A commentary by Keith M. Baumgarten, MD, is linked to the online version of this article at jbjs.org.

The Effect of Femoral and Acetabular Version on Clinical Outcomes After Arthroscopic Femoroacetabular Impingement Surgery

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Background: The impact of proximal femoral and combined femoral and acetabular version on patient-reported outcomes after arthroscopic surgery for femoroacetabular impingement (FAI) remains undefined. The purpose of this study was to identify associations of proximal femoral version as well as combined version (McKibbin index) with disease-specific, validated, patient-reported outcomes following arthroscopic correction of symptomatic FAI.

Methods: A prospective hip arthroscopy registry was utilized to evaluate 243 patients who underwent arthroscopic surgery to correct FAI. Femoral version and the McKibbin index were measured prospectively on preoperative computed tomography scans. Disease-specific, patient-reported outcomes included the modified Harris hip score (mHHS) and the Hip Outcome Score (HOS) ADL (Activities of Daily Living) and Sports subscales. Disease impact on quality of life was determined with use of the International Hip Outcome Tool (iHOT-33). Comparative analyses were used to evaluate the impact of femoral version on changes in patient-reported outcome scores; multiple regression was used to adjust for potential confounders.

Results: The patient cohort contained 243 patients (123 female and 120 male) with a mean age of 29.2 years and a mean postoperative follow-up of twenty-one months (range, twelve to forty-two months). The cohort experienced significant improvements ($p < 0.001$) in all patient-reported outcome measures, with most patients improving by at least the minimal clinically important difference for all of these measures. The mean improvement was 20 points for the mHHS, 15 for the HOS ADL, 23 for the HOS Sports, and 23 for the iHOT-33. When stratified by femoral version, the postoperative improvements in patients with relative femoral retroversion (<5° anteversion) were clinically important but of significantly smaller magnitude than those in the other version groups. We did not find any associations between the McKibbin index and any patient-reported outcomes.

Conclusions: Although clinically important improvements can be expected after arthroscopic FAI surgery in all femoral version groups, patients with relative femoral retroversion (<5° femoral anteversion) may experience less improvement than those with normal or increased version.

Level of Evidence: Prognostic Level II. See Instructions for Authors for a complete description of levels of evidence.

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It has been previously established that abnormal femoral torsion is associated with long-term development of osteoarthritis[1]. Furthermore, femoral torsion impacts the terminal range of motion and affects secondary dynamic hip stabilizers[2-4]. Although this concept has been well developed in the arthroplasty literature[5,6], similar research following corrective surgery in native hips has been hindered by the lack of detailed three-dimensional CT (computed tomography) models and corresponding clinical outcomes data.

Patient-reported outcomes are considered the gold standard when performing clinical outcomes research in a surgical cohort[7]. Despite the paucity of patient-reported outcomes in cohorts with femoroacetabular impingement (FAI), excessive femoral retroversion has been considered by some to be a relative contraindication to corrective FAI surgery because of concerns regarding exacerbation of cam deformity and failure to improve functional internal rotation despite adequate osteoplasty[1,8]. To our knowledge, the clinical relevance of excessive femoral version, particularly with regard to patient selection for hip preservation surgery, has not been addressed to date.

The primary purpose of the present study was to investigate the association between proximal femoral version and disease-specific, patient-reported clinical outcomes following arthroscopic decompression of FAI. The secondary purpose was to investigate associations of combined femoral and acetabular version (the McKibbin index) with patient-reported outcomes. Such information would build on existing data on improvements in range of motion[4] to offer patients considering this procedure vital, evidence-based prognostic data based on measurable hip indices. As such, our primary null hypothesis was that there would be no associations between proximal femoral version and any of four disease-specific, validated, patient-reported outcome scores: the modified Harris hip score (mHHS), Hip Outcome Score (HOS) Activities of Daily Living (ADL) and Sports subscales, and International Hip Outcome Tool (iHOT-33). Our secondary null hypothesis was that there would be no associations between the McKibbin index and the patient-reported outcomes.

