Treatment of femoroacetabular impingement: a systematic review

Joshua D. Harris · Brandon J. Erickson · Charles A. Bush-Joseph · Shane J. Nho

Abstract The purpose of this review is to determine if there is a difference in outcomes after: (1) nonsurgical vs surgical treatment of FAI; (2a) surgical dislocation with greater trochanteric osteotomy, (2b) anterior mini-open, (2c) arthroscopic plus mini-open, and (2d) arthroscopic surgery for FAI; (3) difference in complication and re-operation rates; and (4a) labral refixation and (4b) labral debridement for labral injuries. A systematic review of multiple databases was performed after PROSPERO registration and using PRISMA guidelines. Level I-IV evidence clinical studies with minimum 2-year follow-up were included. Data were compared using 2-sample and 2-proportion Z-test calculators. Study methodological quality was analyzed using Modified Coleman Methodology Score (MCMS). Recommendations were made using SORT (Strength Of Recommendation Taxonomy). Twenty-nine studies were included (2369 subjects; 2507 hips). MCMS was poor. Mean subject age was $34.4+/-8.4$ years and mean follow-up was $3.1+/-0.9$ years. Statistically significant differences were observed following both nonsurgical and surgical treatment, with greater ($P<0.05$) improvements following surgery (SORT B), without consistent significant differences observed between different surgical techniques (SORT C). There was a greater ($P<0.05$) reoperation and complication rate following surgical dislocation vs mini-open and arthroscopic techniques (SORT A). Clinical outcomes were significantly better ($P<0.05$) following labral refixation vs debridement (SORT B). Outcomes of operative treatment of femoroacetabular impingement are significantly better than nonsurgical management. Surgical treatment significantly improves outcomes, with no consistent significant differences exhibited between open and arthroscopic techniques. Open surgical dislocation has significantly greater reoperation and complication rates vs mini-open and arthroscopic techniques. Outcomes of labral refixation are significantly better than debridement in patients with labral injuries.

Keywords Hip · Femoroacetabular impingement · Arthroscopy · Surgical dislocation · Labral tear

Introduction

Femoroacetabular impingement (FAI) is a common cause of hip pain that may lead to osteoarthritis [1]. Cam and pincer FAI are 2 distinct anatomic entities that may lead to abnormal articular congruity and subsequent chondrolabral injury [1]. The acetabular labrum is an important structure involved in the normal hip articulation and is commonly injured in FAI [2•]. However, radiographic abnormalities suggestive of FAI have been demonstrated in asymptomatic patients and the natural history of the FAI hip is not completely known [3]. Significant hip-specific [4••], general health-specific [5], and quality-of-life [5] questionnaire improvements have been observed in early- and mid-term follow-up in symptomatic patients undergoing FAI hip preservation surgery. Nonetheless, it is unknown whether FAI and labral surgery has the potential to affect the incidence or progression of osteoarthritis of the hip [6].

Very little literature has been published on the nonoperative treatment of FAI [7]. Further, to date, there have not been any investigations comparing nonoperative and operative treatment. In addition, there is little data in the literature that compares outcomes of the most commonly-utilized surgical techniques in FAI. Management of the acetabular labrum (debride, repair, refixation, reconstruct) is controversial. Therefore, the purpose of this systematic review was to answer the following 4 questions:

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1. Is there a difference in clinical outcomes after (a) nonsurgical and (b) surgical treatment of FAI?
2. Is there a difference in clinical outcomes after (a) surgical dislocation with greater trochanteric osteotomy; (b) anterior mini-open; (c) arthroscopic plus mini-open; and (d) arthroscopic surgery for FAI?
3. Is there a difference in complication and re-operation rates after (a) surgical dislocation with greater trochanteric osteotomy; (b) anterior mini-open; (c) arthroscopic plus mini-open; and (d) arthroscopic surgery for FAI?
4. Is there a difference in clinical outcomes after (a) labral refixation and (b) labral debridement for labral injuries in patients with FAI?

The authors hypothesize that clinical outcomes are significantly better following surgical vs nonsurgical treatment of FAI. The authors hypothesize that there is no significant clinical outcome difference between different surgical techniques for treatment of FAI. The authors hypothesize that the complication and reoperation rate is highest following surgical dislocation and mini-open techniques vs arthroscopy. The authors hypothesize that clinical outcomes are significantly better following labral refixation vs debridement.

Materials and methods

A systematic review was conducted according to PRISMA guidelines (Preferred Reporting Items for Systematic reviews and Meta-Analyses) using a PRISMA checklist [8]. Systematic review registration was performed using the PROSPERO International prospective register of systematic reviews (registration number CRD42013004001) [9]. Two reviewers independently conducted the search on March 1, 2013 using the following databases: Medline, Cochrane Central Register of Controlled Trials, SportDiscus, and CINAHL. The electronic search citation algorithm utilized was: (((((((((((((labrum [Title/Abstract]) OR labral [Title/Abstract])) OR ((femoroacetabular [Title/Abstract]) AND impingement [Title/Abstract]))) AND hip [Title/Abstract]) NOT shoulder [Title/Abstract]) NOT subacromial [Title/Abstract]) NOT elbow [Title/Abstract]) NOT wrist [Title/Abstract]) NOT hand [Title/Abstract]) NOT knee [Title/Abstract]) NOT ankle [Title/Abstract]) NOT foot [Title/Abstract] AND (English [lang]). English language Level I–IV evidence (2011 update by the Oxford Centre for Evidence-Based Medicine [10]) clinical outcome studies with minimum 2-year follow-up were eligible. Medical conference abstracts were ineligible for inclusion. All references within included studies were cross-referenced for inclusion if missed by the initial search. Duplicate subject publications within separate unique studies were not reported twice. The study with

longer duration follow-up, greater number of subjects, or more explicit reporting of rehabilitation was retained for inclusion. Level V evidence reviews, letters to the editor, basic science, biomechanical studies, open hip surgery, imaging, surgical technique, and classification studies were excluded. Inclusive studies necessarily reported post-operative rehabilitation protocols. Qualitative and quantitative reporting of specific rehabilitation parameters was analyzed. Those studies that otherwise would have been eligible for inclusion and analysis (eg, 2 years clinical follow-up after hip arthroscopy) that failed to include any post-operative rehabilitation protocol were excluded.

