International Orthopaedics (SICOT) (2012) 36:903–914
DOI 10.1007/s00264-011-1443-z

REVIEW ARTICLE

Femoroacetabular impingement syndrome management: arthroscopy or open surgery?

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Received: 17 October 2011 / Accepted: 21 November 2011 / Published online: 22 December 2011

Abstract

Purpose This review explores the scientific evidence for clinical, functional and imaging outcomes after surgical management of Femoroacetabular Impingement (FAI) syndrome, and assesses the methodological quality of the published literature reporting this issue.

Methods The medical literature databases of Pubmed, Medline, Ovid, Google Scholar and Embase were searched for articles published in English, Spanish, French and Italian, using a combination of the keywords 'femoro-acetabular impingement syndrome', 'postoperative outcomes', 'open surgery', and 'arthroscopic management'. To address three main questions, we extracted data on demographic features, operative techniques, postoperative rehabilitation regimens, imaging features, pre and postoperative hip scores. Complications and conversion to arthroplasty were also investigated.

Results Thirty-one studies published have reported clinical, functional and imaging outcomes after open and arthroscopic management of FAI syndrome. The modified Coleman methodology score (CMS) averaged 56.2 (range, 30–81). From extracted data, it was shown that arthroscopy, open surgery and arthroscopic surgery followed by mini open surgery are comparable for functional results, biomechanics, and return to sport. Progression of OA and conversion to hip arthroplasty are dependent on preoperative status of cartilage and osteoarthritis and type of management. Debridement and osteoplasty provide better results than debridement only. Significantly improved outcomes have been recorded in patients undergoing labral refixation than resection. The Coleman methodology score showed great heterogeneity in terms of study design and outcome assessment, and generally low methodological quality.

Conclusion Although open and minimally invasive procedures allow athletes to return to professional sports activity, they are contraindicated in patients with severe osteoarthritis and cartilage degeneration.

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Introduction

Femoroacetabular impingement syndrome (FAI) is the first cause of pain and discomfort in young active non-dysplastic patients [1, 2]. Two types of impingement, pincer and cam, respectively arising from an abnormal morphology of the femur and acetabulum, alter the biomechanics of the hip, and result in limited and painful range of motion, mostly in flexion and internal rotation. A minority (14%) presents pure femoroacetabular impingement, and most patients (86%) have a combination of both forms, the so called “mixed pincer and cam impingement”. The spectrum of abnormalities of the femur and acetabulum have been widely described [1, 3], but the knowledge about the long-term effects of this pathology is still scanty, and available studies, with short follow-ups, partially clarify this concern. In the short term, these abnormal configurations may become painful and symptomatic, impair functional and athletic performance, and induce young athletes to change level and/or type of sport, or even to retire early from sport activity. As cartilage damage and early osteoarthrosis may be developed [1, 4], early diagnosis and treatment are needed. In pincer impingement, common in dysplastic patients [5], the chronic abnormal loading of the acetabular rim (pincer-effect) results in early labral injury and long-term degenerative changes [6, 7] whereas in cam impingement, more frequent in non-dysplastic hips, the long-term evolution arises from an abnormal contact of the femoral neck against the acetabular rim (cam-effect). At present, the best line of management is still controversial, and there is no consensus on the efficacy of treatment. Hip dislocation and open osteochondroplasty have been the standard in the past [1], but favourable outcomes and reduced postoperative complications are increasingly observed in patients undergoing less invasive arthroscopic procedures [8, 9]. These emergent techniques avoid the trauma typically related to open procedures, and spare the soft tissues, with a complication rate less than 1.5%. We reviewed systematically the relevant evidence published on clinical and functional effects of open, arthroscopic, and combined mini-open and arthroscopic procedures for management of FAI syndrome. We wish to address the question of whether surgical treatment for FAI improves symptoms and functional outcomes and what is the standard surgical procedure.

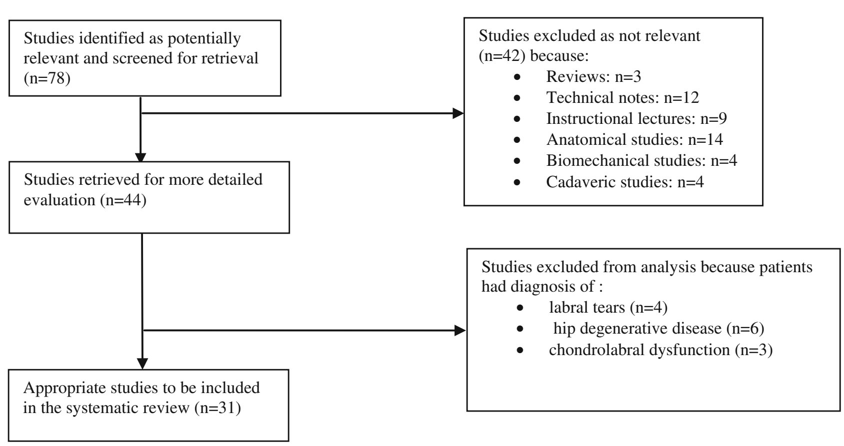
As many systematic reviews have been published on this issue in the last year, we assessed the methodological quality of these papers using a validated and reliable scoring system, the modified Coleman methodology score (CMS) [10–17].

