EDITOR'S CHOICE

Hip arthroscopy for intra-articular pathology: a systematic review of outcomes with and without femoral osteoplasty

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ABSTRACT

Background Arthroscopy is increasingly used to improve pain and function in athletes with hip joint pathology. Surgical techniques have evolved to utilise arthroscopic femoral osteoplasty to address potential morphological contributors to pathology.

Purpose Investigate pain and function outcomes following hip arthroscopy with and without femoral osteoplasty in individuals with intra-articular hip pathology.

Study design Systematic review.

Methods A comprehensive search strategy identified studies that evaluated the outcome over at least 3 months following arthroscopy for intra-articular hip pathology, using patient-reported outcomes of pain and/or function. Methodological quality was evaluated (Downs and Black scale), and effect sizes calculated when sufficient data were available.

Results Twenty-nine studies of moderate methodological quality were included. Of 16 studies investigating arthroscopy alone, two studies showed large effects (3.12–5.46) at 1–2 years. Pain reduction and functional improvement (median 47%) were consistently reported by the remaining 14 studies up to 10 years postsurgery. Of 15 studies investigating arthroscopy with osteoplasty, nine papers showed mostly large effects (0.78–2.93) over 6–28 months. Adverse events were minimal (7% of participants, 12 studies, predominantly transient neuropraxia (83%)).

Conclusion Current evidence indicates that hip arthroscopy can significantly reduce pain and improve function in patients with intra-articular hip pathology. While benefits of arthroscopy alone can persist up to 10 years postsurgery, effects of osteoplasty beyond 3 years need to be established. Future studies should investigate rehabilitation in this population, and the impact of surgery on development of osteoarthritis.

INTRODUCTION

Intra-articular hip pathology is a common cause of hip and/or groin pain,[1 2] and may be associated with considerable morbidity in young active populations.[3 4] In recent years, arthroscopic surgery has contributed to advancements in assessment and management of hip pathology; however, the complex anatomical nature and multifactorial sources of pain within the hip and groin regions continue to make diagnosis and management of such injuries a challenge to clinicians.[5] Hip labral tears have been identified at arthroscopy in patients with moderate to severe groin pain,[3] and professional National Hockey League (NHL) players with long-standing hip and groin pain.[4] Ligamentum teres pathology has also been observed during arthroscopy in athletes presenting with hip and groin pain.[6] The total number of hip arthroscopies performed internationally is growing rapidly, with more than 30 000 procedures performed in 2008, and an expected annual increase of 15%.[7] Moreover, surgical techniques have advanced significantly in recent years. Initial procedures typically involved debridement (eg, of the labrum and/or cartilage). With improvement in surgical techniques and advancement in understanding of hip pathology, the recent focus has been on addressing abnormal bony morphology (ie, cam- or pincer-type femoro-acetabular impingement (FAI)). Studies to date have demonstrated that FAI and acetabular dysplasia are strongly associated with the increased severity of labral pathology[8] and may play a significant role in the development of early hip osteoarthritis.[9–11] Current techniques have expanded to include osteoplasty of the femoral neck and/or acetabulum as well as the debridement/repair of the acetabular labrum in an effort to address intra-articular hip pathology and the long-term implications of abnormal bony morphology (ie, cam- or pincer-type FAI).

There is an increasing body of literature examining the outcomes of pain and physical function after hip arthroscopy.[12–16] Data from studies involving arthroscopic labral debridement demonstrate good short- to medium-term results. Two systematic reviews evaluated the outcomes of hip arthroscopy for labral pathology, reporting 65–85% patient satisfaction up to 40 months postsurgery.[13 15] However, patient satisfaction was reduced in the presence of significant chondropathy.[15] Four systematic reviews have evaluated outcomes following hip arthroscopy for FAI, with all concluding that short-term outcomes (up to 2.5 years) are positive.[12–14 16] Pain reduction, improved physical function or increased patient satisfaction were reported for all included studies in the reviews by Baldwin *et al*[14] (six studies) and Ng *et al*[12] (23 studies). The remaining two systematic reviews reported similar percentages of FAI patients who achieved good or excellent outcomes (67–93%)[13] and improvements in pain and function (68–96%).[16] Once again, poor outcomes were observed in the presence of co-existing chondropathy.[12 13] Thus, while it appears that there are short-term positive outcomes following hip arthroscopy for FAI, longer-term results remain unclear.

While the published systematic reviews have increased understanding of outcomes after hip arthroscopy, they are associated with notable limitations. Importantly, all reviews were limited by the lack of randomised clinical trials (RCTs) available for inclusion; none used validated critical appraisal tools to analyse the quality of included studies, and effect sizes for outcomes were calculated in one study only.[12] Since the most recent of these reviews, there have been a further 21 studies published investigating hip arthroscopy outcomes, and findings of these may alter previous conclusions. Furthermore, the published systematic reviews consider pathologies such as labral tears and FAI to be separate entities. Since contemporary practice indicates that hip pathologies often co-exist, it is inappropriate to restrict eligibility criteria according to individual hip pathologies. Appraisal of studies on the basis of surgery (ie, arthroscopy alone, or combined with osteoplasty) may be a more appropriate and clinically meaningful approach.

The objective of this study was to conduct a systematic review examining the outcomes of pain and physical function following hip arthroscopy for intra-articular hip joint pathologies.

MATERIALS AND METHODS

The systematic review protocol was developed according to guidelines outlined in the PRISMA Statement.[17] Literature search criteria and methods were proposed and agreed upon by three authors (JK, NC and KC), and were established a priori to minimise selection bias.

Eligibility criteria

Studies were included that utilised participants aged 17 years or over who were scheduled for or had undergone hip arthroscopy surgery as a primary intervention for intra-articular hip pathology. Studies that followed participants over at least 3 months, and utilised a patient-reported measure of pain and/or function, were included. All quantitative study designs were considered, including RCTs and other prospective or retrospective study designs (minimum level IV evidence).[18 19] Studies were excluded if (1) they performed open surgeries; (2) they addressed infection, osteoarthritis or synovial chondramatosis as primary pathology; (3) they were case series with less than five participants or (4) they were published in a language other than English or in a non-peer-reviewed journal. This systematic review included all non-osteoarthritic pathologies. Papers where osteoarthritis was the primary pathology were excluded, due to significant differences in outcomes observed in previous systematic reviews between participants with and without osteoarthritis.[12 16] As such, we felt that the outcomes for hip arthroscopy in which osteoarthritis was the primary pathology warranted a separate review outside the scope of this study.

Search strategy

A comprehensive, reproducible search strategy was performed on the following databases between January 1990 and May 2010: Scopus, Medline, CINAHL, Pubmed, Ausport, SportsDiscus, PEDro, the Cochrane Library, PsychINFO and Google scholar. January 1990 was selected for retrieval of the earliest record due to the paucity of literature prior to this date, and vast changes in this procedure over the past two decades (Appendix 1 see online for search strategy). Reference lists of suitable studies were manually searched for relevant papers.

Titles and abstracts were screened for potentially relevant studies by two independent reviewers (AS and MM). Any disagreements regarding inclusion were resolved by an independent arbitrator (KC). Full text versions of identified studies were retrieved for final eligibility screening.

