BJO

HIP

Ten-year outcome following surgical treatment of femoroacetabular impingement

DOES THE EVOLUTION OF SURGICAL TECHNIQUE INFLUENCE OUTCOME?

G. Grammatopoulos, P. Laboudie, D. Fischman, R. Ojaghi, A. Finless, P. E. Beaulé

From The Ottawa Hospital, Ottawa, Canada

Aims

The primary aim of this study was to determine the ten-year outcome following surgical treatment for femoroacetabular impingement (FAI). We assessed whether the evolution of practice from open to arthroscopic techniques influenced outcomes and tested whether any patient, radiological, or surgical factors were associated with outcome.

Methods

Prospectively collected data of a consecutive single-surgeon cohort, operated for FAI between January 2005 and January 2015, were retrospectively studied. The cohort comprised 393 hips (365 patients; 71% male (n = 278)), with a mean age of 34.5 years (SD 10.0). Over the study period, techniques evolved from open surgical dislocation (n = 94) to a combined arthroscopy-Hueter technique (HA + Hueter; n = 61) to a pure arthroscopic technique (HA; n = 238). Outcome measures of interest included modes of failures, complications, reoperation, and patient-reported outcome measures (PROMs). Demographic, radiological, and surgical factors were tested for possible association with outcome.

Results

At a mean follow-up of 7.5 years (SD 2.5), there were 43 failures in 38 hips (9.7%), with 35 hips (8.9%) having one failure mode, one hip (0.25%) having two failure modes, and two hips (0.5%) having three failure modes. The five- and ten-year hip joint preservation rates were 94.1% (SD 1.2%; 95% confidence interval (CI) 91.8 to 96.4) and 90.4% (SD 1.7%; 95% CI 87.1 to 93.7), respectively. Inferior survivorship was detected in the surgical dislocation group. Age at surgery, Tönnis grade, cartilage damage, and absence of rim-trimming were associated with improved preservation rates. Only Tönnis grade was an independent predictor of hip preservation. All PROMs improved postoperatively. Factors associated with improvement in PROMs included higher lateral centre-edge and α angles, and lower retroversion index and BMI.

Conclusion

FAI surgery provides lasting improvement in function and a joint preservation rate of 90.4% at ten years. The evolution of practice was not associated with inferior outcome. Since degree of arthritis is the primary predictor of outcome, improved awareness and screening may lead to prompt intervention and better outcomes.

Cite this article: *Bone Jt Open* 2022;3-10:804–814.

Keywords: Femoroacetabular impingement, Outcome, Hip, Arthroplasty

Correspondence should be sent to Paul E. Beaulé; email: pbeaule@toh.ca

doi: 10.1302/2633-1462.310.BJO-2022-0114.R1

Bone Jt Open 2022;3-10:804–814.

Introduction

Femoroacetabular impingement (FAI) is a well-recognized cause of hip pain and an established cause of early osteoarthritis

Table I. Patient demographic details and morphological findings of the whole cohort, subdivided by surgical technique.

Parameter	Cohort	Surgical dislocation	HA + Hueter	HA	p-value
Hips, n	393	94	61	238	
Mean age, yrs (SD)	34.5 (10.0)	32.4 (9.4)	40.2 (7.9)	33.9 (10	< 0.001*
Male, n (%)	278 (71)	86 (91)	44 (72)	148 (63)	< 0.001†
Mean BMI, kg/m² (SD)	26.5 (4.6)	26.7 (4.5)	29.1 (5.3)	25.8 (4.3)	0.003*
Mean follow-up, yrs (SD)	7.5 (2.5)	9.5 (3)	8.8 (1.6)	6.3 (1.5)	< 0.001*
Morphology, n (%)					< 0.001†
Cam	284 (72.3)	64 (67)	32 (52)	188 (79)	
Pincer	22 (5.6)	9 (9)	1 (2)	12 (5)	
Mixed	87 (22.1)	22 (23)	28 (46)	37 (16)	
Radiological findings					
Mean LCEA, ° (SD)	38.4 (16.4)	48.6 (19.3)	39.3 (15.6)	33.8 (13.1)	< 0.001*
Mean Tönnis angle, ° (SD)	-0.9 (11)	-5.9 (9.8)	-2.7 (12.3)	1.6 (10.8)	< 0.001*
Mean α angle, ° (SD)	58.6 (12.4)	63.1 (14.7	59.3 (10.2)	56.5 (11.4)	< 0.001*
Mean extrusion index (SD)	16.6 (9.6)	10.5 (10)	15.7 (9.7)	19.4 (8	< 0.001*
Mean retroversion index (SD)	14 (17.5)	5.9 (14.4)	15.9 (19.4)	16.8 (17.2)	< 0.001*
Mean joint space < 2 mm, n (%)	42 (11)	4 (4)	5 (8)	33 (14)	0.016†
Tönnis OA grade, n (%)					0.001†
0	121(30.8)	23(24)	12 (20)	86 (36)	
1	232 (59)	59(62)	40 (65)	133 (56)	
2	30 (7.6)	12(13)	9 (15)	9 (4)	

*Kruskal-Wallis test.
†Chi-squared test.
HA, hip arthroscopy; LCEA, lateral centre-edge angle; OA, osteoarthritis; SD, standard deviation.

Fig. 1

Preoperative, immediate postoperative, and ten-year follow-up anteroposterior radiograph of a patient who underwent open surgical dislocation, labral repair, and femoral osteochondroplasty for the treatment of cam type femoroacetabular impingement.

(OA).[1-5] When nonoperative measures fail to improve symptoms, surgical management is the treatment of choice aiming to preserve the native hip, alleviate symptoms, and perhaps reverse or halt the degenerative process.[6,7]

FAI surgical treatment has significantly evolved over the last two decades. Surgical dislocation was favoured initially, with very good early and mid-term results,[8-11] and some recent long-term data.[12] Surgical dislocation advanced our understanding of FAI and its pathomechanisms, allowing for the evolution of arthroscopic techniques, which are now the most common treatment modality for FAI, with surgical dislocation now reserved for more complex and combined deformities. Although excellent arthroscopic short-term outcome results have been described in the literature (between two and five years),[13-17] longer-term data,[18,19] as well as outcome data on how arthroscopic compares to open treatment of FAI,[20] is limited.

The primary aim of this study was to determine the ten-year outcome of FAI treatment surgery, including the ten-year hip preservation rate and patient-reported outcome measures (PROMs). The secondary outcomes were to assess whether the evolution of practice from open to

Table II. Surgical findings and type of procedure performed for the whole cohort, subdivided by surgical technique.

Parameter	Cohort	Dislocation	HA + Hueter	HA	p-value*
Acetabular cartilage damage (Beck), n (%)					0.265
Normal	73 (19)	23 (24)	7 (11)	43 (18)	
Malcia	28 (7)	6 (6)	5 (8)	17 (7)	
Debonding	37 (9)	4 (4)	7 (11)	26 (11)	
Cleavage	151 (38)	32 (34)	25 (41)	94 (39)	
Defect	64 (16)	20 (21)	8 (13)	36 (15)	
Surgical procedure, n (%)					
FOCP	371 (94)	86 (91)	60 (98)	225 (95)	0.095
Rim-trimming	74 (19)	41 (43)	2 (3)	31 (13)	< 0.001
Chondrolabral debridement	248 (63)	53 (56)	41 (67)	154 (65)	0.008
Labral repair	140 (36)	47 (50)	0 (0)	93 (39)	< 0.001
Microfracture	47 (12)	21 (22)	3 (5)	23 (10)	0.003
Labral reconstruction	7 (1.8)	7 (7)	0 (0)	0 (0)	< 0.001

*Chi-squared test.
FOCP, femoral osteochondroplasty; HA, hip arthroscopy.

