15.2	64.7 ± 6.4	.084
HOS-ADL	63.6 ± 17.8	65.6 ± 17.8	69.7 ± 11.2	.836
HOS-SS	47.7 ± 19.7	40.3 ± 22.4	54.0 ± 24.8	.104
iHOT-12	32.1 ± 23.5	33.9 ± 18.3	27.4 ± 18.8	.568
VAS pain	49.3 ± 26.7	57.9 ± 23.6	58.3 ± 18.0	.602
2-year follow-up				
mHHS	90.4 ± 8.5	80.5 ± 16.9	84.0 ± 13.6	.122
HOS-ADL	94.1 ± 9.3	87.2 ± 15.8	87.9 ± 13.8	.224
HOS-SS	89.5 ± 12.0	73.5 ± 26.7	78.2 ± 24.7	.112
iHOT-12	88.6 ± 10.3	71.5 ± 26.3	63.8 ± 27.0	.105
VAS pain	7.9 ± 7.1	23.9 ± 24.8	25.7 ± 21.5	.065
VAS satisfaction	87.9 ± 12.2	78.9 ± 25.3	74.0 ± 28.1	.659

[a]Data are reported as mean ± SD. HOS-ADL, Hip Outcome Score–Activities of Daily Living; HOS-SS, Hip Outcome Score–Sports Subscale; iHOT-12, 12-item International Hip Outcome Tool; mHHS, modified Harris Hip Score; NT, normal torsion; SA, severe antetorsion; SR, severe retrotorsion; VAS, visual analog scale.

TABLE 5
Rates of PASS and SCB Achievement Compared by Femoral Torsion Stratification[a]

	SR (<0°)	NT (0°-25°)	SA (>25°)	P Value
PASS				
mHHS	100.0	68.2	69.2	.054
HOS-ADL	84.6	68.9	62.5	.407
HOS-SS	83.3	62.6	64.3	.355
iHOT-12	100.0	69.8	50.0	**.039**[b]
VAS pain	100.0	57.6	33.3	**.001**[b,c]
Any PRO[d]	100.0	71.4	56.3	**.029**[b]
SCB				
mHHS	83.3	55.0	53.8	.160
HOS-ADL	76.9	49.7	43.8	.140
HOS-SS	76.9	45.1	57.1	.071
iHOT-12	100.0	69.0	50.0	**.040**[b]
VAS pain	84.6	49.3	33.3	**.043**[b,c]
Any PRO[d]	92.3	59.7	50.0	**.043**[b]

[a]Data are reported as percentage. Bolded *P* values indicate a statistically significant difference among the groups ($P < .05$, analysis of variance). HOS-ADL, Hip Outcome Score–Activities of Daily Living; HOS-SS, Hip Outcome Score–Sports Subscale; iHOT-12, 12-item International Hip Outcome Tool; mHHS, modified Harris Hip Score; NT, normal torsion; PASS, Patient Acceptable Symptom State; SA, severe antetorsion; SCB, substantial clinical benefit; SR, severe retrotorsion; VAS, visual analog scale.

[b]Post hoc significance ($P < .0166$) between the SR and SA groups.

[c]Post hoc significance ($P < .0166$) between the SR and NT groups

[d]Any PRO indicates mHHS, HOS-ADL, HOS-SS, iHOT-12, or VAS pain.

TABLE 6
Rates of PASS and SCB Achievement Compared by Alternative Femoral Torsion Stratification[a]

	Retrotorsion (<5°; n = 43)	Normal Torsion (5°-20°; n = 102)	Antetorsion (>20°; n = 38)	P Value
PASS				
mHHS	30 (75)	62 (72.9)	20 (60.6)	.334
HOS-ADL	28 (65.1)	75 (75)	22 (59.5)	.168
HOS-SS	23 (56.1)	63 (69.2)	20 (60.6)	.307
iHOT-12	23 (71.9)	54 (73)	20 (60.6)	.419
VAS pain	30 (71.4)	59 (62.8)	12 (33.3)	**.001**[b]
Any PRO[c]	31 (72.1)	79 (77.5)	22 (57.9)	.072
SCB				
mHHS	25 (64.1)	52 (61.2)	12 (37.5)	**.041**
HOS-ADL	22 (51.2)	56 (56.0)	14 (37.8)	.168
HOS-SS	21 (50.0)	46 (49.5)	15 (44.1)	.846
iHOT-12	23 (71.9)	53 (71.6)	20 (60.6)	.484
VAS pain	26 (61.9)	49 (52.1)	12 (33.3)	**.038**[b,d]
Any PRO[c]	28 (65.1)	66 (64.7)	18 (47.4)	.145

[a]Data are reported as n (%). Bolded *P* values indicate a statistically significant difference among the groups ($P < .05$, analysis of variance). HOS-ADL, Hip Outcome Score – Activities of Daily Living; HOS-SS, Hip Outcome Score – Sports Subscale; iHOT-12, 12-item International Hip Outcome Tool; mHHS, modified Harris Hip Score; PASS, Patient Acceptable Symptom State; SCB, substantial clinical benefit; VAS, visual analog scale.