Materials and Methods

Patient Selection

This study was approved by our institutional review board. A prospective registry of demographic, biometric, and outcomes data for all hip arthroscopy procedures performed by the senior surgeon (B.T.K.) was queried. All patients who were younger than sixty years of age; who underwent an index primary hip arthroscopy procedure without a psoas release from October 1, 2010, to October 1, 2012, with a primary diagnosis of FAI; and who had relevant preoperative and one-year postoperative assessments including one or more of the four outcomes instruments were considered for inclusion (n = 255). Twelve patients were excluded because they underwent contralateral hip surgery within one year of the postoperative assessment (staged bilateral procedures), leaving 243 patients in the final cohort that was analyzed.

Indications and Surgical Technique

Initial patient evaluation included a focused history, physical examination, and radiographs (anteroposterior pelvis and extended-neck lateral of the affected hip). Range of motion (including flexion, internal rotation at 90° of flexion, and external rotation) was recorded with use of a goniometer and was available for 93% of the cohort (227 of the 243). Preoperative radiographs and CT scans were examined for signs of FAI, including an increased alpha angle, femoral head asphericity, loss of head-neck offset, and/or focal acetabular retroversion. Any patients with radiographic findings of dysplasia (lateral center-edge angle of <20°, anterior center-edge angle of <20°, Tönnis angle of >10°, and/or posterior wall undercoverage) or degenerative changes greater than Tönnis grade I were treated by other means such as redirectional osteotomy and were not included in the present study. The radiographic signs of FAI were corroborated with physical findings, including limited flexion and internal rotation and a positive impingement test, to secure a diagnosis. All patients underwent hip arthroscopy only after a complete course of physical therapy, oral anti-inflammatory medication, and activity modification was unsuccessful in relieving persistent, refractory pain and/or mechanical symptoms.

Hip arthroscopy was performed with the patient in the supine position[9]. An interportal capsulotomy was performed to fully visualize and address the intra-articular and extra-articular sources of impingement and was repaired prior to the end of the procedure. Labral refixation was performed if the tissue quality and tear pattern were amenable to repair and the labrum was not ossified. Femoral head-neck osteoplasty was performed in the peripheral compartment after removal of traction and gentle hip flexion of 30° to 40°. Intraoperative fluoroscopy confirmed restoration of offset (>9 mm) on the extended-neck lateral view, femoral head sphericity (alpha angle of <50°), and proximal-distal correction from the physeal scar to the intertrochanteric line as assessed on six views (anteroposterior-internal rotation, anteroposterior-neutral, anteroposterior-external rotation, Dunn view-90° hip flexion, Dunn view-45° hip flexion, and frog-leg lateral)[10]. An intraoperative dynamic assessment of clearance with hip flexion and internal rotation was performed to confirm improvement in range of motion.

Data Analysis

An attending musculoskeletal radiologist calculated the femoral version on preoperative low-dose CT scans by measuring the plane along the length of the femoral neck axis in an oblique-axial slice (containing the long axis of the femoral neck from its center to its base) as referenced from the posterior condylar axis of the distal aspect of the femur in the axial plane[1,2,10-17]. Femoral version was evaluated as a categorical predictor variable, utilizing previously defined subgroups: normal (5° to 20°), increased (>20°), and decreased (<5°). These groups have also been utilized in previous research[4] and were based on a previous case-control study performed by Ito et al.[18] at the AO/ASIF Research Institute. The authors quantified version in patients with symptomatic FAI and in healthy asymptomatic controls. Patients with FAI had decreased version compared with controls (mean [and standard deviation], 10° ± 5° compared with 16° ± 4°). In an effort to include the widest reasonable range of values for "normal" version in the present study, we selected one standard deviation above and below these established means (i.e., 5° to 20°) as normal; <5° was considered decreased version, and >20° was considered increased version.