Quality evaluation

The Downs and Black checklist[20] was used to appraise the methodological quality of included studies (see online Appendix 2 for checklist) since it has adequate reliability and validity for assessing RCTs and non-randomised studies.[20–22] Included studies were rated by two independent reviewers (JK and NC), who were blinded to author, affiliations and publishing journal. Any disagreements between reviewers were

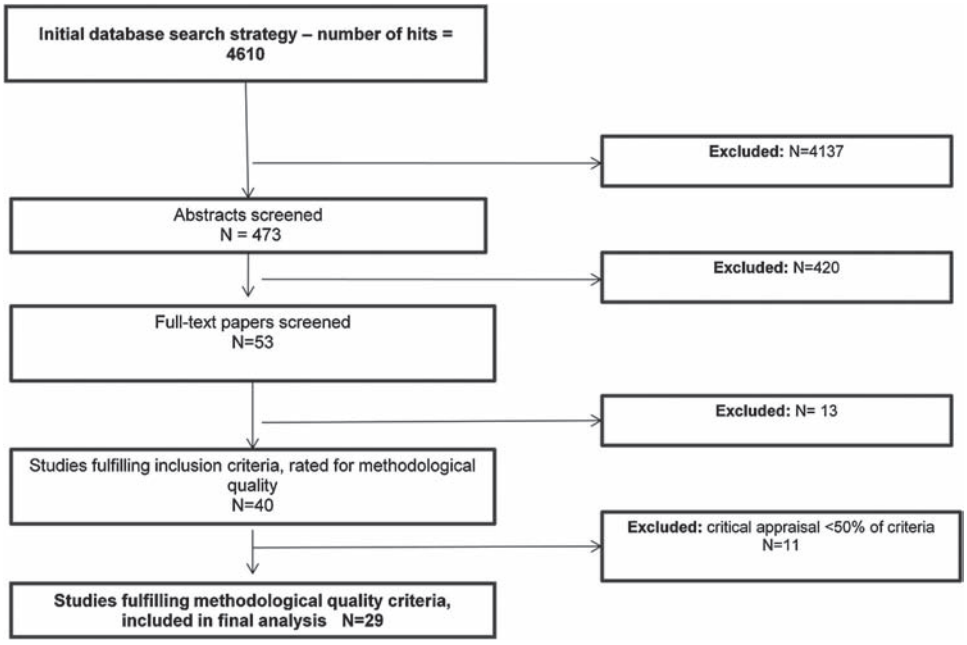

Figure 1 Flow chart of search results.

Table 1 Summary of outcome measures used in 29 studies evaluating the outcomes of hip arthroscopy surgery

Outcome measured	Outcome measure used	Number of studies	Studies using measure	Reliability, validity and responsiveness (non-hip arthroscopy conditions)	Reliability, validity and responsiveness in hip arthroscopy	Reference
Pain						
	VAS	6	37–39 41 45 48	Reliable Valid	NR	77 78
Pain and function						
	MHHS	21	4 30 33–36 40 45–56	Valid	Valid	42
	HHS	2	32 44	Reliable Valid	NR	43
	NAHS	7	33 34 37–39 41 47	Reliable Valid	Reliable Valid	42
	HOS	1	47	Reliable Valid Responsive	Reliable Valid Responsive	42 79
	SF-36	1	46	Reliable Valid	NR	43
	WOMAC	2	58 59	Reliable Valid	NR	80 81
	PMA	1	59	Reliable Valid	NR	82
	DQ	1	36	NR	NR	36
	SF-12	1	45	Reliable Valid	NR	83
Function						
	SFS	1	38	NR	NR	84

DQ, dance questionnaire; HHS, Harris hip score; HOS, hip outcome score; MHHS, modified Harris hip score; NAHS, non-arthritic hip score; NR, not reported; PMA, Postel Merle d'Aubigne score; SF-12, short form 12; SF-36, short form 36; SFS, sports frequency score; VAS visual analogue scale; WOMAC, Western Ontario and McMaster universities osteoarthritis index.

discussed in a consensus meeting and an independent arbitrator (KC) employed when consensus could not be met. To maintain a benchmark of moderate to high-study quality, it was agreed a priori that studies that scored a total score of greater than 13 points were included in the final evaluation.

Data management and statistical analysis

Inter-rater agreement on the Downs and Black criteria was evaluated using the κ statistic.[23]

Data were extracted by one reviewer (JK). Population characteristics (age, gender, pathology, duration of symptoms), outcome measures utilised, length of follow-up and details of surgical interventions were collated. In order to allow consideration of surgical outcomes in the context of treatment risks, information regarding adverse events was also obtained.

Mean and SD for each outcome measure were extracted for calculation of effect sizes. Where sufficient data were not presented, corresponding authors were contacted to request additional data. Effect sizes were calculated as the difference between the preoperative and follow-up means, divided by the within-group preoperative SD.[24] Effect size magnitude was interpreted as: ≥0.8 large effect; 0.5–0.8 moderate effect and 0.2–0.5 weak effect[24–26]; 95% CI for effect sizes were estimated by dividing the lower or upper CI for the mean difference by the population SD.[27]

RESULTS

Search strategy

The comprehensive search strategy identified 473 papers for evaluation beyond title level, and 53 papers for full-text evaluation (figure 1). On further evaluation of full texts (JK, ZM and NC), 13 papers were excluded, including two studies where the primary pathology of participants was osteoarthritis.[28 29] Forty studies fulfilled all inclusion criteria and underwent critical appraisal.

Methodological quality

The initial overall agreement between the two independent raters was very high (κ=0.820), concurring on 990 of a possible 1080 items. Consensus was reached on all items following initial discussion. Inter-rater reliability for individual items ranged from κ=0.404 (moderate agreement) to κ=1.0 (perfect agreement).

Methodological quality scores of the 40 included studies varied widely, from 9 to 21 of 31 points (mean 15 (SD 3)) (see online Appendix 3). Eleven papers received a quality score of less than or equal to 13 and were subsequently excluded from further analysis, leaving 29 papers for final inclusion. Two papers were included in non-osteoplasty and osteoplasty groups.[30 31]

Participants

Participant characteristics varied between the 29 included studies (tables 1 and 2). Sample sizes ranged from 10[32] to 166[33] participants. One study included only female participants,[32] while two studies utilised athletic populations of male-only elite sports (United States (NHL), Australian Rules Football).[4 34] The remaining 26 studies had representation from both genders, with the percentage of women ranging from 25%[33] to 61%.[35] The mean age of individual cohorts ranged from 20 years[36] to 47 years,[37] while the overall mean age across all studies was 35[4] years. While most studies included participants based on pathology, three studies utilised the activity type as an inclusion