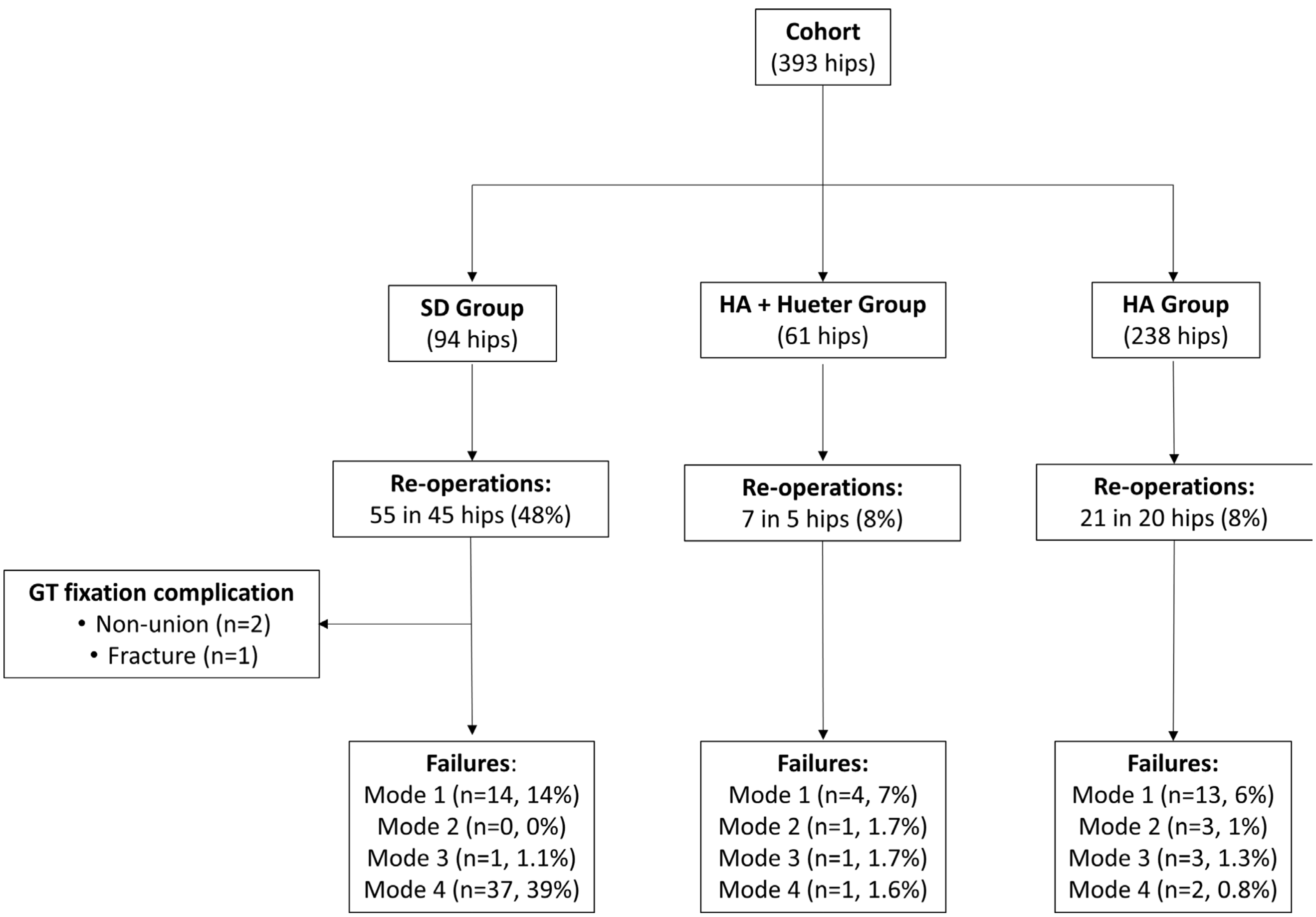

Fig. 2

Reoperations and failures among the cohort and the three surgical groups. GT, greater trochanter; HA, hip arthroscopy; SD, surgical dislocation.

arthroscopic techniques was associated with differing outcomes and determine any patient, radiological, or surgical factors associated with long-term outcome.

Methods

This is a single-centre, single-surgeon, retrospective, institutional review board-approved cohort study.

Table III. Modes of failure and type of related reoperation among the cohort and the three surgical groups.

Mode of failure	Cohort	Surgical dislocation	HA + Hueter	HA	p-value*
Mode 1, n					
Hip arthroplasty	31	14	4	13	0.054
Mode 2, n					
Hip Scope	1	0	0	1 (rim-trim)	0.511
PAO	3	0	1 (anteverting)	2 (1 anteverting, 1 instability)	
Mode 3, n					
Hip scope	5	1 (labral tear)	1 (residual cam)	3 (3 labral tears)	0.952
Mode 4, n					
Hip scope	3	0	1 adhesiolysis	2 (1 adhesiolysis, 1 loose anchor)	0.858
GT fracture	1	1	0	0	

*Chi-squared test.
GT, greater trochanter; HA, hip arthroscopy; PAO, periacetabular osteotomy.

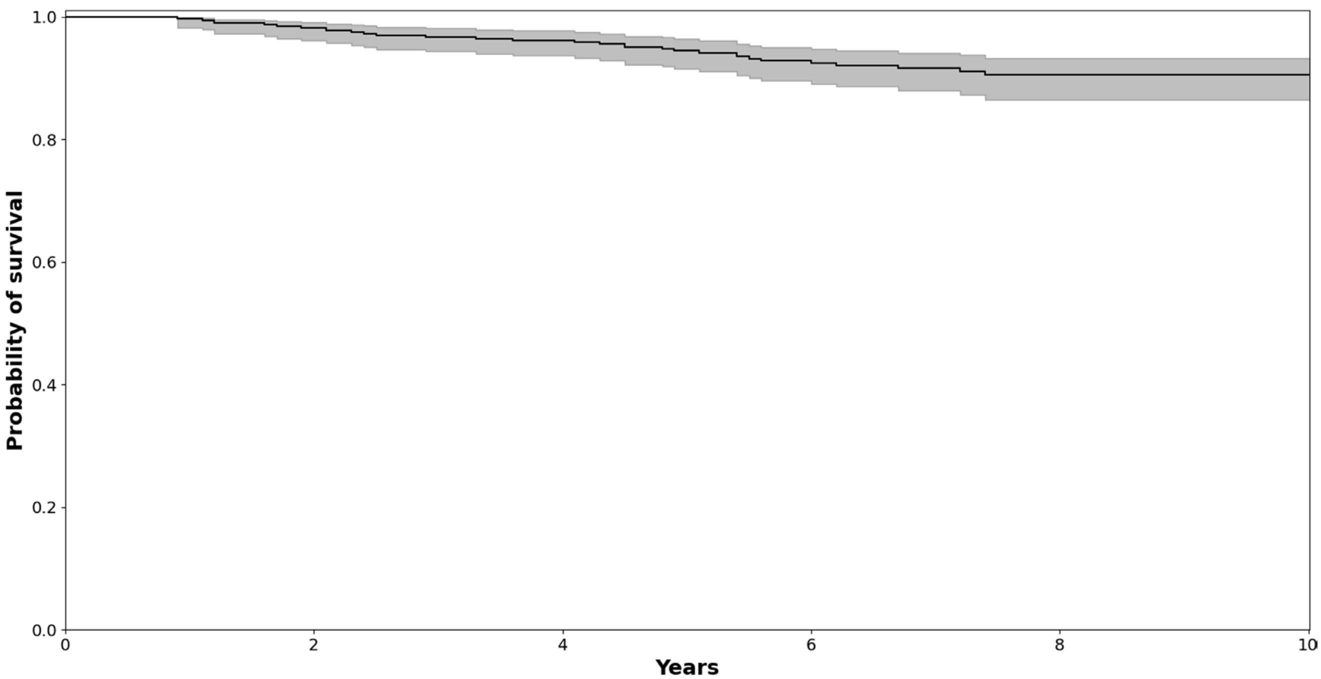

Fig. 3

Survival analysis for the whole cohort with conversion to arthroplasty as the endpoint.