The McKibbin index is a measure of combined femoral and acetabular version developed to evaluate children with developmental dysplasia of the hip[19]. Although it has not been validated in FAI, a modification of the McKibbin index was used to quantify combined version. In this modification, acetabular version was determined as the mean version at the 1-o'clock, 2-o'clock, and 3-o'clock positions in order to account for global acetabular version (rather than that in a single axial slice) and was added to the femoral version. Additional demographic, biometric, and surgical variables were collected in the registry. Prospectively collected, disease-specific, patient-reported outcomes included the mHHS[20] and the HOS ADL and Sports subscales[21,22]. Disease impact on quality of life was determined with use of the iHOT-33[23]. Clinically important differences in patient-reported outcomes were based on previously established values (8 points for the mHHS, 5 for the HOS ADL subscale, 6 for the HOS Sports subscale, and 10 for the iHOT-33[7]. Most of the included patients completed all four outcome instruments preoperatively and postoperatively; however, because of the logistics of the data collection, the mHHS was completed by 95% of the included cohort (230 of 243 subjects) at both time points; the HOS ADL, by 92% (223); the HOS Sports, by 86% (210); and the iHOT-33, by 78% (190).

Data were analyzed with use of SAS software (version 9.3; SAS Institute, Cary, North Carolina). Continuous variables were assessed for normality with

TABLE I Baseline Characteristics of the Study Cohort*

Variable	Decreased Version, N = 37	Normal Version, N = 149	Increased Version, N = 57	P Value†	Significant Pairwise Comparisons‡
Age§ *(yr)*	28 ± 9	30 ± 11	29 ± 10	0.630	—
Female sex	41%	50%	58%	0.257	—
BMI§ *(kg/m²)*	25 ± 4	24 ± 4	24 ± 4	0.112	—
Left side	38%	46%	40%	0.612	—
Alpha angle§ *(deg)*	65 ± 13	64 ± 12	63 ± 12	0.620	—
Femoral version§ *(deg)*	−2 ± 5	13 ± 5	27 ± 6	<0.001#	Decreased < normal < increased
Acetabular version§ *(deg)*	10 ± 7	9 ± 7	10 ± 7	0.966	—
McKibbin index§ *(deg)*	8 ± 8	23 ± 8	36 ± 10	<0.001#	Decreased < normal < increased
Preop. ROM§ *(deg)*					
IR at 90° flexion	6 ± 6	12 ± 8	22 ± 15	<0.001#	Decreased < normal < increased
Flexion	104 ± 7	105 ± 8	109 ± 8	0.011#	Decreased < increased; normal < increased
ER	44 ± 10	42 ± 9	42 ± 10	0.617	—
Procedure *(no.)*				0.017#	**
Isolated cam	10	24	5		
Isolated rim	1	3	6		
Combined	26	122	46		

*Decreased version was <5°, normal version was 5° to 20°, and increased version was >20°. ROM = range of motion, IR = internal rotation, and ER = external rotation. †Compared among the three version groups with ANOVA. ‡P < 0.05 with pairwise two-tailed t test. §The values are given as the mean and the standard deviation. #Significant difference among groups. **Distribution of pathologies was different in the increased version group, with fewer isolated cam and more isolated rim procedures than in the other groups.

use of the Shapiro-Wilk test and quantile-quantile plots. Demographics, preoperative radiographic indices, preoperative range of motion, and intraoperative procedures were compared among the three femoral version groups with ANOVA (analysis of variance) for continuous variables and with the chi-square test or Fisher exact test for categorical variables, with post hoc pairwise comparisons when appropriate. Changes in patient-reported outcome scores were tested for significance with the paired t test. The independent-samples t test was used to compare changes in patient-reported outcome scores and in range of motion between patients with increased or decreased femoral version and patients with normal version. Multiple regression was used to adjust for potential confounders (see Appendix). The percentage of patients who improved by at least the MCID (minimal clinically important difference) for each instrument was compared among groups with the chi-square test and logistic regression; effect sizes are presented as both unadjusted and adjusted odds ratios (ORs) with 95% confidence intervals (CIs). The Spearman rank correlation coefficient was used to explore relationships between the McKibbin index and the change in each clinical outcome score.

Because this was an analysis of all patients enrolled in a prospective registry, an a priori power calculation was not performed. All comparative analyses were two-tailed, and a p value of 0.05 was considered significant.

Source of Funding

There was no external funding for this study.