Participants/subjects/patients of interest in this systematic review were enrolled in a clinical trial with a minimum of 2-years follow-up following nonoperative or operative treatment (intervention) of FAI. Specific surgical techniques of interest were intra-articular procedures including arthroscopic, mini-open, arthroscopic plus mini-open, or open greater trochanteric osteotomy-based surgical dislocation with femoral osteochondroplasty, pincer acetabuloplasty, labral debridement, or refixation/repair, loose body removal, articular cartilage surgery, capsular repair/plication or release, iliopsoas release, and ligamentum teres debridement. Study and subject demographic parameters analyzed included year of publication, years of subject enrollment, presence of study financial conflict of interest, number of subjects and hips, gender, age, body mass index (BMI), diagnoses treated, and surgical procedures performed. Clinical outcome scores sought were the NAHS (nonarthritic hip score), iHOT-12 or 33 (international Hip Outcome Tool - 12 or 33), HOS (Hip Outcome Score - ADL [activities of daily living] and Sports), mHHS (modified Harris Hip Score), HOOS (Hip disability and Osteoarthritis Outcome Score), SF-12 (Short-Form), UCLA activity score, Tegner activity score, and Merle d'Aubigne Postel score. Radiographs and MRI data were extracted when available. Study methodological quality was evaluated using the MCMS (Modified Coleman Methodology Score) [11].

Femoroacetabular cam, pincer, and "mixed" impingement were defined variably across all studies (Table 1), mostly using a combination of radiographic criteria and a coincident physical exam. Radiographic parameters assessed were: alpha angle (via radiograph or MRI), lateral and anterior center edge angle, crossover sign, posterior wall sign, ischial spine sign, and acetabular index. The Tonnis classification (Grade 0 [no signs of osteoarthritis], Grade I [increased sclerosis, slight joint space narrowing, no or slight loss of head sphericity], Grade II [small cysts, moderate joint space narrowing, moderate loss of head sphericity], and Grade III [large cysts, severe joint space narrowing, severe head deformity]) was utilized for classification of degenerative changes of the hip [12].

Table 1 Heterogeneity in defining cam and pincer femoroacetabular impingement across all studies analyzed. In addition, there was heterogeneity in defining acetabular retroversion, focal anterior acetabular overcoverage, coxa profunda, acetabular protrusio, and loss of sphericity of femoral head. MRI (magnetic resonance imaging)

Cam	Pincer
• Alpha angle on radiographs (or MRI)	• Relative acetabular retroversion
○ Greater than 40° on oblique radiograph	○ Cross-over sign
○ Greater than 50° on lateral radiograph	○ Prominent ischial spine sign
○ Greater than 50° on MR arthrogram	○ Positive posterior wall sign
○ Greater than 55° on oblique radiograph	○ Lateral center edge angle greater than 25°
○ Greater than 55° on cross-table lateral radiograph	• Focal anterior overcoverage
○ Loss of sphericity of femoral head	○ Cross-over sign
▪ Extension of lateral epiphysis onto cephalad neck	○ Negative posterior wall sign
▪ Pistol grip deformity with extension of lateral epiphysis down to base of femoral neck	○ Lateral center edge angle greater than 25°
○ Reduction in head-neck offset	• Coxa profunda
○ Bump, herniation pit, and abnormal alpha angle	○ Tear drop (floor of fossa) medial to ilioischial line
	○ Lateral center edge angle greater than 35°
	• Acetabular protrusio
	○ Medial aspect of femoral head medial to ilioischial line
	○ Lateral center edge angle greater than 40°
	• Pincer divot at femoral head-neck junction

