Minimum 10-Year Outcomes of Adolescents Undergoing Contemporary Hip Arthroscopic Surgery for Femoroacetabular Impingement Syndrome

A Propensity Score–Matched Analysis

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Background: Prior studies have shown that adolescent patients achieve more favorable outcomes after hip arthroscopic surgery for femoroacetabular impingement syndrome (FAIS) compared to adult patients at short-term and midterm follow-up, but a limited number of studies have compared these groups at a minimum 10-year follow-up.

Purpose: To compare patient-reported outcome (PRO) scores, achievement rates of clinically significant outcomes, and reoperation-free survivorship between adolescent and adult patients after hip arthroscopic surgery for FAIS at a minimum 10-year follow-up.

Study Design: Case series; Level of evidence, 4.

Methods: A retrospective chart review was performed on patients who underwent primary contemporary hip arthroscopic surgery for FAIS, including chondrolabral preservation, surgical correction of FAIS, and capsular repair, between January 2012 and November 2013 with a minimum 10-year follow-up. Adolescent patients (aged 10-19 years) were propensity score matched 1:1 to adult patients (aged $\geq$20 years), controlling for sex, body mass index, Tönnis grade, duration of pain, physical activity status, and back pain. PRO scores were collected preoperatively and at 10-year follow-up, including those for 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–12 (iHOT-12), visual analog scale (VAS) for pain, and VAS for satisfaction. The cohort-specific minimal clinically important difference, Patient Acceptable Symptom State (PASS), and substantial clinical benefit (SCB) were calculated and compared between groups. Reoperation-free survivorship was compared.

Results: Overall, 50 adolescent patients (mean age, 17.0 $\pm$ 1.7 years) were matched to 50 adult patients (mean age, 33.0 $\pm$ 9.3 years) with a mean follow-up of 10.4 $\pm$ 0.4 years. No differences in preoperative PRO scores were observed. Adolescents achieved greater 10-year HOS-ADL, HOS-SS, mHHS, iHOT-12, VAS pain, and VAS satisfaction scores compared to adults ($P < .05$ for all). Adolescents showed superior achievement rates of the PASS (98% vs 79%, respectively; $P = .015$) and SCB (88% vs 67%, respectively; $P = .035$) for any PRO measure compared with adults. No differences in total hip arthroplasty–free survivorship (100% vs 94%, respectively; $P = .083$) or revision-free survivorship (90% vs 94%, respectively; $P = .473$) were found.

Conclusion: Adolescent patients treated with contemporary hip arthroscopic surgery for FAIS, including chondrolabral preservation, surgical correction of FAIS, and capsular repair, showed superior 10-year PRO scores and achievement rates of the PASS and SCB compared to a propensity score–matched group of adult patients, despite comparable short-term and midterm PROs.

Keywords: adolescents; hip arthroscopic surgery; long-term follow-up

Femoroacetabular impingement syndrome (FAIS) is a prevalent source of young adult hip pain and a known cause of early osteoarthritis in the hip, with an estimated prevalence of up to 15%.[8,15] Hip arthroscopic surgery has emerged as a reliable therapeutic intervention to address FAIS, with promising results. The bulk of the literature on FAIS tends to focus on the adult population, with long-term studies showing excellent functional outcomes and survivorship in appropriately indicated patients,

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particularly with the use of contemporary hip arthroscopic techniques including chondrolabral preservation, surgical correction of FAIS, and capsular repair.[2,11,18-20,32]

Less is known about outcomes after the surgical treatment of FAIS in the adolescent population, which can present unique challenges because of patient anatomic considerations, activity levels, and long-term expectations. Notably, hip arthroscopic surgery in adolescent patients poses theoretical risks such as osteonecrosis of the femoral head, iatrogenic slipped capital femoral epiphysis, and growth disturbances, which are comparatively less of a concern in adult patients.[17,21] Because of these concerns, some surgeons have advocated for physeal-sparing femoral osteoplasty or avoiding femoral osteoplasty altogether in patients with open physes, although others argue that incomplete resection of cam-type FAIS results in persistent hip pain and an increased risk for revision hip arthroscopic surgery.[13,17,21,31] In terms of outcomes, prior studies have highlighted success with the surgical management of FAIS in adolescent patients at short-term and midterm follow-up, including superior patient-reported outcome (PRO) scores and achievement rates of clinically significant outcomes (CSOs) compared to appropriately matched adult patients.[12,21] However, few long-term follow-up studies have compared the outcomes of adolescent patients to adult patients.[38] A thorough understanding of the long-term implications of hip arthroscopic surgery in adolescent patients, and how they relate to their nonadolescent counterparts, is informative regarding the known natural history of FAIS and for patient counseling, setting expectations, and shared decision making for treatment.[51]

The purpose of this study was to compare minimum 10-year PRO scores, achievement rates of CSOs, and reoperation-free survivorship between adolescent patients and a propensity score–matched group of adult patients undergoing contemporary hip arthroscopic surgery for FAIS. We hypothesized that adolescent patients would achieve superior PRO scores, achievement rates of CSOs, and reoperation-free survivorship compared to adult patients.