Results

The patient cohort contained 243 patients (123 female and 120 male) with a mean age of 29.2 years and a mean postoperative follow-up of twenty-one months (range, twelve to forty-two months) (Table I). Combined cam and rim decompression was performed in 194 patients; isolated cam decompression, in thirty-nine; and isolated rim/subspine decompression, in ten. The distribution of FAI pathology was different in the increased version group, with fewer isolated cam procedures and more isolated rim procedures than in the other two version groups ($p = 0.02$; ANOVA). Femoral version was normal (5° to 20°) in 149 patients, increased (>20°) in fifty-seven, and decreased (<5°) in thirty-seven. The mean McKibbin index was 24° ± 12° (range, −8.3° to 64.3°). Both femoral version and McKibbin index values were normally distributed. The size of any cam-related cartilage delamination was <1 cm^2 in all cases. Five patients (2%) had femoral head chondral pathology requiring microfracture. Labral pathology was present in 241 patients (99%), with 194 (80%) receiving labral repair and forty-seven (19%) receiving labral debridement. There were no differences in the distribution of chondral pathology, labral pathology, or labral procedures among the version groups; moreover, there were no associations between these parameters and any patient-reported outcome ($p > 0.05$ for all).

The decreased femoral version group had less preoperative internal rotation in flexion than the normal and increased version groups ($p < 0.001$) and less preoperative hip flexion than the increased version group ($p = 0.003$). The increased version group had greater preoperative internal rotation in flexion and hip flexion than the normal version group ($p < 0.001$ and 0.017,

TABLE II Postoperative Change in ROM in Other Groups Compared with the Normal Version Group*

Variable	Version Group	Postop. Change in ROM† *(deg)*	Unadjusted Difference in Means (95% CI) *(deg)*	P Value‡	Adjusted Difference in Means (95% CI) *(deg)*	P Value§
IR at 90° flexion	Decreased	20 ± 7	4 (1 to 8)	0.017#	−1 (−4 to 2)	0.507
	Normal	15 ± 8	Reference	Reference	Reference	Reference
	Increased	10 ± 15	−5 (−12 to 1)	0.101	1 (−2 to 4)	0.450
Flexion	Decreased	0 ± 8	1 (−3 to 5)	0.715	−1 (−5 to 4)	0.679
	Normal	−1 ± 8	Reference	Reference	Reference	Reference
	Increased	−5 ± 17	−4 (−11 to 3)	0.252	−4 (−8 to 0)	0.077
ER	Decreased	−2 ± 12	−3 (−8 to 2)	0.221	−1 (−2 to 1)	0.506
	Normal	2 ± 9	Reference	Reference	Reference	Reference
	Increased	3 ± 11	1 (−3 to 6)	0.632	0 (−2 to 1)	0.550

*Decreased version was <5°, normal version was 5° to 20°, and increased version was >20°. ROM = range of motion, IR = internal rotation, and ER = external rotation. †The values are given as the mean and the standard deviation. ‡Independent-samples t test; relative to normal version group. §Adjusted for alpha angle and preop. range of motion with multiple regression; relative to normal version group. #Significantly different from normal version group.

respectively). The decreased version group experienced larger postoperative improvements in internal rotation in flexion than the normal version group (p = 0.017); however, this difference was not significant after adjustment for the preoperative alpha angle and range of motion, indicating that this difference was due to this group's expectedly lower preoperative internal rotation. There were no differences in postoperative improvements in hip flexion or external rotation between version groups, either before or after adjustment for the preoperative alpha angle and range of motion (Tables I and II).

Postoperative changes in outcome scores were compared between patients with increased or decreased femoral version

TABLE III Postoperative Change in Hip-Specific Patient-Reported Outcomes in Other Groups Compared with the Normal Version Group*