Our prospective hip preservation surgery database was queried to identify hips with a minimum five-year follow-up. Between 2005 and 2015, 412 hips that underwent surgical FAI treatment were reviewed. All patients had failed nonoperative treatment for at least six months. Exclusion criteria included previous hip surgery (n = 2), the presence of features of residual paediatric disease (e.g. slipped capital femoral epiphysis and Perthes' disease) (n = 15), and the concomitant presence of symptomatic dysplasia requiring a periacetabular osteotomy (n = 2). The morphological type associated with FAI was classified by the lead surgeon (PEB) at the time of surgery and divided into three groups (cam, pincer, or mixed) using previously defined characteristics.[21,22] The resulting 393 hips (365 patients) formed the study cohort.

Over the study period, three different surgical FAI techniques were performed, reflecting the worldwide evolution of practice over the same time period: surgical dislocation, hip arthroscopy combined with Hueter approach (HA+ Hueter),[23,24] and hip arthroscopy alone (HA). The mean age was 34.5 years (standard deviation (SD) 10.0) and the majority were male (n = 278; 71%) (Table I). Overall, 94 hips were operated upon with an open surgical hip dislocation (n = 94), 61 hips underwent HA + Hueter, and the remaining 238 hips underwent HA. There were 284 hips with cam morphology, 22 hips with pincer morphology (18 global over-coverage and four acetabular isolated retroversion), and 87 hips with combined FAI (cam-pincer morphology with 60 global over-coverage and 27 isolated acetabular retroversion).

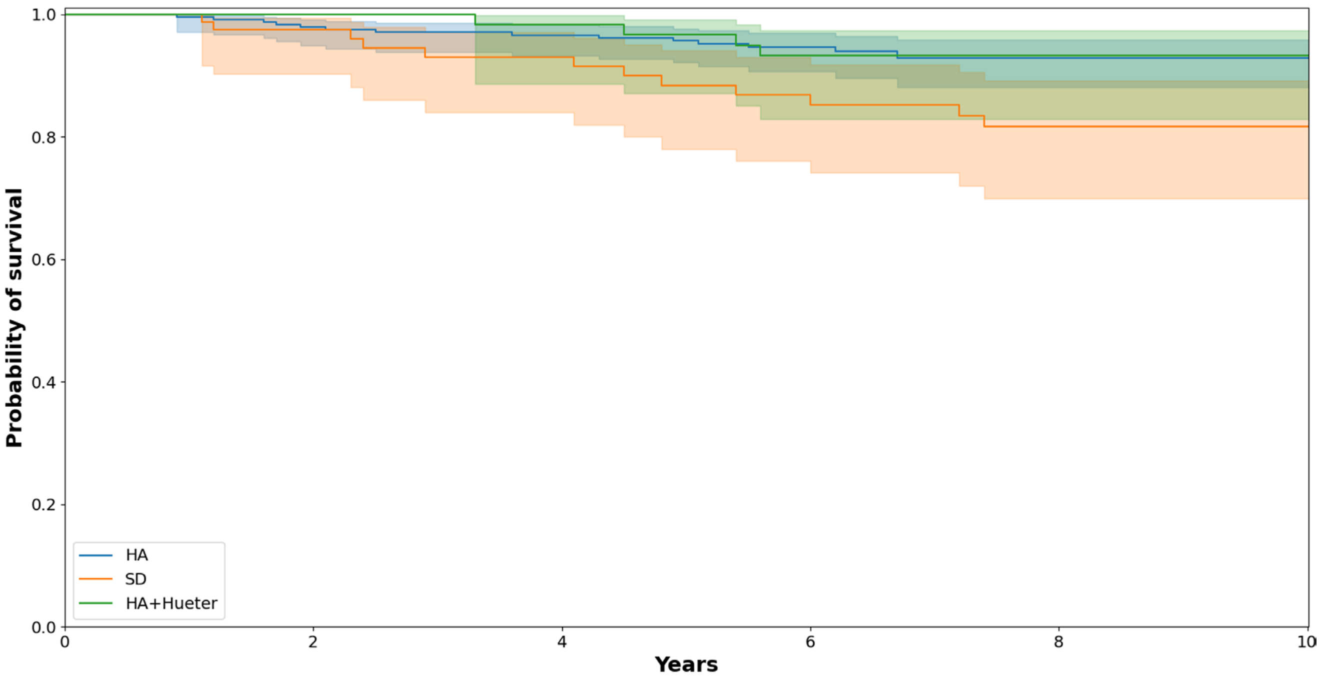

Fig. 4

Survival analysis, color coded for the three surgical groups. HA, hip arthroscopy only; SD,surgical dislocation.

Table IV. Five- and ten-year survivorship for the whole cohort and the three different surgical groups.

Survival	Cohort	Surgical dislocation	HA + Hueter	HA	p-value*
5-yr survival (95% CI)	94.1 (91.8 to 96.4)	88.3 (80.7 to 95.9)	96.6 (93.2 to 98.2)	95.7 (93.2 to 98.2)	0.048
10-yr survival (95% CI)	90.4 (87.1 to 93.7)	81.6 (72.2 to 91.0)	93.2 (86.7 to 99.7)	92.9 (89.2 to 96.6)	0.018

*Log-rank test.
CI, confidence interval; HA, hip arthroscopy.

Surgical details. The surgical dislocation technique and mid-term outcomes have been previously published (Figure 1).[9,11] Arthroscopic treatment of FAI was initially introduced in 2005, and was combined with a Hueter approach for the femoral osteochondroplasty (FOCP) after addressing the central compartment pathology. Starting in 2009 after further training, the senior surgeon moved to a pure arthroscopic technique, slowly expanding to larger cam deformities. After three years, most of the FAI treatment was performed arthroscopically, with open surgical dislocation being reserved for more complex cases, e.g. those requiring extensive FOCP superior-laterally around the vascular pedicle and/or circumferential rim-trimming for global over-coverage. Arthroscopic surgery was performed in a supine position with a traction table, with a two-portal technique and a small, inter-portal capsulotomy. The central compartment was inspected and treated first, including any labral pathology. Following release of traction, attention was turned to the peripheral compartment were a FOCP was performed. Thus, in 2006, the percentage of arthroscopies and surgical dislocations was close to 50% each, while in 2012, 85% of cases were done only arthroscopically.

Surgical details are summarized in Table II. A FOCP was performed in 371 hips (94%). A rim-trim was performed in 74 of the 109 hips with pincer morphology. Whenever possible the labrum was repaired (n = 140; 36%); 62 labral repairs were performed after rim-trim to reattach the labrum (surgical dislocation group). Otherwise, isolated labral-chondral debridement was performed (n = 248; 63%). A total of 47 hips (12%) underwent microfracture for acetabular chondral defects. The treating surgeon avoided labral resection to the bony rim and that labral debridement only involved the intra-articular-facing portion of the labrum at the junction of the acetabular cartilage, thus maximizing preservation of labral tissue.