Methods

Search and study selection

We searched for relevant studies published in Pubmed, Medline, Ovid, Google Scholar and Embase databases using the combined keywords ‘femoro-acetabular impingement syndrome’, ‘postoperative outcomes’, ‘open surgery’, and ‘arthroscopic management’, with no limit for year of publication. We included studies in English, Spanish, French and Italian, published in peer-reviewed journals, reporting data on clinical, functional and imaging outcomes of patients with femoroacetabular impingement syndrome who had undergone arthroscopic or open surgery. Biomechanical reports, studies on animals, cadavers, in vitro or animal studies, case reports, literature reviews, technical notes, letters to editors, and instructional courses were also excluded. Two authors (RP and ADB) independently assessed the abstract of each publication, selecting on the basis of its content, and excluding papers without abstract available. When the inclusion or exclusion were not possible from the abstract, we downloaded the full-text versions. The reference lists of the selected articles were fully reviewed by hand to identify articles not included at the first electronic search. Figure 1 summarises the significant steps of our search and explains the reasons for exclusion. Considering all the journals, we first identified the abstracts of 74 articles, but we downloaded the full text of 40, because they described the outcomes of patients who had undergone open and arthroscopic surgery. All the authors retrieved, reviewed, and discussed all the 40 articles, excluding 12 studies because they reported outcomes of patients without a defined diagnosis of FAI, and tested biomechanical and imaging methods of

Fig. 1 Schematics of inclusion and exclusion of studies



assessment. At the end of the study selection process, 31 relevant publications were included.

Quality assessment

Two investigators (RP and ADB) selected the studies, and separately evaluated the methodological quality of each article twice with the Coleman methodology score (CMS) [10]. The CMS is a ten-criteria scoring list with a final score from 0 to 100 (Table 1), which is a perfect score representing a study design that largely avoids the influence of chance, various biases, and confounding factors. The two investigators discussed scores where more than a two point difference was evident, until consensus was reached.

Data extraction

The data were extracted from each study included in our investigation, without contacting the author(s) to verify the accuracy of the extracted data and obtain further information. Extracted data, assessed by using different scales, allowed quantification of the postoperative good–excellent clinical results, the real entity of the improvement after surgery. Instrumental diagnostic methods (radiographs, MRI and CT) and classification radiographic systems were taken in account to report about imaging outcomes and, eventually, postoperative hip joint degenerative changes. We also extracted preoperative and postoperative alpha angle values to define whether impingement deformities had been biomechanically corrected.

Merle D'Aubignè hip scores [3, 18] ranging from 15 to 18 points and Harris hip rates higher than 80 points [19] were considered as good or excellent outcomes. Furthermore, rates of complications and conversion to arthroplasty were helpful to investigate safety, effectiveness, and reliability of both open and arthroscopic procedures. The intra-class correlation coefficient was calculated to quantify the agreement between the Coleman scores of the two independent assessors. Spearman correlation was used to assess correlation between the year of publication and the Coleman score. Correlation was calculated between Coleman score and good–excellent reported rates. Analysis was performed using SPSS software (version 16.0, Chicago, Illinois).

Results

Since 2004, 31 relevant studies have reported on clinical and imaging outcomes after open and arthroscopic hip surgery for femoroacetabular impingement. The total number of patients included in the various studies was 1713, with 1141 (67%) males and 562 (33%) females, and the numbers varied from five [20] to 200 [21]. Patients were operated upon at an average age ranging from 19.7 [22] to 47.3 years [23], after an average period from one month [24] to ten years [25] from the onset of symptoms. Based on extracted data, "cam type" impingement was found in 901 hips (57.9%), "pincer type" in 74 (4.8%), and "combined cam pincer" in 580 (37.3%). In total, 1230 patients underwent arthroscopy, 229 underwent open surgery, and 254 received arthroscopy followed by the open anterior approach.

Preoperative assessment

Standardised conventional antero-posterior pelvic and lateral cross-table radiographs supported the first clinical suspicion of FAI disease in almost all studies. In the scenario of FAI syndrome, if magnetic resonance with gadolinium arthrography is the standard to assess type of impingement, status and extent of labral and cartilage lesions [18–20, 26–33], theedimensional computed tomography reconstruction is used to map the bony architecture of suspected areas [19, 21, 25, 27,