Table 2 Summary of results for hip arthroscopy without osteoplasty

Study characteristics				Sample characteristics						Effect size at follow up	
Paper (total score using Downs and Black appraisal)	Intervention	Pathology	Sample size	Inclusion criteria	Gender	Age (years)†	Duration of symptoms (months)‡	Follow up (months)†	Outcome	Effect size (95% CI)	Study conclusions (where effect size=ID)
Bardakos[31] (19)	Labral and chondral debridement	Labral	47	Isolated CAM	10F; 14M	35	NR	12	MHHS	ID	MHHS pre 55; post 77; improved 22 points
Burnett[3](17)	Labral debridement Other[9]	Labral	66	Labral tear	47F; 19M	38	21(2–156)	16.4	MHHS	ID	MHHS: pre 62; post 83; improved 21 points
Byrd[51] (19)	Arthroscopy	Labral; other[1–7]	35 (38 hips)	NR	17F; 18M	38	21 (1–156)	24	MHHS	ID	MHHS pre 57; post 85; improved 28 points
Byrd[52] (15)	Labral and chondral debridement Other[9–11]	Labral; other[6 7]	48	Dysplasia	28F, 20M	34	29(2–180)	27	MHHS	ID	MHHS improved 27 points
Byrd[53] (18)	Other[10]	Other[6]	23	Ligamentum teres lesion	14F; 9M	28	29	28.5(.5–144)	MHHS	ID	MHHS pre 47; post 90; improved 43 points
Byrd[54] (16)	Labral and chondral debridement	Labral; other[4 7]	26	Labral tear	13F; 13M	46	NR	24	MHHS	ID	MMHS pre 52; post 81; improved 29 points
Byrd[55] (15)	Labral and chondral debridement	Labral; other[1 4–6]	15	Injury onset during sport	4F; 11M	31	NR	120	MHHS	ID	MHHS pre 51, post 96; improved 45 points
Byrd[56] (16)	Arthroscopy	Labral; other[1 2 4–6]	50 (52 hips)	Various disorders	23F; 27M	38	NR	120	MHHS	ID	MHHS pre 56; post 81; improved 25 points
Freedman[46] (15)	Arthroscopy	Labral	24	Labral tear	13F; 11M	37	NR	24	MHHS SF-36	ID	MHHS pre NR; post 70
Kamath[50] (18)	Labral and chondral debridement Other[9 12]	Labral	42	Labral tear	32F; 20M	42	NR	58	MHHS	ID	MHHS pre 56.8; post 80.4; improved 23.6 points
Kocher[36] (15)	Labral debridement	Labral	30	Dancer with labral tear	29F; 1M	20	20 (14.1–38)	19.6	MHHS	5.46 (4.95 to 5.98)	
Nepple[30] (16)	Labral and chondral debridement	Labral; other[7 8]	23	Cam lesion; labral tear	11F; 12M	37	NR	28	MHHS	ID	MHHS pre 59.8; post 83.1; improved 23.3 points
Philippon[4 47] (20)	Other[13]	Labral	47	Labral degeneration	15F; 32M	47	37[17–50]	18	MHHS	ID	MHHS pre 62; post 85; improved 23 points
Prather[35] (15)	Arthroscopy	Labral; other[7 8]	130	Early intra-articular disorders	93F; 37M	31	NR	15.9	MHHS	3.12 (2.87 to 3.36)	
Streich[48] (18)	Labral and chondral debridement	Labral	50	Labral tear without FAI, dysplasia	29F; 21M	33	NR	34	MHHS VAS	ID	MHHS pre 59.8; post 72.2 improved 12.4 points VAS pre 6; post 4; improved 2 points
Yamamoto[32] (14)	Labral debridement	Labral; other[2]	10	Labral tear and dysplasia	10F	33	NR	8	HHS	ID	HHS pre 64.5; post 92.5; improved 28 points

†Mean (SD).
‡Range.
[1]Osteoarthritis;[2]dysplasia;[3]Perthes disease;[4]avascular necrosis;[5]synovitis;[4]synovial chondromatosis;[6]ligamentum teres;[7]chondropathy;[8]FAI;[9]microfracture;[10]LT debridement;[11]removal loose bodies;[12]labral repair;[13]labral reconstruction.
F, female; FAI, femoro-acetabular impingement; HHS, Harris hip score (*score range 0–100 points, 100 points=best possible outcome)*; ID, insufficient data; M, male; MHHS, modified Harris hip score (*score range 0–100 points, 100 points=best possible outcome)*; NR, not reported; VAS, visual analogue scale (*score range 0–10 points, 0 points=best possible outcome).*

criteria[4 34 36] The mean symptom duration prior to surgery was reported in 11 studies, ranging from 6 to 36 months, with the mean duration being 24[8] months.

Outcome scores

The included studies utilised 11 patient-reported outcomes (PROs) of pain and function (table 1). The Non-arthritic Hip Score (NAHS) was reported by seven studies[33 34 37–41] and has been shown to be reliable and valid in a hip arthroscopy cohort.[42 43] The Harris Hip Score (HHS) includes an observer measure of the hip range of motion in addition to the PROs and was used in two studies.[32 44] The most frequently used measure was the modified Harris Hip Score (MHHS) (21 studies),[4 30 33–35 40 45–56] which was adapted from the HHS (physical range of motion measures removed). While the MHHS has construct validity for hip arthroscopy,[42] its reliability has not been tested. The Hip Outcome Score (HOS) was utilised in only one study;[47] however, this is the only outcome measure with demonstrated responsiveness in a hip arthroscopy population,[42] which is the ability of the measure to detect a change (either improvement or worsening of pain and function) over time.[57]

Findings

The 29 included studies were grouped, based on the primary surgical procedure: hip arthroscopy without femoral osteoplasty, and hip arthroscopy with femoral osteoplasty. No studies used an RCT design. Most studies reported treating several pathologies concurrently at the time of arthroscopy. Follow-up times ranged from 4 months to 10 years. Seven studies reported sufficient data for effect size calculation[36 40 41 44 49 58 59] (tables 2 and 3). The authors of the remaining studies were contacted and six replied.[33–35 38 39 45] Wherever effect sizes were unable to be calculated, study conclusions were presented.

Adverse events

Adverse events were reported by 12 the 29 studies. Adverse events were reported in 52 of 700 participants (7%) across the 12 studies. These included transient pudendal nerve hypoesthesia (n=22),[36 37 39 41 48 50] transient lateral femoral cutaneous nerve hypoesthesia (n=14),[37 39 41 50 52 53 56] transient sciatic nerve hypoesthesia (n=6),[37 39 41 45] heterotrophic bone formation (n=7),[44 45] myositis ossificans (n=1),[56] tear of labia minora[37](n=1) and complex regional pain syndrome (n=1).[3]

Hip arthroscopy without femoral osteoplasty

Sixteen papers investigated the outcomes of hip arthroscopy without femoral osteoplasty[30 32 35 36 45–48 50–56] (table 2). Only three papers utilised a prospective design[31 47 48] and the remaining papers retrospective. The majority of studies were case series, with only two comparative studies.[30 31] The mean quality score for the 16 studies was 16, with the highest score of 20 only obtained by one study.[47]

A range of intra-articular hip pathologies were investigated, including labral pathology,[3 31 47 48] isolated ligamentum teres pathology[53] and labral pathology co-existing with other pathology (table 2). Despite the variation in pathologies recorded, postoperative improvements in pain and function were consistently reported. Furthermore, improvements were maintained over longer follow-up periods, with improvements seen up to 10 years.

Of the 16 studies, the effect sizes could only be calculated for two.[35 36] Significant large effects on the MHHS were found for both studies 1–2 years after surgery (figure 2). However, the characteristics of included participants differed between the two studies. Kocher *et al*[36] examined the effect of labral debridement in 30 ballet dancers (mean age 20 years) with labral pathology as their primary diagnosis, while Prather *et al*[35] performed arthroscopy on 130 individuals (mean age 31 years) in whom labral pathology co-existed with unspecified FAI and chondropathy. Kocher *et al*[36] also reported poor

