Review Article

pISSN: 2287-3260 / eISSN: 2287-3279
Hip Pelvis 2025;37(2):87-102
https://doi.org/10.5371/hp.2025.37.2.87

Hip & Pelvis

Arthroscopic Procedure for Femoroacetabular Impingement Syndrome in Adolescents: A Systematic Review and Meta-analysis

Sameer Rathore, FRCS, Sonu Mehta, MRCS*, Avinash Rai, FRCS†, Faisal Mohammed, MRCS‡

Department of Trauma and Orthopaedics, Royal Berkshire Hospital, Reading, UK
*Department of Trauma and Orthopaedics, Glan Clwyd Hospital, Rhyl, UK**
Department of Trauma and Orthopaedics, University Hospital of North Tees, Stockton-on-Tees, UK†
Department of Trauma and Orthopaedics, Ysbyty Gyynedd Hospital, Bangor, UK‡

Femoroacetabular impingement (FAI) is caused by aberrant anatomy involving the proximal femur with or without the acetabulum resulting in mechanical impingement. FAI's effects can be devastating in the young. In recent studies, significant associations have been found between skeletal immaturity, FAI, and sports involvement. Hip arthroscopy for FAI has been demonstrated to produce good results. We opted to update the review and meta-analysis to further narrow the research gap in the literature by including recently published studies and a comprehensive review of the arthroscopic approach for FAI. Prior to January 1, 2024, PubMed, Embase, and Google Scholar databases were searched for the studies with data on surgical procedures and patient-related outcomes for arthroscopic FAI. RevMan 5.2 was utilized to calculate the pooled mean differences with a 95% confidence interval to compare reported postoperative and preoperative patients' outcomes. In total, 24 studies of adolescent subjects with a mean age of less than 20 years, including 1,619 patients and 1,767 hips, were included. Eleven studies included acetabuloplasty and femoroplasty as major treatments. When preoperative and postoperative outcomes were compared, statistically significant changes were seen in the mHHS (modified Harris hip score), HOS-ADL (Hip Outcome Score–Activities of Daily Living), HOS-SSS (Hip Outcome Score–Sports-Specific Subscale), i-HOT (International Hip Outcome Tool 12 questions), NAHS (Nonarthritic Hip Score), and the visual analog scale. Numbness, neuropraxia and infections were seen in only 12 patients. This meta-analysis demonstrated overall improvements in hip pain, quality of life, and hip function along with few complications.

Keywords: Hip arthroscopy, Femoroacetabular impingement, Adolescent, Meta-analysis

INTRODUCTION

Femoroacetabular impingement (FAI) is described as hip pain caused by aberrant anatomy involving the proximal femur with or without the acetabulum resulting in mechanical impingement. Large circle hip rotation and atypical, recurrent contact between the bony prominences cause soft tissue damage in the femoroacetabular joint. Over time, persistent, recurrent damage may cause hip pain and diminished function. Pincer lesions of the acetabulum and cam deformity of the femoral head and neck junction are examples of aberrant bone characteristics[1]. The effects of FAI can be especially devastating in the young, as evidenced by their bimodal age distribution[2]. Recent research has found significant associations between skeletal imma-

Correspondence to: Sameer Rathore, FRCS https://orcid.org/0000-0002-6590-5199
Department of Trauma and Orthopaedics, Royal Berkshire Hospital, London Road, Reading RG1 5AN, UK
E-mail: dr.sameer.rathore@gmail.com

Received: March 5, 2024 **Revised:** June 3, 2024 **Accepted:** June 12, 2024

turity, FAI, and sports involvement[2,3]. Hip arthroscopy for FAI has been demonstrated to produce good results, including pain management and a return to athletics or other activities, that are just as beneficial as, or superior than, open approaches[4]. Radiographic evidence is the most widely utilized criteria for FAI operational surgery. However, clinical testing and symptomatology should be considered carefully as well before operating. Not every FAI patient requires surgery, and, for some abnormalities, arthroscopic therapy may not be possible. The ideal patient for arthroscopic treatment of focal impingement (FAI) is a young, non-arthritic individual with clinical and radiological evidence of focal impingement[4,5].

Timely arthroscopic correction of problematic FAI often prevents deterioration in the hips, early osteoarthritis, and function loss according to Wyles et al.[6]. Migliorini and Maffulli[7] reported outstanding results in a systematic review of 406 adolescents (470 hips), with a revised rate of 5% at the 30.4-month mean follow-up, significant enhancements in pain around the hip, hip function, and overall quality of life. A similar systematic review by Huang et al.[8] demonstrated there was a marked improvement and minimal incidence of complications or reoperations following surgery in all patient-related outcomes. Additionally, high patient satisfaction after surgery was noted[8]. Both reviews had limitations in that only a small number of studies were included and there was paucity of data on long-term FAI patient follow-up. In this study, we decided to update the systematic review and meta-analysis to further fill the research gap of the literature by including recently published studies and a comprehensive review of the arthroscopic approach for FAI.

METHODS

1. Search Strategies

Electronic databases; PubMed, Embase, and Google Scholar from the time of their founding to January 1, 2024 were utilized to find pertinent research. The database search was conducted without any language restrictions. The search employed proper Boolean operations to combine medical subject headings and the keywords "FAI," "femoroacetabular impingement syndrome," "adolescent," and "arthroscopy". To find additional relevant literature, we also looked through the references of every study returned by our search parameters and papers that were part of earlier evaluations. In addition to searching grey literature by utilizing OpenGrey and Google Scholar, thesis repositories and preprint services were explored. In the reporting of this meta-analysis, PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria were followed.

2. Criteria for Inclusion

1) Studies providing data on the primary hip arthroscopic treatment of FAI
2) Patients with FAI undergoing primary hip arthroscopy were adolescents (a mean age of less than 20 years)
3) Such studies with a follow-up period of at least one year
4) Studies which had enough data on surgical procedure/patient-related outcomes/complications/radiological comparisons

3. Exclusion Criteria

Patients with follow-up periods of less than 1 year, duplicate studies, abstracts, case reports, case series, systematic reviews and narrative or literature reviews, and nonhuman studies were excluded.

4. Data Extraction and Assessments of Quality

After reviewing the original articles, we chose the ones that met our predetermined eligibility requirements. During the selection process, differences of opinion were discussed and settled by third reviewer (A.R.). The following headings were used to extract the data: author, publication year, study region, study design, age (median/mean age of sample), sex (male/female), sample size (number of patients/number of hips), and follow-up duration. A Microsoft Excel version 2013 (Microsoft Corp.) spreadsheet was created for data extraction.

The International Hip Outcome Tool 12 questions (i-HOT), revision event rate, alpha angle, satisfaction, modified Harris hip score (mHHS), Hip Outcome Score (HOS)–Activities of Daily Living (HOS-ADL), HOS–Sports-Specific Subscale (SSS), and Nonarthritic Hip Score (NAHS) were also extracted for meta-analysis.

The quality of each study returned by database search was evaluated using the Newcastle–Ottawa Scale (NOS), which is broken down into three categories: exposure, comparability, and selection[9]. Any differences between separate study assessments were resolved through the input of a third party. Studies scoring six or above were deemed eligible for inclusion, and studies scoring seven or higher were deemed to be of high quality.

5. Data Synthesis and Statistical Analysis

All analyses were performed by using RevMan 5.2. To evaluate the mean change in scores, pooled mean differences (MD) with a 95% confidence interval (CI) were calculated to compare reported outcomes of postoperative and preoperative patients. The Cochrane Q-test and the I^2 statistic were used to measure statistical heterogeneity; results of $P<0.1$ or $I^2>50\%$ were regarded as evidence of statistically significant heterogeneity heterogeneity. In the event of high heterogeneity, the Random Effect Model (DerSimonian–Laird approach) was utilized. If $I^2<50\%$, the effect was pooled using a fixed-effect model[10,11]. The funnel plot was considered to find the publication bias[12].

RESULTS

1. Study Characteristics

Fig. 1 shows a flowchart that depicts the study selection process in accordance with PRISMA guidelines[13]. A total of 3,647 (PubMed, 761; Embase, 411; Google Scholar, 1,990) studies were found through database searches. After the duplicate articles were removed, titles and abstracts were used to further filter the 2,188 remaining articles. After screening, the remaining 99 full-text articles were evaluated based on pre-determined eligibility requirements. Ultimately, this study includes 24 full-text publications with information on FAI arthroscopy for adolescents (Fig. 1).

