Association Between Orientation and Magnitude of Femoral Torsion and Propensity for Clinically Meaningful Improvement After Hip Arthroscopy for Femoroacetabular Impingement Syndrome

A Computed Tomography Analysis

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Background: Femoral torsion imaging measurements and classifications are heterogeneous throughout the literature, and the influence of femoral torsion on clinically meaningful outcome improvement after hip arthroscopy for femoroacetabular impingement syndrome (FAIS) has not been well studied.

Purpose: To (1) perform a computed tomography (CT)–based analysis to quantify femoral torsion in patients with FAIS and (2) explore the relationship between the orientation and magnitude of femoral torsion and the propensity for clinically meaningful outcome improvement after hip arthroscopy.

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

Methods: Consecutive patients who underwent hip arthroscopy for FAIS between January 2012 and April 2018 were identified. Inclusion criteria were the presence of preoperative CT imaging with transcondylar slices of the knee and minimum 2-year outcome measures. Exclusion criteria were revision hip arthroscopy, Tönnis grade >1, congenital hip condition, hip dysplasia (lateral center-edge angle <20°), and concomitant gluteus medius or minimus repair. Torsion groups were defined as severe retrotorsion (SR; <0°), moderate retrotorsion (MR; 0°-5°), normal torsion (N; 5°-20°), moderate antetorsion (MA; 20°-25°), and severe antetorsion of antetorsion (SA; >25°). Treatment did not differ based on femoral torsion. Patient characteristics and clinical outcomes were analyzed, including the Hip Outcome Score–Activities of Daily Living (HOS-ADL), Hip Outcome Score–Sports Subscale (HOS-SS), modified Harris Hip Score (mHHS), international Hip Outcome Tool (iHOT-12), visual analog scale (VAS) for pain, and VAS for satisfaction. Achievement of the minimal clinically important difference (MCID) and patient acceptable symptom state (PASS) by torsion stratification was analyzed using the chi-square test. Inter- and intrarater reliabilities for CT measurements were 0.980 ($P < .001$) and 0.974 ($P < .001$), respectively.

Results: The study included 573 patients with a mean ± SD age and body mass index of 32.6 ± 11.8 years and 25.6 ± 10.6, respectively. The mean ± SD femoral torsion for the study population was 12.3° ± 9.3°. After stratification, the number of patients within each group and the mean ± SD torsion for each group were as follows: SR (n = 36; –6.5° ± 7.1°), MR (n = 80; 2.8° ± 1.4°), N (n = 346; 12.3° ± 4.1°), MA (n = 64; 22.2° ± 1.4°), and SA (n = 47; 30.3° ± 3.7°). No significant differences in age, body mass index, sex, tobacco use, workers' compensation status, or participation in physical activity were observed at baseline. No significant differences were seen in pre- and postoperative VAS pain, mHHS, HOS-ADL, HOS-SS, iHOT-12, or postoperative VAS satisfaction among the cohorts. Furthermore, no statistically significant differences were found in the proportion of patients who achieved the MCID or the PASS for any outcome among the groups.

Conclusion: The orientation and severity of femoral torsion at the time of hip arthroscopy for FAIS did not influence the propensity for clinically significant outcome improvement.

Keywords: femoral torsion; minimal clinically important difference; MCID; hip arthroscopy; femoroacetabular impingement syndrome; computed tomography

The American Journal of Sports Medicine
1–9
DOI: 10.1177/03635465211021610

Arthroscopic hip preservation surgery, consisting of correction of cam and pincer morphology, labral pathology, and capsular management, has become widely adopted given its reproducible improvements in outcomes and low morbidity.[6,15,41] Coinciding with the expansion of hip arthroscopy has been a focused effort to better understand both patient and procedural factors associated with patient outcomes.[14,26-28,30] These investigations have led to enhanced prognostication in the form of augmented clinical decision making, appropriate patient selection, and expectation guidance. Although much progress has been made to this end, a proportion of patients remain unsatisfied or improve to a lesser degree after hip arthroscopy than do their counterparts. Therefore, identifying other determinants of outcome improvement remains an essential area of further investigation.

Anatomic variation among patients is a widely studied phenomenon for many orthopaedic conditions; such anatomic variation has been demonstrated to have a significant influence on morbidity in select patients and may account for continued discrepancies in outcomes.[7,21,24,37,40] For example, the evolving understanding of the spinopelvic relationship and morbidity in total hip arthroplasty has shown that this relationship influences impingement and dislocation risk, although it has been recognized as a considerable determinant only in recent years.[12,17,44] Likewise, accounting for anatomic variations in patients who undergo hip arthroscopy has only recently been considered but may hold prognostic value. Lerch et al[31] used 3-dimensional based simulations to demonstrate that patients who had femoroacetabular impingement and decreased femoral version had less flexion and internal rotation at 90° of flexion compared with asymptomatic controls and that the majority of impingement was intra-articular. Subsequently, femoral version has been thought to influence impingement risk, perhaps more than does cam morphology,[25] and may contribute to outcomes after hip arthroscopy.[9,29] However, definitions of version and modalities to quantify version are heterogeneous, as previous studies have used measurements of femoral torsion and femoral version, as well as the terms themselves, interchangeably.[5,8,9,32] Therefore, it is imperative to explore the potential influence of femoral torsion alone on clinically meaningful outcome improvement after hip arthroscopy; further defining this association may be of great clinical benefit.