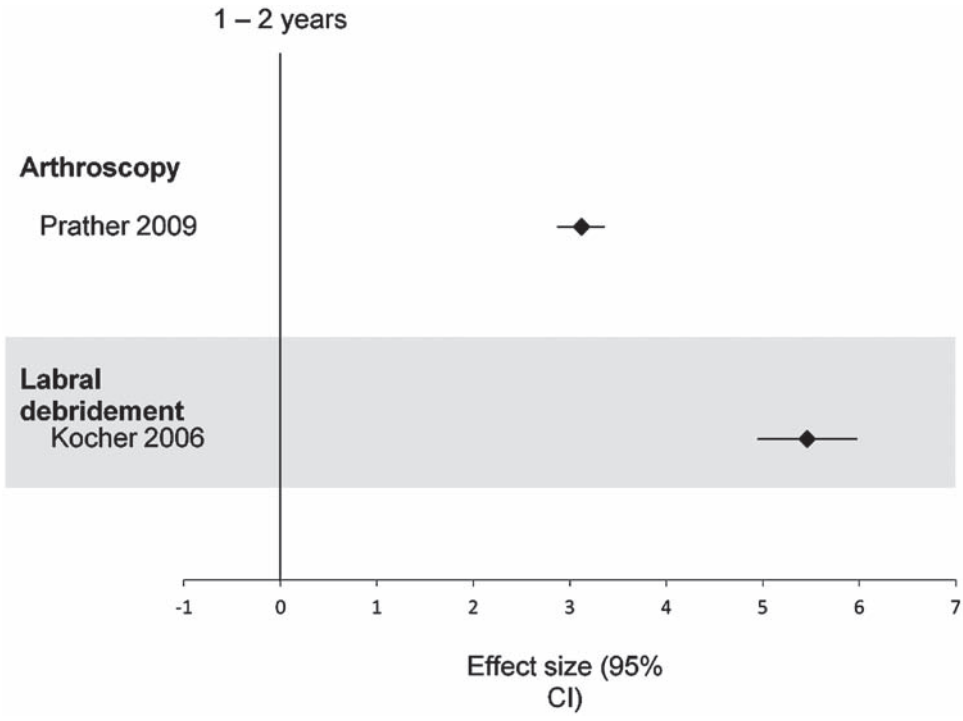

Figure 2 Effect sizes 1–2 years following arthroscopy without osteoplasty. Positive value favours intervention. Significant effect denoted by positive CI (CI).

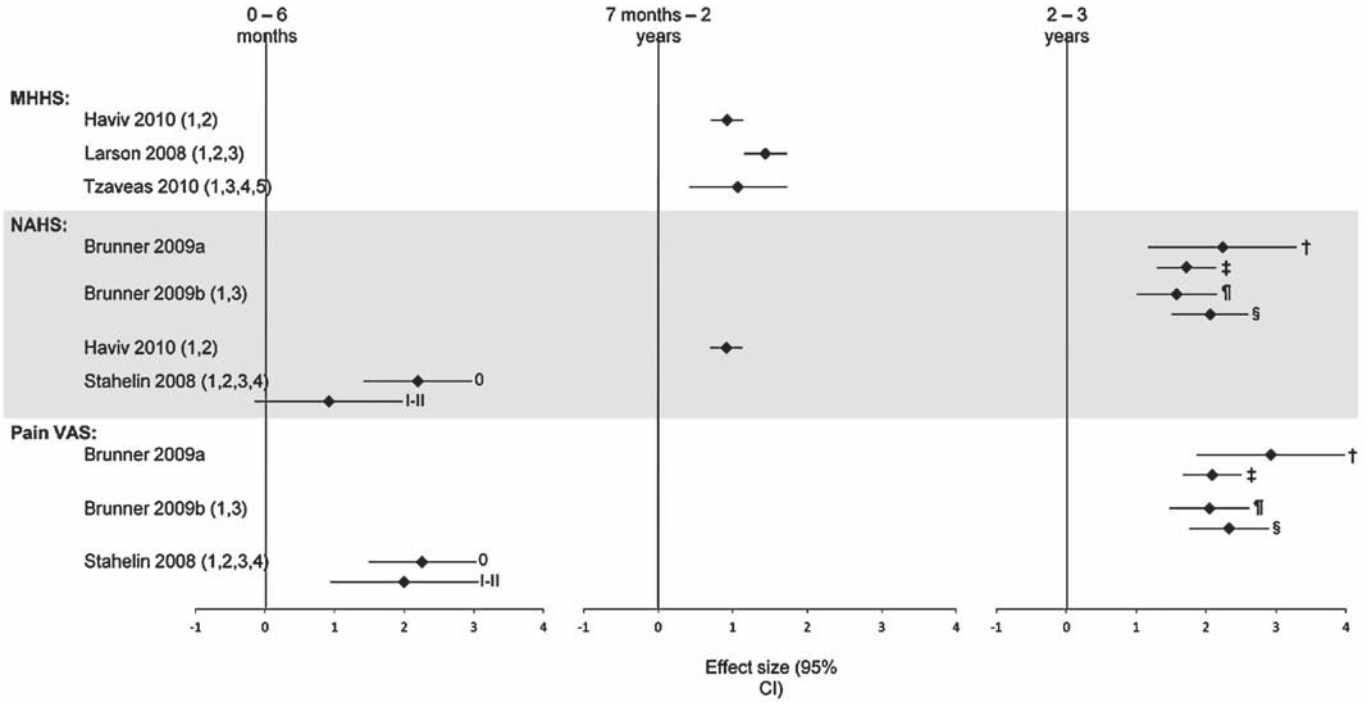

Figure 3 Effect sizes up to 3 years following arthroscopy with osteoplasty. Positive value favours intervention. Significant effect denoted by positive CI. Numbers in brackets indicate the intervention performed with femoral osteoplasty. 1: Labral debridement; 2: microfracture; 3: chondral debridement; 4: labral debridement; 5: chondral repair. 0: Tonnis 0 classification; I–II: Tonnis I–II classification; † no sport participation; ‡ sport participation; no CT navigation; § CT navigation.

outcomes of pain and function in those who had a co-existing chondral flap.

Of the remaining 14 studies, 12 used the MHHS as the primary PRO,[30 47 48 50–56] while Yamamoto[32] utilised the HHS. All but one study reported a statistically significant improvement of greater than 20 points (representing a percentage improvement of 34–88%)[3 54] following surgery. Streich *et al*[48] found an improvement of 12 points (20%) on the MHHS, along with a decrease of 2 points of 10 (33%) on a pain visual analogue scale (VAS). This suggests a postoperative improvement in pain alongside a smaller improvement in function.

One study retrospectively examined the effects of hip arthroscopy in 23 participants (mean age 28 years) with arthroscopically diagnosed isolated ligamentum teres pathology resulting from trauma.[53] An improvement of 43 points (MHHS) was observed at a mean follow-up of 28 months and no differences in the outcome based on the type of trauma, the degree of rupture (full vs partial) or the presence of co-existing pathology.

All studies that reported the outcome separately for different hip pathologies found worse outcome to be associated with co-existing chondropathy at arthroscopy.[51 55 56] Byrd and Jones[51] found the greatest mean difference in MHHS at 24 months (29 points) for participants without chondropathy, compared with those with chondropathy (16 points). A later study by Byrd and Jones[56] reported that participants with no preoperative chondropathy demonstrated greater mean improvement on the MHHS at 10 years (39 points), compared with participants with preoperative chondropathy (five points).

Hip arthroscopy with femoral osteoplasty

Of 15 studies that examined the outcomes of hip arthroscopy with femoral osteoplasty (table 3), nine were prospective in design[4 31 37–41 49 58] and six were retrospective.[30 33 34 44 45 59] Only three studies utilised comparative designs[30 31 39] with the majority being case series. The methodological quality was similar to those that investigated arthroscopy only, with scores ranging from 16 to 21 (mean score 17). Importantly, the comparative studies did not adequately randomise individuals to either group, blind subjects or observers, and thus were susceptible to bias.