Most of the included papers were retrospective, from the USA, and used adolescent subjects with a mean age of less than 20 years. The minimum sample size

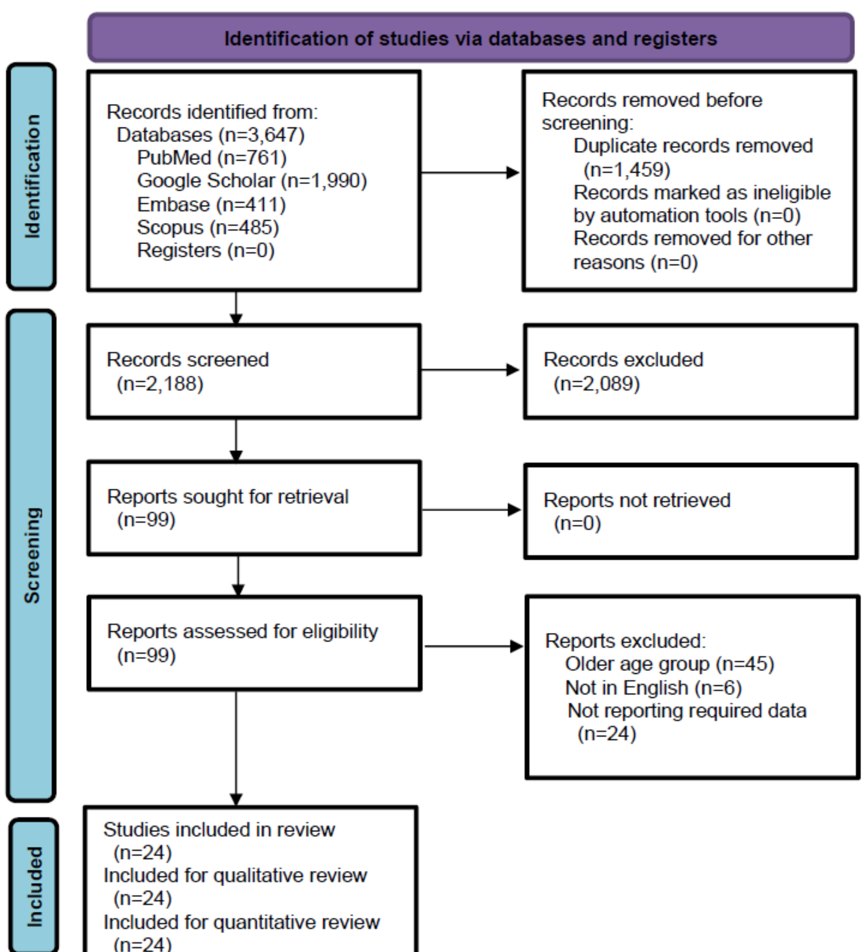

Fig. 1. PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) flow chart of the study selection process[13].

was ten and the maximum was 249, with a total of 1,619 patients and 1,767 hips. In the majority of studies, the number of male subjects exceeded the number of females. The follow-up period was greater than 1 year in all the included studies except the three studies that followed up the patients for more than 5 years. NOS scores ranged from 6 to 8. Studies were not excluded based on NOS score (Table 1)[14-37].

2. Surgical Procedure

Fourteen studies provided details of surgical procedures performed on adolescents. Eleven studies included acetabuloplasty and femoroplasty as major treatments along with labral repair/reconstruction. Capsular release/repair and ligamentum teres debridement were other procedures performed. Table 2 provides further details on surgical techniques used in each study.

Table 1. Baseline Demographic Table of the Included Studies

Study	Study design	Location	Sample size/ hips (n)	Mean follow-up (yr)	Sex, M:F	Age (yr)	FAI type	NOS scale score (out of 10)
Barastegui et al.[14] (2023)	Retrospective	Spain	14/14	3.21	11:3	15.44 (11.97-16.96)	NA	8
Beck et al.[15] (2021)	Retrospective	USA	85/85	5	20:65	17.6±2.5	NA	6
Byrd et al.[16] (2016)	Retrospective	USA	104/116	3.1	47:57	16 (12-17)	28% cam, 14% pincer, 58% mixed	7
Chandrasekaran et al.[17] (2017)	Retrospective	USA	90/90	2.55	13:77	16.3 (13.2-17.97)	NA	8
Menge et al.[18] (2021)	Prospective	USA	60/70	12	49:21	16±1.2	13% cam, 11% pincer, 76% mixed	7
Cvetanovich et al.[19] (2018)	Retrospective	USA	37/42	2.35	11:26	17 (≤18)	26% cam, 74% mixed	7
Fabricant et al.[20] (2012)	Retrospective	USA	21/27	1.5	12:9	17.6 (14.5-19.9)	19% cam, 11% pincer, 70% mixed	7
Winge et al.[21] (2021)	Retrospective	Copenhagen	29	NA	11:18	16.3 (12.7-19.8)	NA	6
Larson et al.[22] (2019)	Retrospective	USA	28/37	3.31	21:7	15.9 (12.8-18.3)	NA	8
Lee at al.[23] (2022)	Retrospective	USA	96	6.01	74:22	15.8±61.3	NA	8
Litrenta et al.[24] (2020)	Retrospective	USA	69/81	3.76	20:61	15.9 (13.1-18)	NA	7
Maldonado et al.[25] (2023)	Retrospective	USA	249/287	2.21	215:72	16.3±1.3	NA	7
Maldonado et al.[26] (2022)	Retrospective	USA	27/22	2	10:13	25.8±6.3	NA	7
McConkey et al.[27] (2019)	Prospective	USA	24/36	2	10:14	15.7 (≤18)	25% cam, 14% pincer, 61% mixed	8
Morris et al.[28] (2024)	Prospective	USA	55	NA	42	16.2±1.4	NA	8
Newman et al.[29] (2016)	Prospective	USA	84/84	3.75	16:68	16 (14-18)	17% cam, 6% pincer, 77% mixed	8
Nwachukwu et al.[30] (2017)	Prospective	USA	47/47	1	15:32	16.5 (≤18)	NA	6
Fukase et al.[31] (2022)	Prospective	USA	157	0.74	109:48	16.8 (16.6-17.1)	NA	8
Perets et al.[32] (2017)	Prospective	USA	10/11	2.97	0:10	14.7 (13.2-15.9)	NA	8
Philippon et al.[33] (2012)	Prospective	USA	60/65	3	17:43	15 (15.3-15.8)	10% cam, 15% pincer, 75% mixed	6
Ruzbarsky et al.[34] (2023)	Prospective	USA	111/134	2	37:74	16.4±1.1	NA	8
Saks et al.[35] (2022)	Prospective	USA	47/50	3.125	189:9	19.5±7.3	NA	8
Serbin et al.[36] (2023)	Prospective	USA	81/91	2	67:24	16.23	NA	6
Tran et al.[37] (2013)	Prospective	Australia	34/41	1.16	29:5	15.7 (11-18)	78% cam, 22% mixed	7

Values are presented as number, mean only, mean (range), or mean±standard deviation.
M: male, F: female, FAI: femoroacetabular impingement, NOS: Newcastle–Ottawa Scale, NA: not available.

3. Radiological Findings

Six out of sixteen studies that reported preoperative values demonstrated statistically significant declines in alpha angle after surgery. Serbin et al.[36] showed a higher reoperation risk for hip arthroplasty when the lateral center-edge angle was less than 22, FEAR (Femoro-Epiphyseal Acetabular Roof) index was greater than or equal to 8.7, sharp angle was greater than 44, and Tonnis angle was greater than six. The mean lateral center edge angle, anterior center edge angle, acetabular inclination, Tonnis grade, sharp angle and minimum joint space were some of the radiological findings described in other studies[15,22,24,25,32,33,35].

4. Patient Reported Outcomes

1) mHHS

Fifteen studies, including 1,188 hips treated with arthroscopic surgery, found a considerable increase in mHHS mean scores measured preoperatively and postoperatively at the 2-3 year follow-up visit (MD 27.09, 95% CI 23.82 to 30.37, P<0.00001). A random-effect model was applied as there was considerable heterogeneity (I^2=83%, P<0.00001) (Fig. 2A). Both prospective and retrospective study subgroup analyses revealed significant increases in mHHS scores after surgery (MD 27.83, 95% CI 23.56 to 32.09, P<0.00001, I^2=81% and MD 26.17, 95% CI 21.59 to 30.75, P<0.0001, I^2=80%, respectively) (Fig. 2B). Both analyses had significant heterogeneity. High heterogeneity was attributable to differences in sample size, age group of study population and study design. The funnel plot shows the publication bias because of the numerous studies outside the plot (Fig. 3). To account for the heterogeneity, we conducted a sensitivity analysis by excluding each study at a time. The result of which is tabulated in the Table 3.

2) HOS-ADL

Eight studies, including 638 hips treated with arthroscopic surgery, found a considerable increase in the HOS-ADL mean scores measured preoperatively and postoperatively at the 2-3 year follow-up visit (MD 24.80, 95% CI 23.22 to 26.38, P<0.00001). As there was no considerable heterogeneity (I^2=13%, P=0.33), a fixed-