METHODS

Patients

Institutional review board approval was obtained for conducting this study. A retrospective chart review was performed, identifying all patients who underwent hip arthroscopic surgery for FAIS between January 2012 and November 2013. Patients were required to have clinical and radiographic diagnoses of symptomatic FAIS refractory to nonoperative management, including hip pain for $\geq$3 months, a positive anterior hip impingement test finding, and radiographic evidence of either cam-type (alpha angle $>$55° on 90° Dunn lateral radiography) or pincer-type (lateral center-edge angle [LCEA] $>$40°, acetabular index $<$0°, or presence of a crossover sign on anteroposterior pelvis radiography) FAIS.[2,5,22] Patients were required to have failed nonoperative management for $\geq$3 months, including activity modification, oral anti-inflammatory medications, and physical therapy, before hip arthroscopic surgery.[2] Exclusion criteria included prior ipsilateral hip arthroscopic surgery, concomitant hip procedures (iliotibial band lengthening, core decompression, gluteus medius/minimus repair, subchondroplasty), Tönnis grade $\geq$2 osteoarthritis on preoperative radiography, morphological hip disorders (slipped capital femoral epiphysis, Legg-Calvé-Perthes disease), and no minimum 10-year follow-up.

Data Collection

Collected baseline patient information from the time of surgery included age, sex, body mass index (BMI), presence of lower back pain, history of a psychiatric disorder, workers' compensation status, preoperative hip pain duration $\geq$2 years, and endorsement of regular physical activity. Regular physical activity was defined as preoperative physical activity $\geq$1 time per week.

Radiographs were obtained preoperatively and postoperatively. The radiographic series included anteroposterior pelvis, false profile, and 90° Dunn lateral views. On anteroposterior pelvis radiographs, the LCEA, Tönnis angle, and Tönnis grade were measured.[16,49] On false profile radiographs, the anterior-center edge angle was measured.[16] On 90° Dunn lateral radiographs, the alpha angle was measured.[16,29]

Cartilage defects identified intraoperatively were graded using the Beck classification for defects of the acetabulum and the ICRS (International Cartilage Regeneration & Joint Preservation Society) classification for defects of the femoral head.[3,8,37,39]

PRO scores were collected preoperatively and at 2-, 5-, and 10-year follow-up. PROs included scores for 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

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Tool–12 (iHOT-12), visual analog scale (VAS) for pain, and VAS for satisfaction.[23,30,35,36,43] Reporting of the iHOT-12 score for this study began at the 2-year postoperative time point, as the iHOT-12 was not published before the inclusion start date for this study.[23]

Preoperatively, PRO scores were collected within 30 days before surgery through emailed forms. Patients who failed to complete the emailed forms then completed the PRO measures in the preoperative holding area. Postoperatively, at the designated time points, the PRO measures were emailed to patients. Overall, 3 email and 3 telephone reminders were sent to patients to encourage them to submit their postoperative PRO scores. Patients who failed to complete the PRO measures after the 6 total reminders were deemed lost to follow-up. Secondary surgery, including revision hip arthroscopic surgery and conversion to total hip arthroplasty (THA), was recorded, along with the time to secondary surgery.

Surgical Procedures

The senior author (S.J.N.) performed all surgical procedures in this study. Patients were positioned supine with a perineal post on the traction table. General anesthesia was used for all patients. Fluoroscopic guidance was used to establish an anterolateral portal. The arthroscope was inserted, and a modified midanterior portal was then created under direct visualization from the arthroscope. The central compartment was inspected for the presence of labral tears and chondral defects. Interportal capsulotomy was performed. Labral tears were repaired using 2 to 4 single-loaded suture anchors fixed with a looped circumferential stitch.[48] In patients with normal acetabular coverage (LCEA >25°), acetabuloplasty was performed to facilitate healing of the labral repair site while taking care to avoid further disrupting the chondrolabral junction. In patients with borderline acetabular coverage (LCEA 18°-25°), rim decortication was not performed to avoid iatrogenic worsening of acetabular undercoverage. Chondral defects were debrided. Femoroplasty was then performed through either interportal capsulotomy or T-type capsulotomy based on the intraoperative ability to adequately conduct femoral osteochondroplasty. Complete resection of cam-type FAIS was performed, irrespective of whether the physis was open or closed. Fluoroscopy was used to verify adequate osteoplasty of the femoral neck. Osteoplasty was confirmed on dynamic examination. Capsular repair was then performed on all patients using nonabsorbable sutures.[6] Standard postoperative protocols were used for all patients.[34]

Statistical Analysis

Propensity score matching was performed to compare adolescent and adult patient groups while limiting the effect of known confounders. The adolescent group included patients aged 10 to 19 years at the time of surgery, in accordance with the World Health Organization's definition,[1,47] and the adult group included patients aged ≥20 years at the time of surgery. Propensity score matching was performed, controlling for sex, BMI, Tönnis grade, pain duration ≥2 years, physical activity status, and back pain. Matching was performed in R (Version 4.1.0; R Core Team).