Nine papers presented sufficient data for effect size calculation across six outcome measures (figure 3).[33 38 39 41 44 45 49 58 59] Significant large effects were mostly seen on all outcomes (MHHS, NAHS, VAS, WOMAC and PMA) up to 28 months following osteoplasty for cam-type and combined FAI, with additional labral and chondral debridement as appropriate. Six studies demonstrated positive postoperative outcomes, with five reporting an improvement of greater than 20 points on at least one measure.[4 30 31 37 40] However, Singh *et al*[34] found smaller improvements in their cohort of elite Australian Rules Football players (mean age 22 years), which may be attributed to higher preoperative scores and increased likelihood of ceiling effects. Two studies of participants with FAI differed from this trend. Although Stahelin *et al*[41] reported a large significant effect on the NAHS in patients with FAI without co-existing osteoarthritis, the effect was largely diminished and not significant when osteoarthritis (Tonnis grade I or II) co-existed. Interestingly, the presence of osteoarthritis did not change the outcome on a pain VAS. Ilizaliturri *et al*[58] demonstrated a significant moderate effect of surgery in those with FAI, although the modest effect size may be partly due to high preoperative scores.

The three comparative studies[30 31 38] examined the outcomes of two arthroscopic techniques for isolated cam-type impingement. Bardakos and colleagues[31] prospectively examined the effect of femoral osteoplasty compared with arthroscopy alone. A significantly higher proportion of participants

Table 3 Summary of results for hip arthroscopy with osteoplasty

Study characteristics				Sample characteristics						Effect size at follow up	
Paper (total score using Downs and Black appraisal)	Intervention	Pathology	Sample size	Inclusion criteria	Gender	Age (years)†	Duration of symptoms (months)‡	Follow-up (months)†	Outcome	Effect size (95% CI)	Study conclusions (where effect size=ID)
Bardakos[31] (19)	Femoral osteoplasty	Cam FAI	24	Isolated CAM	10F; 14M	33	NR	12	MHHS	ID	MHHS pre 59; post 83; improved 24 points
	Other[4 5]	Other[1]									
Brunner[38 39] (17)	Femoral osteoplasty	Cam FAI	53	FAI	12F; 41M	42	NR	28	NAHS	NAHS no sport 2.24 (1.17 to 3.30)	
										NAHS sport 1.72 (1.30 to 2.14)	
			Sport=45						VAS	VAS no sport 2.93 (1.87 to 3.99)	
			No sport=8							VAS sport 2.09 (1.67 to 2.51)	
Brunner[38 39] (21)	Femoral osteoplasty	Cam FAI	Group 1–25 (CTN)	Cam FAI	11F; 39M	42	NR	26	NAHS	VAS CTN 2.33 (1.76 to 2.90)	
										VAS no CTN 2.05 (1.48 to 2.62)	
										NAHS CTN 2.06 (1.51 to 2.61)	
	Other[4 5]		Group 2–25 (no CTN)						VAS	NAHS no CTN 1.58 (1.01 to 2.15)	
Gédouin[59] (17)	Femoral osteoplasty	FAI unspecified	38	FAI, positive impingement test	5F; 33M	36	6 Months–10 years	15	WOMAC	WOMAC 1.18 (0.69 to 1.66)	
	Other[4–6]	Other[1]							PMA	PMA 1.16 (0.71 to 1.62)	
Haviv[33] (17)	Femoral osteoplasty	Cam FAI	170	Cam FAI, acetabular chondral lesions	34F; 132M	37	37[13–64 77–84]	22	MHHS	MHHS 0.93 (0.71 to 1.14)	
	Other[4]	Other[2]							NAHS	NAHS 0.92 (0.70 to 1.13)	
Horisberger[28 37] (17)	Femoral osteoplasty	Cam FAI	88 (105 hips)	Cam or mixed FAI	28F; 60M	40	40.9[16–57 77–79]	28	NAHS	ID	NAHS pre 56.7; post 84.6; improved 27.9
		Combined FAI							VAS		VAS pre 5.5; post 1.5; improved 4 points
	Other[4–6]	Other[1 2]									
Ilizaliturri[58] (18)	Femoral osteoplasty	Cam FAI	19	Cam FAI	8F; 11M	34	34[25–40]	24	WOMAC	0.78 (0.12 to 1.44)	
	Other[4 5]	Other[1 2]									
Larson[45] (16)	Femoral osteoplasty	Cam FAI	96	FAI	42F; 54M	34	34.7[15–57 77]	9	MHHS	MHHS 1.44 (1.15 to 1.73)	VAS pre 6.74; post 1.88; improved 4.86 points
		Combined FAI							VAS		SF12 pre 60.2; post 77.7 improved 17.5 points
	Other[4 5 8]	Other[1 2]							SF12		
Nassif[44] (17)	Femoral osteoplasty	FAI unspecified	135	FAI	65F; 70M	32	32.7[3 14–50]	22	HHS	1.64 (1.40 to 1.88)	
	Other[4 5]	Other[1 2]									
Nepple[30] (16)	Femoral osteoplasty	Cam FAI	25	Cam lesion; labral tear	8F; 17M	33	NR	20	MHHS	ID	MHHS pre 64.5; post 90.5; improved 26 points
	Other[4 5]	Other[1 2]									

Continued

Table 3 Continued

Study characteristics				Sample characteristics						Effect size at follow up	
Paper (total score using Downs and Black appraisal)	**Intervention**	**Pathology**	**Sample size**	**Inclusion criteria**	**Gender**	**Age (years)†**	**Duration of symptoms (months)‡**	**Follow-up (months)†**	**Outcome**	**Effect size (95% CI)**	**Study conclusions (where effect size=ID)**
Philippon[40 71] (17)	Femoral osteoplasty	Cam FAI	112	FAI, chondrolabral dysfunction	62F; 50M	40	34 (25.2-42.8)	28	MHHS	ID	MHHS pre 58; post 84; improved 26 points
		Pincer FAI							HOS		HOS ADL pre 70; post 87; improved 17 points
		Combined FAI							NAHS		
	Other[4 5 7–9]	Other[1 2]									NAHS pre 66; post 81; improved 15 points
Philippon[4 47] (16)	Femoral osteoplasty	Cam FAI	28	Professional ice hockey player, unilateral hip pain	0F; 28M	27	19 (1.5 – 99)	24	MHHS	ID	MHHS pre 70; post 95; improved 25 points
		Pincer FAI									
		Combined FAI									
	Other[5 8]	Other[1 2]									
Singh[34] (16)	Femoral osteoplasty	Cam FAI	24 (27 hips)	ARF players, hip/groin pain not responding to conservative treatment	0F; 24M	22	NR	22	MHHS	ID	MHHS pre 86; post 96; improved 10 points
		Pincer FAI									
		Combined FAI							VAS		NAHS pre 81; post 96; improved 15 points
	Other[4 5 8]	Other[1–3]									
Stähelin[41] (17)	Femoral osteoplasty	Cam FAI	22	Symptomatic Cam FAI	7F; 15M	42	NR	6	NAHS	NAHS Tonnis 0; 2.2 (1.42 to 2.98)	
										NAHS Tonnis I-II; 0.92 (–0.15 to 1.98)	
										VAS Tonnis 0; 2.26 (1.49 to 3.04)	
	Other[4 5 8]	Other[1 2]							VAS	VAS Tonnis I-II; 2.0 (0.94 to 3.07)	
Tzaveas[49] (17)	Femoral osteoplasty	Cam FAI	19	Acetabular chondral defects	14F; 5M	36	NR	12	MHHS	0.07 (0.42 to 1.73)	
	Other[4 5 8 10]	Other[1 2]									