Table 1 Coleman methodology scores and criteria

Section score (maximum score)	Mean	Standard deviation	Range	Median
Part A				
Study size (10)	5.5	3.8	0–10	4
Mean duration of follow-up (10)	3.5	1.8	0-5	5
No. of surgical procedures (10)	7.0	3.7	0–10	10
Type of study (15)	0.4	2.0	0–10	0
Diagnostic certainty (5)	4.4	1.0	2–5	5
Description of surgical procedure (5)	4.1	1.5	0–5	5
Description of postoperative rehabilitation (10)	5.1	3.6	0–10	6.5
Part B				
Outcome measures (10)	7.5	1.7	3–10	7
Outcome assessment (15)	8.8	1.5	5–12	9
Selection process (15)	9.8	2.4	4–15	10
Total score (100)	56.04	8.2	46–81	56

29, 31, 34]. Ten [18, 20, 29, 35–37] studies reported on open surgical decompression, 18 studies [9, 19, 21, 23–28, 30, 34, 38–41] on arthroscopy, and three on arthroscopy followed by open anterior femoral osteoplasty [31–33]. Debridement and microfractures of cartilage lesions were made in 14 studies [9, 19, 23, 24, 27–30, 35, 38, 41, 42], a large femoral neck cyst was excised in one patient [26], and interthrocanteric and periacetabular osteotomy were carried out in seven patients [43]. The description of the postoperative rehabilitation program scored 6 points or more in 19 studies (59.3%) and 0 in four studies. Twenty-one of the 27 selected (78%) studies reported a satisfactory description of subject selection criteria and 25 (93%) used validated scoring systems with good reliability and sensitivity. The "outcome assessment" section scored adequately in 20 articles (64.5%). Seventeen studies [9, 19, 21, 24, 26, 32–34, 36–40, 42] used the modified Harris hip score, four studies the Merle d'Aubignè scale [3, 18, 25, 43], and five studies the WOMAC Index score [25, 27, 29, 30, 41]. The non arthritic hip score (NAHS) was used in four studies [9, 23, 28, 33], the hip outcome score was administered in two studies [22, 44], while VAS rating [26] and combined VAS and SF-12 criteria [19] were used in one study each. The average Coleman methodology scores for each item are given in Table 1, whereas the CMS of each article is listed in Table 2. Finally, five studies [20, 24, 35] rated outcomes in terms of return to sport activity and return to preoperative range of

Table 2 Sample data

Study	Date of publication	Sample size	Sample mean age (years)	Sex ratio (M:F)	Mean follow-up (months)	Management	Coleman score (CMS)
Bardakos et al. [39]	2008	71	34.3	1.09	NA	Arthroscopy	56
Beaulé et al. [29]	2007	34	40.5	1.1	37.2	Open surgery	60
Beck et al. [3]	2004	19	36	2.8	56.4	Open surgery	61
Bedi et al. [5]	2011	10	25.9	NA	10.9	Arthroscopy	30
Bizzini et al. [20]	2007	5	21.4	5	32.4	Open surgery	55
Byrd and Jones [21]	2009	200	33.4	2.2	16	Arthroscopy	64
Byrd and Jones [40]	2009	26	46	1	120	Arthroscopy	49
Clohisy et al. [48]	2010	35	34	4	26.4	Arthroscopy and open anterior approach	53
Espinosa et al. [18]	2006	52	30	1.7	96	Open surgery	48
Gedouin et al. [25]	2010	110	31	2.4	10	Arthroscopy	53
Gedouin et al. [41]	2010	38	36	6.6	15.6	Arthroscopy	59
Hartmann and Gunther [26]	2009	33	31	1.06	15	Arthroscopy	60
Haviv et al. [9]	2010	166	37	3.9	22	Arthroscopy	73
Haviv and O'Donnell [45]	2010	82	29	4.5	26	Arthroscopy	67
Horisberg et al. [28]	2010	88	40.9	2.1	27.6	Arthroscopy	72
Horisberg et al. [23]	2010	20	47.3	4.0	36	Arthroscopy	49
Ilizaliturri et al. [27]	2007	13	30.6	1.2	30	Arthroscopy	43
Ilizaliturri et al. [30]	2008	19	34	1.4	NA	Arthroscopy	52
Larson and Giveans [19]	2008	96	34.7	1.3	9.9	Arthroscopy	59
Larson and Giveans [34]	2009	71	28.9	2.1	18.8	Arthroscopy	57
Laude et al. [31]	2009	91	33.4	1.1	58.3	Arthroscopy and open anterior approach	64
Lincoln et al. [32]	2009	14	37	2.5	24	Arthroscopy and open anterior approach	55
Murphy et al. [43]	2004	23	35.4	1.3	62.4	Open surgery	53
Naal et al. [22]	2011	22	19.7	22	45.1	Open surgery	57
Nho et al. [44]	2011	47	22.8	2.6	27	Arthroscopy	71
Peters and Erickson [42]	2006	29	NA	1.2	96	Open surgery	56
Peters et al. [37]	2010	94	28	1.4	26	Open surgery	59
Philippon et al. [35]	2007	45	31	14	19.2	Open surgery	46
Philippon et al. [38]	2009	112	40.6	1.24	27.6	Arthroscopy	81
Philippon et al. [24]	2010	28	27	28	24	Arthroscopy	56
Yun et al. [36]	2009	14	35.8	6	27.6	Open surgery	49

movement (internal and external rotation) (Table 3). The average modified Coleman methodology score was 56.2 (range from 30 [5] to 81.0 [28, 38]). The inter-class correlation coefficient of 0.73 showed a high correlation between the Coleman methodology scores awarded to each scientific article by each independent marker.