The purpose of the current study was to perform a computed tomography (CT)–based analysis to quantify femoral torsion in patients with femoroacetabular impingement syndrome (FAIS) and to explore the relationship between the orientation and magnitude of femoral torsion and the propensity for clinically significant outcome improvement after hip arthroscopy. We hypothesized that clinically meaningful outcome improvement would differ based on the method of femoral torsion classification, with patients classified as having severe retrotorsion or antetorsion achieving the lowest relative proportion of clinically meaningful improvement.

METHODS

Patient Selection

This study received institutional review board approval to prospectively collect and retrospectively analyze imaging and clinical outcomes of patients who underwent hip arthroscopy for FAIS by the senior author (S.J.N.). Inclusion criteria were primary hip arthroscopy for FAIS between January 2012 and April 2018, clinical and radiographic diagnosis of symptomatic FAIS, failure of nonoperative management (physical therapy, oral anti-inflammatory drugs, and/or intra-articular cortisone injection), minimum 2-year follow-up, and CT imaging of the pelvis and transcondylar slices of the knee. Exclusion criteria were revision hip surgery, Tönnis grade >1, developmental hip disorders (Legg-Calvé-Perthes disease, slipped capital femoral epiphysis), moderate to severe hip dysplasia (lateral center-edge angle <20°), and simultaneous gluteus medius or minimus repair. Patients with mild or borderline hip dysplasia (lateral center-edge angle >20°) were included.

Of the 2519 consecutive patients undergoing hip arthroscopy between January 2012 and April 2018, a total of 741 patients had the CT imaging necessary for measurement of femoral torsion. There are several reasons that a majority of potentially eligible patients did not have adequate CT imaging to assess femoral torsion. First, the senior author specializes in treatment of FAIS, and many patients are referred from other physicians with previous CT imaging that does not include knee imaging. Second, the initial evaluation for FAIS involves collection of multiple radiographs. In an effort to minimize radiation exposure in a young patient cohort, the senior author has gradually transitioned to magnetic resonance imaging (MRI) for assessment of hip morphologic characteristics. Although many patients have MRI scans that would allow for measurement of femoral torsion, the literature has

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Submitted October 1, 2020; accepted March 1, 2021.

One or more of the authors has declared the following potential conflict of interest or source of funding: J.C.W. has received hospitality payments from Allergan, DePuy Synthes Sales, Medical Device Business Services, Zimmer Biomet Holdings, and Smith & Nephew; speaking fees from Synthes GmbH; and consulting fees from DePuy Orthopaedics. S.J.N. has received research support from Allosource, Arthrex Inc, Athletico, DJ Orthopaedics, Linvatec, Miomed, Smith & Nephew, and Stryker; consulting fees from Stryker and Ossur; and royalties from Ossur and Stryker. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

demonstrated that there are clinically important differences in torsion measured on MRI scans and CT images. Therefore, these patients were not included in this study.

Quantification and Classification of Femoral Torsion

Patients were stratified based on CT-based femoral torsion measurements made by an orthopaedic surgeon and a trained biomedical engineer (F.S.B. and A.C.N.), under the senior author's supervision. The CT scan acquisition entailed the following scan parameters: 120 kV, 250 mA, 0.625-mm slice thickness, 512 × 512 acquisition matrix, and an in-plane resolution of <1 × 1 mm. All CT images contained the pelvis and transcondylar slices of the knee. All CT images were exported as Digital Imaging and Communication in Medicine files and stored in our institutional picture archiving and communication system. CT-based measurements were made on a single transverse slice using a modified version of a method previously described by Hernandez et al[18] and others.[23,43,45] The slice best showing the femoral head, femoral neck, and greater trochanter was selected. The angle between 2 lines was used to measure femoral torsion. The first line was drawn from the center of the femoral head through the midpoint of the femoral neck, and the second line was drawn connecting the posterior aspect of the femoral condyles (Figure 1). The angle formed between these lines was considered the femoral torsion. For intrarater reliability, femoral torsion was measured by an orthopaedic surgeon (F.S.B.) on 2 separate occasions with >1 month between measurements. A trained biomedical engineer (A.C.N.) also measured femoral torsion for interrater reliability. Inter- and intrarater reliability were assessed using a 2-way mixed-effects model for absolute agreement. Inter- and intraclass correlation coefficients were 0.980 (95% CI, 0.967-0.986; $P < .001$) and 0.974 (95% CI, 0.969-0.978; $P < .001$), respectively. For the purpose of blinding, the 2 reviewers did not have access to patients' outcome scores.