Table 2. Types of Surgical Procedures Performed in the Included Studies

Study	Total hips	Surgical procedure
Newman et al.[29] (2016)	84	Acetabuloplasty-70, femoroplasty-85, labral debridement-12, labral reconstruction-3, labral repair-67, acetabular microfracture-1, femoral head microfracture-1
Philippon et al.[33] (2012)	65	Acetabuloplasty-50, femoroplasty-50, labral debridement-11, labral repair-54, chondroplasty-2, ligamentum teres treatment-36
Litrenta et al.[24] (2020)	81	Acetabuloplasty-54, femoroplasty-56, labral debridement-12, labral reconstruction-1, labral repair-66, synovectomy-6, capsular plication and repair-70, capsular release-11, trochanter bursectomy-13, ligamentum teres treatment-9, iliopsoas fractional lengthening-59
Perets et al.[32] (2017)	11	Acetabuloplasty-8, femoroplasty-11, labral debridement-1, labral repair-10, capsular plication and repair-11, ligamentum teres treatment-1, iliopsoas fractional lengthening-10
Chandrasekaran et al.[17] (2017)	90	Acetabuloplasty-90, femoroplasty-90, labral debridement-13, labral reconstruction-1, labral repair-76, capsular plication and repair-74, capsular release-16, trochanter bursectomy-1, ligamentum teres treatment-19, iliopsoas fractional lengthening-65
Nwachukwu et al.[30] (2017)	47	Acetabuloplasty-37, femoroplasty-12, labral debridement-7, labral repair-40
Cvetanovich et al.[19] (2018)	37	Labral tear-37, labral repair-35, synovectomy-35, acetabular rim trimming-31, femoral osteochondroplasty-37, capsular closure-37
Tran et al.[37] (2013)	41	Labral debridement-13, labral repair-7
Barastegui et al.[14] (2023)	14	Femoral osteoplasty-9, acetabular osteoplasty-6, labral suture-13, cartilage stabilization-5
Lee et al.[23] (2022)	64	Labral repair-47, labral debridement-15, labral reconstruction-2, capsular closure-58, acetabuloplasty-42, femoroplasty-40
Maldonado et al.[25] (2023)	23	Labral reconstruction-23, capsular repair-14, acetabuloplasty-19, femuroplasty-19
Maldonado et al.[26] (2022)	287	Labral repair-258, labral debridement-3, labral reconstruction-26, capsular closure-245, femuroplasty-234, acetabuloplasty-128, ligamentum teres debridement-25
Fukase et al.[31] (2022)	157	Labral repair-143, labral debridement-10, labral reconstruction-2, acetabuloplasty and femuroplasty-139, ligamentum teres debridement-139, capsular closure-151, plication-121
Saks et al.[35] (2022)	50	Labral repair-38, labral debridement-11, reconstruction-1, capsular treatment-50, femoroplasty-44

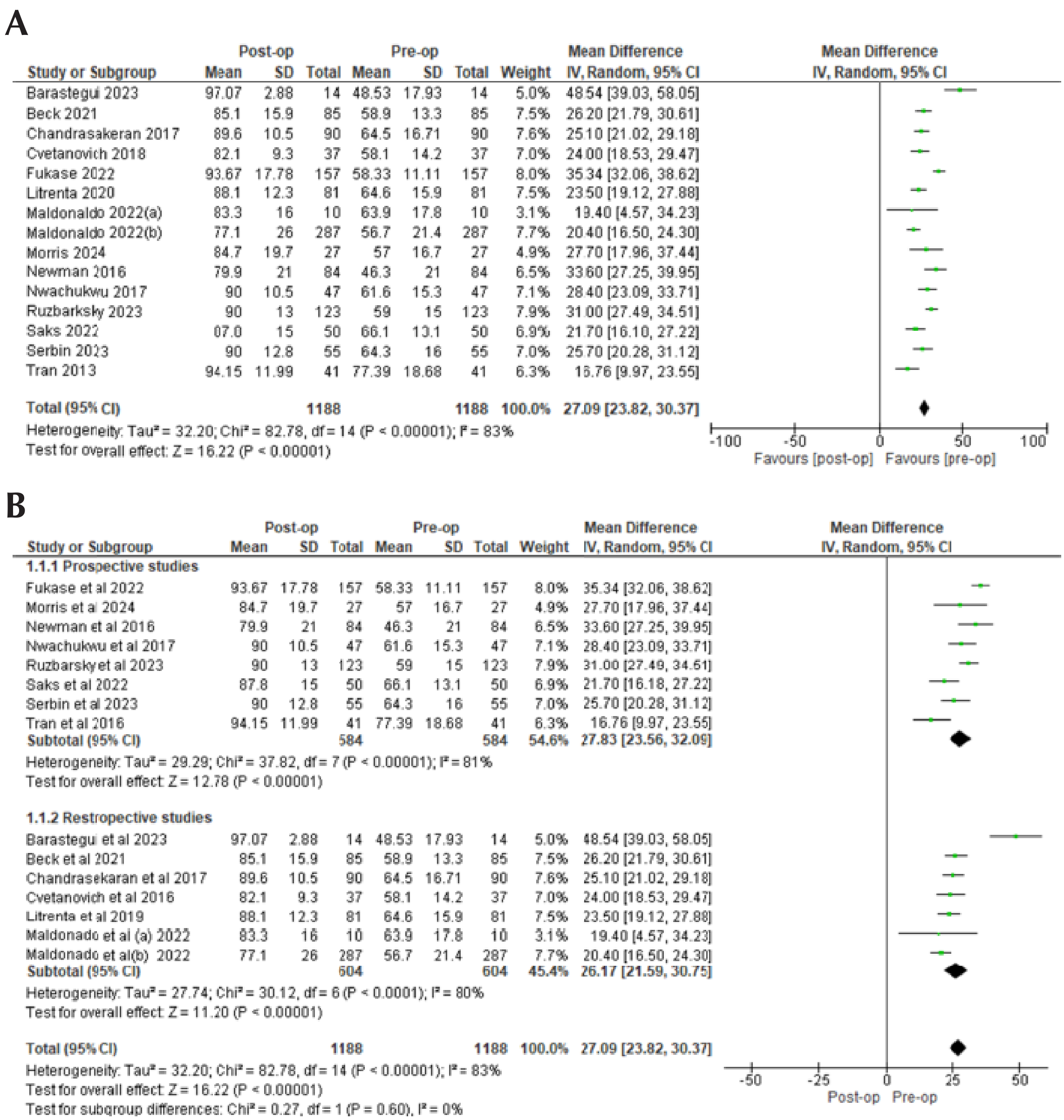

Fig. 2. (A) Mean differences between preoperative and postoperative modified Harris hip score (mHHS) scores. (B) Mean differences between preoperative and postoperative mHHS scores of the prospective and retrospective study subgroups.

effect model was applied (Fig. 4A).

Prospective and retrospective subgroup study analyses revealed significant increases in the HOS-ADL postoperative scores (MD 25.42, 95% CI 23.45 to 27.39, P<0.00001, I^2=30% and MD 23.66, 95% CI 21.01 to 26.32, P<0.00001, I^2=0%), respectively (Fig. 4B).

Sensitivity analysis was conducted by excluding each study at a time to account for heterogeneity. The results are tabulated in Table 4.

3) HOS-SSS

Twelve studies, including 1,065 hips treated with

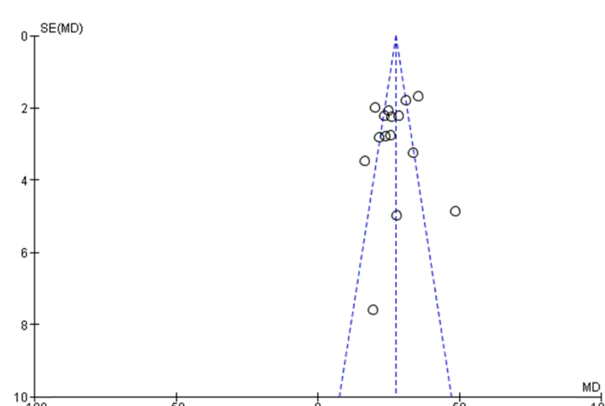

Fig. 3. Publication bias for studies with reported modified Harris hip score outcomes.

Table 3. Sensitivity Analysis for Modified Harris Hip Score Outcomes

	MD	95% CI	*P*-value	I^2 (%)
Prospective studies				
All studies included	27.83	23.56, 32.09	<0.00001	81
Excluding Fukase et al.[31] (2022)	26.57	22.47, 30.66	<0.00001	72
Excluding Morris et al.[28] (2024)	27.82	23.22, 32.42	<0.00001	84
Excluding Newman et al.[29] (2016)	27.02	22.31, 31.72	<0.00001	83
Excluding Nwachukwu et al.[30] (2017)	27.69	22.79, 32.60	<0.00001	84
Excluding Ruzbarsky et al.[34] (2023)	27.22	21.97, 32.47	<0.00001	84
Excluding Saks et al.[35] (2022)	28.77	24.46, 33.07	<0.00001	79
Excluding Serbin et al.[36] (2023)	28.11	23.35, 32.87	<0.00001	83
Excluding Tran et al.[37] (2013)	29.36	25.61, 33.11	0.0008	74
Retrospective studies				
All studies included	26.17	21.59, 30.75	<0.00001	80
Excluding Barastegui et al.[14] (2023)	23.61	21.68, 25.54	<0.00001	0
Excluding Beck et al.[15] (2021)	26.32	20.73, 31.90	<0.00001	83
Excluding Chandrasekaran et al.[17] (2017)	26.57	20.84, 32.29	<0.00001	83
Excluding Cvetanovich et al.[19] (2018)	26.68	21.27, 32.09	<0.00001	83
Excluding Litrenta et al.[24] (2020)	26.85	21.23, 32.47	<0.00001	83
Excluding Maldonado et al.[25] (2023)	26.67	21.84, 31.49	<0.00001	83
Excluding Maldonado et al.[26] (2022)	27.41	22.19, 32.63	<0.00001	79

MD: mean differences, CI: confidence interval.