The CMSs show no evidence of a statistically significant association with the publication year ($r=0.3$; $p=0.23$), demonstrating that more recent scientific articles did not score better than older studies.

Clinical outcomes

Methods of assessment and relative values have been reported in detail in Table 4. One hundred forty-two of 181 (78.5%) arthroscopically managed patients [19, 34, 39] and 135 of 169 patients (80%) [3, 18, 20, 33, 35] undergoing open surgical dislocation and hip decompression reported good or excellent results. As reported in Table 5, in all studies postoperative scores were significantly improved compared to preoperative scores, regardless of the procedure performed. Mean improvement in modified HHS score after surgery was 24 for arthroscopy, 19.7 for open surgical dislocation, and 19.1 for the combined approach. With regard to arthroscopy, combined debridement and osteoplasty provide better, though not significant, outcomes than debridement only [39]. When performing arthroscopic femoral osteoplasty for treatment of cam FAI, additional microfracturing for grades III/IV cartilage lesions does not change outcomes [21]. A recent study on patients undergoing bilateral arthroscopy for bilateral cam type impingement has shown that there is no significant difference in outcomes between patients with bilateral and unilateral hip pain at presentation, with higher improvement after their second operation than the first [45].

With regard to management of labral tears, labral re-fixation provides significantly higher scores than debridement alone ($p<.0.01$), with higher success rates (94%) after open acetabular trimming and femoral osteochondroplasty [18] than arthroscopic procedure [34] (89.7%). While debridement alone improves pain score two years after surgery, labral repair relieves symptoms at one year. In arthroscopy, labral repair provides higher modified Harris hip scores than labral debridement alone, with no significant difference (87 vs 81, $p=0.10$) [38] (Table 4). From a multivariable analysis, preoperative score, joint space narrowing≥2 mm, and labral repair rather than debridement are predictors of higher postoperative scores [38].

Range of motion and biomechanics

Arthroscopy significantly improves hip flexion, from 111.2° at baseline to 119.9° postoperatively, and internal rotation at 90° of hip flexion, from 11.5° to 23.9°. After arthroscopy and open surgery, hip flexion improved from 94.1° to 110° and internal rotation from 7.1° to 12.3°. Concerning open approach we did not find any data.

Biomechanically, alpha angle decreased from a mean of 72.9 to a mean of 48.8 after arthroscopy, from an average value of 69.3 to an average value of 43.4 after open surgical decompression, and from a mean of 64.5 to 43.3 for patients who had undergone arthroscopy followed by a mini open anterior approach. Biomechanically, by comparing these procedures, we found no significant differences.

Return to sport activity

Among five ice hockey players undergoing open surgical decompression for FAI syndrome, three athletes were fully reintegrated in the team and two played for farm teams [20]. In another study including 45 patients managed by open surgical decompression, of 42 (93%) athletes who had returned to professional sport activity, 35 (78%) were still active at a professional level at an average 1.6-year follow-up. Of five patients requiring a further operation, three benefitted from arthrolysis of the adhesions and returned to professional play, whereas two retired because of signs and symptoms of osteoarthritis [35]. At a mean of 45.1 months from open dislocation for combined impingement, 21 of 22 patients (95.5%) still competed professionally, one gave up his career and participated in recreational sports only. Nineteen of these 21 patients (90.5%) maintained their pre-symptomatic level, and two were active in minor leagues but still played professionally. Nineteen patients (86.4%) were satisfied with their sports ability. Thirteen patients (59.1%) had improved their sports ability; six (27.2%) indicated no change; and three (13.6%) experienced a deterioration [22]. Philippon et al. [24] reported on return to sports activity after arthroscopy in 28 professional hockey players, all of them returned to skating/hockey drills at an average period of 3.8 months (range, one to five) from the operation, playing an average number of 94 NHL games (range, 3–252). Two players required another hip arthroscopy after a new injury. The time to return to play was not associated with age ($p=0.4$), preoperative ($p=0.1$) and postoperative scores ($p=0.2$), or time from injury to surgery ($p=0.8$). Age was negatively related to the number of games played ($r=-0.48$; $p=0.009$), whereas time from injury to surgery influenced significantly the time to return to play, i.e. players who received surgery within one year from the time of injury returned to sport earlier than patients who waited more than one year. Indeed, time from injury to surgery had no relationship with pre- or postoperative Harris hip scores. As shown by Nho et al., 79% of patients returned to play at a mean of 9.4 months (range, four to 26 months) from arthroscopy. Almost all these patients achieved the same level of competition and were still active at two years [44].