Outcome	MCID	Version Group	Postop. Change in Score (95% CI)	Unadjusted Difference in Means (95% CI)	P Value†	Adjusted Difference in Means (95% CI)	P Value‡
mHHS	8	Decreased	14 (9 to 20)	−8 (−14 to −2)	0.007§	−8 (−14 to −3)	0.004§
		Normal	22 (20 to 25)	Reference	Reference	Reference	Reference
		Increased	20 (15 to 25)	−2 (−8 to 3)	0.349	0 (−5 to 6)	0.959
		Entire cohort	20 (18 to 23)	—	—	—	—
HOS ADL	5	Decreased	11 (5 to 17)	−4 (−11 to 2)	0.205	−7 (−12 to −2)	0.008§
		Normal	16 (12 to 19)	Reference	Reference	Reference	Reference
		Increased	15 (11 to 19)	0 (−6 to 5)	0.891	2 (−3 to 6)	0.528
		Entire cohort	15 (12 to 17)	—	—	—	—
HOS Sports	6	Decreased	12 (4 to 20)	−15 (−25 to −5)	0.004§	−13 (−23 to −4)	0.008§
		Normal	27 (21 to 32)	Reference	Reference	Reference	Reference
		Increased	21 (14 to 28)	−5 (−14 to 4)	0.239	0 (−9 to 10)	0.912
		Entire cohort	23 (19 to 27)	—	—	—	—
iHOT-33	10	Decreased	19 (10 to 28)	−16 (−26 to −7)	0.001§	−16 (−25 to −7)	<0.001§
		Normal	35 (31 to 40)	Reference	Reference	Reference	Reference
		Increased	28 (21 to 35)	−7 (−15 to 1)	0.095	−5 (−14 to 3)	0.219
		Entire cohort	31 (27 to 34)	—	—	—	—

*MCID values adapted from Kemp et al.[7]. Decreased version was <5°, normal version was 5° to 20°, and increased version was >20°. †Independent-samples t test; relative to normal version group. ‡Adjusted for age, sex, BMI, procedure, range of motion, length of follow-up, and preop. scores with multiple regression; relative to normal version group. §Significantly different from normal version group.

TABLE IV Percentage of Patients in Other Groups Compared with the Normal Version Group Who Improved by at Least the MCID for Each Patient-Reported Outcome*

Outcome	MCID	Version Group	Patients Who Improved by at Least the MCID	Unadjusted OR (95% CI)	P Value†	Adjusted OR (95% CI)	P Value‡
mHHS	8	Decreased	54%	0.34 (0.16 to 0.72)	0.004§	0.32 (0.14 to 0.72)	0.006§
		Normal	78%	Reference	Reference	Reference	Reference
		Increased	74%	0.82 (0.40 to 1.70)	0.593	0.80 (0.37 to 1.73)	0.576
		Entire cohort	73%	—	—	—	—
HOS ADL	5	Decreased	60%	0.67 (0.31 to 1.44)	0.305	0.52 (0.21 to 1.27)	0.151
		Normal	69%	Reference	Reference	Reference	Reference
		Increased	77%	1.49 (0.71 to 3.12)	0.290	1.55 (0.68 to 3.51)	0.297
		Entire cohort	70%	—	—	—	—
HOS Sports	6	Decreased	59%	0.46 (0.20 to 1.03)	0.056	0.43 (0.18 to 1.03)	0.058
		Normal	76%	Reference	Reference	Reference	Reference
		Increased	73%	0.84 (0.40 to 1.80)	0.657	0.92 (0.42 to 2.04)	0.837
		Entire cohort	73%	—	—	—	—
iHOT-33	10	Decreased	66%	0.33 (0.14 to 0.82)	0.014§	0.33 (0.13 to 0.84)	0.020§
		Normal	85%	Reference	Reference	Reference	Reference
		Increased	80%	0.68 (0.28 to 1.67)	0.400	0.65 (0.26 to 1.64)	0.364
		Entire cohort	81%	—	—	—	—

*MCID values adapted from Kemp et al.[7]. Decreased version was <5°, normal version was 5° to 20°, and increased version was >20°. †Chi-square test; relative to normal version group. ‡Adjusted for age, sex, BMI, length of follow-up, and preop. scores with multiple regression; relative to normal version group. §Significantly different from normal version group.

and the reference group of patients with normal version, both with and without adjustment for potential confounders, by means of independent-samples t tests and multiple regression. After adjusting for potential confounders (age, sex, BMI [body mass index], procedure, preoperative range of motion, preoperative scores, and length of follow-up) by means of multiple regression, patients with relative retroversion (<5° of anteversion) demonstrated a decreased magnitude of improvement in all outcome measures compared with patients with normal version, a finding that was both clinically important and significant (Table III). Seventy percent to 81% of patients in the version groups reached at least the MCID for each patient-reported outcome measure. Compared with the normal version group, the decreased femoral version group had lower odds of improving by at least the MCID for all patient-reported outcome scores, but this difference only reached significance for the mHHS (p = 0.006) and iHOT-33 (p = 0.02) (Table IV; see Appendix).