Torsion classifications were defined as severe retrotorsion (SR; <0° of antetorsion), moderate retrotorsion (MR; 0°-5°of antetorsion), normal torsion (N; 5°-20° of antetorsion), moderate antetorsion (MA; 20°-25° of antetorsion), and severe antetorsion (SA; >25° of antetorsion). This stratification was chosen based on previous literature classifications[9,34] and review of the torsion measurement technique and imaging used in comparison with previous literature[23]; this stratification also represented the most balanced distribution within our cohort. To confirm that torsion classification was not a confounding variable in assessment of the study results, we performed an additional subgroup analysis based on the classifications previously outlined by Lerch et al,[32] defining torsion in the following manner: SR (<0° of antetorsion), MR (0°-10° of antetorsion), N (10°-26° of antetorsion), MA (26°-35° of antetorsion), and SA (>35° of antetorsion). In addition to femoral torsion, the cranial acetabular version was measured on the axial CT slice,[32,45] and the anterior inferior iliac spine type was assessed as described by Hetsroni et al[19] and others.[3,20]

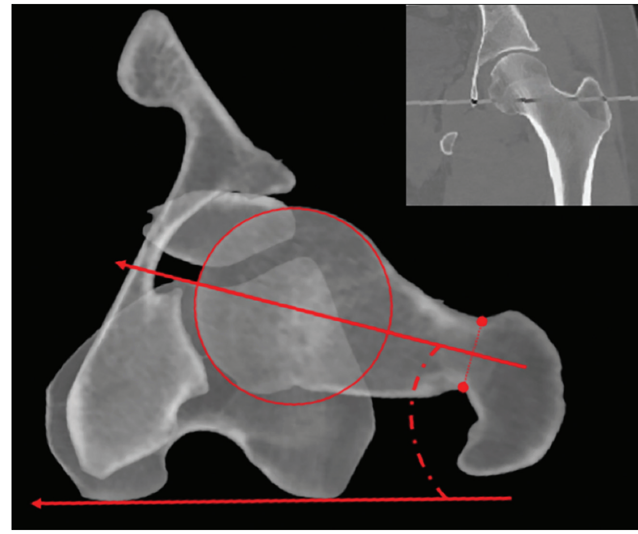

Figure 1. Femoral torsion was based on the angle between a line connecting the posterior condyles of the knee and a line from the center of the femoral head to the center of the femoral neck.

Functional Outcome Evaluations

The participants completed patient-reported outcome instruments at preoperative visits and at a minimum of 2 years postoperatively. Patient-reported outcome measures included the Hip Outcome Score–Activities of Daily Living (HOS-ADL),[35] Hip Outcome Score–Sports Subscale (HOS-SS),[36] modified Harris Hip Score (mHHS),[2] international Hip Outcome Tool (iHOT-12),[13] and visual analog scale (VAS) for pain and satisfaction. The minimal clinically important difference (MCID) for the HOS-ADL, HOS-SS, mHHS, iHOT-12, and VAS for pain was calculated based on one-half of the standard deviation of the difference between preoperative and postoperative scores for the study cohort for each measure: mHHS (threshold, 8.76), HOS-ADL (threshold, 10.14), HOS-SS (threshold, 15.01), iHOT-12 (threshold, 13.73), and VAS for pain (threshold, 21.6). The 2-year scores required to achieve the Patient Acceptable Symptom State (PASS) were based on previous literature and were as follows: mHHS (threshold, 74),[4] HOS-ADL (threshold, 87),[4] HOS-SS (threshold, 75),[4] iHOT-12 (threshold, 63),[42] and VAS for pain (threshold, 21.6).[1]

Surgical Technique

All hip arthroscopies were performed by a single fellowship-trained hip surgeon (S.J.N.) as previously described in the literature.[11,16] An interporal capsulotomy was created to establish access to the central compartment. After access was established, procedures included acetabuloplasty, labral debridement or labral repair depending on labral condition, and chondral lesion debridement to stable margins. A vertical T-capsulotomy was performed for assessment of cam deformity. A comprehensive cam resection was performed

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

	SR	MR	N	MA	SA	*P* Value
No. of patients	36	80	346	64	47	
Patient characteristics						
Age, y	36.4 ± 12.6	32.1 ± 12.2	32.8 ± 11.7	31.0 ± 11.1	31.0 ± 12.7	.282
Body mass index	26.8 ± 5.8	25.0 ± 5.2	25.3 ± 5.0	27.7 ± 28.4	24.7 ± 4.9	.157
Female	69.4	58.8	65.0	68.8	78.7	.214
Smoking	14.3	14.1	9.4	11.1	10.9	.737
Sports	69.4	74.7	75.3	78.1	78.3	.883
Workers' compensation	8.6	7.6	5.0	4.8	2.2	.637