Cohort-specific CSO thresholds were established. The minimal clinically important difference (MCID) was calculated using the one-half standard deviation distribution-based method, consistent with previous descriptions.[9,41,50] The Patient Acceptable Symptom State (PASS) and substantial clinical benefit (SCB) were calculated using the anchor-based method.[9,50] For the PASS, the anchor question was as follows: "Taking into account all the activities you have during your daily life, your level of pain, and also your functional impairment, do you consider that your current state is satisfactory?"[9] Patients answered either "yes" or "no." For the SCB, the anchor question was as follows: "Since your surgery, has there been any change in your daily functioning and nonsporting activities related to your treated hip?"[9] Patients answered from 1 of 15 responses: (1) a very great deal worse, (2) a great deal worse, (3) a good deal worse, (4) moderately worse, (5) a little worse, (6) somewhat worse, (7) almost the same/hardly any worse, (8) no change, (9) almost the same/hardly any better, (10) somewhat better, (11) a little better, (12) moderately better, (13) a good deal better, (14) a great deal better, and (15) a very great deal better.[9] PASS and SCB thresholds were determined with the Youden *J* method to identify the optimal threshold with the greatest sensitivity and specificity for identifying successful outcomes.[46] An area under the curve ≥0.70 was deemed clinically significant.[9] For establishing SCB thresholds, patients selecting options 13 to 15 were compared to patients selecting options 7 to 9 on receiver operating characteristic analysis.[9] After establishing cohort-specific CSO thresholds, the achievement rates of the MCID, PASS, and SCB were recorded for each PRO measure and for any PRO measure.

Continuous data were reported as the mean with standard deviation. Categorical data were reported as the percentage. For continuous data, normality was assessed using the Shapiro-Wilk test. A 2-sided independent *t* test was used for normally distributed data, and the Mann-Whitney *U* test was used for nonnormally distributed data. For categorical data, comparisons were performed using the chi-square test and Fisher exact test, as indicated. Kaplan-Meier survival analysis was performed to compare THA-free survivorship and revision hip arthroscopic surgery–free survivorship between the groups using the log-rank test. Statistical significance was determined with an a priori alpha level of $P < .05$. An a priori power analysis was performed for the primary outcome of comparing 10-year PRO scores between groups. Based on prior literature using the assumption that a difference in the mHHS score of 8 points between groups is clinically significant, our study required 25 patients in each of the 2 groups, allocated in a 1:1 ratio, to achieve 80% power.[24] All statistical analyses were performed in R (Version 4.1.0).

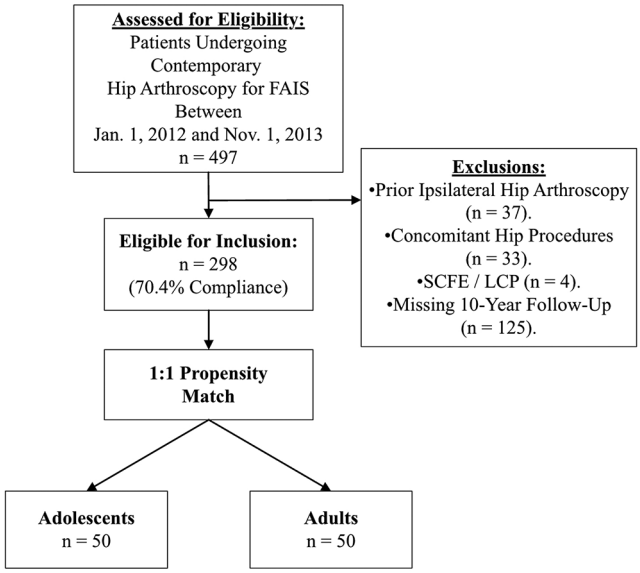

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) diagram for patient selection. Contemporary hip arthroscopic surgery consisted of chondrolabral preservation, surgical correction of femoroacetabular impingement syndrome (FAIS), and capsular repair. LCP, Legg-Calvé-Perthes disease; SCFE, slipped capital femoral epiphysis.

RESULTS

Between January 1, 2012, and November 1, 2013, the senior author performed 497 hip arthroscopic procedures for FAIS with chondrolabral preservation, surgical correction of FAIS, and capsular repair (Figure 1). Of these, exclusions included 37 for having undergone prior ipsilateral hip arthroscopic surgery, 33 for undergoing concomitant hip procedures, and 4 for having morphological hip disorders. There were 125 patients missing a minimum 10-year follow-up, leaving 298 patients eligible for study inclusion with a minimum 10-year follow-up compliance rate of 70.4%. After propensity score matching, 50 adolescents were matched to 50 adults. The mean follow-up time was 10.4 ± 0.4 years.