Statistical analysis

Study descriptive statistics were calculated. Continuous variable data were reported as mean ± standard deviation from the mean. Weighted means and standard deviations were calculated for all subject, hip, and surgical parameters. Categorical variable data was reported as frequency with percentages. For all statistical analysis either measured and calculated from study data extraction or directly reported from the individual studies, $P < 0.05$ was considered statistically significant. Study, subject, and surgical outcomes data were compared using 2-sample and 2-proportion Z-test calculators with alpha 0.05 because of the difference in sample sizes between compared groups.
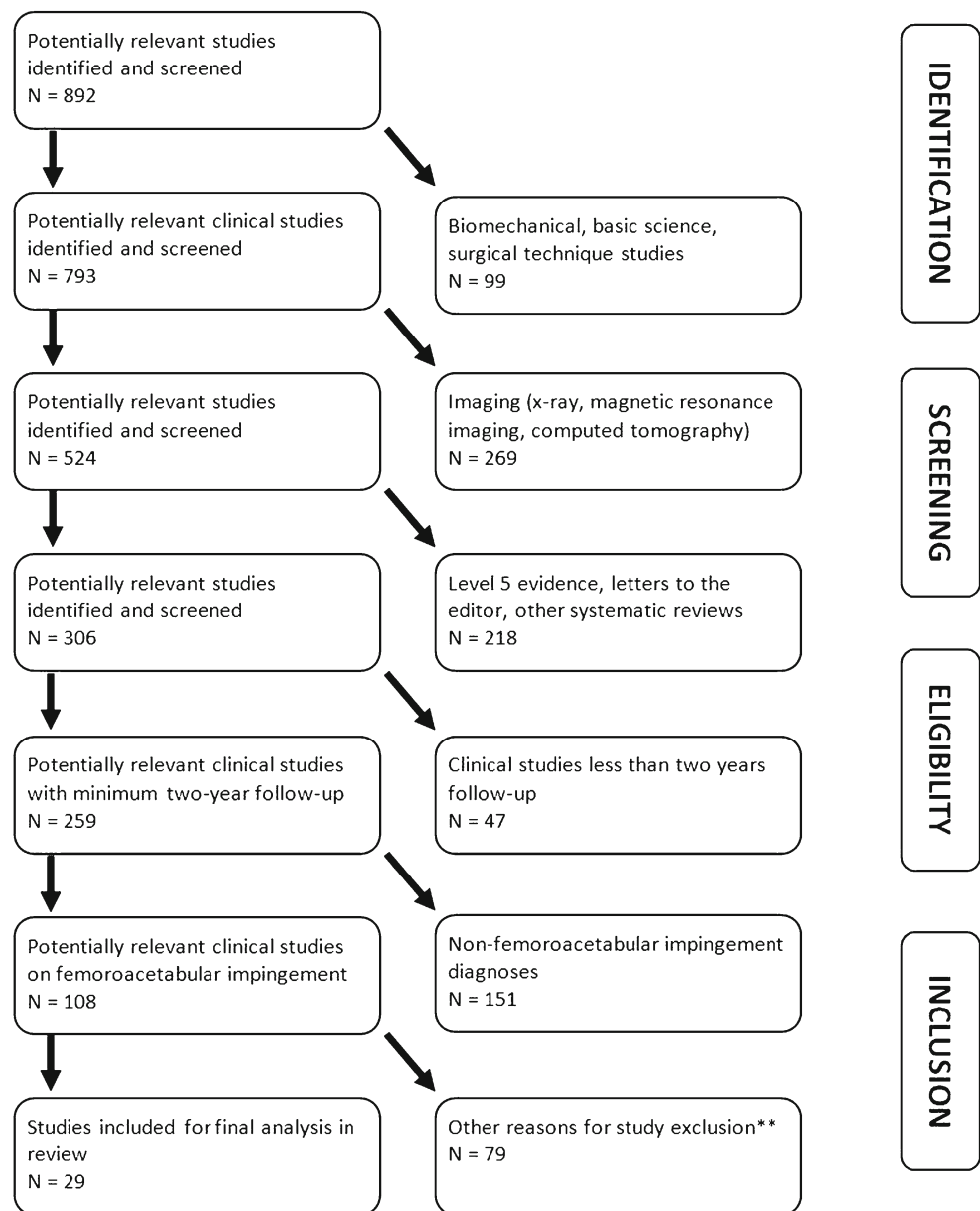
Results

Twenty-nine studies (Fig. 1), mostly level IV evidence (83 %), were included for analysis in the systematic review [2•, 4••, 5, 7, 13–18, 19•, 20–37] (Table 2). Fifty-nine percent of studies (17 out of 29) denied the presence of any financial conflict of interest, while 14 % (4 studies) failed to report either the presence or absence of a financial conflict. Most studies (72 %) were single-center investigations from the United States of America (52 %), Switzerland (21 %), or the United Kingdom (10 %). Mean MCMS was 37.4±8.2 (poor rating). The 3 highest scoring MCMS items were: (1) length of follow-up, (2) description of treatment, and (3) description of inclusion criteria. The 5 lowest scoring MCMS items were: (1) blinding, (2) randomization, (3) power analysis, (4) clinical effect size measurement, and (5) number needed to treat analysis. There were 2369 subjects analyzed with more males (60 %) than females, mean age 34.4±8.4 years, normal mean BMI (24.5±2.6 kg/m^2). Patients were, on average, symptomatic for over 2 years prior to treatment initiation (25.6±15.1 months) with a mean follow-up of 3.09±0.9 years.

Prior to commencing treatment, there was no significant difference ($P > 0.05$) for comparison of all groups with regard to mean level of evidence, subject age, or mean MCMS (Table 3). However, there were significantly fewer subjects undergoing mini-open (11 % of all hips) and arthroscopy plus mini-open (6.1 %) techniques vs surgical dislocation (24 %) and arthroscopic (59 %) techniques. Further, there were significantly more males in the mini-open group vs arthroscopic ($P=0.008$; Z=2.6) and surgical dislocation groups ($P=0.03$; Z=2.2). In addition, length of clinical follow-up was shorter in the mini-open vs arthroscopic ($P=0.01$; Z=2.5), surgical dislocation ($P>0.001$; Z=3.8), and arthroscopic plus mini-open ($P>0.001$; Z=3.7) groups. Similarly, length of follow-up was shorter in the arthroscopic vs surgical dislocation (p=0.02; Z=2.4) and arthroscopic plus mini-open ($P=0.01$; Z=2.5) groups.

There was a large number of different clinical outcome tools utilized following treatment: NAHS, HOS (ADL), HOS (Sports), mHHS, VAS, WOMAC overall (and subscores pain, stiffness, and function), UCLA activity score,

Fig. 1 PRISMA flowchart.
****Other reasons for study
exclusion: duplicate study
populations (8), physical exam
studies (18), periacetabular
osteotomy studies (12), outcome
score validation studies (8),
surveys (1), revision surgery (9),
rehabilitation studies (7), hip
trauma (13), and no clinical
outcomes reported (1)