[a]Baseline patient characteristics were analyzed using analysis of variance (Kruskal-Wallis) or chi-square test. Continuous variables are reported as mean ± SD. Categorical variables are reported as frequency (ie, percentage). MA, moderate antetorsion; MR, moderate retrotorsion; N, normal torsion; SA, severe antetorsion; SR, severe retrotorsion.

to address any abnormal femoral bony morphology. Once the cam section was complete, a dynamic examination under direct arthroscopic visualization and fluoroscopic guidance 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 interporal segment. Rehabilitation was performed as previously described.[33] Because the current study was retrospectively designed, changes in surgical management based on femoral torsion were not investigated as an intervention, and all patients underwent the same management regardless of femoral torsion.

Statistical Analysis

Continuous variables are presented as mean ± SD. Categorical variables are presented as percentage. The Shapiro-Wilk test of normality was used to determine whether data were normally distributed. The Levene test was used to determine homogeneity of variances. Parametric continuous variables were analyzed using the paired *t* test or analysis of variance, whereas nonparametric data were analyzed using the Mann-Whitney *U* or the Kruskal-Wallis test. The chi-square test 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 Corp).

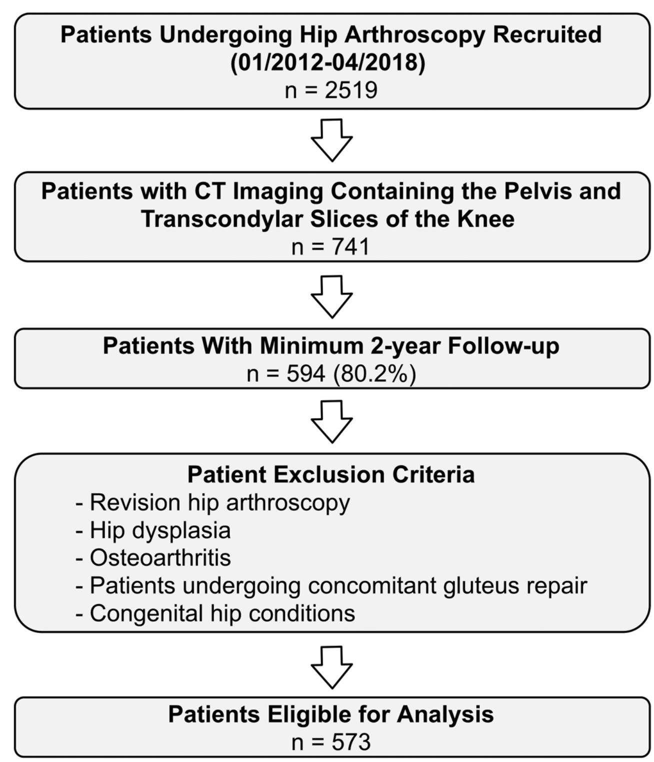

Figure 2. Flowchart of patient selection, including inclusion and exclusion criteria. CT, computed tomography.

RESULTS

Patient Characteristics

Of the 741 patients with CT imaging necessary for measurement of femoral torsion, 594 patients (80.2%) completed patient-reported outcome measures at a minimum of 2 years; an additional 21 patients were excluded because they underwent revision surgery (n = 7), had moderate or severe hip dysplasia (n = 9), had a Tönnis grade >1 (n = 1), or underwent concomitant gluteus medius or minimus repair (n = 4) (Figure 2). The mean age and body mass index (BMI) were 32.6 ± 11.8 years and 25.6 ± 10.6, respectively, and 66.0% of patients were female (Table 1). A post hoc power analysis was performed using a medium effect size (η^2 = 0.06; Cohen *F* = 0.25), α error probability of .05, and a sample size of 573, indicating our study was sufficiently powered to 0.9995.

Analysis of patient characteristics revealed no significant differences in age, BMI, sex, tobacco use, workers' compensation status, or participation in physical activity at baseline. The mean follow-up time was 28.0 months for the cohort. The procedures performed for the cohort are summarized in Table 2.

TABLE 2
Frequency of Procedures Performed for the Entire Study Population

Procedure	Frequency, %
Femoroplasty	100.00
Capsular repair or plication	100.00
Synovectomy	96.84
Labral repair	96.84
Acetabuloplasty	94.56
Microfracture	4.59
Trochanteric bursectomy	4.04
Psoas release	0.88
Iliotibial band release	0.35
Excision heterotopic ossification	0.35
Gluteus medius repair	0.00

The mean femoral torsion for the entire study population was 12.3° ± 9.3° (Figure 3). After stratification based on magnitude and orientation of femoral torsion, the number of patients within each group and the mean torsion within the group were as follows: SR (n = 36; –6.5° ± 7.1°), MR (n = 80; 2.8° ± 1.4°), N (n = 346; 12.3° ± 4.1°), MA (n = 64; 22.2° ± 1.4°), and SA (n = 47; 30.3° ± 3.7°) (Figure 4).