Patient and Radiographic Characteristics

The adolescent and adult groups were found to be similar in baseline patient and radiographic characteristics, with the exception being age (Table 1). The adolescent group had a mean age of 17.0 ± 1.7 years at the time of surgery, while the adult group had a mean age of 33.0 ± 9.3 years at the time of surgery ($P < .001$). No difference in comorbidities was found between the groups.

Procedures Performed and Intraoperative Findings

The procedures performed and intraoperative cartilage defect grades are summarized in Table 2. No differences were found in the severity of acetabular ($P = .726$) or femoral head ($P > .999$) cartilage defects between groups.

PRO Scores

Comparisons of PRO scores between the adolescent and adult groups are summarized in Figure 2 and Table 3. Similar preoperative PRO scores were observed between groups. Except for the HOS-SS, the adolescent group showed comparable PRO scores at the 2- and 5-year time points compared with the adult group, but at 10-year follow-up, adolescents achieved more favorable PRO scores. For the HOS-SS, adolescents achieved better 2-, 5-, and 10-year scores compared to adults.

Clinically Significant Outcomes

Cohort-specific MCID, PASS, and SCB thresholds were defined (Table 4). Clinically significant area under the curve values were found for all anchor-based thresholds. Comparable achievement rates of the MCID were shown between the adolescent and adult groups ($P = .241$) (Figure 3). The adolescent group showed superior achievement rates of the PASS for any PRO measure (98% vs 79%, respectively; $P = .015$) and of the SCB for any PRO measure (88% vs 67%, respectively; $P = .035$) compared to the adult group.

Survivorship

Comparable THA-free survivorship was observed between the adolescent and adult groups on Kaplan-Meier survival analysis ($P = .083$) (Figure 4A). The adolescent group showed 100% THA-free survivorship, and the adult group showed 94% THA-free survivorship. For the 3 adult patients who underwent conversion to THA, the times to THA conversion were 5.0, 6.7, and 7.0 years.

Similarly, comparable revision hip arthroscopic surgery–free survivorship was demonstrated between the adolescent and adult groups on Kaplan-Meier survival analysis ($P = .473$) (Figure 4B). The adolescent group showed 90% revision-free survivorship, and the adult group showed 94% revision-free survivorship. Of the 5 adolescent patients who underwent revision hip arthroscopic surgery, 2 were for excision of heterotopic ossification at 1.1 and 2.0 years, 1 was for a labral retear at 4.7 years, and 2 were for unknown reasons at 1.4 and 9.0 years (these 2 patients underwent their revision procedure by an outside provider). Of the 3 adult patients who underwent revision hip arthroscopic surgery, 1 was for excision of heterotopic ossification at 1.2 years, and the other 2 were for unknown reasons at 2.6 and 4.2 years (these 2 patients underwent their revision procedure by an outside provider).

DISCUSSION

The most important findings of this study were that (1) adolescent and adult patients showed successful outcomes

TABLE 1
Patient and Radiographic Characteristics[a]

	Adolescents (n = 50)	Adults (n = 50)	*P* Value
Follow-up, y	10.4 ± 0.6	10.2 ± 0.3	.254
Age, y	17.0 ± 1.7	33.0 ± 9.3	**<.001**
Female sex	76	76	.814
BMI, kg/m^2	22.3 ± 3.1	22.5 ± 2.9	.745
Physical activity	92	96	.678
Lower back pain	2	2	>.999
Psychiatric history	14	12	>.999
Workers' compensation	2	2	>.999
Hip pain ≥2 y	18	22	.803
Preoperative alpha angle, deg	63.1 ± 10.8	64.4 ± 11.8	.597
Postoperative alpha angle, deg	38.1 ± 3.9	38.6 ± 4.0	.616
LCEA, deg	29.5 ± 5.2	31.2 ± 5.6	.121
Tönnis angle, deg	6.1 ± 4.7	6.1 ± 4.3	.998
Tönnis grade			>.999
0	100	100	
1	0	0	

[a]Data are shown as mean ± SD or %. Bold typeface indicates significance at $P < .05$. BMI, body mass index; LCEA, lateral center-edge angle.

TABLE 2
Procedures Performed and Intraoperative Findings[a]

	Adolescents (n = 50)	Adults (n = 50)	*P* Value
Labral repair	100	100	>.999
Acetabuloplasty	78	90	.171
Femoroplasty	98	96	>.999
Capsular repair	100	100	>.999
Beck grade of acetabular cartilage defects			.726
0	78	70	
1	4	6	
2	16	18	
3	0	0	
4	2	6	
ICRS grade of femoral head cartilage defects			>.999
0	88	90	
1	8	8	
2	2	0	
3	0	2	
4	2	0	

[a]Data are shown as %. ICRS, International Cartilage Regeneration & Joint Preservation Society.

at a minimum 10-year follow-up after contemporary hip arthroscopic surgery for FAIS; (2) adolescent patients demonstrated superior 10-year PRO scores and achievement rates of the PASS and SCB compared to a propensity score–matched group of adult patients, despite minimal differences in PROs seen between groups at short-term and midterm follow-up; and (3) adolescent patients had revision-free survivorship of 90% at 10-year follow-up, with no cases of conversion to THA.