Radiological details. All patients had standardized preoperative, radiological evaluation as previously described: anteroposterior (AP) pelvis, 90° Dunn view, and cross-table lateral.[21] Preoperative radiological analysis was performed on AP supine pelvic radiographs using Hip2Norm, a validated software (University of Bern, Switzerland).[25] Several acetabular and femoral parameters were recorded, including lateral centre-edge angle (LCEA), acetabular index, α angle, joint space narrowing, percentage femoral head coverage, extrusion index, retroversion index,

Table V. Factors associated with hip joint preservation rate and conversion to hip arthroplasty.

Factor	10-yr survival, % (SD; 95% CI)	p-value*
Demographic factors		
Age (yrs)		0.018
< 35	94.7 (1.8; 91.2 to 98.2)	
> 35	86.3 (2.8; 80.8 to 91.8)	
Sex		0.640
Male	90.8 (2; 86.9 to 94.7)	
Female	89.8 (3.1(83.8 to 95.8)	
BMI (kg/m^2)		0.707
< 30	86.6 (3.3; 80.1 to 93.1)	
> 30	87.2 (5.4; 76.7 to 97.7)	
Morphology group		0.067
Cam	90.8 (2.1; 86.7 to 94.9)	
Pincer	69.4 (13.7; 42.6 to 96.2)	
Mixed	91.9 (3.2; 85.7 to 98.1)	
Radiological factors		
Tönnis grade		< 0.001
0	99.1 (0.9; 97.4 to 100)	
1	89 (2.4; 84.3 to 93.7)	
2	68.4 (9.3; 50.4 to 86.4)	
LCEA, °		0.532
< 35	92 (2.2; 87.7 to 96.3)	
> 35	88.7 (2.8; 83.2 to 94.2)	
α angle, °		0.640
< 70	91.3 (1.9; 87.6 to 95)	
> 70	88.4 (4.7; 80.9 to 95.9)	
Acetabular index, °		0.887
< 0	89.1 (2.8; 83.6 to 94.6)	
> 0	91.7 (2.1; 87.6 to 95.8)	
Joint space, mm		0.246
< 2	84.9 (6.4; 72.4 to 97.4)	
> 2	90.8 (1.9; 87.1 to 94.5)	
Surgical factors		
Cartilage damage; per Beck)		0.061
1 to 2	96.4 (2.1; 92.3 to 100)	
≥ 3	88.5 (2.2; 84.4 to 92.8)	
Rim-trimming		0.032
No	91.4 (1.9; 87.8 to 95)	
Yes	79.2 (6.8; 59.9 to 86.5)	
Microfracture		0.346
No	88.4 (2.2; 84.1 to 92.7)	
Yes	95.2 (3.3; 88.7 to 100)	
Labral repair		0.338
No	88.9 (2.3; 84.4 to 93.4)	
Yes	87 (5.3; 76.6 to 97.4)	

*Log-rank test.
CI, confidence interval; LCEA, lateral centre-edge angle; SD, standard deviation.

Table VI. Cox regression analysis of factors associated with hip joint preservation rate. Significant factors ($p < 0.1$) in the Kaplan-Meier survival analysis were included in the analysis.

Factor	β co-efficient (95% CI)	p-value*
Age	0.58 (0.23 to 1.44)	0.236
Tönnis grade	9.31 (1.19 to 72.52)	0.033
Beck cartilage damage	0.32 (0.09 to 1.1)	0.067
Rim-trimming	0.58 (0.20 to 1.75)	0.336
FAI group morphology	0.8 (0.3 to 2.6)	0.293
Surgical group	0.38 (0.47 to 7.3)	0.237

*Cox regression analysis.
CI, confidence interval; FAI, femoroacetabular impingement.

crossover sign, joint space width, and Tönnis grade.[22,26] All measurements were performed by a hip preservation fellow not directly involved with patient care of this cohort (DF).

Surgical technique comparisons. Differences between the surgical technique groups were detected. In the HA group, there were more female patients, and the mean age and BMI were greater (Table I). Patients who underwent surgical dislocation had greater LCEA and α angle, and lesser acetabular, extrusion, and retroversion indexes (Table I). In addition, patients who underwent HA were more likely to have Tönnis grade 1 compared to the other groups (Table I). A greater proportion of cases in the surgical dislocation group underwent rim-trimming and labral repair. All these factors were therefore accounted for in subsequent multivariate analyses (Table II).

Outcome measures. All outcomes of interest were prospectively recorded. Length of outcome was determined from the last clinical encountered. Primary outcome was preservation of the hip joint with total hip arthroplasty as end point. Other outcomes included adverse events as defined by Sink et al[27] and reoperation. In addition, we determined modes of joint preservation failure (Mode 1, arthritis progression leading to arthroplasty; Mode 2, incorrect diagnosis/procedure; Mode 3, malcorrection; and Mode 4, unintended consequence of the initial surgical intervention).[28] Removal of symptomatic screws for trochanteric-sided pain was not considered a complication.

Secondary outcomes of interest included PROMs which were collected preoperatively and at latest follow-up using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC),[29] Hip Disability and Osteoarthritis Outcome Score (HOOS), activites of daily living (ADL), sports recreation activities (SRA),[30] and the University of California, Los Angeles Activity Score.[31] The minimal clinically important difference (MCID) and the patient-acceptable symptom state (PASS) were determined for the HOOS subscales. The MCID values were five points for HOOS-ADL and six points for HOOS-SRA. Furthermore, we determined PASS values as described by Chahal et al[32] as 87 for the HOOS-ADL and 75 for the HOOS-SRA.

All outcomes were described for the whole cohort and then compared for the three surgical subgroups. Furthermore, patient, disease, radiological, and surgical factors were tested for possible association with outcome