Imaging Characteristics

Preoperative CT imaging parameters are described in Table 3. Preoperative radiographic imaging parameters are described in Table 4. Between-group comparisons revealed significant differences in the anterior center-edge angle (P = .049) and the frequency of posterior wall sign (P = .031). Furthermore, differences between groups were observed regarding mean postoperative alpha angle measured on the anteroposterior view as well as Dunn lateral view ($P < .05$).

Clinical Outcomes Analysis

Analysis of patient-reported outcome measures revealed no significant differences in mHHS, HOS-ADL, HOS-SS, iHOT-12, or VAS for pain or satisfaction at baseline or latest follow-up (Table 5). Subsequently, we analyzed the proportion of patients achieving the MCID and the PASS at latest follow-up. This analysis revealed that there were no significant differences in the rate of MCID or PASS achievement for any outcome measure based on the orientation and magnitude of femoral torsion (Table 6).

Femoral Torsion Subanalysis: Does Torsion Classification Influence Clinically Meaningful Outcome?

Although the analysis of clinically meaningful outcome improvement across torsion classifications was appropriately powered, we sought to control for the potential scenario wherein the use of this specific classification stratification contributed to the observation of nonsignificant differences.

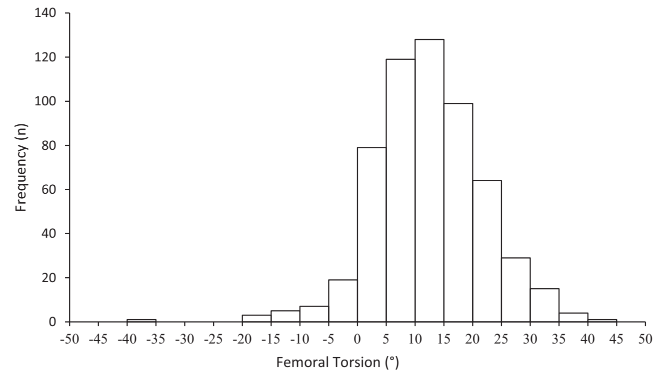

Figure 3. Histogram of femoral torsion frequency by 5° increments. Mean ± SD, 12.3° ± 3.0°.

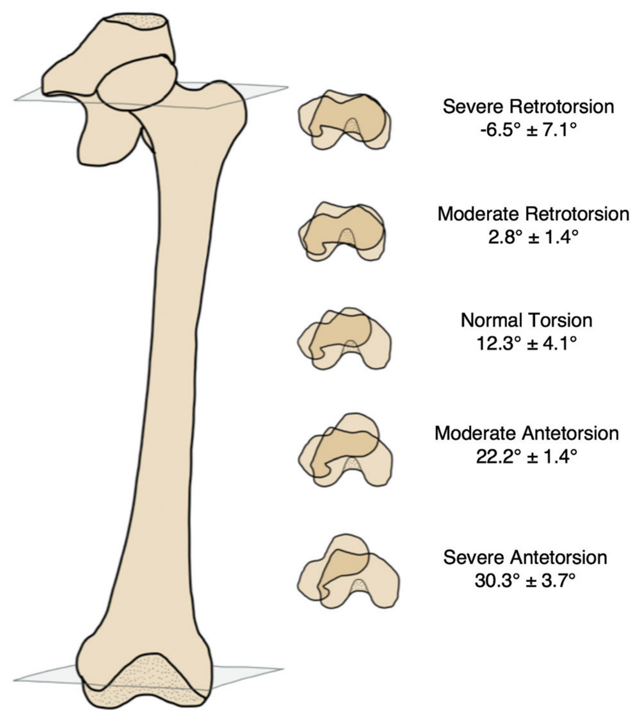

Figure 4. Diagram displaying the location of femoral torsion measurements as well as the mean ± SD torsion for the groups included in this study.

Patients were therefore classified based on the following groupings: SR (<0° of antetorsion), MR (0°-10° of antetorsion), N (10°-26° of antetorsion), MA (26°-35° of antetorsion), and SA (>35° of antetorsion). This resulted in a total of 36 patients in the SR group, 199 in the MR group, 291 in the N group, 42 in the MA group, and 5 in the SA group. Chi-square analysis confirmed that no statistically significant differences existed based on femoral torsion orientation or magnitude for the MCID or PASS of any outcome measure using this alternative classification ($P > .05$ for all).