An initial trial of nonoperative management in patients with FAIS remains paramount, regardless of patient age. In an adolescent cohort of 93 hips, Pennock et al[45] demonstrated that 83% of hips were able to be treated successfully with nonoperative measures, although the remaining 17% of hips showed persistent symptoms refractory to nonoperative management. While the treatment algorithm remains largely consistent for indicating adolescent and adult patients for surgical correction of FAIS, published outcomes on adolescent patients after hip arthroscopic surgery for FAIS remain sparse. At a minimum 1-year follow-up, Byrd et al[12] compared 122 adolescent hips to 122 adult hips that underwent hip arthroscopic surgery for FAIS, showing superior mHHS scores in the adolescent group at all time points compared

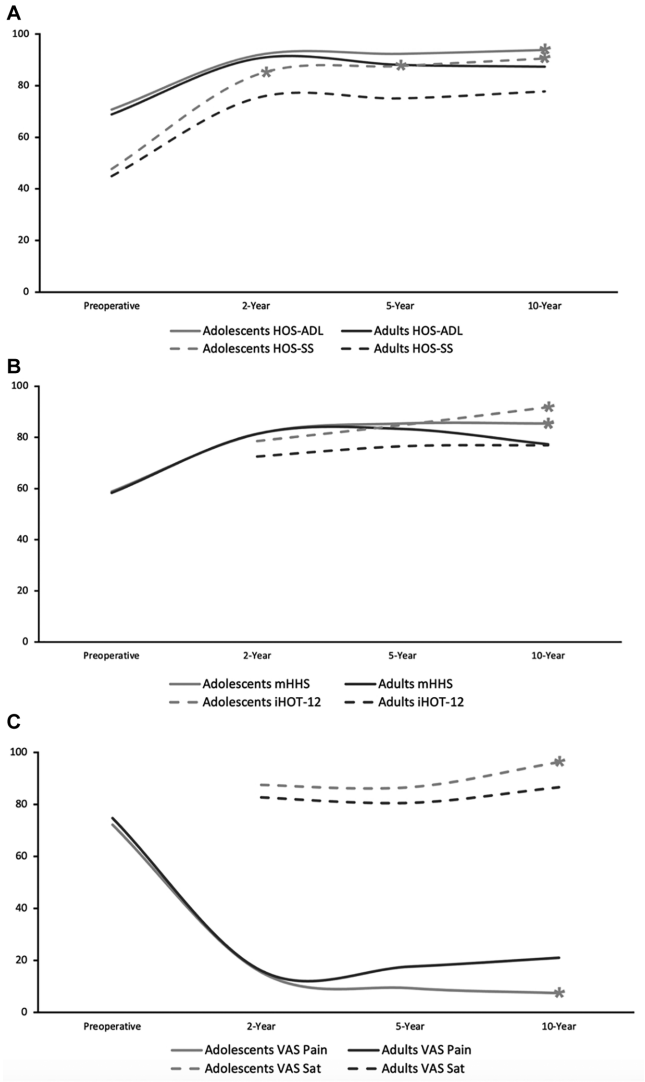

Figure 2. Patient-reported outcome scores for the adolescent and adult groups preoperatively and at 2, 5, and 10 years. (A) Hip Outcome Score–Activities of Daily Living (HOS-ADL) and Hip Outcome Score–Sports Subscale (HOS-SS) scores. (B) Modified Harris Hip Score (mHHS) and International Hip Outcome Tool–12 (iHOT-12) scores. (C) Visual analog scale for pain (VAS pain) and visual analog scale for satisfaction (VAS sat) scores. *Significant difference between groups at the corresponding time point at $P < .05$.

to the adult group, including preoperatively and at 3-, 12-, 24-, and 60-month follow-up, although these findings were not without potential confounders. Namely, the adult group underwent capsular repair in only 43% of cases compared to 70% of cases in the adolescent group. In the context of an ongoing paradigm shift in hip arthroscopic surgery, a recent systematic review by Kaplan et al[25] comprising 8 articles and 387 patients highlighted the importance of capsular repair in achieving more favorable outcomes after hip arthroscopic surgery for FAIS, as patients who underwent capsular repair showed lower revision hip arthroscopic surgery rates compared to patients who did not undergo capsular repair (3.1%-15.4% vs 15.4%-25.5%, respectively). In a pair of adolescent case series at a minimum 5-year follow-up, Litrenta et al[33] and Beck et al[7] separately showed in 44 hips and 85 hips,

TABLE 3
Patient-Reported Outcome Scores[a]