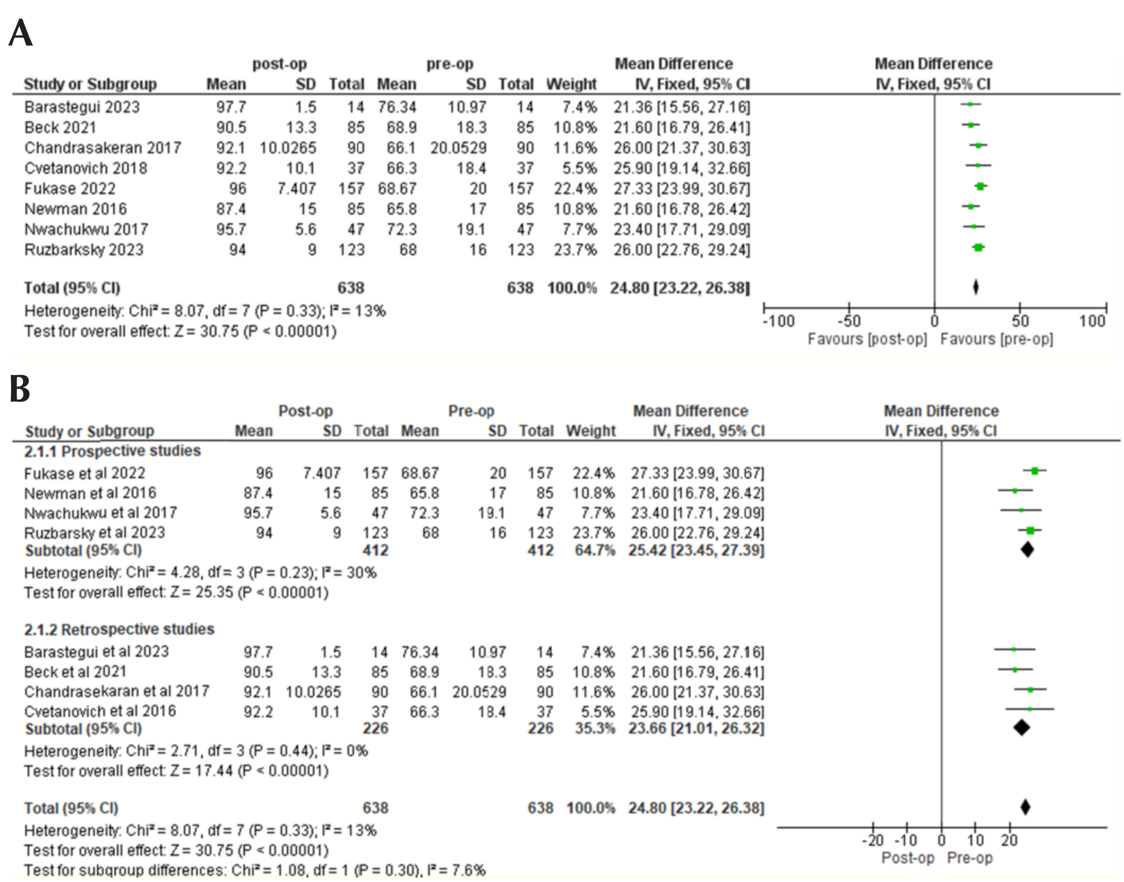

Fig. 4. (A) Mean differences in Hip Outcome Score–Activities of Daily Living (HOS-ADL) preoperative and postoperative scores. (B) Mean differences in HOS-ADL preoperative and postoperative scores of the prospective and retrospective study subgroups.

Table 4. Sensitivity Analysis for HOS-ADL (Hip Outcome Score–Activities of Daily Living) Outcomes

	MD	95% CI	*P*-value	I^2
Prospective studies				
All studied included	25.42	23.45, 27.39	<0.00001	30
Excluding Fukase et al.[31] (2022)	24.40	21.97, 26.84	<0.00001	15
Excluding Newman et al.[29] (2016)	26.18	24.03, 28.33	<0.00001	0
Excluding Nwachukwu et al.[30] (2017)	25.69	23.60, 27.79	<0.00001	46
Excluding Ruzbarsky et al.[34] (2023)	24.52	20.79, 28.26	<0.00001	51
Retrospective studies				
All studies included	23.66	21.01, 26.32	<0.00001	0
Excluding Barastegui et al.[14] (2023)	24.28	21.29, 27.27	<0.00001	0
Excluding Beck et al.[15] (2021)	24.57	21.38, 27.76	<0.00001	0
Excluding Chandrasekaran et al.[17] (2017)	22.52	19.27, 25.76	<0.00001	0
Excluding Cvetanovich et al.[19] (2018)	23.26	20.36, 26.15	<0.00001	10

MD: mean differences, CI: confidence interval.

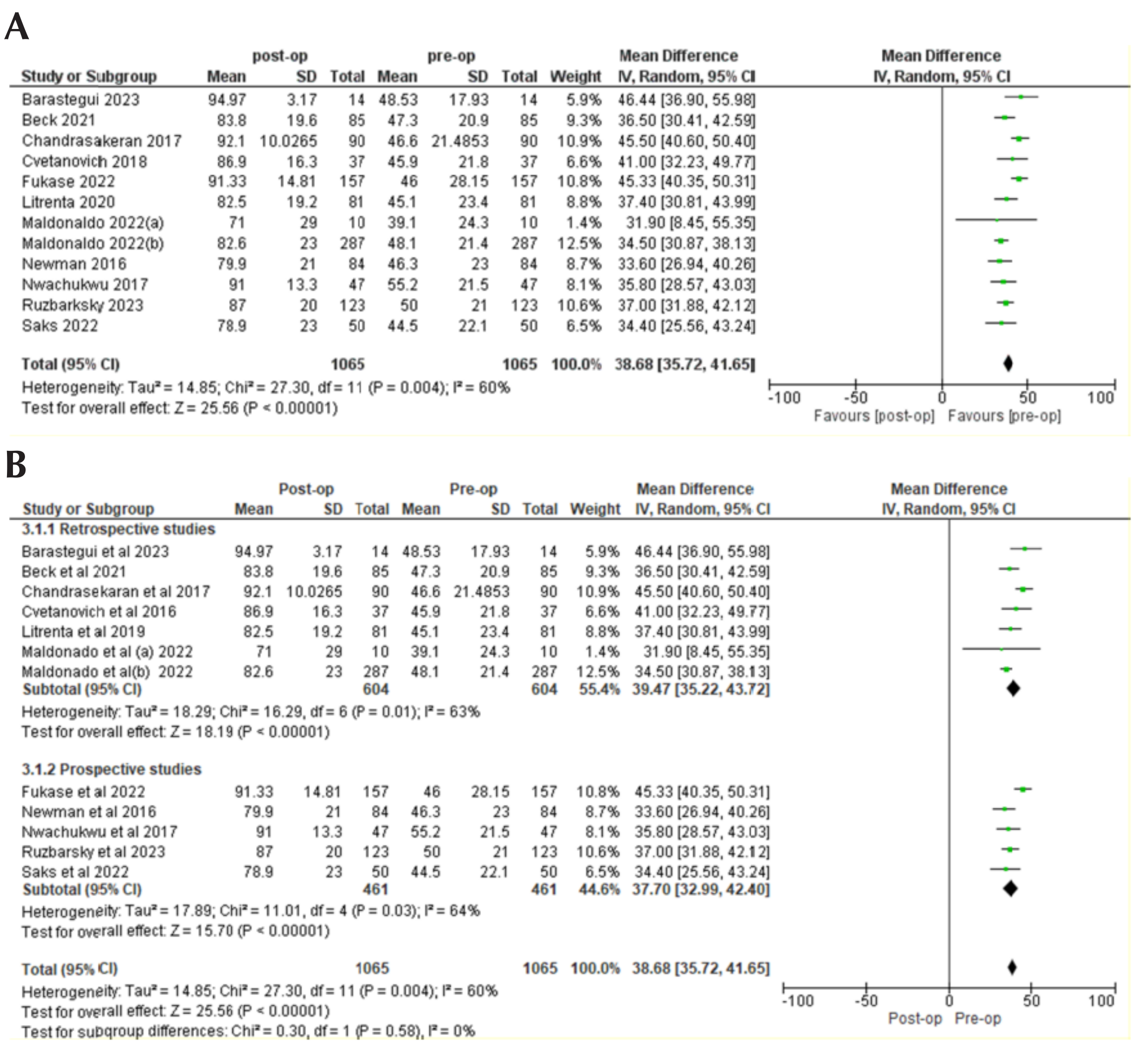

Fig. 5. (A) Mean differences in preoperative and postoperative Hip Outcome Score–Sports-Specific Subscale (HOS-SSS) scores. (B) Mean differences in preoperative and postoperative HOS-SSS scores of prospective and retrospective study subgroups.

arthroscopic surgery, demonstrated statistically significant increases of HOS-SSS mean scores measured preoperatively and postoperatively (MD 38.68, 95% CI 35.72 to 41.65, P<0.00001). As there was considerable heterogeneity (I^2=60%, P=0.004), a random-effect model was applied (Fig. 5A).

Subgroup analysis of prospective and retrospective studies revealed significant increases in the postoperative HOS-SSS scores (MD 37.70, 95% CI 32.99 to 42.40, P<0.00001, I^2=64% and MD 39.47, 95% CI 35.22 to 43.72, P<0.00001, I^2=63%) respectively (Fig. 5B).

To account for heterogeneity, a sensitivity analysis was conducted by excluding each study at a time. Sensitivity analysis results are tabulated in Table 5.

High heterogeneity was attributable to differences in sample size, age group of the study subjects and study design. The funnel plot also described the publication bias as some studies were outside the funnel plot imparting asymmetrical arrangements of the included studies (Fig. 6).

4) NAHS

Six studies, including 559 hips treated with arthroscopic surgery, demonstrated statistically significant increases of NAHS mean scores measured preoperatively and, at certain times, postoperatively (MD 23.26, 95% CI 21.47 to 25.06, P<0.00001). As no heterogeneity was observed (I^2=0%, P=0.51), a fixed-effect model was applied (Fig. 7A).