TABLE 3
Preoperative Computed Tomography Parameters Compared by Stratification of Femoral Torsion[a]

	SR	MR	N	MA	SA	*P* Value
Acetabular version, deg	15.2 ± 5.5	16.7 ± 5.0	17.2 ± 5.2	17.3 ± 5.6	18.2 ± 5.4	.104
AIIS type						
Type 1	68.6	62.0	64.3	55.6	71.7	.566
Type 2	31.4	35.4	34.5	44.4	26.1	
Type 3	0.0	2.5	1.2	0.0	2.2	

[a]Values are expressed as mean ± SD or frequency (ie, percentage). AIIS, anterior inferior iliac spine; MA, moderate antetorsion; MR, moderate retrotorsion; N, normal torsion; SA, severe antetorsion; SR, severe retrotorsion.

TABLE 4
Radiographic Parameters Compared by Stratification of Femoral Torsion[a]

	SR	MR	N	MA	SA	*P*- Value
Preoperative						
Alpha angle—AP	63.2 ± 18.8	66.9 ± 18.0	65.8 ± 17.4	68.5 ± 18.1	68.6 ± 15.5	.495
Alpha angle—Dunn	57.4 ± 9.5	60.3 ± 11.7	61.0 ± 12.6	61.7 ± 12.0	61.9 ± 13.2	.580
Anterior center-edge angle	33.3 ± 6.6	34.5 ± 7.6	33.9 ± 7.3	37.1 ± 6.8	33.7 ± 4.3	**.049**
Lateral center-edge angle	30.4 ± 6.8	31.4 ± 7.3	31.9 ± 6.3	32.7 ± 6.1	30.5 ± 5.3	.164
Tönnis angle	6.8 ± 4.4	6.9 ± 4.7	6.2 ± 4.4	5.3 ± 4.1	6.7 ± 4.2	.319
Posterior wall sign	22.2	44.2	33.9	49.2	34.0	**.031**
Coxa profunda	70.6	44.6	50.0	43.5	44.7	.088
Protrusio acetabuli	2.9	0.0	0.9	1.6	0.0	.560
Tönnis grade 1	0.0	11.5	5.3	1.6	6.5	.051
Ischial spine sine	37.1	23.4	25.1	26.6	29.8	.559
Crossover sign	11.4	9.3	15.3	21.0	4.3	.088
Postoperative						
Alpha angle—AP	42.7 ± 4.8	45.3 ± 9.6	46.5 ± 9.5	47.7 ± 11.8	45.0 ± 7.4	**.045**
Alpha angle—Dunn	35.5 ± 5.1	37.2 ± 5.7	38.4 ± 6.8	40.2 ± 9.4	39.6 ± 7.2	**<.001**
Lateral center-edge angle	28.9 ± 5.4	30.0 ± 5.3	29.8 ± 6.0	30.7 ± 6.1	28.1 ± 4.4	.275
Tönnis angle	6.8 ± 4.1	6.5 ± 4.1	6.3 ± 4.8	5.6 ± 4.6	6.9 ± 4.4	.537

[a]Angles are expressed in degrees as mean ± SD; all other values are expressed as frequency (ie, percentage). Boldface *P* values indicate statistical significance. AP, anteroposterior; MA, moderate antetorsion; MR, moderate retrotorsion; N, normal torsion; SA, severe antetorsion; SR, severe retrotorsion.

TABLE 5
Preoperative and Latest Follow-up Patient-Reported Outcomes Compared by Stratification of Femoral Torsion[a]

	SR	MR	N	MA	SA	*P* Value
Preoperative assessment						
mHHS	58.1 ± 14.4	58.9 ± 13.6	60.4 ± 14.4	63.1 ± 13.9	60.2 ± 13.2	.737
HOS-ADL	59.1 ± 22.3	64.8 ± 18.4	65.4 ± 20.4	66.9 ± 16.3	63.9 ± 17.8	.599
HOS-SS	39.7 ± 23.7	44.0 ± 22.5	44.0 ± 24.3	43.0 ± 19.7	40.4 ± 22.2	.797
iHOT-12	29.7 ± 12.7	35.8 ± 15.0	37.5 ± 19.6	37.5 ± 17.3	38.4 ± 13.9	.485
VAS–pain	66.8 ± 17.5	60.6 ± 23.6	59.0 ± 21.7	61.6 ± 23	67.8 ± 21.8	.117
Latest follow-up assessment						
mHHS	81.3 ± 22.7	79.8 ± 16.1	81.6 ± 17.3	81.0 ± 15.6	80.8 ± 16.6	.595
HOS-ADL	88.6 ± 14.7	85.4 ± 14.1	87.6 ± 16.2	87.1 ± 13.9	86.5 ± 17.2	.291
HOS-SS	79.0 ± 23.2	71.5 ± 24.6	76.9 ± 24.8	72.2 ± 26.2	78.2 ± 22.9	.144
iHOT-12	71.6 ± 27.0	74.9 ± 21.4	73.2 ± 25.9	69.4 ± 25.8	74.4 ± 23.2	.926
VAS–pain	16.8 ± 21.9	18.3 ± 20.0	19.5 ± 23.2	21.6 ± 24.1	21.4 ± 21.9	.663
VAS–satisfaction	90.4 ± 15.5	82.9 ± 23.5	82.1 ± 25.4	76.3 ± 29.2	78.9 ± 24.4	.108