†Mean (SD).
‡ Range.
[1]Labral pathology; [2]chondropathy; [3]synovitis; [4]Labral debridement; [5]Chondral debridement; [4]Microfracture; [6]Removal loose bodies; [7] Synovectomy; [8]Labral repair; [9]Acetabular osteoplasty; [10]Chondral repair (fibrin adhesive)
Cam FAI, lesion at femoral head neck junction; CTN, CT-based navigation system; FAI, femoro-acetabular impingement; F, female; ID, insufficient data; HHS, Harris hip score *score range 0–100 points, 100 points=best possible outcome*; M, male; MHHS, modified Harris hip score *score range 0–100 points, 100 points=best possible outcome*; NAHS, non-arthritic hip score *(score range 0–100 points, 100 points=best possible outcome)*; NR, not reported; PMA, Postel Merle d'Aubigne score (*score range 0–18 points, 18 points=best possible outcome)*; THA, total hip arthroplasty; Tonnis, preoperative grading of osteoarthritis using Tonnis scale; VAS, visual analogue scale *(score range 0–10 points, 0 points=best possible outcome)*; WOMAC, Western Ontario and McMaster universities osteoarthritis index *(score range 0–100 points, 100 points=best possible outcome).*

who received the osteoplasty reported excellent or good results compared with arthroscopy alone (p=0.043), although no difference was observed in the postoperative MHHS between surgical groups (p=0.11). Similarly, Nepple and colleagues[30] compared two groups who underwent hip arthroscopy with or without femoral osteoplasty for the treatment of cam-type impingement. Unlike Bardakos *et al*, group allocation within this retrospective study was determined by the time of surgery, as procedures performed at later dates utilised operative techniques that included osteoplasty. The authors reported a significantly higher MHHS in the osteoplasty group 1 year after surgery (p=0.019), and a near-significant trend towards higher MHHS at 2-year follow-up (p=0.056). They also reported a significantly higher likelihood of poor outcome in the non-osteoplasty group (p=0.044). Brunner *et al*[38] prospectively evaluated the addition of a CT-Based Navigation System Prototype to arthroscopic femoral osteoplasty for cam-type impingement. While large effect sizes were found (NAHS and pain VAS) in both groups, there were no between-group differences.

The presence of osteoarthritis at the time of surgery was associated with poorer outcome in two studies.[40 59] Gedouin[59] demonstrated the effect sizes of 1.17 (WOMAC) and 1.29 (PMA) in participants with FAI without co-existing chondropathy, compared with 0.80 (WOMAC) and 0.87 (PMA) in those with chondropathy. Similarly, Philippon[40] found that radiographic preoperative hip joint space greater than 2.0 mm was the predictive of greater MHHS at 28 months follow-up.

DISCUSSION

Findings of this systematic review indicate that patients with intra-articular hip pathology experience short-term and long-term improvements in pain and physical function following hip arthroscopy, with or without femoral osteoplasty, that appear to be maintained over time. This is despite the heterogeneity seen in study quality, populations and methodologies. Only three studies included patients based on activity level. This could be utilised as an inclusion criterion in future studies to provide further homogeneity to cohorts, therefore providing clinicians with a more accurate reflection on the outcomes for individual patients. Notably, the current review included 12 papers examining hip arthroscopy without osteoplasty and nine papers with osteoplasty that were not included in previous systematic reviews.

Based on findings of 16 studies, current evidence suggests that patients with intra-articular hip pathology will have less pain and increased function for up to 10 years after arthroscopy without femoral osteoplasty. The percentage change in outcome scores ranged from 20%[48] to 88%,[55] with a median change of 47%. This magnitude of improvement was also seen 10 years after surgery, with three studies reporting 10 year outcome scores of 88, 56 and 45%, respectively.[54–56] This finding advances on previous systematic reviews, which noted improvements up to 5 years, and may provide confidence for clinicians and patients who are uncertain about the likely long-term benefits of hip arthroscopy surgery. Similarly, evidence from 15 studies demonstrates that patients will also report improvements in pain and function following arthroscopy with femoral osteoplasty. As osteoplasty for FAI is a relatively new procedure, as evidenced by the publication of all included studies in the past 3 years (2008–2010), current follow-up periods only extend to 2.5 years leaving uncertainty regarding the longer-term outcomes of this intervention. Furthermore, the impact of FAI surgery on the development of osteoarthritis of the hip remains unknown.

While the heterogeneity in study methods precludes direct comparisons between hip arthroscopy with and without osteoplasty, inspection of effect sizes (figures 2 and 3) indicates similar short-term outcomes between surgical procedures. Only two studies compared the outcomes between osteoplasty and no osteoplasty for patients with FAI.[30 31] Despite inconsistent methodologies, both studies reported better outcomes in those who had undergone osteoplasty, with more osteoplasty patients reporting an excellent outcome (83% vs 60%, p=0.043)[31] or a change of 40%.[30] While this needs to be confirmed using rigorous RCT methods, it appears that hip osteoplasty produces short-term results at least as good as those obtained by hip arthroscopy alone.

The radiological feature of cam-type or pincer-type FAI may result in damage to other hip structures, ultimately resulting in pain perception and hip-related symptoms. Hence, hip osteoplasty is increasingly performed to enable greater range of hip joint motion, with the aim of preventing further impingement episodes. Furthermore, since FAI or acetabular dysplasia may lead to early hip osteoarthritis,[9 11] hip osteoplasty may play a role in the prevention of structural disease progression. However, until the long-term benefits of osteoplasty are demonstrated with respect to changing the natural course of OA, or rigorous head-to-head comparisons are made with hip arthroscopy alone, any potential additional benefits are theoretical.

Although this systematic review did not specifically examine the effects of hip arthroscopy on individuals with structural hip joint disease (chondropathy through to osteoarthritis), 6 of the 29 papers compared surgical outcomes between those with and without joint disease.[4 48 51 55 56 59] In patients with advanced chondropathy or pre-existing osteoarthritis, the outcomes for function and pain were lower when arthroscopy was performed alone[48 51 56] or with osteoplasty.[59] These results are similar to those reported at the knee.[60] Indeed, arthroscopic knee surgery is not recommended as an intervention to address pain and impaired function in patients with knee osteoarthritis[61 62] due to minimal positive effects observed. Therefore, it is important that future studies investigate the impact of joint disease on hip arthroscopy outcomes, and whether arthroscopy can alter the natural progression of symptomatic or structural disease in patients with FAI and/or other intra-articular hip pathology.

The potential for adverse events associated with hip arthroscopy is an important factor in the clinical decision-making process regarding the appropriateness of surgery for an individual. While the reported incidence was low (7%), it must be considered that only 12 of the 29 studies reported adverse events data. Nevertheless, this complication rate compares favourably with that of knee arthroscopy, where rates of 13–58% have been reported in populations undergoing arthroscopic anterior cruciate ligament (ACL) reconstructive surgery of the knee.[63 64] The majority (83%) of the adverse events reported (43 of 52) were of transient neuropraxia.

This is the first systematic review to appraise the methodological quality of included studies. Interestingly, the exclusion of studies of poorer quality did not influence the conclusions, when compared with previous systematic reviews. This enhances confidence in the previous and the current findings. Quality appraisal revealed several methodological issues associated with the current hip arthroscopy literature. This

is apparent in the overall quality rating scores, which ranged from 29% to 68% on the Downs and Black scale, and resulted in the exclusion of 11 studies. Foremost, of the 29 studies retained for analysis, only three studies[30 31 39] included a control or a comparison group, while the remaining 26 were case series. Unlike RCTs, case series do not allow for improvements due to placebo or natural recovery to be documented, as noted in a RCT for arthroscopic knee surgery.[65] To date, there are no RCTs examining outcomes following hip arthroscopy. Although the use of non-controlled study designs makes it difficult to implement the methodological features such as allocation concealment and participant and assessor blinding to decrease the risk of bias, the methodological quality of such studies can be enhanced by utilising prospective designs and blinded examiners.