Table 3 Success rate

Author	Rate of success	Conversion to hip arthroplasty	Factors predisposing to hip arthroplasty
Bardakos et al. [39]	59% in control group vs 83% in study group according to Harris hip score	–	
Beaulé et al. [29]	NA	–	
Beck et al. [3]	54.2% had excellent good scores according to Merle d'Aubignè hip score	5 patients (26.3%) open	Preoperative osteoarthritis, 1 with untreated ossified labrum
Bedi et al. [5]		–	
Bizzini et al. [20]	60%	–	
Byrd and Jones [21]	NA	1 patient (0.5%) arthroscopy	Extensive grade IV acetabular and femoral cartilage lesions
Byrd and Jones [40]	NA	8 patients (30.8%) arthroscopy	Preoperative osteoarthritis
Clohisy et al. [33]	71% had excellent good scores according to Harris hip score	–	
Espinosa et al. [18]	85% according to Merle d'Aubignè hip	–	
Gedouin et al. [25]	77% overall satisfaction rate	5 (4.5%) arthroscopy	Preoperative osteoarthritis
Gedouin et al. [41]	79% overall satisfaction rate	–	
Hartmann and Gunther [26]	78.8%	–	
Haviv et al. [9]	NA	–	
Haviv and O'Donnell [45]		–	
Horisberg et al. [28]	NA	9 hips (9%) arthroscopy	Five with preoperative Tonnis grade II and four with Tonnis grade I; grade 3 osteochondral lesion in four hips and five with grade 2. No difference in terms of alpha values
Horisberg et al. [23]	NA	8 hips (40%) arthroscopy	Tonnis grades I-II osteoarthritis and marked advanced cartilage deterioration
Ilizaliturri et al. [27]	NA		
Ilizaliturri et al. [30]	NA	1 patient (5.3%) arthroscopy	Advanced osteoarthritis
Larson and Giveans [19]	74.5%		
Larson and Giveans [34]	66.7% in debridement group vs 89.7% in refixed group according to Harris hip score	1 patient (1.4%) arthroscopy	
Laude et al. [31]	NA	9 patients (9.9%) arthroscopy and open anterior approach	Deep acetabular lesions (10.9 mm), Beck grade 5 cartilage lesion and older age (40.3 years)
Lincoln et al. [32]	NA	1 patient (7.1%) arthroscopy and open anterior approach	Tonnis grade II and a large (> 2 cm) chondral flap
Murphy et al. [43]	NA	–	
Naal et al. [22]	86.4%	–	
Nho et al. [44]	NA	–	
Peters and Erickson [42]	NA	3 patients (10.3%) open surgery	Progressive arthrosis; Outerbridge grade IV cartilage lesion of the acetabulum
Peters et al. [37]	NA	5 patients (5.3%) open surgery	Four with severe acetabular articular cartilage delamination (Outerbridge Grade IV) and one with slipped capital femoral epiphysis
Philippon et al. [35]	93% returned to sport activity	–	
Philippon et al. [38]	NA	10 patients (8.9%)	Older age at the time of arthroscopy (58 vs 39 years, p=0.001), significantly less joint space on all three weightbearing surfaces on their preoperative radiographs (p=0.001), significantly lower mean

Table 3 (continued)

Author	Rate of success	Conversion to hip arthroplasty	Factors predisposing to hip arthroplasty
			preoperative modified HHS (47 vs 60, $p=0.026$). Cartilage changes. Patients with microfracture on both the femoral head and the acetabulum were also more likely to undergo a THR ($p=0.001$)
Philippon et al. [24]	100% returned to sport activity	–	
Yun et al. [36]	NA	–	

Radiographic classification, hip osteoarthritis and conversion to total hip arthroplasty

Radiographic features of degenerative joint disease changes were classified according to the Tonnis grading system [46] in 18/31 (58.1%) studies [3, 18, 19, 23, 25, 28, 31–35, 41–43], to the Kellgren Lawrence classification [47] in one study [26] and non specifically in two studies [30, 40]. On the other hand, articular cartilages have been assessed intra-operatively in 19 studies, according to the Outerbridge and Beck classifications. From extracted data, progression of OA and conversion to hip arthroplasty depend on preoperative status of cartilage and osteoarthritis, and type of management. Although microfractures for high grade cartilage lesions relieve symptoms and improve hip function in the short term [3], these patients may deteriorate over time, with clinical and imaging progression of OA, or even the need for hip arthroplasty [42]. The progressive development of arthritis, often symptomatic, may result in significantly worse outcomes than those observed in patients with an history of trauma, in the absence of arthritic changes [40]. However, surgery improves baseline symptoms [41].