Similarly, subgroup analyses of prospective and retrospective studies revealed significant increases in postoperative NAHS scores (MD 20.48, 95% CI 13.67 to 27.30, P<0.00001, I^2=59% and MD 20.39, 95% CI 14.19 to 26.59, P<0.00001, I^2=73%), respectively (Fig. 7B).

5) Visual analog scale (VAS)

Six studies, including 603 hips treated with arthroscopic surgery, demonstrated statistically significant declines in VAS mean scores measured preoperatively and postoperatively (MD –3.87, 95% CI –4.16 to –3.59, P<0.00001). As no heterogeneity was observed,

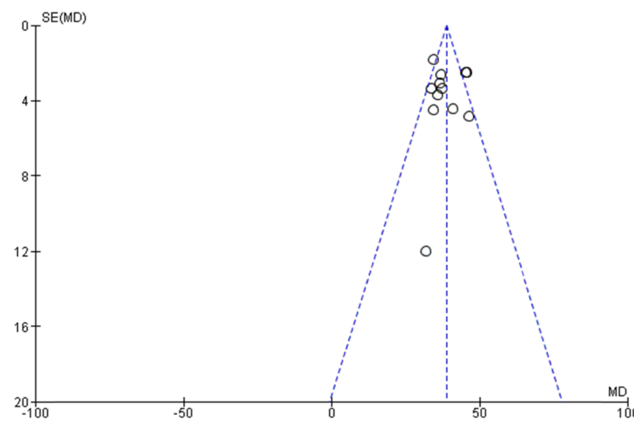

Fig. 6. Publication bias for studies with reported HOS-SSS (Hip Outcome Score–Sports-Specific Subscale) outcomes.

Table 5. Sensitivity Analysis for HOS-SSS (Hip Outcome Score–Sports-Specific Subscale) Outcomes

	MD	95% CI	P-value	I^2
Retrospective studies				
All studies included	39.47	35.22, 43.72	<0.00001	63
Excluding Barastegui et al.[14] (2023)	38.59	34.22, 42.97	<0.00001	63
Excluding Beck et al.[15] (2021)	40.12	35.01, 45.23	<0.00001	68
Excluding Chandrasekaran et al.[17] (2017)	37.34	34.08, 40.60	<0.00001	24
Excluding Cvetanovich et al.[19] (2018)	39.28	34.46, 44.10	<0.00001	24
Excluding Litrenta et al.[24] (2020)	39.91	34.82, 45.00	<0.00001	69
Excluding Maldonado et al.[25] (2023)	39.72	35.29, 44.15	<0.00001	69
Excluding Maldonado et al.[26] (2022)	40.92	36.87, 44.98	<0.00001	40
Prospective studies				
All studies included	37.70	32.99, 42.40	<0.00001	64
Excluding Fukase et al.[31] (2022)	35.56	32.28, 38.85	<0.00001	0
Excluding Newman et al.[29] (2016)	38.69	33.40, 43.98	<0.00001	64
Excluding Nwachukwu et al.[30] (2017)	38.03	32.30, 43.77	<0.00001	71
Excluding Ruzbarsky et al.[34] (2023)	37.72	31.39, 44.06	<0.00001	72
Excluding Saks et al.[35] (2022)	38.24	32.84, 43.65	<0.00001	70

MD: mean differences, CI: confidence interval.

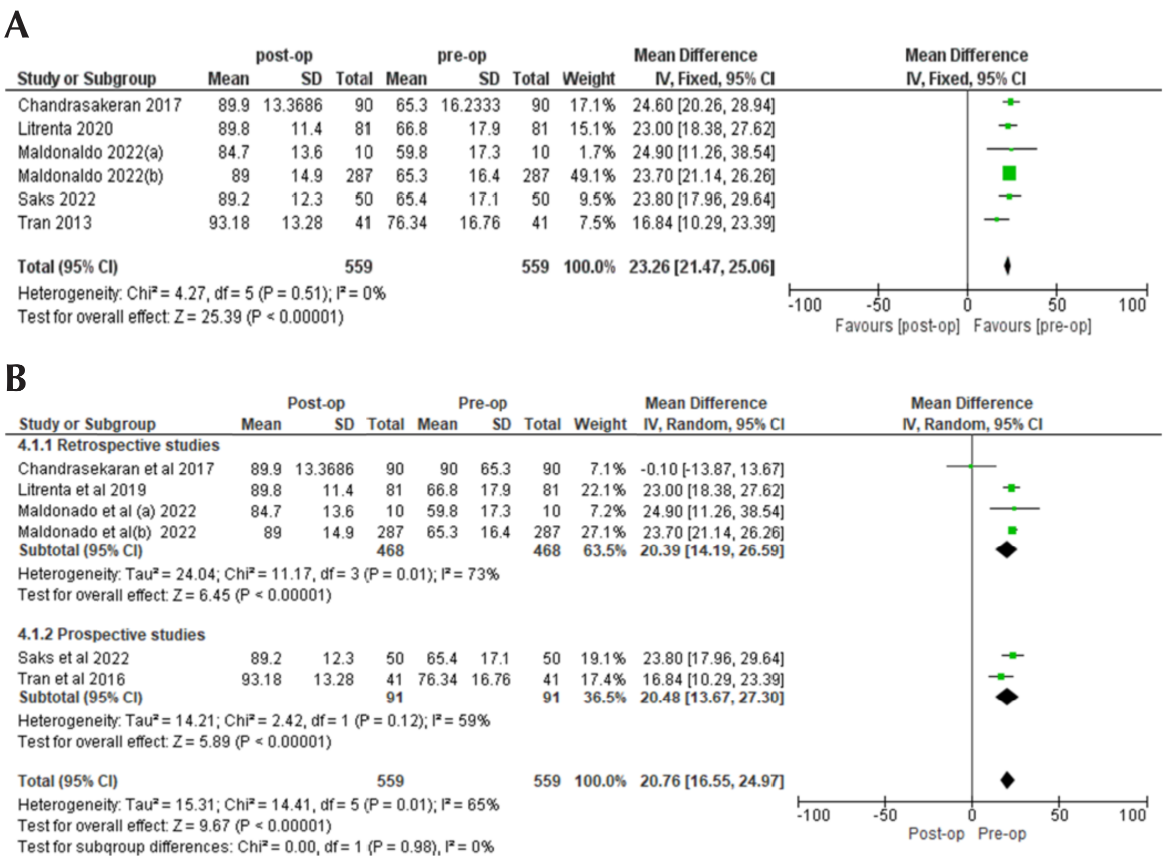

Fig. 7. (A) Mean differences in preoperative and postoperative Nonarthritic Hip Score (NAHS) scores. (B) Mean differences in preoperative and postoperative NAHS scores of the prospective and retrospective study subgroups.

(I^2=0%, P=0.91), a fixed-effect model was applied (Fig. 8A).

Subgroup analyses of prospective and retrospective studies revealed significant improvements in postoperative pain (MD of the VAS pain –4.00, 95% CI –4.86 to –3.14, P<0.00001 and MD –3.86, 95% CI –4.17 to –3.55, P<0.00001, I^2=0%), respectively (Fig. 8B).

6) i-HOT

Four studies, including 469 hips treated with arthroscopic surgery, demonstrated statistically significant increases of i-HOT scores measured preoperatively and, postoperatively (MD 29.81, 95% CI 16.17 to 43.45, P<0.0001). As substantial heterogeneity was observed (I^2=95%, P<0.00001), a random-effect model was applied (Fig. 9A).

While subgroup analysis of prospective studies revealed non-significant increments in postoperative i-HOT scores (MD 22.63, 95% CI –19.51 to 64.77, P=0.29, I^2=98%), the subgroup of retrospective studies indicated significant improvements in postoperative i-HOT scores (MD 35.94, 95% CI 32.79 to 39.09, P<0.00001, I^2=0%). Retrospective subgroup analysis revealed no heterogeneity among the included studies (Fig. 9B).

High heterogeneity was attributable to differences in sample size, age group of the study subjects, and study design.

SATISFACTION SCORES

Mean satisfaction scores in research performed by Chandrasekaran et al.[17] along with Philippon et al.[33] were 8.29 and 8.8, respectively. Despite the lack of quantitative data, a high degree of overall patient satisfaction was observed in the McConkey's study[27] and Tran et al.'s study[37]. Menge et al.[18] reported a revision cohort's satisfaction score of 7. Ruzbarsky et al.[34] had a mean score of 8.5 while Saks et al.[35] had 7.9. Two Maldonado et al.[25,26] studies had mean satisfaction scores of 7.7 and 8.8. These results have all demonstrated the great degree of patient satisfaction.