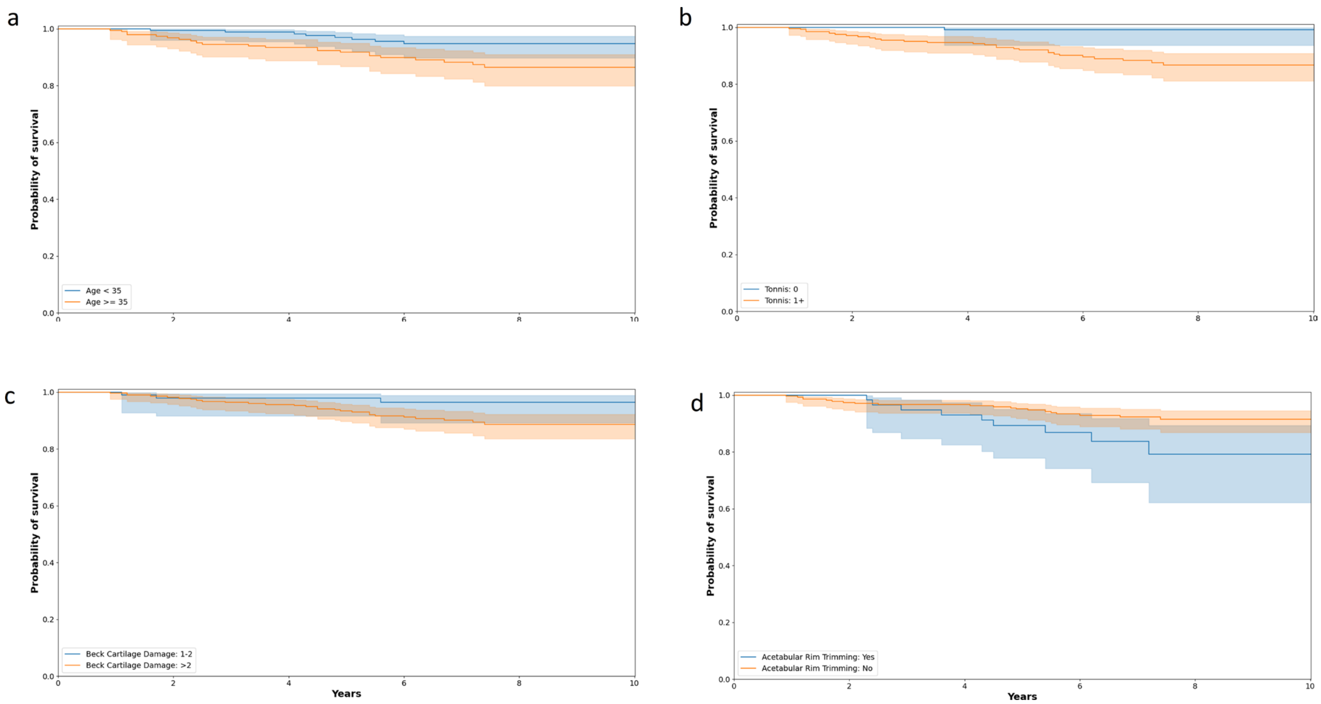

Fig. 5

Survival analysis, colour-coded for the factors associated with survival and a) age, b) Tönnis grade, c) cartilage damage per Beck, and d) rim-trimming as a part of surgery.

following surgery. Age and BMI were categorized for the survivorship analysis.

Statistical analysis. Data are reported in accordance with STrengthening the Reporting of OBservational studies in Epidemiology guidelines.[33] Data were summarized using descriptive statistics including count and percentages for categorical variables. Continuous variables were described using the mean and SD, and categorical variables were presented with total count and percentages. The chi-squared and Fisher's exact tests were used to test for differences between categorical variables, and the Kruskal-Wallis test was used for continuous variables. A multivariable binary logistic regression model was fitted to assess the impact of patient, disease, radiological, and surgical factors on joint preservation rate and achieving MCID and PASS, while adjusting for potential confounders. The variables included in the multivariable logistic regression model were selected based on the statistically significant results ($p < 0.1$) of univariate logistic regression model including only one potential predictor. Kaplan-Meier survival curves were used to determine joint preservation rate. A Cox regression analysis was run to determine factors associated with failure. The level of significance was set at $p < 0.05$. The variables included in the analysis were selected based on the statistically significant results of the univariate analysis. All analysis was performed using SPSS for Mac 9 v. 27 (IBM, USA).

Results

Mode of failure and reoperations. At a mean follow-up of 7.5 years (SD 2.5; ranging from 1.1 (early conversion to arthroplasty) to 14.2), there were 43 failures in 38 hips (9.7%), 35 hips (8.9%) having one failure mode, one hip (0.25%) having two failure modes, and two hips (0.5%) having three failure modes. The most common mode of failure was mode 1 (n = 31; 7.8%), followed by mode 3 (n = 5; 1%), mode 2 (n = 4; 1%), and mode 4 (n = 4; 1%) (Figure 2; Table III). A total of 37 patients (39% of surgical dislocations) underwent removal of screws.

Survival. The mean time to arthroplasty was 3.9 years (SD 2.0) and was not different between surgical groups (p = 0.477, Kruskal-Wallis test). For the whole cohort, the five- and ten-year hip joint preservation rates were 94.1% (SD 1.2; 95% CI 91.8 to 96.4) and 90.4% (SD 1.7; 95% CI 87.1 to 93.7), respectively (Figure 3). Inferior survivorship was detected in the surgical dislocation group at both five and ten years (Figure 4; Table IV). Age at surgery (below 35 years), Tönnis grade (0), cartilage damage per Beck et al[2] (≤ 2) absence of rim-trimming were associated with improved preservation in the univariate analysis (Table V; Figure 5). In the cox regression analysis, only Tönnis grade, was an independent predictor of hip preservation (Table VI).

PROMs. PROMs were available for 274 hips (70%) preoperatively and 218 hips (56%) postoperatively. There

Table VII. Patient-reported outcome measures.

PROM	Cohort	Surgical dislocation	HA + Hueter	HA	p-value
WOMAC (SD)					
Preoperative	60 (21)	58 (19)	62 (20)	61 (21)	0.572*
Postoperative	75 (21)	77 (20)	71 (24)	75 (21)	0.424*
Change	19 (26)	30 (33)	13 (22)	17 (24)	0.115*
HOOS-ADL (SD)					
Preoperative	65 (23)	64 (20)	65 (20)	66 (24)	0.590*
Postoperative	78 (21)	81 (19)	74 (24)	78 (22)	0.426*
Change	17 (26)	24 (28)	14 (23)	15 (25)	0.306*
MCID, %	65	77	64	62	0.251†
PASS, %	47	50	39	49	0.495†
HOOS-SRA (SD)					
Preoperative	43 (26)	36 (23)	49 (23)	43 (27)	0.033*
Postoperative	63 (27)	67 (26)	61 (28)	63 (28)	0.571*
Change	22 (31)	36 (31)	14 (29)	21 (30)	0.027*
MCID, %	71	86	67	68	0.108†
PASS, %	46	48	37	48	0.432†
UCLA (SD)					
Preoperative	6.9 (2.6)	6.9 (2.6)	6.6 (2.8)	6.9 (2.6)	0.783*
Postoperative	7.2 (2.4)	7.6 (2.2)	7.1 (2.5)	7.1 (2.5)	0.559*
Change	0.9 (3.8)	2.5 (4.5)	1.9 (4.3)	0.1 (3)	0.003*

*Kruskal-Wallis test.
†Chi-squared test.
ADL, activities of daily living; HA, hip arthroscopy; HOOS, Hip Disability and Osteoarthritis Outcome Score; MCID, minimal clinically important difference; PASS, patient-acceptable symptom state; PROM, patient-reported outcome measure; SD, standard deviation; SRA, sports recreation activities; UCLA, University of California, Los Angeles Activity Score; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

Table VIII. Review of the literature on long-term survival and its predictors after femoroacetabular impingement surgery.

Study	Surgical technique	10-yr hip preservation rate, %	Factors influencing survival
Current study	Surgical dislocation, HA + Hueter, and HA	90.4	Surgical technique, age, Tönnis grade, rim-trimming
Steppacher et al[12,36]	Surgical dislocation	89	Age, BMI, LCEA, posterior acetabular coverage
Menge et al[18]	HA	66	Age, joint space < 2 mm, microfracture
Byrd and Jones[35]	HA (but not FAI as diagnosis)	72	Preoperative OA, avascular necrosis
Ceylan et al[37]	HA + Hueter	90.92	Age, BMI, duration of symptoms, acetabular dysplasia and retroversion, higher α angle, cartilage damage, and labral resection.

FAI, femoroacetabular impingement; HA, hip arthroscopy; LCEA, lateral centre-edge angle; OA, osteoarthritis.

was a significant improvement for all PROMs (Table VII). Complete pre- and postoperative PROMs were available for 218 hips (56%); there was no difference between those with PROMs available or not between the three treatment groups (p = 0.099, chi-squared test). MCID for HOOS-ADL and HOOS-SRA was achieved for 65% (118/181) and 71% of cases (129/181), respectively. PASS for HOOS-ADL was achieved in 47% of cases (106/224) and PASS for HOOS-SRA was achieved in 46% of cases (100/219). There were significant differences between groups regarding the improvements of the PROMs with better improvement in the surgical dislocation group for HOOS-SRA (p = 0.027, Kruskal-Wallis test), and UCLA (p = 0.003, Kruskal-Wallis test). Patients who achieved MCID for HOOS-ADL had higher LCEA (38.6 (SD 14.6) vs 33.7 (SD 12.3); p = 0.022, Mann-Whitney U test) and lower retroversion index (16.7 (SD 15.6) vs 11.8 (SD 16.5); p = 0.024, Mann-Whitney U test) compared to those who did not achieve MCID for HOOS-ADL. Patients who achieved PASS for HOOS-ADL had lower BMI (25.0 (SD 3.8) vs 27.6 (SD 5.2); p = 0.001, Mann-Whitney U test) and higher preoperative α angles (58.5 (SD 13.1) vs 55.4 (SD 11.9); p = 0.031, Mann-Whitney U test) compared to those who did not achieve PASS for HOOS-ADL.