As reported by Horisberg et al. [23], patients with preoperative severe degenerative changes (higher Tönnis grades), regardless of cartilage grade degeneration, are more likely to worsening in hip scores, pain and range of motion, and to undergo total hip arthroplasty ($p=0.03$). Labral resection and labral repair result in significant radiographic differences. After resection, the average Tonnis grade changed from 0.6 at baseline to 1.2 at one year, and 1.3 at two years. On the other hand, once the labrum had been reattached, Tonnis grade did not change at one year (0.5) and increased to 0.8 after two years [18].

Late complications

As reported in Table 6, heterotopic ossification is the most frequent complication [19, 21, 29, 31, 34, 48]. Many patients underwent a new arthroscopy in the index hip for persistent symptoms, further debridement, lysis of adhesions, management of mechanical symptoms, inadequate decompression, and advanced osteoarthritis [21]. A few patients had neurapraxia of the sciatic, pudendal, and lateral femoral cutaneous nerves [19, 21, 34, 40]. All these patients recovered within a few months.

After arthroscopic management, some patients had traction related complications, such as nerve numbness, nerve palsies, dysesthesia, and transient anesthesia. All resolved within a few months.

Discussion

Over the years, increasingly sophisticated imaging techniques have allowed better definition of FAI syndrome, which was otherwise unknown until a few decades ago. In the literature, the pathological, anatomical, imaging and surgical aspects of pincer and cam types have been widely investigated [49], but knowledge about the long-term evolution of this disease is scanty. The trend to prefer conservative measures, reserving surgery to symptomatic patients [50, 51], pushes us to clarify the best management and the role of surgery in management of FAI syndrome. Surgery not only relieves symptoms and encourages the return to sport activity, but also improves prognosis of concomitant and pre-existing degenerative joint disease [20, 35]. Pooling the data from several studies [9, 35, 52–54], open labral debridement and osteoplasty have been recognised as successful procedures, with highly satisfactory and favourable Harris hip and Merle d'Aubignè scores [3, 18, 29, 42, 43], whereas arthroscopy is less traumatic for soft tissues and more encouraging in terms of rapid recovery and return to sport activity [35, 55], allowing 93% of patients to return to their pre-injury sport and 78% to remain active at the last follow-up [35]. Arthroscopy is more technically demanding, and anterolateral and anterior portals are close to the femoral neurovascular bundle [56]. In a recent study on 37 subjects undergoing revision arthroscopy for persistence of groin pain, findings of FAI were still evident at imaging and surgery, probably because they were not or were inadequately addressed at the index surgery [8]. This demonstrates that checking the head sphericity after osteochondroplasty may be problematic [31], especially in the early stages of the

Table 4 Preoperative and postoperative outcome scores

Author	Surgery	Score	Preoperative	Postoperative	*p* value
Bardakos et al. [39]	Arthroscopy	Modified Harris hip score	Control group 55 (37–72) Study group 59 (52–64)	Control group 77 (59–87) Study group 83 (75–87)	0.11 (NS, intergroup difference)
Beaulé et al. [29]	Open surgery	WOMAC score	61.2 ±20	81.4±16	< 0.001
Beck et al. [3]	Open surgery	Merle d'Aubignè score	14.1	16.5	0.015
Bedi et al. [5]	Arthroscopy	Modified Harris hip score	65.9	89.1	
Bizzini et al. [20]	Open surgery	NA			
Byrd and Jones [21]	Arthroscopy	Modified Harris hip score			
Byrd and Jones [40]	Arthroscopy	Modified Harris hip score	52	81	< 0.001
Clohisy et al. [48]	Arthroscopy and Open anterior	Modified Harris hip score	63.8 (35–85)	87.9 (54–100)	<0.0001
Espinosa et al. [18]	Open surgery	Merle d'Aubignè score	Gr 1: 12 (8–13)	Gr 1: 15 (10–18)	0.0009
			Gr 2: 12 (5–16)	Gr 2: 17 (13–18)	<0.0001
					0.01: Intergroup difference
Gedouin et al. [25]	Arthroscopy	WOMAC score	60.3 (32–96)	83 (37–100)	< 0.001
Gedouin et al. [41]	Arthroscopy	Merle d'Aubignè score	14.6 (11–18)	17.2 (12–18)	< 0.001
Hartmann and Gunther [26]	Arthroscopy	Modified Harris hip score	63.9 (31–83)	85.1 (64–100)	< 0.001
Haviv et al. [9]	Arthroscopy	Modified Harris hip score	70.7 (26–100)	86.1 (36–100)	< 0.001
Haviv and O'Donnell [45]	Arthroscopy	Modified Harris hip score	Gr 1: 77	Gr 1: 94	
			Gr 2: 67	Gr 2: 93	
Horisberg et al. [28]	Arthroscopy	Non Arthritic hip score (NAHS)	56.8 (15–92.5)	84.6. (47.5–100)	< 0.001
Horisberg et al. [23]	Arthroscopy	Non Arthritic hip score (NAHS)	47.15 (23.75–66.25)	78.3 (63.75–95.0)	0.004
Ilizaliturri et al. [27]	Arthroscopy	WOMAC score	77.7 (74–82)	87.4 (80–94)	0.0001
Ilizaliturri et al. [30]	Arthroscopy	WOMAC score	NA	NA	
Larson and Giveans [19]	Arthroscopy	Modified Harris hip score	60.8	82.7	< 0.001
Larson and Giveans [34]	Arthroscopy	Modified Harris hip score	NA	NA	< 0.01 intergroup difference
Laude et al. [31]	Arthroscopy and Open anterior approach	Non arthritic hip score (NAHS)	54.8±12	83.9±16	<0.000001 no difference (p=0.13) at the last follow-up between patients with refixation (86±11) and without refixation (82±19)
Lincoln et al. [32]	Arthroscopy and Open anterior approach	Modified Harris hip score	63.8±5.1	76.1±4.8	0.01
Murphy et al. [43]	Open surgery	Merle d'Aubignè score	13.2 (11–15)	16.9 (13–18)	< 0.001
Naal et al. [22]	Open surgery	Hip outcome score		94.5 (activity of daily living subscale) 89.1 (sport subscale)	
Nho et al. [44]	Arthroscopy	Modified Harris hip score	68.6	88.5	0.002
Peters and Erickson [42]	Open surgery	Modified Harris hip score	70	87	< 0.0001
Peters et al. [37]	Open surgery	Modified Harris hip score	67 (43–87)	91 (48–100)	< 0.0001
Philippon et al. [35]	Open surgery	NA	NA	NA	NA
Philippon et al. [38]	Arthroscopy	Modified Harris hip score	58	84.3	
Philippon et al. [24]	Arthroscopy	Modified Harris hip score	70 (57–100)	95 (74–100)	0.001
Yun et al. [36]	Open surgery	Modified Harris hip score	76 (72–81)	93 (87–98)	NA