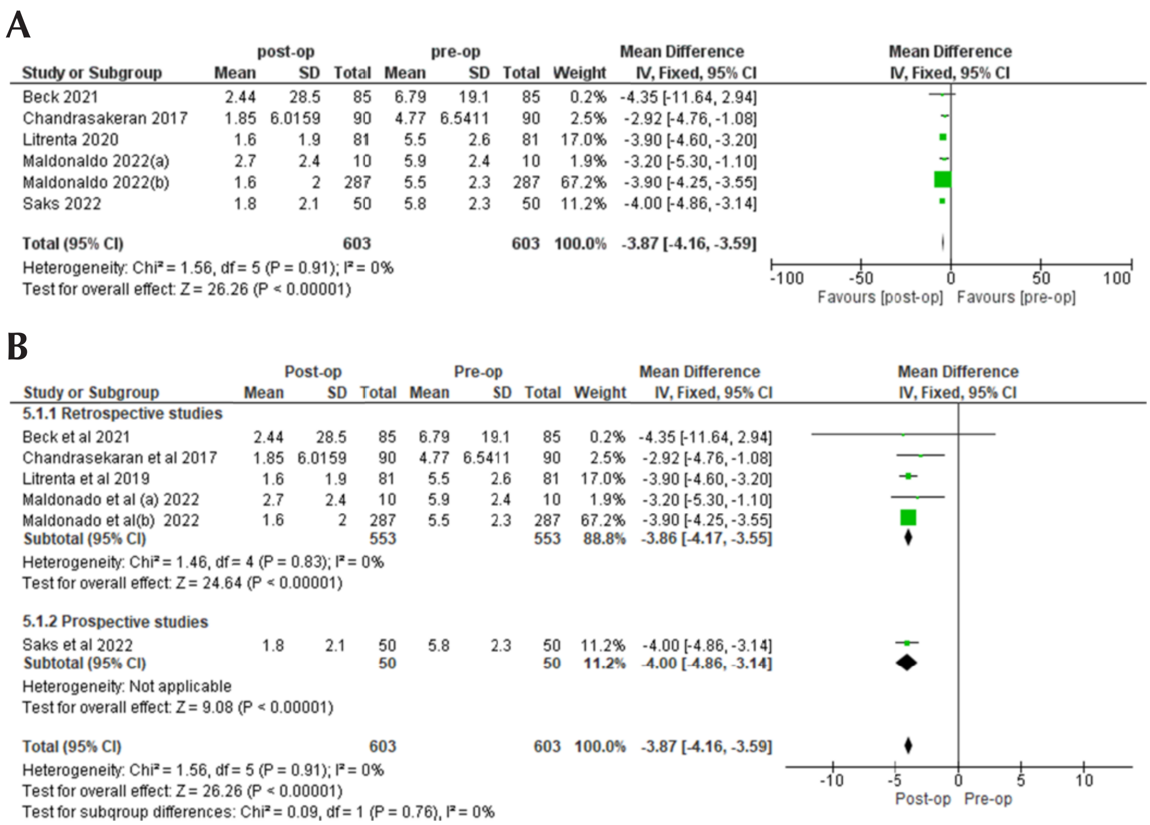

Fig. 8. (A) Mean differences in preoperative and postoperative visual analog scale (VAS) pain scores. (B) Mean differences in preoperative and postoperative VAS pain scores of the prospective and retrospective study subgroups.

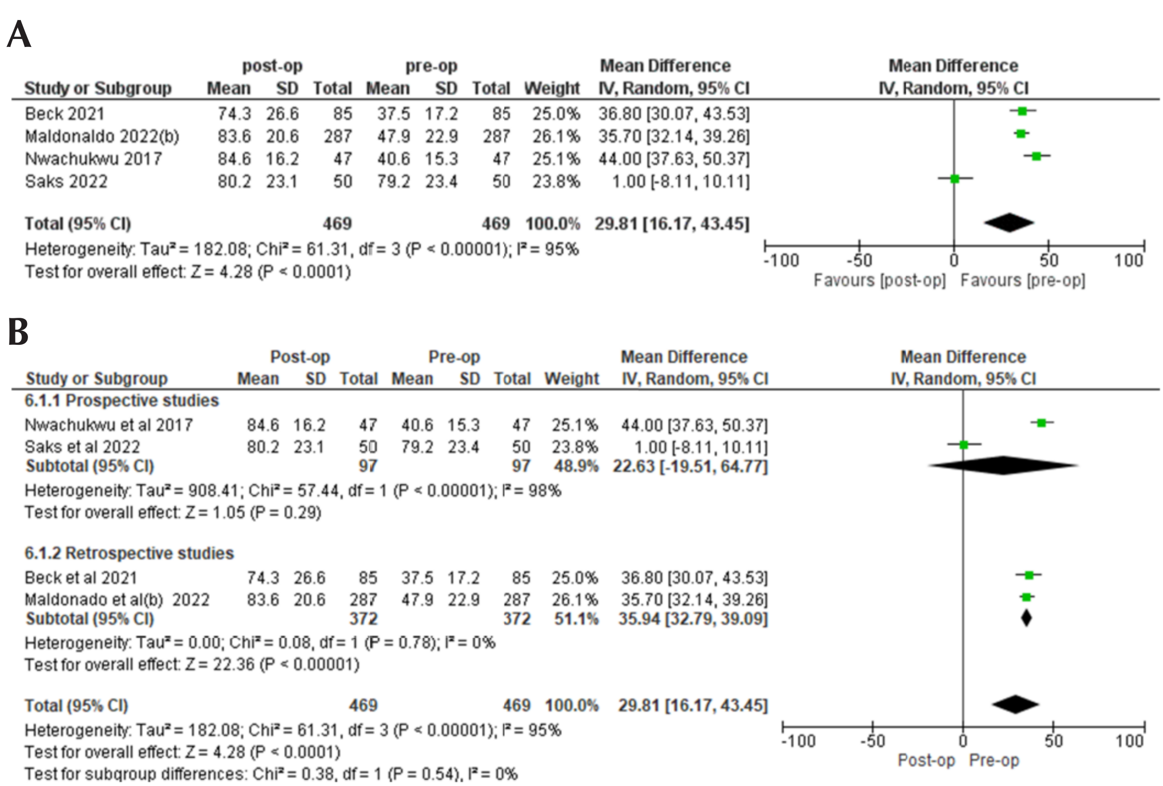

Fig. 9. (A) Mean differences in preoperative and postoperative International Hip Outcome Tool (12 questions) (i-HOT) scores. (B) Mean differences in preoperative and postoperative i-HOT scores of the prospective and retrospective study subgroups.

COMPLICATIONS

Complications were rare. At the final follow-up, adverse effects of the arthroscopic procedure to treat FAI were only documented in approximately 12 hips out of 1,767 (0.679%) in all the included studies. Three instances of neuropraxia involving pudendal nerve were reported. This effect was temporary in all cases. Additionally, two mild infections and five occurrences of numbness were recorded. In a study by Winge et al.[21], one case experienced erectile dysfunction, whereas lateral thigh impairment was noted in another case. The Maldonado et al.'s study[26] showed that the pooled incident of cam recurrence for the patients was 1.7%, and the incident of heterotopic ossification was 5.5%.

REVISION RATES

Revision varied from 0% to 10% for the 13 studies examined. Surgical revision ranged between 4 months and 6.2 years. Surgical revision became necessary due to adhesions and new injuries related to physical activities like sports. Table 6 elucidates the types of revision surgery required in these studies. Fukase et al.[31] demonstrated no statistically significant variations in revision rate of hip arthroscopy (P=0.46) among adolescents and a similar adult study group.

RATE AND TIME TO RETURN TO ACTIVITY

According to a study by Barastegui et al.[14], at one year following surgery, 100% of the subjects were back engaging in active competition, with a mean recovery time of 5.93±2.09 months (range, 3-10 months). At the time of the final follow-up, 92.86% of patients were found participating in competitive football.

Table 6. Details of Revision Surgeries

Study	Revision surgery details
Chandrasekaran et al.[17] (2017)	Five patients required revision procedures within the 2-year follow-up period in the form of: Selective debridement, capsular release
Byrd et al.[16] (2016)	Four patients required revision surgery in the form of: Excision of capsulolabral adhesions with healed labrum Acetabuloplasty with labral refixation and revision femoroplasty Excision of capsulolabral adhesions, revision femoroplasty with healed labrum Excision of capsulolabral adhesions with healed labrum
Winge et al.[21] (2021)	Two patients required revision surgeries in the form of: Resection of capsulolabral adherences
Lee et al.[23] (2022)	Nine patients required revision surgeries in the form of: Labral treatment (repair, debridement, reconstruction, capsular closure/plication) Acetabuloplasty Femoroplasty
Litrenta et al.[24] (2020)	There were 6 patients (7.4%) who underwent revision arthroscopy at a mean of 37.3 months postoperatively.
Maldonado et al.[25] (2023)	The rate of secondary hip arthroscopy was 5.8% (18 patients) at an average time 39.4 months.
Maldonado et al.[26] (2022)	Thirteen hips (12 patients) underwent a revision arthroscopic labral reconstruction.
Fukase et al.[31] (2022)	Fourteen patients required revision surgeries in the form of: Labral treatment (repair, debridement, reconstruction) Isolated acetabuloplasty (rim trimming) Isolated femoroplasty (cam resection) Acetabuloplasty and femoroplasty
Perets et al.[32] (2017)	One hip (9.1%) underwent a subsequent arthroscopy procedure at 31.1 months postoperatively due to a subsequent injury.
Philippon et al.[33] (2012)	Eight hips needed a second-look hip arthroscopy and was performed at a mean of 26 months (range, 10-46 months) after the index procedure. During the second surgery, all hips were diagnosed as having capsulolabral adhesions, and lysis of adhesions was performed.
Ruzbarsky et al.[34] (2023)	Ten patients required revision surgery at an average of 2.3 years. Capsulolabral adhesion lysis was performed.