	Adolescents	Adults	*P* Value
Preoperative			
HOS-ADL	70.8 ± 16.7	68.9 ± 17.6	.582
HOS-SS	47.7 ± 25.2	44.9 ± 25.1	.593
mHHS	58.8 ± 12.5	58.3 ± 13.6	.858
VAS pain	72.1 ± 14.9	74.7 ± 17.2	.467
2 y			
HOS-ADL	91.8 ± 10.0	90.5 ± 10.5	.525
HOS-SS	84.1 ± 18.5	75.2 ± 23.0	**.042**
mHHS	81.3 ± 10.3	81.4 ± 12.4	.966
iHOT-12	78.5 ± 17.2	72.5 ± 26.4	.300
VAS pain	15.4 ± 16.7	16.0 ± 21.1	.867
VAS satisfaction	87.5 ± 13.4	82.7 ± 21.7	.200
5 y			
HOS-ADL	92.4 ± 11.9	88.1 ± 13.9	.166
HOS-SS	87.6 ± 17.8	75.1 ± 29.1	**.038**
mHHS	85.4 ± 12.8	83.3 ± 17.1	.580
iHOT-12	84.8 ± 23.3	76.5 ± 27.8	.233
VAS pain	9.3 ± 17.3	17.6 ± 23.7	.106
VAS satisfaction	86.6 ± 25.6	80.6 ± 24.7	.334
10 y			
HOS-ADL	93.9 ± 10.4	87.4 ± 17.4	**.047**
HOS-SS	90.5 ± 15.7	77.8 ± 28.0	**.016**
mHHS	85.4 ± 9.8	77.3 ± 17.1	**.013**
iHOT-12	91.8 ± 13.6	76.9 ± 24.8	**.002**
VAS pain	7.4 ± 14.8	21.0 ± 27.1	**.005**
VAS satisfaction	96.3 ± 7.5	86.6 ± 23.8	**.027**

[a]Data are shown as mean ± SD. Bold typeface indicates significance at $P < .05$. HOS-ADL, Hip Outcome Score–Activities of Daily Living; HOS-SS, Hip Outcome Score–Sports Subscale; iHOT-12, International Hip Outcome Tool–12; mHHS, modified Harris Hip Score; VAS, visual analog scale.

TABLE 4
Clinically Significant Outcomes[a]

	MCID	PASS		SCB	
	Threshold	Threshold	AUC	Threshold	AUC
HOS-ADL	8.2	84.3	0.976	90.1	0.738
HOS-SS	14.6	55.8	0.979	86.2	0.762
mHHS	8.7	74.3	0.955	86.3	0.765
iHOT-12	—	62.5	0.936	95.6	0.841
VAS pain	–13.9	21.2	0.870	6.4	0.733

[a]AUC, area under the curve; HOS-ADL, Hip Outcome Score–Activities of Daily Living; HOS-SS, Hip Outcome Score–Sports Subscale; iHOT-12, International Hip Outcome Tool–12; MCID, minimal clinically important difference; mHHS, modified Harris Hip Score; PASS, Patient Acceptable Symptom State; SCB, substantial clinical benefit; VAS, visual analog scale.