[a]Values are expressed as mean ± SD. HOS-ADL, Hip Outcome Score–Activities of Daily Living; HOS-SS, Hip Outcome Score–Sports Subscale; iHOT-12, international Hip Outcome Tool-12; MA, moderate antetorsion; mHHS, modified Harris Hip Score; MR, moderate retrotorsion; N, normal torsion; SA, severe antetorsion; SR, severe retrotorsion; VAS, visual analog scale.

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

	SR	MR	N	MA	SA	*P* Value
MCID						
mHHS	91.3	74.5	75.0	59.5	81.3	.056
HOS-ADL	88.5	69.1	69.5	69.4	69.7	.374
HOS-SS	72.7	76.6	71.8	69.6	75.0	.947
iHOT-12	73.7	87.1	75.9	65.5	78.9	.406
VAS–pain	79.2	83.6	79.9	76.7	89.7	.669
Any PRO	83.3	92.5	89.4	83.6	92.1	.420
PASS						
mHHS	65.6	67.1	71.7	71.9	78.3	.690
HOS-ADL	63.9	60.5	67.8	60.9	68.1	.672
HOS-SS	60.6	53.5	64.9	54.2	64.1	.311
iHOT-12	60.0	72.5	71.4	62.2	72.2	.524
VAS–pain	75.0	66.2	65.2	57.9	58.7	.484
Any PRO	75.0	65.0	71.1	65.6	74.5	.625

[a]Values are expressed as frequency (ie, percentage). HOS-ADL, Hip Outcome Score–Activities of Daily Living; HOS-SS, Hip Outcome Score–Sports Subscale; iHOT-12, international Hip Outcome Tool-12; MA, moderate antetorsion; MCID, minimal clinically important difference; mHHS, modified Harris Hip Score; MR, moderate retrotorsion; N, normal torsion; PASS, Patient Acceptable Symptom State; PRO, patient-reported outcome; SA, severe antetorsion; SR, severe retrotorsion; VAS, visual analog scale.

DISCUSSION

The main findings of the current study are as follows: (1) the orientation and severity of femoral torsion did not significantly influence propensity for clinically meaningful outcome improvement after hip arthroscopy for FAIS; (2) clinical outcomes based on femoral torsion did not differ when we compared 2 reliable and validated classification schemes; and (3) using a single imaging modality, we quantified a range of femoral torsion values for a large population of patients with primary hip arthroscopy. These findings have prognostic implications and highlight the need for methodological consistency in future literature seeking to investigate the relationship between femoral torsion and clinical outcomes.

In the current study, we found that clinically meaningful outcome improvement in both physical function and pain did not differ based on femoral torsion. For patients with severe femoral antetorsion or retrotorsion, rates of achieving MCID ranged from 69.7% to 92.1%; in patients with normal torsion, rates of achieving MCID ranged from 69.5% to 89.4%. Evaluation of PASS achievement rates also did not significantly differ. Unlike previous literature, the current study found that femoral torsion was not a significant anatomic factor that influenced outcome improvement. Domb et al[6] found that patients with borderline dysplasia and excessive femoral anteversion (defined as >20°) experienced inferior outcomes and a higher rate of reoperations compared with their matched counterparts, although those investigators did not assess clinically meaningful outcome improvement and had a small sample of 36 patients. Fabricant et al[9] evaluated a patient cohort less than half the size of that in the current study and obtained acetabular and femoral version measurements on CT images using oblique axial slices. Those investigators categorized version as decreased (<5° of anteversion), normal (5°-20° of anteversion), and increased (>20° of anteversion). They found that patients with decreased femoral version had smaller improvements in mHHS and iHOT-33 scores compared with patients who had normal antetorsion. Ferro et al[10] categorized femoral version and torsion on MRI scans as low (<5° of anteversion), normal (5°-15° of anteversion), and high (>15° of anteversion) and found that patient-reported outcomes did not differ at 2 years postoperatively. Jackson et al[22] measured femoral version on MRI and magnetic resonance angiography scans and defined retroversion as <−2°, normal version as −2° to 18°, and anteversion as >18°. This group found that postoperative patient-reported outcome scores did not significantly differ. Finally, using MRI, Lall et al[29] compared the midterm outcomes of 59 patients with femoral retroversion and 59 patients with normal femoral version. This group found no statistically significant differences in pain, satisfaction, or patient-reported outcome measures including the mHHS, HOS-SS, and Nonarthritic Hip Score. Although Lall et al did not investigate the outcomes of patients with excessive anteversion, their results are in accordance with those of the current study in that they did not observe differences in clinical outcomes based on the degree of femoral morphology.