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┌─────────────────────────┐
│ Potentially relevant     │
│ studies identified and   │                                                    IDENTIFICATION
│ screened                 │
│ N = 892                  │
└─────────────────────────┘
         │
         ▼
┌─────────────────────────┐          ┌─────────────────────────┐
│ Potentially relevant     │─────────▶│ Biomechanical, basic     │
│ clinical studies         │          │ science, surgical        │
│ identified and screened  │          │ technique studies        │
│ N = 793                  │          │ N = 99                   │
└─────────────────────────┘          └─────────────────────────┘
         │
         ▼
┌─────────────────────────┐          ┌─────────────────────────┐
│ Potentially relevant     │─────────▶│ Imaging (x-ray, magnetic │
│ studies identified and   │          │ resonance imaging,       │        SCREENING
│ screened                 │          │ computed tomography)     │
│ N = 524                  │          │ N = 269                  │
└─────────────────────────┘          └─────────────────────────┘
         │
         ▼
┌─────────────────────────┐          ┌─────────────────────────┐
│ Potentially relevant     │─────────▶│ Level 5 evidence,        │
│ studies identified and   │          │ letters to the editor,   │
│ screened                 │          │ other systematic reviews │
│ N = 306                  │          │ N = 218                  │
└─────────────────────────┘          └─────────────────────────┘
         │
         ▼
┌─────────────────────────┐          ┌─────────────────────────┐
│ Potentially relevant     │─────────▶│ Clinical studies less    │
│ clinical studies with    │          │ than two years           │        ELIGIBILITY
│ minimum two-year         │          │ follow-up                │
│ follow-up  N = 259       │          │ N = 47                   │
└─────────────────────────┘          └─────────────────────────┘
         │
         ▼
┌─────────────────────────┐          ┌─────────────────────────┐
│ Potentially relevant     │─────────▶│ Non-femoroacetabular     │
│ clinical studies on      │          │ impingement diagnoses    │
│ femoroacetabular         │          │ N = 151                  │
│ impingement  N = 108     │          │                          │
└─────────────────────────┘          └─────────────────────────┘
         │
         ▼
┌─────────────────────────┐          ┌─────────────────────────┐
│ Studies included for     │─────────▶│ Other reasons for study  │        INCLUSION
│ final analysis in review │          │ exclusion**              │
│ N = 29                   │          │ N = 79                   │
└─────────────────────────┘          └─────────────────────────┘
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Tegner activity score, SF-12 (PCS and MCS), and Merle d'Aubigne Postel score. No study utilized the HOOS, iHOT-33, or iHOT-12. Various radiographic variables were assessed: Tonnis radiographic arthritis grading, alpha angle, lateral and anterior CEA, crossover sign, posterior wall sign, ischial spine sign, and acetabular index.

Nonoperative vs operative treatment

Pre-treatment, patients undergoing nonoperative treatment had significantly higher NAHS than those undergoing arthroscopy ($P>0.001$; $Z=22.3$), mini-open ($P=0.001$; $Z=19.9$), and arthroscopic plus mini-open ($P>0.001$; $Z=8.5$) (Table 4). At final follow-up, the amount of improvement in NAHS was significantly less in those undergoing nonoperative treatment

vs arthroscopy ($P>0.001$; $Z=4.6$), mini-open ($P>0.001$; $Z=16.4$), and arthroscopic plus mini-open ($P>0.001$; $Z=5.8$) (Table 5).

Pre-treatment, patients undergoing nonoperative treatment had significantly higher mHHS than those undergoing arthroscopy ($P>0.001$; $Z=8.5$), mini-open ($P>0.001$; $Z=11.6$), surgical dislocation ($P=0.001$; $Z=3.3$), and arthroscopic plus mini-open ($P>0.001$; $Z=8.3$) (Table 4). At final follow-up, the amount of improvement in mHHS was significantly less in those undergoing nonoperative treatment vs arthroscopy ($P>0.001$; $Z=8.2$), mini-open ($P>0.001$; $Z=12.6$), and surgical dislocation ($P<0.001$; $Z=4.7$) (Table 5). There was no difference ($P=0.4$; $Z=0.8$) in mHHS improvement between nonoperative and arthroscopic plus mini-open treatment.

Table 2 Demographic variables of included studies, subjects, and hips

Parameter	Value (%)
Number of studies	29
Financial conflict of interest	
Private present	8
Public present	1 [a]
Absent	17
Not reported	4
Levels of evidence (number of studies)	3.76±0.64
I	1 (3.4%)
II	0 (0%)
III	4 (14%)
IV	24 (83%)
Number of centers (number of studies)	
Single-center	21 (72%)
Multi-center	8 (28%)
Country of publication (number of studies)	
United States of America	15
Switzerland	6
United Kingdom	3
Others	7 [b]
Mean modified Coleman Methodology Score	37.4±8.16
Number of subjects	2369
Males	1415 (60%)
Females	954 (40%)
Mean age	34.4±8.4 y
Mean body mass index	24.5±2.6 kg/m²
Mean duration of pre-operative symptoms	25.6±15.1 mo
Mean length of follow-up	3.09±0.88 y
Number of studies with independent observer at follow-up	6 (21%; 497 subjects, 21% of subjects)
Number of studies utilizing patient satisfaction questionnaire	7 (24%)
Number of hips	2507
Right	362 (58%)
Left	257 (42%) [c]
Surgical treatment	2470
Nonsurgical treatment	37

[a] One study reported both a private and public source of financial conflict of interest.

[b] Australia, New Zealand, South Korea, Mexico, France, Canada, Egypt.

[c] Right- vs left-sidedness reported in only 619 hips.

Range-of-motion measurement was performed in 6 studies (1 nonoperative, 5 operative). Following nonoperative treatment, flexion decreased 7° and internal rotation increased 0.6° at 2-years post-treatment. Flexion and internal rotation increased 10.3° and 11.8°, respectively (arthroscopy; 2 studies). Flexion and internal rotation increased 10° and 18.9°, respectively (mini-open; 1 study). Flexion and internal rotation increased 12° and 3°, respectively (surgical dislocation; 1 study). Flexion and internal rotation increased 15.9° and 5.2°, respectively (arthroscopy plus mini-open; 1 study).