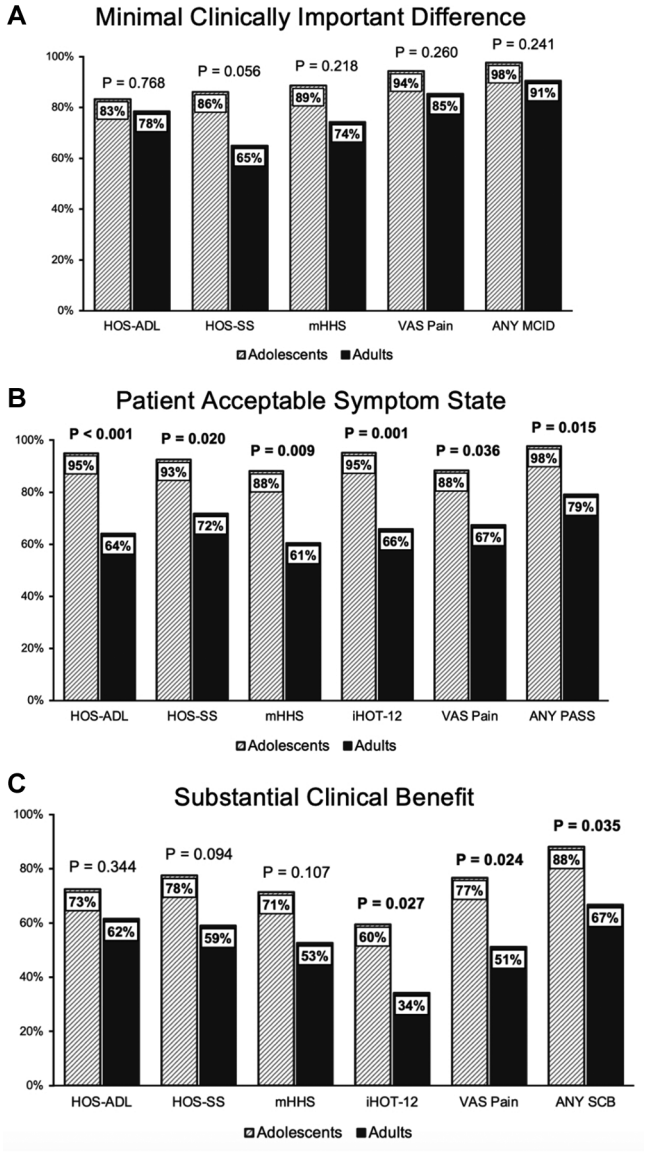

Figure 3. Achievement of clinically significant outcomes for the adolescent and adult groups at a minimum 10-year follow-up. (A) Minimal clinically important difference (MCID) achievement. (B) Patient Acceptable Symptom State (PASS) achievement. (C) Substantial clinical benefit (SCB) achievement. Bold typeface indicates statistical significance between groups at $P < .05$. HOS-ADL, Hip Outcome Score–Activities of Daily Living; HOS-SS, Hip Outcome Score–Sports Subscale; iHOT-12, International Hip Outcome Tool–12; mHHS, modified Harris Hip Score; VAS pain, visual analog scale for pain.

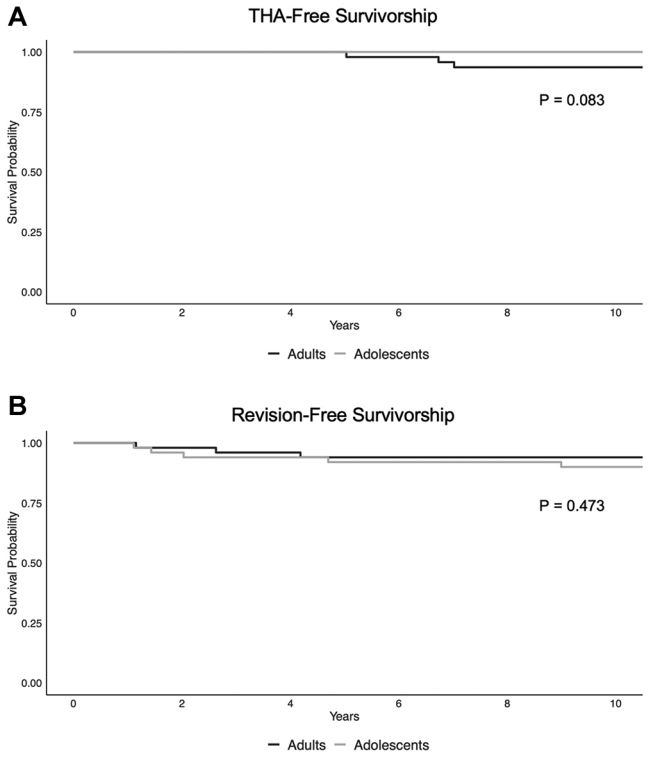

Figure 4. Kaplan-Meier survival analysis for (A) total hip arthroplasty (THA)–free survivorship and (B) revision hip arthroscopic surgery–free survivorship of the adolescent and adult groups at a minimum 10-year follow-up.

respectively, that adolescents achieved successful and durable improvements in outcomes after hip arthroscopic surgery with capsular repair in 86.4% and 100% of cases, respectively, including significantly improved PROs through 5-year follow-up. At a minimum 10-year follow-up, Menge et al[38] reported in a case series of 70 hips that adolescents attained high PASS achievement rates for the HOS-ADL, HOS-SS, and mHHS, ranging from 84% to 90%, although a comparison group of adult patients was not provided. Our study supports the findings of these studies by demonstrating sustained improvements in PRO scores and high achievement rates of CSOs at a minimum 10-year follow-up in adolescent patients treated with modern hip arthroscopic surgery for FAIS, with achievement rates of the MCID, PASS, and SCB for any PRO measure of 98%, 98%, and 88%, respectively, in our adolescent group.

Our study further expands on Menge et al's[38] reporting of adolescent patient outcomes after hip arthroscopic surgery for FAIS at a minimum 10-year follow-up by offering a propensity score–matched comparison group of adult patients with similar baseline characteristics. Propensity score matching of adolescent and adult patient groups in our study controlled for sex, BMI, Tönnis grade, preoperative pain duration $\geq$2 years, endorsement of regular physical activity $\geq$1 time per week, and presence of preoperative back pain, as these were previously shown to be confounders of patient outcomes after hip arthroscopic surgery for FAIS.[14,20,24,27,42,44] After controlling for many potential confounders, our study demonstrated that adolescent patients achieved superior 10-year PRO scores and achievement rates of the PASS and SCB compared to the propensity score–matched group of adult patients, but it remains important to highlight that both the