DISCUSSION

A comprehensive overview of arthroscopic procedures for FAI in adolescents was provided by the meta-analysis undertaken in this study. Surgical procedure, radiological changes, complications, and patient reported outcomes of arthroscopic treatment for FAI syndrome (FAIS) were all highlighted. When all relevant scores were significantly higher at follow-up, adolescents showed positive results and a significant rate of sport return. Significant improvement in HOS-SSS scores further supported a higher rate of sport return. Hip discomfort, function, and overall quality of life improved, as evidenced by the significant improvements in VAS, NAHS, mHHS, HOS-ADL, and patient satisfaction scores. A recent study comparing adult and adolescent hips showed hip arthroscopy for FAI in growing adolescents carried out with a physeal-sparing technique is safe, efficient, and produces better clinical results than those in a matched adult cohort[31].

FAI is a dynamic hip condition that may cause discomfort and disability. FAI also has the potential to progress to arthritis. When symptomatic, surgery can be used to treat FAI if conservative measures are unsuccessful. Surgical treatment for FAI aims to restore normal mechanics and joint sealing by repairing the spherical contour of the femoral head, improve femoral offset, normalize acetabulum coverage, repair or reconstruct chondral damage, and repair or reconstruct the labrum. Due to advancements in technology and technique, the quantity of hip arthroscopy operations carried out globally has escalated. Therefore, hip arthroscopy has been put into place as a common treatment choice for problematic FAI[38].

The Migliorini and Maffulli[7] review included 406 adolescent patients with 470 FAI procedures, with a mean age at surgical intervention of 15.9 years and a mean follow-up time of 30.4 months. At final follow-up, all relevant results were improved (P=0.01 for the VAS, P<0.0001 for the mHHS, P=0.03 for the non-arthritic hip score, P=0.01 for the HOS-ADL, and P<0.0001 for the HOS-SSS)[7]. Similarly, another recent systematic review and meta-analysis by Huang et al.[8] included 832 hips in 753 patients. In this instance, every patient reported a significant improvement in surgical outcome; HOS-SSS was 35.88 (95% CI 33.07 to 38.68, P<0.0001, I^2=0%), HOS-ADL was 23.53 (95% CI 21.21 to 25.85, P<0.0001, I^2=0%), and the NAHS was 22.34 (95% CI 18.40 to 26.28, P<0.0001, I^2=40.9%). The mHHS calculated MD was 24.99 (95% CI 22.88 to 27.10, P<0.0001, I^2=19.9%). A mean reduction in VAS pain score (10-point scale) by 4.03 postoperatively (MD 4.03, 95% CI –4.439 to –3.64, P<0.001, I^2=0%) indicated an improvement in pain levels[8]. Our study revealed the significant improvement in all patient-related postoperative outcomes.

Although there is a research gap in assessing the connection between preoperative imaging and results in the adolescents, radiographic data have additionally been employed to forecast surgery results for adults[39]. A study reveals, after arthroscopic FAI surgical intervention, a statistically significant difference in reported radiographic results among 15 radiographic parameters[24]. Radiography results most frequently reported were femoral offset ratio (17.4%), center edge angle (34.7%), and alpha angle (69.6%)[40]. Previous studies also highlighted the differences in preoperative and postoperative radiological findings[8]. A study by Degen et al.[41] also revealed that, at six weeks postoperatively, alpha angle (mean±standard deviation) had decreased from 55.4°±12.1° preoperatively to 38.7°±4.9° (MD –16.4°, 95% CI –19.8° to –12.9°, P<0.001). In 6 studies out of 16 studies reviewed, our study also found a substantial decrease (P<0.001) in alpha angle following surgery.

Acetabuloplasty was the only procedure where frequency varied significantly between groups; this procedure was more commonly used in skeletally mature patients. This discovery could provide fresh insight into the functional maturity of the skeleton in the formation of pincer deformity as well as the best operable approaches for treating mixed and pincer impingements. The underlying condition that causes pincer impingement must be accurately diagnosed, and this diagnosis might be impacted by development and growth trends[42]. According to Philippon et al.[33], treating the cam lesion during physeal closure will prevent damage to the growth plate and improve overallpatient safety. Compared to adults, adolescents experience cam-type impingement more frequently. Larson et al.[22] used thermal equipment to ablate the anterolateral physis to prevent recurrence of cam lesions. Adolescent skeletal immaturity may induce cam deformity to recur with physeal growth; however, the majority of research did not specifically address the possibility of cam regrowth. Furthermore, iliopsoas fractional lengthening, labral repair, and excision of loose bodies were the most commonly used surgical techniques in studies involving revision cases[8].

Pulmonary embolism, infection within the deep joints, avascular necrosis of the femoral head, and surgical dislocation are major side effects[43]. Examples of minor complications are hematoma, numbness, deep vein thrombosis, and irritation in the lateral thigh from lateral femoral cutaneous nerve damage, passage of instruments or adjustment of ports, painful sexual intercourse, superficial infection, and heterotopic ossification around the hip. The most frequent side effects after hip arthroscopy are numbness and traction neuropraxia[44]. In the Migliorini and Maffulli[7] investigation of 470 procedures, rare complications (n=5) included transient perineal nerve paresthesia in 0.4% (n=2), transient paresthesia of the lateral femoral cutaneous nerve in 0.4% (n=2), and idiopathic temporary neurapraxia in 0.2% (n=1). Out of the total number of procedures, 4.7% (n=22) were revision arthroscopies. The Huang et al.'s study[8] had similar findings. Our review also found few complications and recurrence. Complications like erectile dysfunction and lateral thigh impairment complications were found in the study by Winge et al.[21].

Individuals who suffer from FAI ought to be informed about their increased likelihood for developing osteoarthritis, as research indicates that this condition poses a risk independent of the type of treatment they receive—nonoperative or surgical[45].

LIMITATIONS

Our study had certain limitations. Different follow-up times and different sample sizes provided study heterogeneity so a conservative interpretation of the results is needed. Since several measures and factors were emphasized in the investigation, it was challenging to get complete and consistent data for integration. Furthermore, extended follow-up over a period of time is still necessary to assess long term effects of arthroscopic therapy on adolescents. Similarly, studies comparing radiological outcomes were scarce. Our study also lacked specific information on the revision surgery.

CONCLUSION

Our systematic review and meta-analysis showed overall improvement in hip pain, function, and quality of life in teenagers, as evidenced by considerable improvements in VAS, NAHS, mHHS, HOS-ADL, and good patient satisfaction scores along with radiological outcomes and few complications. Owing to the different limitations of our study, the importance of the interdisciplinary group in diagnosing and managing the condition is warranted. Further research with extended follow-up times and comparison with adults undergoing the same treatment for FAIS should be done.

Funding

No funding to declare.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

REFERENCES

1. Sankar WN, Nevitt M, Parvizi J, Felson DT, Agricola R, Leunig M. Femoroacetabular impingement: defining the condition and its role in the pathophysiology of osteoarthritis. J Am Acad Orthop Surg. 2013;21 Suppl 1:S7-15. https://doi.org/10.5435/jaaos-21-07-s7
2. Agricola R, Heijboer MP, Ginai AZ, et al. A cam deformity is gradually acquired during skeletal maturation in adolescent and young male soccer players: a prospective study with minimum 2-year follow-up. Am J Sports Med. 2014;42:798-806. https://doi.org/10.1177/0363546514524364
3. Byrd JW, Jones KS, Gwathmey FW. Arthroscopic management of femoroacetabular impingement in adolescents. Arthroscopy. 2016;32:1800-6. https://doi.org/10.1016/j.arthro.2016.02.019
4. Nwachukwu BU, Rebolledo BJ, McCormick F, Rosas S, Harris JD, Kelly BT. Arthroscopic versus open treatment of femoroacetabular impingement: a systematic review of medium-to long-term outcomes. Am J Sports Med. 2016;44:1062-8. https://doi.org/10.1177/0363546515587719
5. Peters S, Laing A, Emerson C, et al. Surgical criteria for femoroacetabular impingement syndrome: a scoping review. Br J Sports Med. 2017;51:1605-10. https://doi.org/10.1136/bjsports-2016-096936
6. Wyles CC, Norambuena GA, Howe BM, et al. Cam deformities and limited hip range of motion are associated with early osteoarthritic changes in adolescent athletes: a prospective