One major methodological flaw in the included papers was the lack of known psychometric properties of the outcome measures used. It is recognised that PROs used to measure a change in pain and function following an intervention should demonstrate adequate reliability, validity and responsiveness for that population.[66] However, most of measures used had not been tested for reliability, validity or responsiveness in hip arthroscopy populations. In particular, only one study utilised an outcome measure with demonstrated responsiveness.[47] This greatly impairs the readers' confidence in the accuracy of results reported in the included papers and in effect sizes calculated.[57] In addition, only one study attempted to blind observers to outcomes observed.[38 39] This creates further doubt regarding the efficacy of reported results, as observer-administered outcome measures have been shown to produce higher results than patient-administered measures.[67]

Furthermore, three particular methodological limitations impacted on the ability to compare the effect sizes between studies. First, there was a dearth of data reporting in primary publications, with only 7 of the 29 studies reporting sufficient data for calculation of effect sizes. Second, 12 different outcome measures were utilised. This may be attributed to the relatively recent development of this procedure, and a lack of consensus regarding the most appropriate outcome measures for this diverse population. Third, reported follow-up times varied considerably, ranging from 6 months,[41] to 10 years.[54 56] As hip arthroscopy progresses in popularity and further studies evaluate the outcomes of this procedure, it is essential that a battery of valid and reliable outcome measures specific for this population be established. Short- and long-term follow-up data, beyond the current 10 years, are required across multiple postoperative time points.

While the current review examined surgical outcomes, it is plausible that non-surgical approaches also play an integral role in the management of intra-articular hip pathologies. At the knee, a number of RCTs have directly compared the efficacy of surgery with physical therapy or rehabilitation,[64 68] with all studies noting no superiority of the surgery. In comparison, the clinical commentaries describing rehabilitation of the hip[69–72] have not examined the outcomes of conservative approaches, in isolation or combined with surgical interventions. The importance of the hip musculature is highlighted by their morphological, biomechanical and physiological characteristics[73 74] and changes seen in the hip muscle size in the presence of hip osteoarthritis.[75 76] Future interdisciplinary studies examining the isolated and combined effects of surgery and rehabilitation may assist in guiding patients to the most appropriate treatment choice.

What is already known on this topic

- Hip pathology is a common cause of groin pain in active populations.
- Hip arthroscopic surgery is increasing in prevalence.
- Early surgical procedures typically involved labral/chondral debridement. Previous systematic reviews have noted generally good outcomes, with significant reduction in pain and improved function demonstrated for up to 40 months postsurgery.
- Current surgical procedures also target the underlying pathology/abnormal morphology (eg, femoro-acetabular impingement). While short-term outcomes of hip arthroscopic surgery involving osteoplasty appear to be good, medium- or longer-term results remain unclear.

What this study adds

- Ten-year follow-up data on procedures without osteoplasty demonstrate good results.
- Effect sizes of the benefits observed are similar between surgery involving osteoplasty and no osteoplasty.
- Although some benefit is observed, the presence of chondropathy at the time of surgery results in poorer outcome than cases with normal cartilage.

What remains unknown

- Whether hip arthroscopy with osteoplasty will improve long-term pain and function.
- Whether hip arthroscopy with osteoplasty will impact on long-term development of hip OA.

In summary, current evidence indicates that hip arthroscopy surgery can reduce pain and improve function in patients with intra-articular hip pathology, including FAI, but excluding osteoarthritis as primary pathology. However, these results must be interpreted with caution given the methodological flaws in the included studies. While it has been demonstrated that this improvement can be obtained up to 10 years post-surgery if osteoplasty is not performed, the effects of osteoplasty beyond 3 years have not yet been established. Further high quality comparative studies are required, particularly investigating longer-term effects of osteoplasty and the role of rehabilitation in this patient population, and the outcomes for patients with osteoarthritis.

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81. **Faucher M**, Poiraudeau S, Lefevre-Colau MM, *et al.* Assessment of the test-retest reliability and construct validity of a modified WOMAC index in knee osteoarthritis. *Joint Bone Spine* 2004;**71**:121–7.
82. **Delaunay C**, Epinette JA, Dawson J, *et al.* Cross-cultural adaptations of the Oxford-12 HIP score to the French speaking population. *Orthop Traumatol Surg Res* 2009;**95**:89–99.
83. **Okonkwo OC**, Roth DL, Pulley L, *et al.* Confirmatory factor analysis of the validity of the SF-12 for persons with and without a history of stroke. *Qual Life Res* 2010;**19**:1323–31.
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Appendix 1: Electronic database search strategy

1. Hip
2. "hip joint"
3. "Femoroacetabular joint"
4. 1 OR 2 OR 3
5. Labrum
6. Labral
7. 5 OR 6
8. "Ligamentum teres"
9. "ligamentum capitus femoris"
10. 8 OR 9
11. Arthroscopy
12. "arthroscopic surgery"
13. Scope
14. "keyhole surgery"
15. "minimally invasive surgery
16. 11 OR 12 OR 13 OR 14 OR 15
17. 4 AND 7 AND 10 AND 16
18. Shoulder
19. "glenohumeral joint"
20. "temporomandibular joint"
21. 18 OR 19 OR 20
22. 17 NOT 21
23. Laparoscopy
24. Laparoscopic
25. 23 OR 24
26. 22 NOT 25

Search strategy (condensed form)

Database searched	Search strategy used
Scopus	(hip OR "hip joint" OR "femoroacetabular joint" OR labrum OR labral OR "ligamentum teres") AND (arthroscopy OR "arthroscopic surgery" OR scope OR "keyhole surgery" OR "minimally invasive surgery") (Title/Abstract/Keyword)
Medline	Topic=(hip/ OR "hip joint" OR "femoroacetabular joint" OR labrum OR labral OR "ligamentum teres") AND(((Topic=(arthroscop$/) OR Topic=(arthroscop$ surgery)) OR Topic=(keyhole surgery)) OR Topic=(mimimally invasive surgery))
CINAHL	(hip OR "hip joint") AND (arthroscopy OR "arthroscopic surgery" OR "keyhole surgery" OR "minimally invasive surgery") (all text)
Psych Info	hip OR "hip joint" OR femoroacetabular OR labrum OR labral OR "ligamentum teres") AND (arthroscopy OR "arthroscopic surgery" OR "keyhole surgery" OR "minimally invasive surgery")
Pubmed	(hip OR "hip joint" OR femoroacetabular OR labrum OR labral OR "ligamentum teres") AND (arthroscopy OR "arthroscopic surgery" OR "keyhole surgery" OR "minimally invasive surgery") NOT (shoulder OR "glenohumeral joint" OR "temporomandibular joint") NOT laparoscopy NOT laparoscopic
Ausport	(hip OR "hip joint" OR femoroacetabular OR labrum OR labral OR "ligamentum teres") AND (arthroscopy OR "arthroscopic surgery" OR "keyhole surgery" OR "minimally invasive surgery")
Cochrane Library	(hip OR "hip joint" OR "femoroacetabular joint" OR labrum OR labral OR "ligamentum teres") AND (arthroscopy OR "arthroscopic surgery" OR scope OR "keyhole surgery" OR "minimally invasive surgery") (Title/Abstract/Keyword)
PEDro	(hip OR hip joint) advanced search
Sportsdiscus	(hip OR "hip joint" OR "femoroacetabular joint" OR labrum OR labral OR "ligamentum teres") AND (arthroscopy OR "arthroscopic surgery" OR scope OR "keyhole surgery" OR "minimally invasive surgery") (all text)