Discussion

FAI is a recognized cause of hip pain and a precursor of hip OA.[1,3-5,34] However, contrary to dysplasia, where long-term outcome following acetabular osteotomy has been well-described, the medium- and long-term chances of hip preservation among hips suffering from FAI are still limited.[18,35] The main finding of this study is that the ten-year hip preservation rate following surgical FAI treatment was 90.4%. This is a very promising finding, emphasizing the value of FAI procedures and is in line with other studies that have primarily focused on reporting outcome of FAI treatment using a single technique (Table VIII).

The diagnosis and treatment of FAI has undergone significant evolution over recent years and continues to evolve. This is demonstrated by the dramatic increase in the use of arthroscopic techniques for the treatment, and the description of new treatment options.[38,39] Changing surgical techniques should always be done cautiously, so that patient safety and effectiveness are not compromised.[40] As there has been an evolution of practice in our centre, like others around the world, it was prudent to examine this, and it is reassuring to report that outcome was very good across the three surgical techniques. Hips that underwent HA and HA + Hueter had better chances of joint preservation at ten years (92.9% and 93.2%), compared to the surgical dislocation group (81.6%). A lower ten-year preservation rate in the surgical dislocation group is likely to due to selection bias, as patients in the surgical dislocation group had different demographic characteristics, more complex morphologies, and a greater incidence of radiological joint degeneration, all of which are now recognized hallmarks associated with inferior outcome.[41–44] This is further reflected by more severe intra-articular cartilaginous damage,[45,46] and the need to perform microfracture (22%), compared to the other groups. Perhaps equally importantly, a higher percentage of cases underwent acetabular rim-trimming in the surgical dislocation group, which may be associated with inferior survivorship, a finding consistent with Steppacher et al.[11] The possible negative association of rim-trim with long-term outcome requires further study and could not be independently tested in this cohort. These results are partly in line with the systematic review of Nwachukwu et al[47] comparing open to arthroscopic techniques, which reported found comparable survivorships at four years between open (93%) and arthroscopic (90.5%) techniques. Some studies have concluded that the open technique allows a degree of correction that is difficult to reproduce arthroscopically, and that this possible under-correction may be responsible for a more rapid arthritic progress described.[48–50]

As we have gained a better understanding of what represents abnormal bony morphology, treatment principles have evolved. Acetabular rim-trimming has been shown to negatively influence outcome in the setting of retroversion.[51] It is thus plausible that reoperations which took place secondary to mode 2 failures were due to the lack of appreciation that a periacetabular osteotomy would be more suitable for the treatment of acetabular retroversion compared to isolated arthroscopic management. In our study, age, Tönnis grade, and cartilage damage were correlated with the survival of the native hip joint. The importance of these factors has been previously described in the literature,[41–44] further emphasizing the importance of timely identifications of hips at risk and prompt treatment. Surprisingly, other demographics, and radiological (< 2 mm joint-space narrowing) and surgical findings (labral repair), had no influence on the survival. The value of assessing for joint narrowing preoperatively and repairing the labrum when possible have been illustrated and form part of our current algorithm.[16,18,36,40,44,52]

Surgical FAI treatment is associated with improvement of most PROMs.[8,14,15,17,19,24,53–55] The degree of improvement in PROMs for our patients at last follow-up was consistent with the short- to mid-term literature.[56] It is therefore reassuring concerning the long-term maintenance of improvement in quality of life that one can expect following FAI treatment. We found a significantly greater improvement in the surgical dislocation group compared to the other two groups for all PROMs except HOOS-ADL. This difference may be due to disparities between groups and does not appear to be previously documented.[47] However, it was difficult to compare the different techniques due to a lack of homogeneity of the scores in the different studies.[53] In our study, we observed that the lower BMI, higher LCEA and α angle, and lower Tönnis grade were all correlated with improvement in PROMs. It is postulated that the higher the preoperative α angle, the greater the gain in mobility and improvement of adverse mechanics. The lesser improvement in PROMs in patients with more advanced Tönnis grades was also reported by Larson et al,[16] who observed lower postoperative modified Harris Hip Scores[57] with higher Tönnis grade and cartilage damage on MRI. Steppacher et al[12] also observed a correlation between postoperative outcomes and LCEA, as well as BMI and age.

This study has several limitations. First, it is a retrospective design where patient selection biases are present. However, a prospectively collected database was used, which allows for accurate capture of all pertinent data used for analysis. Second, this is a single-surgeon series and thus suffers from certain operator-dependent biases such diagnosis at the time of surgery. However, all radiological assessments were repeated using a validated tool and clearly identified cam and/or pincer to be present in all hips; hence, all cases satisfied diagnostic radiological criteria. Additionally, the type of procedure performed was similarly determined by the surgeon. Finally, comprehensive PROM data were only captured in 56% of patients, which may lead to selection biases of reported results.

In conclusion, regardless of whether open or arthroscopic surgical technique is used, FAI surgery provides a lasting improvement in functional scores and an acceptable joint preservation rate of 90.4% at ten years. The evolution of practice over the years and transition to arthroscopic techniques was not associated with inferior outcome. Since the degree of OA is the primary predictor of outcome, improving the awareness and screening for FAI and using more sensitive imaging modalities may lead to earlier intervention and better outcome.[58]

Take home message

- Femoroacetabular impingement (FAI) surgery provides a lasting improvement in functional scores and an acceptable joint preservation rate of 90.4% at ten years.
- The evolution of practice over the years and transition to arthroscopic techniques was not associated with inferior outcome.
- Since degree of arthritis is the primary predictor of outcome, improving the awareness and screening for FAI, and using more sensitive imaging modalities, may lead to earlier intervention and better outcome.