Clinical outcomes of surgical treatment

Pre-operatively, patients undergoing arthroscopic plus mini-open surgery had significantly higher NAHS than those undergoing arthroscopy ($P=0.01$; $Z=2.6$), but not different from those undergoing mini-open ($P=0.3$; $Z=0.97$) (Table 4). At 2 years following surgery, patients undergoing mini-open and arthroscopic plus mini-open had significantly higher NAHS those undergoing arthroscopy ($P<0.001$; $Z=28.6$ and $P<0.001$; $Z=4.5$, respectively). However, there was no significant difference in NAHS at 2 years post-operatively between those undergoing mini-open and arthroscopic plus mini-open ($P=0.78$; $Z=0.28$). At final follow-up, the amount of improvement in NAHS was significantly greater in those undergoing mini-open treatment vs arthroscopy ($p<0.001$; $Z=27.3$) and arthroscopic plus mini-open ($P<0.001$; $Z=8.4$) (Table 5). In addition, the degree of improvement in NAHS was significantly greater in those undergoing arthroscopic plus mini-open vs arthroscopy ($P=0.003$; $Z=3.0$).

Prior to surgery, patients undergoing surgical dislocation had significantly higher mHHS than those undergoing arthroscopy ($P<0.001$; $Z=7.5$), mini-open ($P<0.001$; $Z=12.4$), and arthroscopic plus mini-open ($P<0.001$; $Z=7.2$) (Table 4). At 2 years following surgery, patients undergoing surgical dislocation had significantly higher mHHS than those undergoing arthroscopy ($P<0.001$; $Z=13.1$), mini-open ($P<0.001$; $Z=7.6$), and arthroscopic plus mini-open ($P<0.001$; $Z=6.6$). Similarly, patients undergoing mini-open had significantly higher mHHS than those undergoing arthroscopy ($P<0.001$; $Z=3.7$) and arthroscopic plus mini-open ($P<0.001$; $Z=4.1$). Patients undergoing arthroscopy had significantly greater mHHS than those undergoing arthroscopic plus mini-open ($P=0.006$; $Z=2.8$). At final follow-up, the amount of improvement in mHHS was significantly greater in those undergoing mini-open treatment vs arthroscopy ($P<0.001$; $Z=10.7$), surgical dislocation ($P<0.001$; $Z=11.1$), and arthroscopic plus mini-open ($P<0.001$; $Z=7.4$) (Table 5). Similarly, the amount of improvement in mHHS was significantly greater in those undergoing arthroscopy vs surgical dislocation ($P<0.001$; $Z=4.6$) and arthroscopic plus mini-open ($P<0.001$; $Z=4.7$). Patients undergoing surgical dislocation had significantly greater mHHS improvement than those undergoing arthroscopy plus mini-open ($P=0.01$; $Z=2.5$).

Labral repair vs labral debridement

Fourteen studies (1847 subjects) performed both labral repair and debridement in the investigation. However, 6 studies failed to compare the 2 groups. Thus, 8 studies (753 subjects)

Table 3 Comparison of all groups analyzed in this review

	Arthroscopic	Mini-open	Surgical dislocation	Arthroscopy + mini-open	Nonoperative treatment
Number of studies	12	2	11	3	1
Number of patients	1405	255	526	146	37
Number of hips	1448 [b]	274	597	151 [b]	37
Level of evidence	3.58±0.72	3.50±0.70	3.91±0.78	4±0.80	4
Age (y)	37.2±12.1	35.3 ±1.41	35.4±5.31	35.1±1.93	33±5
Length of clinical follow-up (years)	3.00±0.58	2.26±0.07	3.54±1.05	3.97±1.62	2.21±1.5
MCMS	40.8±9.54	35.5±3.54	34.5±7.55	35.7±4.16	39
Diagnosis					
Isolated cam FAI	915	69	200	45	28
Isolated pincer FAI	187	0	56	0	0
Mixed FAI	346	49	341	6	37
Labral injury	1388	nr [a]	498	139 [a]	nr
Procedures					
Femoral cam osteochondroplasty	1335	274	581	51	n/a
Acetabular pincer rim trimming	536	nr	221	nr	n/a
Labral debridement	1014	90	236	98	n/a
Labral repair / refixation	309	184	226	40	n/a
Ligamentum teres debridement	46	0	0	0	n/a
Iliopsoas release	23	0	0	0	n/a
Microfracture (acetabulum)	112	0	67	3	n/a

MCMS Modified Coleman Methodology Score, *n/a* not applicable.

[a] Number of patients/hips with FAI or labral injuries (*nr* not reported) in both studies.

[b] 44 % arthroscopies performed in supine position (711 hips), 56 % performed in lateral decubitus position (888 hips).

compared these 2 groups (Table 6). Four studies demonstrated significantly ($P<0.05$) better clinical outcomes (HOS ADL, HOS Sports, mHHS [2 separate studies], SF-12, VAS pain, patient satisfaction, and Merle d'Aubigne) at 2 to 3.5 years following labral repair vs debridement. However, 4 other studies demonstrated no difference ($P>0.05$) in clinical outcomes (mHHS [2 separate studies] and NAHS [2 separate studies]) at 2.2 to 4.9 years following labral repair or debridement.

Radiographic outcomes

Prior to commencing treatment, there were 1329 hips with a radiographic evaluation for osteoarthritis (Tonnis grade). Eighty-nine percent (1182 hips) were Tonnis grade 0 or 1; 11 % (143 hips) were Tonnis grade 2, and 0.3 % (4 hips) were Tonnis grade 3. Pre-operatively, the proportion of hips with Tonnis grade 0 or 1 was significantly greater in those undergoing arthroscopy plus mini-open vs mini-open ($P<0.001$; $Z=4.2$) and surgical dislocation ($P=0.006$; $Z=2.8$). Pre-operatively, the proportion of hips with Tonnis grade 0 or 1 was significantly greater in those undergoing arthroscopy vs mini-open ($P<0.001$; $Z=5.1$) and surgical dislocation ($P=0.005$; $Z=2.8$). There was no difference in Tonnis grading between arthroscopic plus mini-open and

arthroscopic treatments. There was insufficient post-operative data to determine any change in Tonnis grade following treatment.