Appendix 2: Downs and Black checklist for non-randomized studies

ALL CRITERIA	DESCRIPTION OF CRITERIA (with additional explanation as required, determined by consensus of raters)	POSSIBLE ANSWERS
1	**Is the hypothesis/aim/objective of the study clearly described?** Must be explicit	Yes/No
2	**Are the main outcomes to be measured clearly described in the Introduction or Methods section?** If the main outcomes are first mentioned in the Results section, the question should be answered no. **ALL** primary outcomes should be described for YES	Yes/No
3	**Are the characteristics of the patients included in the study clearly described?** In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given. Single case studies must state source of patient	Yes/No
4	**Are the interventions of interest clearly described?** Treatments and placebo (where relevant) that are to be compared should be clearly described.	Yes/No
5	**Are the distributions of principal confounders in each group of subjects to be compared clearly described?** A list of principal confounders is provided. YES = age, severity	Yes/No
6	**Are the main findings of the study clearly described?** Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions.	Yes/No
7	**Does the study provide estimates of the random variability in the data for the main outcomes?** In non normally distributed data the inter-quartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported	Yes/No
8	**Have all important adverse events that may be a consequence of the intervention been reported?** This should be answered yes if the study demonstrates that there was a comprehensive attempt to measure adverse events (COMPLICATIONS BUT NOT AN INCREASE IN PAIN).	Yes/No
9	**Have the characteristics of patients lost to follow-up been described?** If not explicit = NO. RETROSPECTIVE – if not described = UTD; if not explicit re: numbers agreeing to participate = NO. Needs to be >85%	Yes/No
10	**Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?**	Yes/No
11	**Were the subjects asked to participate in the study representative of the entire population from which they were recruited?** The study must identify the source population for patients and describe how the patients were selected.	Yes/No/UTD
12	**Were those subjects who were prepared to participate representative of the entire population from which they were recruited?** The proportion of those asked who agreed should be stated.	Yes/No/UTD
13	**Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive?** For the question to be answered yes the study should demonstrate that the intervention was representative of that in use in the source population. Must state type of hospital and country for YES.	Yes/No/UTD
14	**Was an attempt made to blind study subjects to the intervention they have received?** For studies where the patients would have no way of knowing which intervention they received, this should be answered yes. Retrospective, single group = NO; UTD if > 1 group and blinding not explicitly stated	Yes/No/UTD
15	**Was an attempt made to blind those measuring the main outcomes of the intervention?** Must be explicit	Yes/No/UTD
16	**If any of the results of the study were based on "data dredging", was this made clear?** Any analyses that had not been planned at the outset of the study should be clearly indicated. Retrospective = NO. Prospective = YES	Yes/No/UTD
17	**In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls?** Where follow-up was the same for all study patients the answer should yes. Studies where differences in follow-up are ignored should be answered no. Acceptable range 1 yr follow up = 1 month each way; 2 years follow up = 2 months; 3 years follow up = 3months.....10years follow up = 10 months	Yes/No/UTD
18	**Were the statistical tests used to assess the main outcomes appropriate?** The statistical techniques used must be appropriate to the data. If no tests done, but would have been appropriate to do = NO	Yes/No/UTD
19	**Was compliance with the intervention/s reliable?** Where there was non compliance with the allocated treatment or where there was contamination of one group, the question should be answered no. Surgical studies will be YES unless procedure not completed.	Yes/No/UTD
20	**Were the main outcome measures used accurate (valid and reliable)?** Where outcome measures are clearly	Yes/No/UTD

	described, which refer to other work or that demonstrates the outcome measures are accurate = YES. ALL primary outcomes valid and reliable for YES	
21	**Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population?** Patients for all comparison groups should be selected from the same hospital. The question should be answered UTD for cohort and case control studies where there is no information concerning the source of patients	Yes/No/UTD
22	**Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same time?** For a study which does not specify the time period over which patients were recruited, the question should be answered as UTD. Surgical studies must be <10 years for YES, if >10 years then NO	Yes/No/UTD
23	**Were study subjects randomised to intervention groups?** Studies which state that subjects were randomised should be answered yes except where method of randomisation would not ensure random allocation.	Yes/No/UTD
24	**Was the randomised intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?** All non-randomised studies should be answered no. If assignment was concealed from patients but not from staff, it should be answered no.	Yes/No/UTD
25	**Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?** In nonrandomised studies if the effect of the main confounders was not investigated or no adjustment was made in the final analyses the question should be answered as no. If no significant difference between groups shown then YES	Yes/No/UTD
26	**Were losses of patients to follow-up taken into account?** If the numbers of patients lost to follow-up are not reported = unable to determine.	Yes/No/UTD
27	**Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance <5%** Sample sizes have been calculated to detect a difference of x% and y%.	1-5

AUTHOR	CRITERIA																												TOTAL	(%)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27			
Brunner 2009a																													21	(68)
Philippon 2010																													20	(65)
Bardakos 2008																													19	(61)
Byrd 2000																													19	(61)
Byrd 2004																													18	(58)
Ilizaliturri 2008																													18	(58)
Kamath 2009																													18	(58)
Streich 2009																													18	(58)
Brunner 2009																													17	(55)
Burnett 2006																													17	(55)
Gédouin 2010																													17	(55)
Haviv 2010																													17	(55)
Horisberger 2010																													17	(55)
Nassif 2010																													17	(55)
Philippon 2009																													17	(55)
Stähelin 2008																													17	(55)
Tzaveas 2010																													17	(55)
Byrd 2009																													16	(52)
Byrd 2010																													16	(52)
Larson 2008																													16	(52)
Nepple 2009																													16	(52)
Philippon 2010a																													16	(52)
Singh 2010																													16	(52)
Byrd 2009																													15	(48)
Byrd 2003																													15	(48)
Freedman 2006																													15	(48)
Kocher 2006																													15	(48)
Prather 2009																													15	(48)
Yamamoto 2005																													14	(45)
Byrd 2009																													13	(42)
Byrd 2001																													13	(42)
Byrd 2002																													13	(42)
Jerosch 2006																													13	(42)
Potter 2005																													13	(42)
Philippon 2007																													12	(39)
Walton 2004																													12	(39)
Kim 2007																													11	(35)
Santori 2000																													11	(35)
Boyer 2008																													10	(32)
Parvizi 2009																													9	(29)
TOTAL (/40)	37	30	1	27	34	39	9	27	30	25	0	5	0	1	1	18	3	29	40	4	3	24	1	1	11	21	40	**15.43**	**50%**
AGREEMENT (κ)	**1.0**	**0.59**	**0.91**	**0.44**	**0.40**	**0.72**	**0.96**	**0.92**	**0.74**	**0.93**	**1.0**	**0.49**	**1.0**	**0.80**	**0.81**	**0.61**	**0.87**	**0.71**	**1.0**	**0.68**	**0.51**	**0.93**	**1.0**	**0.91**	**0.43**	**0.60**	**1.0**	**0.82**	

Appendix 3. Methodological quality ratings of reviewed papers, and inter-rater agreement, on the Downs and Black critical appraisal tool (N = 42). Listed in descending order of quality rating. Dark grey shading represents a score of "yes"; light grey "unable to determine"; white "no". Criterion #27 is scored out of 5 (see Appendix 2), dark grey represents a score > 0.