NA not available

Table 5 Type of management and outcome improvement

Variable	Arthroscopy	Open surgery	Combined arthroscopy and mini open approach
mHHS			
Articles	10	4	3
Mean preoperative score	64.1	71	63,9
Mean postoperative score	88.1	90.7	83
Mean improvement	24	19.7	19,1
WOMAC			
Articles	4	1	–
Mean preoperative score	68.75	61.2	–
Mean postoperative score	83.6	81.4	–
Mean improvement	14.85	20.2	–
Merle D'Abignè Score			
Articles	1	2	
Mean preoperative score	14.6	12.6	
Mean postoperative score	17.2	16.5	
Mean improvement	2.6	2.9	
NAHS			
Articles	2	–	1
Preop	52		75.1
Postoperative score (mean)	81.5		90.2
Mean improvement	29.5		15.1

learning curve, when some arthroscopic osteochondroplasty procedures may be incomplete. Therefore, at the beginning of this practice, fluoroscopic control and specially-designed spherometer gauges can be helpful to improve femoral assessment and favour an adequate osteochondroplasty. In cam type impingement, a combined arthroscopic and modified open approach could improve the quality of the osteoplasty of femoral head and neck [33].

In pincer impingement, debridement only is appropriate to manage degenerative changes in the over-coverage region of the labrum [32], but an additional labral refixation, when indicated, provides earlier recovery and superior clinical and radiographic outcomes compared to labral excision [18, 19, 31, 39]. Open acetabular trimming and femoral osteochondroplasty [18] seem to provide success rates higher than those observed after arthroscopic procedures [34], but we could not compare the data given the heterogeneity of the scores. However, as evident from the extracted data, arthroscopy, open surgery and arthroscopic followed by mini open surgery are comparable for functional results (Table 5), biomechanics, and return to sport [56]. According to available data, we can not state if surgery modifies the evolution of osteoarthritis in young patients and contributes to prevent the development of OA. Few methods have been used to assess pre-existing osteoarthritis and cartilage status, allowing determination of homogeneity in study findings. Postoperative failure and subsequent conversion to total hip arthroplasty are influenced by preoperative clinical and imaging findings [56]. Open dislocation and debridement show a higher rate of conversion to total hip arthroplasty, particularly in patients with pre-existing severe osteoarthritis and cartilage lesions [3, 23, 37, 43]. Concomitant cartilage lesions and degenerative changes result in lower clinical and functional scores [9], short-term pain relief, no evidence of long-term satisfactory outcomes, higher failure rate, and even conversion to total hip arthroplasty [23]. However, almost all information on cartilage status have been extracted from studies in which arthroscopy was performed. Young patients are the best candidates. Though providing high return to professional sport activity level [24, 35], there is no evidence to propose a surgical procedure to patients with concomitant advanced osteoarthrosis and cartilage deterioration [23].