Measurement and comparison of pre- and post-operative alpha angles were performed on AP, "oblique", cross-table lateral, false-profile lateral, Dunn lateral, and frog-leg lateral radiographs and also on MRI axial series parallel to femoral neck. Change in alpha angle on AP views was 18.1° and 22.8° on lateral views; and 23.9° on MRI with series parallel to the femoral neck. There was insufficient post-operative data to make valid comparison between different surgical techniques on change in alpha angle using similar imaging techniques.

Re-operations and complications

There were 361 overall re-operations (349 unplanned, 12 planned for removal of hardware) (14.4 % rate of reoperation; 361/2507 hips) (Table 7). One-hundred and ninety hardware removals were performed following surgical dislocation (178 were unplanned and performed for pain; 12 were planned). There were 78 total hip arthroplasty performed (3.1 % rate of conversion to total hip arthroplasty; 78/2507 hips). There were significantly more re-operations following surgical dislocation vs arthroscopy

Table 4 Weighted means at each stage of treatment

	Pre-treatment	1 y	2 y	3 y	4 y	5 y
Arthroscopy	NAHS (346): 56.9±2.7 HOS ADL (36): 64.2±5.7 HOS Sp (148): 52.4±18.8 mHHS (475): 63.4±4.6	HOS Sp (36): 82.5±8.8	NAHS (145): 82.6±3.7 HOS ADL (36): 86.1±7.3 HOS Sp (47): 91.4±14 mHHS (381): 87.1±5.7	HOS Sp (65): 82 mHHS (159): 90.2±0.99	NAHS (201): 78.2±15.8	*
Mini-open	NAHS (118): 58.9 mHHS (274): 60.3±3.3	*	NAHS (118): 91.4 mHHS (274): 88.7±5.2	*	*	*
Surgical dislocation	NAHS: n/a mHHS (111): 68.2±6.4	*	mHHS (111): 91.3±1.4	*	*	*
Arthroscopy+mini-open	NAHS (135): 60.1±14.4 mHHS (51): 63.8±0.0	*	NAHS (35): 90.9±10.7 mHHS (51): 83.9±8.0	*	*	NAHS (100): 83.9±16
Nonoperative treatment	NAHS (37): 72±4 mHHS (37): 72±6	NAHS (37): 91±5 mHHS (37): 92±4	NAHS (37): 91±5 mHHS (37): 91±4	*	*	*

($P<0.001$; $Z=22.6$), mini-open ($P<0.001$; $Z=9.3$), and arthroscopic plus mini-open ($P<0.001$; $Z=5.0$). There were significantly more re-operations following arthroscopic plus mini-open vs arthroscopy ($P<0.001$; $Z=9.1$) and mini-open ($P=0.007$; $Z=2.7$). There were significantly more re-operations following mini-open vs arthroscopy ($P<0.001$; $Z=5.3$). Other re-operations performed include: repeat arthroscopy for pain/diagnosis with lists of adhesions and debridement (39), repeat femoral osteochondroplasties (15 [11 after open surgical dislocation or mini-open, 4 after arthroscopy]), iliotibial band release (8), hip resurfacing (4), hematoma evacuation (4), incision and drainage for deep infection (2), open capsulectomy (1), suture granuloma excision (1), neuroma excision (1), and 18 reoperations not otherwise specified.

There were significantly more conversions to total hip arthroplasty after surgical dislocation vs arthroscopy ($P=0.007$; $Z=2.7$). There were significantly more conversions to total hip arthroplasty after arthroscopic plus mini-open vs arthroscopy ($P<0.001$; $Z=4.1$). There were significantly more conversions to total hip arthroplasty after mini-open vs arthroscopy ($P<0.001$; $Z=4.0$). All other comparisons within these groups regarding conversion to total hip arthroplasty were not significant ($P<0.05$).

Following surgery, complications were infrequent (Table 7). Temporary nerve palsy was most common after arthroscopic plus mini-open (4.6 %), followed by arthroscopy (1.7 %), and surgical dislocation and mini-open (less than 1 % for both). Heterotopic ossification was most common after surgical dislocation (15 %), followed by mini-open (13 %), arthroscopy plus mini-open (3.3 %), and arthroscopy (less than 1 %). Major complications such as femoral neck fracture (1 subtrochanteric fracture after mini-open; 1 neck

Table 5 Weighted means of amount of change from pre-treatment to final follow-up

	Amount of change from pre-treatment to final follow-up	Length of follow-up (y)
Arthroscopic	NAHS: 23.1±6.4	3.2
	HOS ADL: 21.9±6.4	2
	HOS Sp: 32.7±16.8	2.2
	mHHS: 25.5±5.4	2.3
Mini-open	NAHS: 32.5	2.2
	mHHS: 28.4±1.8	2
Surgical dislocation	NAHS: n/a	n/a
	mHHS: 23.1±4.9	2
Arthroscopy + mini-open	NAHS: 25.7±9.4	4.2
	mHHS: 20.1±8.0	2
Nonoperative treatment	NAHS: 19±4.5	2
	mHHS: 19±4.5	2