Twitter

Follow Ottawa Orthopaedics @ortho_uottawa

References

1. **Bardakos NV**, **Villar RN**. Predictors of progression of osteoarthritis in femoroacetabular impingement: a radiological study with a minimum of ten years follow-up. *J Bone Joint Surg Br*. 2009;91-B(2):162–169.
2. **Beck M**, **Kalhor M**, **Leunig M**, **Ganz R**. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. *J Bone Joint Surg Br*. 2005;87-B(7):1012–1018.
3. **Ganz R**, **Parvizi J**, **Beck M**, **Leunig M**, **Nötzli H**, **Siebenrock KA**. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop*. 2003;417:112–120.
4. **Sankar WN**, **Nevitt M**, **Parvizi J**, **Felson DT**, **Agricola R**, **Leunig M**. Femoroacetabular impingement: defining the condition and its role in the pathophysiology of osteoarthritis. J Am Acad Orthop Surg. 2013;21(1).
5. **Tannast M**, **Goricki D**, **Beck M**, **Murphy SB**, **Siebenrock KA**. Hip damage occurs at the zone of femoroacetabular impingement. *Clin Orthop Relat Res*. 2008;466(2):273–280.
6. **Beaulé PE**, **Speirs AD**, **Anwander H**, **et al**. Surgical correction of CAM deformity in association with femoroacetabular impingement and its impact on the degenerative process within the hip joint. *J Bone Joint Surg Am*. 2017;99-A(16):1373–1381.
7. **Griffin DR**, **Dickenson EJ**, **Wall PDH**, **et al**. Hip arthroscopy versus best conservative care for the treatment of femoroacetabular impingement syndrome (UK fashion): a multicentre randomised controlled trial. *The Lancet*. 2018;391(10136):2225–2235.
8. **Beaulé PE**, **Le Duff MJ**, **Zaragoza E**. Quality of life following femoral head-neck osteochondroplasty for femoroacetabular impingement. *J Bone Joint Surg Am*. 2007;89-A(4):773–779.
9. **Beaulé PE**, **Singh A**, **Poitras S**, **Parker G**. Surgical dislocation of the hip for the treatment of pre-arthritic hip disease. *J Arthroplasty*. 2015;30(9):1502–1505.
10. **Ganz R**, **Gill TJ**, **Gautier E**, **Ganz K**, **Krügel N**, **Berlemann U**. Surgical dislocation of the adult hip a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. *J Bone Joint Surg Br*. 2001;83-B(8):1119–1124.
11. **Steppacher SD**, **Huemmer C**, **Schwab JM**, **Tannast M**, **Siebenrock KA**. Surgical hip dislocation for treatment of femoroacetabular impingement: factors predicting 5-year survivorship. Clin Orthop Relat Res. 2014;472(1):337–348.
12. **Steppacher SD**, **Anwander H**, **Zurmühle CA**, **Tannast M**, **Siebenrock KA**. Eighty percent of patients with surgical hip dislocation for femoroacetabular impingement have a good clinical result without osteoarthritis progression at 10 years. Clin Orthop. 2015;473(4):1333–1341.
13. **Byrd JWT**, **Jones KS**. Arthroscopic management of femoroacetabular impingement in athletes. *Am J Sports Med*. 2011;39 Suppl:7S–13S.
14. **Chen AW**, **Craig MJ**, **Yuen LC**, **Ortiz-Declet V**, **Maldonado DR**, **Domb BG**. Five-year outcomes and return to sport of runners undergoing hip arthroscopy for labral tears with or without femoroacetabular impingement. *Am J Sports Med*. 2019;47(6):1459–1466.
15. **Gedouin J-E**, **May O**, **Bonin N**, **et al**. Assessment of arthroscopic management of femoroacetabular impingement. A prospective multicenter study. Orthop Traumatol Surg Res. 2010;96(8 Suppl):S59–S67.
16. **Larson CM**, **Giveans MR**, **Stone RM**. Arthroscopic debridement versus refixation of the acetabular labrum associated with femoroacetabular impingement: mean 3.5-year follow-up. Am J Sports Med. 2012;40(5):1015–1021.
17. **Nielsen TG**, **Miller LL**, **Lund B**, **Christiansen SE**, **Lind M**. Outcome of arthroscopic treatment for symptomatic femoroacetabular impingement. BMC Musculoskelet Disord. 2014;15(1).
18. **Menge TJ**, **Briggs KK**, **Dornan GJ**, **McNamara SC**, **Philippon MJ**. Survivorship and outcomes 10 years following hip arthroscopy for femoroacetabular impingement: labral debridement compared with labral repair. *J Bone Joint Surg Am*. 2017;99-A(12):997–1004.
19. **Öhlin A**, **Ahldén M**, **Lindman I**, **et al**. Good 5-year outcomes after arthroscopic treatment for femoroacetabular impingement syndrome. Knee Surg Sports Traumatol Arthrosc. 2020;28(4):1311–1316.
20. **Nepple JJ**, **Zaltz I**, **Larson CM**, **et al**. Surgical treatment of femoroacetabular impingement: hip arthroscopy versus surgical hip dislocation: a propensity-matched analysis. *J Bone Joint Surg Am*. 2020;102-A(Suppl 2):51–58.
21. **Barton C**, **Salineros MJ**, **Rakhra KS**, **Beaulé PE**. Validity of the alpha angle measurement on plain radiographs in the evaluation of cam-type femoroacetabular impingement. Clin Orthop Relat Res. 2011;469(2):464–469.
22. **Clohisy JC**, **Carlisle JC**, **Beaulé PE**, **et al**. A systematic approach to the plain radiographic evaluation of the young adult hip. *J Bone Joint Surg Am*. 2008;90-A(Suppl 4):47–66.
23. **Barton C**, **Banga K**, **Beaulé PE**. Anterior Hueter approach in the treatment of femoro-acetabular impingement: rationale and technique. Orthop Clin North Am. 2009;40(3):389–395.
24. **Laude F**, **Sariali E**, **Nogier A**. Femoroacetabular impingement treatment using arthroscopy and anterior approach. *Clin Orthop Relat Res*. 2009;467(3):747–752.
25. **Zheng G**, **Tannast M**, **Anderegg C**, **Siebenrock KA**, **Langlotz F**. Hip2Norm: an object-oriented cross-platform program for 3D analysis of hip joint morphology using 2D pelvic radiographs. *Comput Methods Programs Biomed*. 2007;87(1):36–45.
26. **Busse J**, **Gasteiger W**, **Tönnis D**. A new method for roentgenologic evaluation of the hip joint--the hip factor. *Arch Orthop Unfallchir*. 1972;72(1):1–9.
27. **Sink EL**, **Leunig M**, **Zaltz I**, **Gilbert JC**, **Clohisy J**, **Academic Network for Conservational Hip Outcomes Research Group**. Reliability of a complication classification system for orthopaedic surgery. *Clin Orthop Relat Res*. 2012;470(8):2220–2226.
28. **Beaulé PE**, **Bleeker H**, **Singh A**, **Dobransky J**. Defining modes of failure after joint-preserving surgery of the hip. *Bone Joint J*. 2017;99-B(3):303–309.
29. **Bellamy N**, **Buchanan WW**, **Goldsmith CH**, **Campbell J**, **Stitt LW**. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol*. 1988;15(12):1833–1840.
30. **Nilsdotter AK**, **Lohmander LS**, **Klässbo M**, **Roos EM**. Hip disability and osteoarthritis outcome score (HOOS)--validity and responsiveness in total hip replacement. *BMC Musculoskelet Disord*. 2003;4:10.
31. **Zahiri CA**, **Schmalzried TP**, **Szuszczewicz ES**, **Amstutz HC**. Assessing activity in joint replacement patients. J Arthroplasty. 1998;13(8):890–895.
32. **Chahal J**, **Van Thiel GS**, **Mather RC**, **et al**. The patient acceptable symptomatic state for the modified Harris Hip Score and Hip Outcome Score among patients undergoing surgical treatment for femoroacetabular impingement. *Am J Sports Med*. 2015;43(8):1844–1849.
33. **von Elm E**, **Altman DG**, **Egger M**, **et al**. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg*. 2014;12(12):1495–1499.
34. **Nötzli HP**, **Wyss TF**, **Stoecklin CH**, **Schmid MR**, **Treiber K**, **Hodler J**. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. J Bone Joint Surg Br. 2002;84(4):556–560.
35. **Byrd JWT**, **Jones KS**. Prospective analysis of hip arthroscopy with 10-year followup. *Clin Orthop Relat Res*. 2010;468(3):741–746.
36. **Espinosa N**, **Rothenfluh DA**, **Beck M**, **Ganz R**, **Leunig M**. Treatment of femoro-acetabular impingement: preliminary results of labral refixation. *J Bone Joint Surg Am*. 2006;88-A(5):925–935.
37. **Ceylan HH**, **Vahedi H**, **Azboy I**, **Aali Rezaie A**, **Parvizi J**. Mini-open femoroacetabular osteoplasty: risk factors for failure and conversion to hip arthroplasty. *J Bone Joint Surg Am*. 2020;102-A(12):12.
38. **Philippon MJ**, **Arner JW**, **Crawford MD**, **Bolia IK**, **Briggs KK**. Acetabular labral reconstruction with iliotibial band autograft: outcome and survivorship at a minimum 10-year follow-up. *J Bone Joint Surg Am*. 2020;102-A(18):1581–1587.
39. **Philippon MJ**, **Briggs KK**, **Hay CJ**, **Kuppersmith DA**, **Dewing CB**, **Huang MJ**. Arthroscopic labral reconstruction in the hip using iliotibial band autograft: technique and early outcomes. *Arthroscopy*. 2010;26(6):750–756.