Conclusions and perspectives for the future

Most studies of level III-IV of evidence include small numbers of participants and, importantly, have limited long-term follow-ups. Therefore, randomised trials should be the next logical step for research in this field. We are unable to draw any definitive conclusions about which management is most effective because the long-term consequences of residual bony impingement and secondary degeneration usually appear at mid- and long-term assessments. From the published studies, it appears that these three procedures are grossly equivalent, but more data focusing on preoperative cartilage status and type of impingement are essential. Given the

Table 6 Postoperative complications

Author	Surgery	Postoperative complication
Bardakos et al. [39]	Arthroscopy	–
Beaulé et al. [29]	Open surgery	One patient had failed trochanteric fixation; 1 patient had Brooker grade IV heterotopic ossification; 9 hips persistent bursitis; 6 patients had unsatisfactory outcomes cartilage damage
Beck et al. [3]	Open surgery	
Bedi et al. [5]	Arthroscopy	
Bizzini et al. [20]	Open surgery	
Byrd and Jones [21]	Arthroscopy	Three patients underwent new arthroscopy for mechanical symptoms; 1 neuroapraxia of pudendal nerve; 1 partial neuroapraxia of lateral femoral cutaneous; 1 heterotopic ossification
Byrd and Jones [40]	Arthroscopy	–
Clohisy et al. [48]	Arthroscopy and open anterior	One superficial infection; 1 deep vein thrombosis (in the popliteal vein proximal to the calf); asymptomatic Brooker grade-I heterotopic ossification in 4 hips
Espinosa et al. [18]	Open surgery	–
Gedouin et al. [25]	Arthroscopy	Three patients developed ectopic ossification; 1 patient showed femoral neurapraxia; 1 pudendal neurapraxia and 1 labium majus skin necrosis; 1 patient had a non-displaced stress fracture of the femoral head/neck junction
Gedouin et al. [41]	Arthroscopy	–
Hartmann and Gunther [26]	Arthroscopy	–
Haviv et al. [9]	Arthroscopy	Ten patients underwent re-operation because of persistent symptoms
Haviv and O'Donnell [45]	Arthroscopy	Eight patients underwent reoperation because of persistent symptoms at a mean interval of 33.8 months from the second operation. Of these, 6 were on the first operated side and 2 on the second (contralateral) side
Horisberg et al. [28]	Arthroscopy	12 hips (11%): Dysesthesia/hypesthesia of pudendal and lateral cutaneous femoral nerves in 9, sciatic nerve neurapraxia with hypesthesia of the instep region in 2, a superficial tear of labia minora
Horisberg et al. [23]	Arthroscopy	Two cases (10%) of temporal hypesthesia in the area of nervus cutaneus femoris lateralis
Ilizaliturri et al. [27]	Arthroscopy	–
Ilizaliturri et al. [30]	Arthroscopy	–
Larson and Giveans [19]	Arthroscopy	One partial sciatic nerve neurapraxia; 6 hips (6%) had heterotopic bone formation
Larson and Giveans [34]	Arthroscopy	Four hips (11.1%) in gr 1, and 3 hips (7.7%) in gr 2; 3 patients heterotopic ossification in gr 1 and 0 in gr 2; 2 revision femoral osteochondroplasty for inadequate initial decompression in gr 1; 1 failure of labral anchor suture in 1 patient in gr 2
Laude et al. [31]	Arthroscopy and open anterior approach	One femoral neck fracture; 2 deep infection treated with surgical debridement and antibiotics; 1 revision for heterotopic ossification
Lincoln et al. [32]	Arthroscopy and open anterior approach	One had transient anesthesia in the perineum (hip distraction), 6 had transient anesthesia in the proximal lateral area of innervation of the lateral femoral cutaneous nerve
Murphy et al. [43]	Open surgery	Three early failures: 1 had circumferential osteophyte formation, 2 untreated acetabular dysplasia
Naal et al. [22]	Open surgery	–
Nho et al. [44]	Arthroscopy	–
Peters and Erickson [42]	Open surgery	Four hips (13%) were considered as failure because of pain and or progressive arthrosis
Peters et al. [37]	Open surgery	Two complications related to fixation of the greater trochanter: one early failure of fixation due to failure to acquire cortical screw purchase distally in a female patient and one nonunion in a male patient
Philippon et al. [35]	Open surgery	Five patients required reoperation: 3 underwent lysis of adhesions and 2 had symptomatic treatment of extensive OA
Philippon et al. [38]	Arthroscopy	–
Philippon et al. [24]	Arthroscopy	–
Yun et al. [36]	Open surgery	Three cases of nonunion of the trochanteric osteotomy site, which were treated with internal fixation using a trochanteric plate

present state of the art on this particular issue, we cannot draw any definitive evidence-based conclusions on the best surgery for management of FAI. Apart from assessing preoperative status of cartilage and grading of osteoarthritis, age at surgery, duration of symptoms before surgery, sex, type of sport and daily activities, and preoperative alpha angle measures could be investigated as predictive factors for good functional outcomes or predisposing to development or deterioration of osteoarthritis.

Conflicts of interest All the authors disclose no conflicts of interest. No benefit in any form has been received or will be received from a commercial party related directly or indirectly to the subject of this paper.

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