matched cohort study. Am J Sports Med. 2017;45:3036-43. https://doi.org/10.1177/0363546517719460
7. Migliorini F, Maffulli N. Arthroscopic management of femoroacetabular impingement in adolescents: a systematic review. Am J Sports Med. 2021;49:3708-15. https://doi.org/10.1177/0363546521997138
8. Huang HJ, Zhou X, Huang ZG, et al. Arthroscopic treatment for femoroacetabular impingement syndrome in adolescents: a systematic review and meta-analysis. Clin J Sport Med. 2022;32:608-16. https://doi.org/10.1097/jsm.0000000000001053
9. Table S3-1: Newcastle-Ottawa scale for assessment of quality of included studies--cohort studies [Internet]. London: PeerJ; 2020 Mar 26 [cited 2024 Feb 4]. Available from: https://doi.org/10.7717/peerj.8815/supp-4
10. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003;327:557-60. https://doi.org/10.1136/bmj.327.7414.557
11. Kontopantelis E, Reeves D. Performance of statistical methods for meta-analysis when true study effects are non-normally distributed: a simulation study. Stat Methods Med Res. 2012;21:409-26. https://doi.org/10.1177/0962280210392008
12. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315:629-34. https://doi.org/10.1136/bmj.315.7109.629
13. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. https://doi.org/10.1136/bmj.n71
14. Barastegui D, Seijas R, Alentorn-Geli E, Ferré-Aniorte A, Laiz P, Cugat R. Hip arthroscopy is a successful treatment for femoroacetabular impingement in under-16 competitive football players: a prospective study with minimum 2-year follow-up. Arch Orthop Trauma Surg. 2023;143:2641-6. https://doi.org/10.1007/s00402-022-04584-1
15. Beck EC, Nwachuckwu BU, Jan K, Nho SJ. Hip arthroscopy for femoroacetabular impingement syndrome in adolescents provides clinically significant outcome benefit at minimum 5-year follow-up. Arthroscopy. 2021;37:1467-73.e2. https://doi.org/10.1016/j.arthro.2020.12.188
16. Byrd JW, Jones KS, Gwathmey FW. Femoroacetabular impingement in adolescent athletes: outcomes of arthroscopic management. Am J Sports Med. 2016;44:2106-11. https://doi.org/10.1177/0363546516648325
17. Chandrasekaran S, Darwish N, Chaharbakhshi EO, Lodhia P, Suarez-Ahedo C, Domb BG. Arthroscopic treatment of labral tears of the hip in adolescents: patterns of clinical presentation, intra-articular derangements, radiological associations and minimum 2-year outcomes. Arthroscopy. 2017;33:1341-51. https://doi.org/10.1016/j.arthro.2017.01.048
18. Menge TJ, Briggs KK, Rahl MD, Philippon MJ. Hip arthroscopy for femoroacetabular impingement in adolescents: 10-year patient-reported outcomes. Am J Sports Med. 2021;49:76-81. https://doi.org/10.1177/0363546520973977
19. Cvetanovich GL, Weber AE, Kuhns BD, et al. Clinically meaningful improvements after hip arthroscopy for femoroacetabular impingement in adolescent and young adult patients regardless of gender. J Pediatr Orthop. 2018;38:465-70. https://doi.org/10.1097/bpo.0000000000000852
20. Fabricant PD, Heyworth BE, Kelly BT. Hip arthroscopy improves symptoms associated with FAI in selected adolescent athletes. Clin Orthop Relat Res. 2012;470:261-9. https://doi.org/10.1007/s11999-011-2015-7
21. Winge S, Winge S, Kraemer O, Dippmann C, Hölmich P. Arthroscopic treatment for femoroacetabular impingement syndrome (FAIS) in adolescents-5-year follow-up. J Hip Preserv Surg. 2021;8:249-54. https://doi.org/10.1093/jhps/hnab051
22. Larson CM, McGaver RS, Collette NR, et al. Arthroscopic surgery for femoroacetabular impingement in skeletally immature athletes: radiographic and clinical analysis. Arthroscopy. 2019;35:1819-25. https://doi.org/10.1016/j.arthro.2019.01.029
23. Lee MS, Paraschos OA, Jimenez AE, Owens JS, Maldonado DR, Domb BG. 5-Year arthroscopy-free survivorship and outcomes of adolescents undergoing primary hip arthroscopy: a comparison between traumatic and atraumatic injuries. Am J Sports Med. 2022;50:2613-21. https://doi.org/10.1177/03635465221103255
24. Litrenta J, Mu BH, Ortiz-Declet V, et al. Hip arthroscopy successfully treats femoroacetabular impingement in adolescent athletes. J Pediatr Orthop. 2020;40:e156-60. https://doi.org/10.1097/bpo.0000000000001411
25. Maldonado DR, Kufta AY, Krych AJ, et al. Primary hip arthroscopy for femoroacetabular impingement syndrome in adolescents improves outcomes and clinical benefit achievement rates at short-term follow-up: a multicenter analysis. Arthroscopy. 2023;39:1211-9. https://doi.org/10.1016/j.arthro.2022.11.020
26. Maldonado DR, Glein RM, Saks BR, et al. Minimum 2-year outcomes following arthroscopic hip labral reconstruction in adolescents and young adults. J Pediatr Orthop. 2022;42:83-9. https://doi.org/10.1097/bpo.0000000000001984
27. McConkey MO, Chadayammuri V, Garabekyan T, Mayer SW, Kraeutler MJ, Mei-Dan O. Simultaneous bilateral hip arthroscopy in adolescent athletes with symptomatic femoroacetabular impingement. J Pediatr Orthop. 2019;39:193-7. https://doi.org/10.1097/bpo.0000000000000987
28. Morris WZ, Loewen A, Ulman S, et al. Comparison of gait

and functional outcomes between open and arthroscopic treatment of adolescent and young adult femoroacetabular impingement. J Pediatr Orthop. 2024;44:22-7. https://doi.org/10.1097/bpo.0000000000002532
29. Newman JT, Briggs KK, McNamara SC, Philippon MJ. Outcomes after revision hip arthroscopic surgery in adolescent patients compared with a matched cohort undergoing primary arthroscopic surgery. Am J Sports Med. 2016;44:3063-9. https://doi.org/10.1177/0363546516659656
30. Nwachukwu BU, Chang B, Kahlenberg CA, et al. Arthroscopic treatment of femoroacetabular impingement in adolescents provides clinically significant outcome improvement. Arthroscopy. 2017;33:1812-8. https://doi.org/10.1016/j.arthro.2017.04.008
31. Fukase N, Murata Y, Pierpoint LA, et al. Outcomes and survivorship at a median of 8.9 years following hip arthroscopy in adolescents with femoroacetabular impingement: a matched comparative study with adults. J Bone Joint Surg Am. 2022;104:902-9. https://doi.org/10.2106/jbjs.21.00852
32. Perets I, Gupta A, Chaharbakhshi EO, et al. Does bony regrowth occur after arthroscopic femoroplasty in a group of young adolescents? Arthroscopy. 2017;33:988-95. https://doi.org/10.1016/j.arthro.2017.01.023
33. Philippon MJ, Ejnisman L, Ellis HB, Briggs KK. Outcomes 2 to 5 years following hip arthroscopy for femoroacetabular impingement in the patient aged 11 to 16 years. Arthroscopy. 2012;28:1255-61. https://doi.org/10.1016/j.arthro.2012.02.006
34. Ruzbarsky JJ, Comfort SM, Fukase N, Briggs KK, Vidal LB, Philippon MJ. Timing from symptom onset to hip arthroscopy does not affect patient-reported outcome measures for the treatment of femoroacetabular impingement in adolescent patients. Arthroscopy. 2023;39:2466-73. https://doi.org/10.1016/j.arthro.2023.03.028
35. Saks BR, Monahan PF, Maldonado DR, et al. Pathologic findings on hip arthroscopy in high-level athletes competing in flexibility sports. Am J Sports Med. 2022;50:1028-38. https://doi.org/10.1177/03635465221077002
36. Serbin PA, Youngman TR, Johnson BL, et al. Radiographic predictors of reoperation in adolescents undergoing hip preservation surgery for femoroacetabular impingement. Am J Sports Med. 2023;51:687-93. https://doi.org/10.1177/03635465221147062
37. Tran P, Pritchard M, O'Donnell J. Outcome of arthroscopic treatment for cam type femoroacetabular impingement in adolescents. ANZ J Surg. 2013;83:382-6. https://doi.org/10.1111/j.1445-2197.2012.06197.x
38. Nasser R, Domb B. Hip arthroscopy for femoroacetabular impingement. EFORT Open Rev. 2018;3:121-9. https://doi.org/10.1302/2058-5241.3.170041
39. Sogbein OA, Shah A, Kay J, et al. Predictors of outcomes after hip arthroscopic surgery for femoroacetabular impingement: a systematic review. Orthop J Sports Med. 2019;7:2325967119848982. https://doi.org/10.1177/2325967119848982
40. Dzaja I, Martin K, Kay J, et al. Radiographic outcomes reporting after arthroscopic management of femoroaceabular impingement: a systematic review. Curr Rev Musculoskelet Med. 2016;9:411-7. https://doi.org/10.1007/s12178-016-9366-3
41. Degen RM, Mayer SW, Fields KG, Coleman SH, Kelly BT, Nawabi DH. Functional outcomes and cam recurrence after arthroscopic treatment of femoroacetabular impingement in adolescents. Arthroscopy. 2017;33:1361-9. https://doi.org/10.1016/j.arthro.2017.01.044
42. Hingsammer AM, Bixby S, Zurakowski D, Yen YM, Kim YJ. How do acetabular version and femoral head coverage change with skeletal maturity? Clin Orthop Relat Res. 2015;473:1224-33. https://doi.org/10.1007/s11999-014-4014-y
43. Mardones RM, Gonzalez C, Chen Q, Zobitz M, Kaufman KR, Trousdale RT. Surgical treatment of femoroacetabular impingement: evaluation of the effect of the size of the resection. Surgical technique. J Bone Joint Surg Am. 2006;88 Suppl 1 Pt 1:84-91. https://doi.org/10.2106/jbjs.e.01024
44. Schüttler KF, Schramm R, El-Zayat BF, Schofer MD, Efe T, Heyse TJ. The effect of surgeon's learning curve: complications and outcome after hip arthroscopy. Arch Orthop Trauma Surg. 2018;138:1415-21. https://doi.org/10.1007/s00402-018-2960-7
45. O'Rourke RJ, El Bitar Y. Femoroacetabular impingement. In: StatPearls. StatPearls Publishing; 2025. Available from: https://pubmed.ncbi.nlm.nih.gov/31613479/