In evaluating our secondary hypothesis, Spearman correlation coefficients provided no evidence of an association between the McKibbin index and the change in any outcome score (Spearman rho, 0.07 [95% CI, −0.07 to 0.20] for the mHHS, 0.01 [95% CI, −0.13 to 0.15] for the HOS ADL, 0.0 [95% CI, −0.14 to 0.14] for the HOS Sports, and 0.0 [95% CI, −0.14 to 0.15] for the iHOT-33).

There were four minor intraoperative complications (1.6% of the cohort): superficial femoral head scuffing (n = 3) and fluid extravasation into the peritoneal cavity, which resolved spontaneously (n = 1). Perioperative complications (1.6% of the cohort) included transient sensory nerve paresthesia, which resolved spontaneously (n = 3), and superficial portal site infection, which was successfully treated with oral antibiotics (n = 1). One patient (a forty-four-year-old woman) who underwent combined cam and rim decompression with labral refixation underwent revision surgery for removal of irritating suture material and revision labral refixation at thirty months postoperatively.

Discussion

The primary purpose of this study was to investigate the association between proximal femoral version and disease-specific, patient-reported outcomes following arthroscopic decompression of FAI; the secondary purpose was to evaluate the McKibbin index for similar associations. In the overall cohort, all patient-reported outcomes improved by a clinically important degree. Patients with relative retroversion (<5° of anteversion) had smaller, but still clinically important, improvements in all outcome measures compared with those with normal or increased version when controlling for relevant covariates in multiple regression analysis. Thus, even though these patients had a smaller magnitude of improvement compared with the rest of the cohort, the results of the present study indicate that relative femoral retroversion should not be considered an absolute contraindication to surgical correction of FAI.

To our knowledge, the only previous study that evaluated the impact of version on any postoperative variable was performed by Kelly et al. and involved fifty-six hips[4]. The authors concluded that arthroscopic FAI treatment improved internal rotation in all version groups. These improvements were significantly smaller in magnitude in patients with relative femoral retroversion. Although this important contribution documented improvements in impingement-related range of motion, it remained unclear what should be expected with regard to "gold standard" patient-reported outcomes[7] in a larger cohort. Interestingly, we noted greater improvements in internal rotation in hip flexion in the decreased version group; however, this difference was due to expectedly lower preoperative range of motion. There were no differences in postoperative internal rotation among the version groups. One other study evaluated clinical outcomes in a cohort who underwent arthroscopic psoas lengthening; inferior clinical outcomes were reported in patients with excessive femoral anteversion[2]. The results of that study, however, cannot be extrapolated to the effect of version on arthroscopic correction of FAI in the absence of psoas lengthening.

Another finding of the present study was that the distributions of FAI pathology and intraoperative procedures were different in the increased version group. However, given that the great majority of cases (80%) in the study involved both femoral and acetabular osseous procedures, this finding may be spurious. All osseous resections were performed on the basis of objective intraoperative findings, which were corroborated by previously obtained imaging and physical examination. Rim lesions were confirmed intraoperatively by visualization of impaction injury to the labrum, and cam lesions were confirmed on the basis of an inclusion pattern of delamination at the osteochondral junction.

A rigorous method for measuring femoral version by comparing the difference between the posterior femoral condylar axis and the axis of the femoral neck was utilized in this study[11,15]. This method generates a single independent variable that accounts for the global rotation of the femur (femoral torsion) as well as the localized rotation of the femoral neck (neck version). It does not, however, account for further deformity proximal to the neck (e.g., head tilt), which may introduce further differences in version or rotational mechanics among patients. Future research may focus on quantifying such further deformity by defining the location of rotational morphology. Although assessing the accuracy of our measurement method is impossible in the absence of a globally accepted gold standard, the precision attained by musculoskeletal radiologists is known to be better than that achieved with similar magnetic resonance imaging techniques. The nearly perfect intraobserver correlation of the method that we utilized[11] is fundamental in conferring generalizability of our results to practicing orthopaedic surgeons working with musculoskeletal radiologists.