The discordance between the current study and previous literature is likely a function of the heterogeneity in methods and outcome reporting in previous literature. Although previous studies have identified an association between femoral version and outcomes after hip arthroscopy, some have included both CT- and MRI-based measurements and used different slice orientations; therefore, inconsistencies may exist in the measurement techniques because not all patients underwent measurements on similar modalities. Furthermore, this introduces the potential for measurement bias depending on the individual who quantifies the values of torsion. Another limitation of previous literature is that researchers have used the terms *femoral version* and *femoral torsion* interchangeably, although these are anatomically different variables. Whereas femoral torsion accounts for rotation of the entire femur and the femoral neck, femoral version accounts only for rotation proximal to the lesser trochanter. As such, it is plausible that differences exist in the association between femoral torsion and outcomes based on imaging modality and inherent differences in the quality and segmentation of these images and reliable identification of anatomic structures. We recommend that future studies limit the measurement of femoral version or torsion to 1 modality for consistency and use reproducible and consistent terms regarding femoral version versus torsion. Future studies are warranted to determine whether differences in femoral torsion are observed between imaging modalities and whether imaging modality is associated with clinical outcomes.

In the current study, 5 torsion categories in patients undergoing hip arthroscopy were defined using a combination of previous literature in conjunction with our population distribution: severe retrotorsion (<0°), moderate retrotorsion (0°-5°), normal torsion (5°-20°), moderate antetorsion (20°-25°), and severe antetorsion (>25°). Lerch et al,[32] who sought to quantify the prevalence of femoral version abnormalities in symptomatic hips with FAIS and dysplasia, found that approximately half of their participants had abnormal version. Those investigators categorized torsion as severely decreased (<0° of antetorsion) in 5% of patients, moderately decreased (0°-10° of antetorsion) in 17%, moderately increased (26°-35° of antetorsion) in 18%, and severely increased (>35° of antetorsion) in 12%. Despite claiming to study version, Lerch et al[32] used the torsion measurement technique described by Murphy et al,[39] whereas the current study used a modified method of torsion measurement derived from Hernandez et al.[18] In a separate paper,[23] 52 single human cadaveric femurs were measured using 6 different torsion measurement techniques, and the investigators found significant differences between the techniques of Murphy et al (17.5° ± 7.0°) and Hernandez et al (11.4° ± 7.4°). The differences in measurement technique may explain, in part, the greater mean torsion in the study by Lerch et al[32] (19° ± 14°) in comparison with the present study (12.3° ± 9.3°). In addition, Lerch et al[32] assessed femoral version on both CT images and MRI scans, depending on availability. This may explain the greater variability seen in their study as well as the greater range encompassing their moderate retroversion, normal, and moderate anteversion groups.

By our classification, 39.6% of patients who underwent hip arthroscopy for FAIS had a femoral torsion abnormality, approximately 10% less than that estimated by Lerch et al.[32] This may be due to the inclusion of both MRI and CT modalities in their study, which has been demonstrated as a challenge in previous literature,[23] or the differences in patient populations. However, a large variety of classifications and modalities to measure femoral version and torsion have been used in previous literature, and many measurements have been mixed, described as version when they are torsion measurements, or vice versa.[5,9,10,22] Regardless, this suggests that findings regarding severity and prevalence of femoral torsion in patients with hip arthroscopy may differ based on the imaging modality used. This remains a considerable limitation in the current literature; the research community should advocate for standardization of anatomic measurement methods, and these measurements should be adopted in the literature. In addition, previous studies have shown that seemingly minor changes in patient position at the time of image acquisition may affect femoral torsion measurements, resulting in significant differences in femoral torsion values with as little as 5° of hip flexion or extension.[38] Prognostication and assessment of outcomes may remain heterogeneous and inaccurate until methodological variability is minimized in such studies. Although it remains unknown which imaging modality produces the most accurate depiction and assessment of femoral torsion in these patients, we recommend the use of a single modality for research purposes to avoid misleading conclusions and heterogeneity.

Limitations to the current study should be discussed. First, a minority of potentially eligible patients had adequate CT imaging to assess femoral torsion, which may have introduced selection bias. Second, the use of a single measurement technique for femoral torsion may have limited 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 have limited generalizability. However, this classification was adequately powered, and we also performed a subgroup analysis using a different classification, which also failed to demonstrate significant between-group differences in outcomes based on femoral torsion. Fourth, outcomes were assessed at short-term evaluation, 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 for FAIS did not influence propensity for clinically meaningful outcome improvement.

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