n/a not applicable

Table 6 Comparison of outcomes of labral refixation vs labral debridement

Study	Participants	Intervention	Follow-up (yrs)	Outcomes
Krych, et al. 2013	Females Pincer or mixed FAI	Arthroscopy	2.7	• Significant ($P<.05$) improvements in both groups (HOS ADL and HOS Sp) • Significantly better ($P<.05$) HOS ADL, HOS Sp, and satisfaction in repair group
Malviya, et al. 2012	Cam, pincer, mixed FAI	Arthroscopy	3.2	• No significant difference in mHHS (translated via Rosser Index Matrix to quality of life score) between labral repair and debridement groups
Philippon, et al. 2012	Cam, pincer, mixed FAI	Arthroscopy	3	• Significant ($P<.05$) improvements in HOS ADL, and mHHS • No difference ($P>.05$) in mHHS between labral repair and debridement
Larson, et al. 2012	Pincer, mixed FAI	Arthroscopy	3.5	• Significant ($P<.05$) improvements in both groups (mHHS, SF-12, VAS pain) • Significantly ($P>.05$) better mHHS, SF-12, and VAS in refixation group • 92 % good/excellent results in refixation group; 68 % good/excellent results in debride group
Schilders, et al. 2011	Cam, pincer, mixed FAI	Arthroscopy	2.4	• Significant ($P<.05$) improvements in both groups (mHHS) • Significantly ($P<.05$) better mHHS in refixation group
Chiron, et al. 2012	Cam, mixed FAI	Mini-open	2.2	• Significant ($P<.05$) improvements in both groups (NAHS) • No difference ($P>.05$) in NAHS between labral repair and debridement
Espinosa, et al. 2006	Mixed FAI	Surgical dislocation	2	• Significant ($P<.05$) improvements in both groups (Merle d'Aubigne Postel score) • Significantly ($P<.05$) better improvements in labral repair group at 1 and 2 yrs follow-up • Significantly ($P<.05$) greater radiographic osteoarthritis (Tonnis system) in debridement group (1 and 2 yrs)
Laude, et al. 2009	FAI	Arthroscopy plus mini-open	4.9	• Significant ($P<.05$) improvements in both groups (NAHS) • No difference ($P>.05$) in NAHS between labral refixation and debridement

ADL activities of daily living, *FAI* femoroacetabular impingement, *HOS* Hip Outcome Score, *mHHS* modified Harris Hip Score, *NAHS* nonarthritic hip score, *RCT* randomized controlled trial, *Sp* sports.

fracture after arthroscopic plus mini-open), hip dislocation (none), pulmonary embolus (1 after surgical dislocation), intra-abdominal or intra-thoracic fluid extravasation (none), and death (none) were rare.

Discussion

The purposes of this systematic review were to determine and compare outcomes following treatment of femoroacetabular impingement and hip labral tears. The authors hypothesized that surgical treatment was significantly better than nonoperative treatment. This hypothesis was confirmed (SORT Taxonomy grade B) (Table 8). The authors hypothesized that there was no difference in clinical outcomes between different surgical techniques for FAI. This hypothesis was not confirmed (SORT Taxonomy grade C): due to

heterogeneity across surgical groups, inconsistent outcome measures, and outcomes were observed. Nonetheless, all surgical treatments resulted in statistically significant and clinically relevant improvements in outcomes. The authors hypothesized that re-operations and complications would be higher following surgical dislocation and mini-open techniques vs arthroscopic techniques. This hypothesis was confirmed (SORT Taxonomy grade A). The authors hypothesized that labral refixation/repair would have significantly better outcomes than labral debridement. This hypothesis was confirmed (SORT Taxonomy grade B).

Measurement of outcomes of all fields in medicine is in a transition period from "physician/clinician-administered/-based" to "patient-reported/-based". These patient-reported outcomes are becoming integrated into physician and hospital reimbursement and rankings. Thus, evaluations of treatment outcome require meeting patients' expectations. Most frequently, the reason patients choose surgery is for

Table 7 Reoperations and complications following treatment

	Number of re-operations (% of total subjects)	Number of unplanned re-operations (% of total subjects)	Number of total hip arthroplasties (% of total subjects)	Temporary nerve palsy	Infection	Skin damage	Thromboembolic disease	Heterotopic ossification (Brooker grade)
Arthroscopic	43 (3.0 %)	43 (3.0 %)	23 (1.6 %)	10 LFCN 10 pudendal 2 partial sciatic 2 "foot paresthesias"	1 superficial	1 minor scrotum 1 minor labia	1 SVT	1: 4 2: 0 3: 1
Surgical dislocation	247 (41.4 %)	235 (39.4 %)	21 (3.5 %)	1 partial sciatic	1 superficial	0	1 SVT 1 DVT 1 nonfatal PE	1: 67 2: 19 3: 4 4: 1
Mini-open	27 (9.9 %)	27 (9.9 %)	15 (5.5 %)	1 LFCN	0	0	0	1: 24 2: 8 3: 4
Arthroscopic plus mini-open	29 (19.2 %)	29 (19.2 %)	10 (6.6 %)	6 LFCN 1 pudendal	1 superficial 2 deep	0	1 DVT	1: 4 2: 1 3: 0
Nonoperative	4 (10.8 %)	4 (10.8 %)	0 (0 %)	0	0	0	0	0

LFCN Lateral femoral cutaneous nerve.

If exclude removal of hardware from surgical dislocation group (190 cases), the number of unplanned reoperations in that cohort is 57 (9.6 %)

Table 8 Strength of recommendation definition: (A) Recommendation based on consistent and good-quality patient-oriented evidence. (B) Recommendation based on inconsistent or limited-quality patient-oriented evidence. (C) Recommendation based on consensus, usual practice, opinion, disease-oriented evidence, or case series for studies of diagnosis, treatment, prevention, or screening