adolescent and adult groups showed successful outcomes at 10-year follow-up. Based on the trajectory of PRO scores in Figure 2, it appears that the adolescent group achieved superior 10-year PRO scores compared to the adult group because the adolescent group better maintained their postoperative scores over the course of the study's follow-up period, while the adult group started to show some deterioration in PROs by final follow-up, most notably for the mHHS and VAS pain. The more favorable outcomes observed in adolescent patients are supported by Fukase et al,[21] who showed in a comparative cohort study of 157 adolescent hips and 157 adult hips at a minimum 2-year follow-up and a median 8.9-year follow-up that adolescent patients achieved superior PRO scores at final follow-up and higher achievement rates of the MCID and PASS for multiple metrics compared to adult patients. While Fukase et al[21] controlled for the baseline confounders of sex, BMI, and time to surgery in their matching to an adult comparison group, there were likely additional pertinent confounders not controlled for, as the adolescent group showed higher preoperative HOS-SS and mHHS scores compared to the adult group. These preoperative score differences between groups may limit the interpretation of postoperative score differences. Our study expanded on the comparison of adolescent and adult patient outcomes by both extending to a minimum 10-year follow-up and controlling for additional potential baseline confounders. In doing so, our observation of comparable baseline PRO scores between groups strengthens our conclusion of adolescent patients achieving superior PRO scores and achievement rates of the PASS and SCB at 10-year follow-up.

The superior outcomes observed in adolescents compared to adults after hip arthroscopic surgery warrant careful consideration. Namely, although many known contributors to inferior postoperative outcomes were controlled for via propensity score matching, these were based on preoperative patient characteristics. By 10 years postoperatively, the adult population may have had more comorbidities or concurrent musculoskeletal conditions, adversely affecting their outcomes. Nevertheless, in conjunction with the prior mentioned studies, our study supports that current hip arthroscopic techniques for FAIS in adolescent and adult patients allow for successful outcomes at 10-year follow-up and that adolescent patients can be counseled on the potential for achieving more durable clinical improvements compared to their adult counterparts a decade after their hip arthroscopic surgery.

Our study further demonstrated that the adolescent group achieved 90% revision-free survivorship at a minimum 10-year follow-up, with no cases of conversion to THA. This finding aligns closely with the abovementioned Menge et al[38] study, which also showed 90% revision-free survivorship at a minimum 10-year follow-up, with no cases of conversion to THA. Subsequent revision arthroscopic surgery is of particular concern when managing adolescent patients with hip arthroscopic surgery. Arashi et al[4] reviewed 110 postoperative radiographs at a minimum 2-year follow-up after hip arthroscopic surgery and found that cam regrowth occurred more commonly in adolescent patients (46%) than in adult patients (19%). Both the present study and that of Menge et al[38] found a rate of revision arthroscopic surgery of 10%. While nonnegligible, these findings represent that adolescents undergoing hip arthroscopic surgery have relatively low rates of reoperation at long-term follow-up. The high reoperation-free survivorship may be further explained by the use of modern hip arthroscopic techniques, including labral repair, surgical correction of FAIS, and capsular repair, in all of our study patients and most of the patients reported by Menge et al.[38] Bolia et al[10] showed in a matched comparative study that the absence of capsular repair was associated with a 6.8-fold risk for conversion to THA. Similarly for femoral osteoplasty, Nepple et al[40] demonstrated at a minimum 15-year follow-up that femoral osteoplasty was associated with significantly greater mHHS scores at final follow-up and superior reoperation-free survivorship of 78% compared to patients who did not undergo femoral osteoplasty, with reoperation-free survivorship of only 29% ($P = .003$). Kucharik et al[28] corroborated these findings in their study at a minimum 5-year follow-up in which labral repair was associated with a significantly lower risk of conversion to THA compared to labral debridement (hazard ratio, 0.24; $P = .014$).

Taken together, findings from our study build on prior literature by demonstrating that adolescent patients with FAIS refractory to nonoperative management treated with contemporary hip arthroscopic techniques, including chondrolabral preservation, surgical correction of FAIS, and capsular repair, achieved high 10-year reoperation-free survivorship of 90%, with no cases of conversion to THA.

Limitations

Several limitations are present in our study. First, our study's retrospective design challenges our attribution of causality, despite our use of propensity score matching. Second, our minimum 10-year follow-up compliance rate of 70.4%, while generally considered acceptable for studies of this duration, leaves us vulnerable to potential selection bias.[2,13,26] Third, while propensity score matching controlled for many known confounders, including sex, BMI, Tönnis grade, pain duration, physical activity level, and back pain, additional potential confounders that were not controlled for may exist, which could have confounded the findings of our study. Fourth, our partitioning of patient groups into adolescents and adults was based on the categorical definition provided by the World Health Organization of age 10-19 years denoting adolescents, but we recognize that patient age and maturation reflect a continuum that is inherently oversimplified by this binary classification. Fifth, we were unable to further evaluate patients on the basis of open or closed physes, as the preoperative radiographs for this cohort were no longer available for review. Radiographs were prospectively assessed and recorded, and physis data were not collected.

CONCLUSION

This study concluded that adolescent and adult patients treated with contemporary hip arthroscopic surgery for FAIS, including chondrolabral preservation, surgical correction of FAIS, and capsular repair, achieved significantly improved PROs at a minimum 10-year follow-up, with no cases of conversion to THA in the adolescent group. Furthermore, adolescent patients demonstrated superior 10-year PRO scores and achievement rates of the PASS and SCB compared to a propensity score–matched group of adult patients, despite minimal differences in PROs seen between groups at short-term and midterm follow-up.

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