[b]Post hoc significance ($P < .0166$) between retrotorsion and antetorsion groups.

[c]Any PRO indicates mHHS, HOS-ADL, HOS-SS, iHOT-12, or VAS pain.

[d]Post hoc significance ($P < .0166$) between the normal torsion and antetorsion groups.

patients with NT had greater rates of achievement of SCB in pain VAS ($P < .0167$) (Table 6). There were no other differences on post hoc comparison.

DISCUSSION

The most important findings from this study were that at a minimum of 2 years after primary hip arthroscopy for FAIS, patients with SA (>25°) had lower rates of achievement of clinically significant outcome improvement when compared with patients with NT and SR (<0°). These findings were compared among a large population of primary hip arthroscopy patients using MRI, which is a valid method of measuring femoral torsion,[22] with excellent inter- and intraobserver reliability. These relationships may have implications on the diagnostic and treatment approach for patients being considered for hip arthroscopy for FAIS, particularly with regard to patients with severe femoral anteversion.

Presently, there are conflicting conclusions regarding the impact of femoral torsion on outcomes after hip arthroscopy for FAIS. While hip arthroscopy is an effective treatment for FAIS in patients who fail nonoperative treatment, some surgeons argue that hip arthroscopy alone cannot address bone-related morphological aberrancies such as acetabular dysplasia or extremes of femoral torsion. It is hypothesized that hip arthroscopy cannot effectively treat FAIS with excessive femoral antetorsion because of unaddressed overload on the dysplastic acetabulum and soft tissues, leading to recurrent instability and further chondrolabral degeneration.[12,20] Excessive antetorsion can lead to gait alterations (in-toeing gait), iliopsoas tendinitis, labral tears, and chondral injuries. Psoas tendinitis and labral tears are believed to occur concomitantly more frequently because the antetorted femur relies more on the psoas tendon and anterior labrum for stability.

On the contrary, other groups do argue for the role of arthroscopic management, even for patients with abnormal femoral torsion. Previous literature has demonstrated that clinically important improvements can be expected in all femoral torsion groups after hip arthroscopy.[13,15,19,23,29] However, Fabricant et al[12] showed smaller improvements in the mHHS and iHOT-33 for patients with <5° of antetorsion when compared to patients with normal antetorsion. Additionally, Domb et al[10] found that patients with borderline dysplasia and excessive femoral antetorsion (>20°) experienced inferior outcomes and a higher rate of reoperations compared to their matched counterparts.

However, in a separate study of 278 patients with normal acetabular coverage, Jackson et al reported that femoral anteversion did not have an influence on clinical outcomes after hip arthroscopy.[23] Fabricant et al[12] showed that patients with increased femoral antetorsion have worse results with hip arthroscopy and concomitant psoas release. Ejnisman et al[11] reported on larger labral tears occurring in patients with femoral torsion >15°. These differences in outcomes have not been consistently reported. Lall et al[29] performed a retrospective comparative study of 59 patients with femoral retrotorsion (<0°) versus 59 matched patients with NT (10°-20°) undergoing hip arthroscopy for FAIS and found that both groups showed clinically significant improvements, with no intergroup differences in multiple PROs or the need for revision surgery or total hip replacement at a minimum 5-year follow-up. The authors concluded that femoral retrotorsion should not be considered a contraindication for hip arthroscopy. Similar findings have been reported at shorter follow-up by other authors.