Question	SORT Grade	Recommendation
Clinical outcome difference between nonoperative and operative treatment of FAI?	B	• Based on limited quantity, limited quality, consistent evidence, clinical outcomes are better following surgical treatment vs nonoperative treatment
Clinical outcome difference between 4 most common surgical techniques used in FAI?	C	• Based on good quantity, limited quality, inconsistent evidence, clinical outcomes demonstrated statistically significant, and clinically relevant improvements with all 4 surgical techniques, with no consistent differences exhibited between groups
Difference in reoperations and complications between 4 most common surgical techniques used in FAI?	A	• Based on good quantity, good quality, consistent evidence, reoperation rate, and complication rate was highest following surgical dislocation, and lowest with arthroscopy
Clinical outcomes difference after labral refixation vs debridement for patients with labral injuries in FAI?	B	• Based on good quantity, limited quality, inconsistent evidence, clinical outcomes are better following labral refixation vs labral debridement

alleviating pain (33 %), followed by fear of getting worse (20 %), improved ADL's (16 %), failed nonoperative treatments (11 %), improved sports (10 %), and others (10 %) [38]. Therefore, given the fact that many asymptomatic patients have abnormal radiographs [3], the clinician must exercise judiciousness in patient selection and "treat the patient, and not the x-ray". Further, over 50 % of patients are often overly optimistic with regard to hip pain, sport, and general physical capacity [38]. In addition, significant improvements in any outcome score ("feeling better") (even if met MCID [minimal clinically important difference]) does not necessarily equate to "feeling good" [39]. Thus, a patient-acceptable symptom state (PASS) may not be met. Nevertheless, the clinician must base his/her assessment of outcome on patient-based outcome tools that have appropriate psychometric properties.

There are over 40 different questionnaires utilized to measure outcomes of hip surgery [40]. For general musculoskeletal complaints of the lower limb, the AAOS Outcomes Questionnaires (American Academy of Orthopedic Surgeons) and MFA (Musculoskeletal Functional Assessment) are both patient-reported measures that evaluate the condition of the hip and/or knee musculoskeletal problems [40]. For hip osteoarthritis, the HOOS (derived from WOMAC [Western Ontario and McMaster Universities]) is a patient-reported measure that was designed to acknowledge and evaluate the higher activity levels of patients with osteoarthritis of the hip [40]. In patients with total hip arthroplasties, the Harris Hip Score is the best tool, although it is clinician-measured and reported [40]. In younger, more active, nonarthritic patients, several tools have been recently developed to improve validity, reliability and responsiveness.

The NAHS is frequently used in the evaluation of younger patients with minimal to no radiographic degenerative changes and a symptomatic hip [41]. Although validated

and reliable [41], its development was not ideal, as it arbitrarily chose the number of questions and derived several of them from the WOMAC, which was intended for older, less active patient cohorts. The HOS is, like the NAHS, a patient-reported measure designed to assess outcomes in active patients [42]. However, the HOS has an expanded age range (up to 66 years). It was originally created via evaluation of patients with hip labral tears [42]. It has 2 separate sub-scores: ADL's (activities of daily living) and Sports. It has demonstrated reliability, responsiveness, and construct validity [42–44]. The MCID for the HOS ADL and Sports scores were 9 and 6 points, respectively [43]. More recently, the iHOT (International Hip Outcome Tools) scores (iHOT-33 and iHOT-12) were developed and psychometric properties tested based on meeting of the MAHORN (Multicenter Arthroscopy of the Hip Outcomes Research Network) international group of experts [45•]. The iHOT-33 is a patient-reported health-related quality of life outcome questionnaire with demonstrated reliability, responsiveness, and validity [45•]. The iHOT-33 has an MCID of 6 points [45•]. A shorter version of the iHOT-33 was also recently developed, the iHOT-12, with retention of reliability, responsiveness, and validity [46]. The authors of iHOT scores recommend iHOT-12 for routine clinical practice and iHOT-33 for research. The current systematic review did not identify any study that utilized the iHOT-12 or iHOT-33 and only identified 4 studies (14 %) utilizing HOS, and 7 studies (24 %) utilizing NAHS. Otherwise, all other outcome tools' psychometric properties have not been evaluated in young, active patients with symptomatic FAI.

Limitations

Limitations within a systematic review are related to the studies within which it analyzes. Selection bias was

minimized in the review due to the inclusive nature of studies with levels of evidence I-IV. However, minimum 2-year follow-up may miss early differences in outcomes between analyzed groups. Performance bias was also minimal, due to the inclusion of all types of FAI, all patient demographics, all surgical techniques, and all surgical outcome tools. There was wide heterogeneity in patient demographics, surgical procedures, and outcome measures. This increases practical generalizability (increased external validity, with reduced internal validity). The heterogeneity and use of largely nonvalidated outcome measures and lack of inclusion and correlation with imaging findings introduces detection bias. Transfer bias was minimized with length of follow-up. However, given that the intent of hip preservation surgery is to slow or prevent incidence or progression to osteoarthritis, longer follow-up is certainly necessary. Study design bias is present in that over 80 % of the analyzed studies were level IV case series and only 1 analyzed investigation was a randomized controlled trial. This was further supported with the poor MCMS rating. Publication bias is present in that the authors excluded medical conference abstracts, non-English language studies, and nonpublished English language studies. Future research should continue to strive for higher levels of evidence, longer follow-up, and answer important questions. The authors recognize and support (Level V evidence) that the answers to these questions may already be known, however lack literature support at the current time to make this claim: (1) What is the difference in clinical outcomes of surgical treatment for (a) cam; (b) pincer; and (c) mixed FAI; (2) What is the difference in clinical outcomes of patients with FAI undergoing hip preservation surgery with femoral and acetabular osteochondroplasty vs without femoral and/or acetabular osteochondroplasty; (3) What is the difference in clinical outcomes of patients undergoing hip preservation surgery with complete capsular closure vs incomplete or nonclosure of the capsule; and (4) What is the role of surveillance in asymptomatic FAI.

Conclusions

Outcomes of operative treatment of femoroacetabular impingement are significantly better than nonsurgical management. Surgical treatment significantly improves outcomes, with no consistent significant differences exhibited between open and arthroscopic techniques. Open surgical dislocation has significantly greater reoperation and complication rates vs mini-open and arthroscopic techniques. Outcomes of labral refixation are significantly better than debridement in patients with labral injuries.

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