40. **Slullitel PA**, **Grammatopoulos G**, **Smit K**, **et al**. Hip joint preservation surgery: what every orthopaedic provider needs to know. *Instr Course Lect*. 2021;70:181–208.
41. **Horisberger M**, **Brunner A**, **Herzog RF**. Arthroscopic treatment of femoral acetabular impingement in patients with preoperative generalized degenerative changes. *Arthroscopy*. 2010;26(5):623–629.
42. **Javed A**, **O'Donnell JM**. Arthroscopic femoral osteochondroplasty for cam femoroacetabular impingement in patients over 60 years of age. *J Bone Joint Surg Br*. 2011;93-B(3):326–331.
43. **Philippon MJ**, **Briggs KK**, **Yen Y-M**, **Kuppersmith DA**. Outcomes following hip arthroscopy for femoroacetabular impingement with associated chondrolabral dysfunction: minimum two-year follow-up. *J Bone Joint Surg Br*. 2009;91-B(1):16–23.
44. **Philippon MJ**, **Schroder E Souza BG**, **Briggs KK**. Hip arthroscopy for femoroacetabular impingement in patients aged 50 years or older. *Arthroscopy*. 2012;28(1):59–65.
45. **Anderson LA**, **Peters CL**, **Park BB**, **Stoddard GJ**, **Erickson JA**, **Crim JR**. Acetabular cartilage delamination in femoroacetabular impingement. Risk factors and magnetic resonance imaging diagnosis. *J Bone Joint Surg Am*. 2009;91-A(2):305–313.
46. **Beaulé PE**, **Hynes K**, **Parker G**, **Kemp KA**. Can the alpha angle assessment of cam impingement predict acetabular cartilage delamination? *Clin Orthop Relat Res*. 2012;470(12):3361–3367.
47. **Nwachukwu BU**, **Rebolledo BJ**, **McCormick F**, **Rosas S**, **Harris JD**, **Kelly BT**. Arthroscopic versus open treatment of femoroacetabular impingement: a systematic review of medium- to long-term outcomes. *Am J Sports Med*. 2016;44(4):1062–1068.
48. **Bogunovic L**, **Gottlieb M**, **Pashos G**, **Baca G**, **Clohisy JC**. Why do hip arthroscopy procedures fail? *Clin Orthop Relat Res*. 2013;471(8):2523–2529.
49. **Clohisy JC**, **Nepple JJ**, **Larson CM**, **Zaltz I**, **Millis M**. Academic network of conservation hip outcome research (ANCHOR) members. persistent structural disease is the most common cause of repeat hip preservation surgery. *Clin Orthop*. 2013;471(12):3788–3794.
50. **Meftah M**, **Rodriguez JA**, **Panagopoulos G**, **Alexiades MM**. Long-term results of arthroscopic labral debridement: predictors of outcomes. *Orthopedics*. 2011;34(10):e588–92.
51. **Zurmühle CA**, **Anwander H**, **Albers CE**, **et al**. Periacetabular osteotomy provides higher survivorship than rim trimming for acetabular retroversion. *Clin Orthop Relat Res*. 2017;475(4):1138–1150.
52. **Larson CM**, **Giveans MR**, **Taylor M**. Does arthroscopic FAI correction improve function with radiographic arthritis? *Clin Orthop Relat Res*. 2011;469(6):1667–1676.
53. **Botser IB**, **Smith TW**, **Nasser R**, **Domb BG**. Open surgical dislocation versus arthroscopy for femoroacetabular impingement: a comparison of clinical outcomes. *Arthroscopy*. 2011;27(2):270–278.
54. **Harris JD**, **Erickson BJ**, **Bush-Joseph CA**, **Nho SJ**. Treatment of femoroacetabular impingement: a systematic review. *Curr Rev Musculoskelet Med*. 2013;6(3):207–218.
55. **Hufeland M**, **Krüger D**, **Haas NP**, **Perka C**, **Schröder JH**. Arthroscopic treatment of femoroacetabular impingement shows persistent clinical improvement in the mid-term. *Arch Orthop Trauma Surg*. 2016;136(5):687–691.
56. **Minkara AA**, **Westermann RW**, **Rosneck J**, **Lynch TS**. Systematic review and meta-analysis of outcomes after hip arthroscopy in femoroacetabular impingement. *Am J Sports Med*. 2019;47(2):488–500.
57. **Byrd JW**, **Jones KS**. Prospective analysis of hip arthroscopy with 2-year follow-up. *Arthroscopy*. 2000;16(6):578–587.
58. **Grammatopoulos G**, **Melkus G**, **Rakhra K**, **Beaulé PE**. Does cartilage degenerate in asymptomatic hips with cam morphology? *Clin Orthop Relat Res*. 2019;477(5):962–971.

Author information:
- G. Grammatopoulos, BSc, MBBS, DPhil (Oxon), MRCS, FRCS (Tr&Orth), Staff Orthopaedic Surgeon
- R. Ojaghi, MD, Orthopaedic Resident
- A. Finless, BSc, Undergraduate Student
  Division of Orthopaedic Surgery, The Ottawa Hospital, Ottawa, Canada.
- P. Laboudie, MD, Staff Orthopaedic Surgeon, Division of Orthopaedic Surgery, The Ottawa Hospital, Ottawa, Canada; Service de Chirurgie Orthopedique et traumatologique, Hospital Cochin, Paris, France.
- D. Fischman, MD, Staff Orthopaedic Surgeon, Division of Orthopaedic Surgery, The Ottawa Hospital, Ottawa, Canada; Hospital Militar Santiago, Santiago, Chile.
- P. E. Beaulé, MD, FRCSC, Scientist, Staff Orthopaedic Surgeon, Division of Orthopaedic Surgery, The Ottawa Hospital, Ottawa, Canada; The Ottawa Hospital Research Institute, Ottawa, Canada.

Author contributions:
- G. Grammatopoulos: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing.
- P. Laboudie: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Project administration, Writing – original draft, Writing – review & editing.
- D. Fischman: Conceptualization, Formal analysis, Methodology, Writing – review & editing.
- R. Ojaghi: Conceptualization, Formal analysis, Writing – review & editing.
- A. Finless: Conceptualization, Methodology, Writing – review & editing.
- P. E. Beaulé: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review & editing.

Funding statement:
- The authors received no financial or material support for the research, authorship, and/or publication of this article.

ICMJE COI statement:
- Each author certifies that he or she has no commercial associations that might pose a conflict of interest in connection with the submitted article.

Acknowledgements:
- The authors would like to acknoledge Johanna Dobransky for her administrative support in completing the data collection.

Ethical review statement:
- This research has been approved by the Ottawa Health Science Research Ethics Board prior to data collection and we have complied with ethical principles regarding research with human participants.

Open access funding
- The authors confirm that the open access fee was self-funded.