The hip arthroscopy literature varies widely with regard to torsional characteristics and their impact on the outcomes for treatment of FAIS. Interestingly, our study demonstrated that patients undergoing hip arthroscopy for severe femoral torsion abnormalities were younger than patients with normal femoral torsion; however, these differences did not reach significance ($P = .070$). This suggests that femoral torsion abnormalities may cause symptoms at a younger age. With regard to outcomes, our study found that patients with SR achieved PASS and SCB at higher rates than both the NT and the SA groups. Similar to the aforementioned study by Lall et al,[29] our study similarly adds to this literature and even suggests these patients with SR may have improved outcomes compared with patients with NT or SA. Consideration of the degree or torsion and what actually constitutes "normal" is worth discussion. Lerch et al[30] retrospectively reviewed the torsion of 538 hips in 462 symptomatic FAIS patients. The authors reported that 52% of patients had abnormal femoral torsion, with severe abnormalities in 17%. Overall, the mean torsion of their study group was 19° for male patients and 15° for female patients, while 18% of their cohort had torsion in the range of 26° to 35°. While those authors did not correlate torsion with PROs, they did conclude that abnormalities occur more often than previously thought and recommended that this be assessed before indicating a patient for surgery. We would echo this finding, particularly in revision FAIS settings, that torsion may play a role in a patient's ability to reach a clinically significant outcome improvement.

However, aside from a few surgical technique papers, the literature is very limited with regard to the proper indications and long-term benefit of concomitant arthroscopic FAIS treatment and femoral derotational osteotomy.[20,34] While the long-term benefits of femoral derotational osteotomy have been well-studied in the pediatric cerebral palsy population, the outcomes for patients with FAIS are less well-known.[7,39] Femoral derotational osteotomy is an invasive procedure in comparison with hip arthroscopy; however, multiple techniques have shown promising clinical results with high patient satisfaction.[36] A recent study from Chaharbakhshi et al[6] produced similar findings to the present study, indicating that a small cohort of 12 patients with excessive femoral anteversion improved after hip arthroscopy with labral repair, albeit to a lesser degree than a control group with NT. The authors also suggested that these patients may meet criteria for potential femoral derotational osteotomy, with further studies required to truly identify which patients would benefit most from this invasive procedure. Studies such as ours add to the growing literature on the influence of severe femoral antetorsion on patient outcomes and may help determine which patients would be best suited for surgical procedures other than hip arthroscopy.

Heterogeneity in methodology and outcome reporting may explain some of the differences between our findings and those reported by previous studies. Although previous studies have identified associations between femoral torsion and outcomes after hip arthroscopy, the measurement methodologies have included both CT and MRI and have used different slice orientations, which may introduce the potential for measurement bias. While some studies have demonstrated no difference in femoral torsion measurement performed on MRI and CT,[41] others have demonstrated a mean difference of 8.9°, with larger values measured on CT.[2] In a separate cadaveric study, Kaiser et al[24] demonstrated that slice orientation and the femoral torsion measurement method had a significant influence on femoral torsion values. Additionally, seemingly minute variations in hip flexion or extension during image acquisition may influence torsion measurement.[35] Another limitation to the previous literature is that femoral version and torsion have been used interchangeably. Whereas torsion accounts for rotation of the entire femur and the femoral neck, version only accounts for rotation proximal to the lesser trochanter. We recommend future studies to limit the measurement of femoral version or torsion to 1 modality for consistency as well as the use of reproducible and consistent terminology as it relates to either value. Future studies are warranted to determine whether differences in femoral torsion are observed between imaging modalities and whether torsion stratification by different imaging modality is associated with clinical outcomes.

Limitations

This study is not without limitations. First, only <10% of patients undergoing hip arthroscopy were included due to limited available MRI femoral torsion studies. Second, the use of a single measurement technique for femoral torsion may limit the generalizability of our findings; however, this method has been shown to be reproducible and validated. Third, we classified torsion according to previous literature and our population, which may also limit generalizability. However, a subanalysis was performed utilizing an alternative classification of retrotorsion (<5°), NT (5°-20°), and antetorsion (>20°), which demonstrated that patients with femoral antetorsion achieved lower rates of clinically significant outcome improvement compared with patients with femoral antetorsion and NT. Despite an adequate a priori power, our sample size for SA and SR were relatively small. However, a post hoc power analysis based on the minimum 2-year iHOT-12 scores (Cohen effect size of 5.1), alpha error probability of .05, and a total sample size of 183, indicated that a power $>80\%$ was achieved. This study also fails to capture long-term outcomes. Therefore, further long-term studies are warranted. Finally, outcomes were assessed at the short term, and future studies are warranted to evaluate whether femoral torsion influences mid- to long-term outcomes after hip arthroscopy for FAIS.

CONCLUSION

The orientation and severity of femoral torsion at the time of hip arthroscopy has an influence on the propensity for clinically significant outcome improvement. Specifically, patients with femoral retrotorsion and femoral antetorsion achieved higher and lower rates of clinically significant outcome improvement, respectively.

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