Strengths of this study include a large and uniform patient sample with FAI and prospective registry data collection. Rigorous exclusion criteria eliminated confounding from associated psoas lengthening or tenotomy procedures, occult dysplasia, or degenerative changes of the hip. Fellowship-trained musculoskeletal radiologists measured all radiographic metrics prospectively with use of standardized methodology with known precision[3,10-17,19,24]. To our knowledge, this is the first study to investigate the independent effects of proximal femoral rotational morphology on disease-specific patient-reported outcomes after arthroscopic decompression of FAI. The standardized, validated, hip-specific patient-reported outcome measures that were used have been shown to be reliable measures for active patients with FAI and labral pathology, with the smallest potential for floor and ceiling effects[7,25].

Interestingly, the femoral version categorization was associated with changes in patient-reported outcome scores but the McKibbin index was not. Two possible explanations exist for this finding. First, unlike focal cephalad acetabular version, which is improved intraoperatively with rim decompression, femoral version is not altered during arthroscopic treatment of FAI. Because only acetabular version is improved during the FAI treatment, the preoperative McKibbin index is less predictive of postoperative patient-reported outcomes than femoral version is. It should be noted, however, that rim decompression should not be considered a treatment for acetabular retroversion, as iatrogenic instability can develop. Second, it has been reported that acetabular version is affected by pelvic tilt[24]. It is possible that measuring the McKibbin index is inherently inaccurate, thus biasing its influence on patient-reported outcomes toward the null. To our knowledge, no FAI-specific radiographic measure of combined anteversion exists. The McKibbin index used in the present study was a modification of the original index designed to evaluate infant hip stability, and it has not been specifically validated for use in FAI. Future research could develop and validate a radiographic measure of combined version for use in FAI.

There are limitations to the present study. Although data were collected prospectively, they were analyzed retrospectively, which may lead to selection bias. This potential was minimized with the use of rigorous inclusion and exclusion criteria. In situations in which the independent variable being studied cannot be experimentally altered (e.g., femoral version), large prospective registries remain our greatest resource for analysis of observational data. The mean follow-up of twenty-one months is another limitation. We acknowledge that outcomes may change over time, and evaluating longer-term durability is of greater importance. There has been increased use of hip arthroscopy to treat FAI in selected adolescent athletes[26,27]. Although the results of the present study provide useful data that can be used to counsel young and middle-aged adult patients, they may not be externally valid in adolescents. Furthermore, the CT version measurements made by the musculoskeletal radiologists may not be generalizable to measurements made by orthopaedic surgeons. Finally, it may not be possible to restore maximal, impingement-free motion with osteoplasty in patients with certain rotational deformities without removing an unsafe volume of bone. Correction of posterior impingement by arthroscopy is particularly challenging when a deformity is near or under the lateral epiphyseal vessels. The present study and the study by Kelly et al.[4] confirm this with both patient-reported outcomes and range-of-motion data; however, the present study was not designed to create guidelines for derotational femoral osteotomy, which remains an area of future research interest.

In conclusion, clinical improvement after corrective FAI surgery can be achieved after arthroscopic decompression regardless of femoral and combined version. Patients with femoral version of <5° may achieve smaller but nonetheless clinically important improvements. They can also expect a larger improvement in internal rotation, as a result of their greater limitations of preoperative range of motion. Version abnormalities should not be considered an absolute contraindication to hip arthroscopy. Patients with retroversion should be counseled, however, that the expected clinical improvement may be less than that of patients with similar FAI morphology but normal or increased version. Future research should continue to refine the methodology for measuring the location and degree of femoral rotation as well as define indications for femoral derotational osteotomy. This will clarify whether the location of femoral torsion has any further impact on postoperative clinical outcomes, and whether surgical interventions might optimize clinical outcomes for all patients regardless of femoral version.

Appendix

eA Tables showing the complete multiple regression models for changes in range of motion, patient-reported clinical outcomes, and the percentage of patients experiencing improvements at least equal to the MCID are available with the online version of this article as a data supplement at jbjs.org. ■

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