The Evolution of Hip Arthroscopy: What Has Changed Since 2008—A Single Surgeon's Experience

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Purpose: To compare a single surgeon's first 200 cases of hip arthroscopy with the last 200 cases regarding patient demographic characteristics, indications for surgery, intraoperative findings, procedures performed, and patient-reported outcomes. **Methods:** Data were reviewed for all patients undergoing primary hip arthroscopy between February 2008 and August 2016 performed by a single surgeon. Of the 3,319 patients who underwent hip-preservation surgery during the study period, the first 200 (group A) and last 200 (group B) eligible for minimum 2-year follow-up were included in our analysis. **Results:** Follow-up was available for 187 of 200 patients (93.5%) and 189 of 200 patients (94.5%) in groups A and B, respectively. The groups were similar in age, sex, and body mass index ($P > .05$). Group A included significantly more patients with Tönnis grade 1 (37% vs 21%, $P < .001$). Group B consisted of significantly more ($P < .001$) labral reconstructions (10.2% vs 0%), capsular closures (72.7% vs 26.2%), and gluteus medius repairs (18.2% vs 3.2%). Femoroplasty was performed for smaller cam lesions in group B, resulting in smaller postoperative alpha angles ($45.7° \pm 7.9°$ vs $42.4° \pm 6.3°$, $P < .001$). Group B exhibited significantly higher patient-reported outcomes at minimum 2-year follow-up ($P < .05$). In addition, in group B, greater proportions of patients achieved the minimal clinically important difference and patient acceptable symptomatic state ($P < .05$). **Conclusions:** This study shows the noteworthy evolution in the management of the prearthritic adult hip occurring between 2008 and 2016. This includes improvements in preoperative patient evaluation and patient selection. In addition, the proportion of patients undergoing labral reconstruction, capsular plication, and femoroplasty has increased significantly. These developments, as well as increased surgical experience, may have contributed to improved surgical outcomes. **Level of Evidence:** Level III, retrospective comparative trial.

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Hip arthroscopy has emerged as a successful procedure in treating hip pathologies, and there has been a surge in the number of hip arthroscopies performed over the past 2 decades. In 2003, Ganz et al.[1] identified femoroacetabular impingement (FAI) and labral tears as potential causes of hip arthritis, as well as correctable causes of adult groin pain and disability. An increased understanding of the pathomechanics in the hip coupled with improvements in arthroscopic technology has led to a rise in the number of cases performed annually. Registry studies have shown an increase of more than 500% in hip arthroscopies performed between 2005 and 2013.[2-4]

Along with the growth in knowledge and surgical techniques, 2 randomized controlled trials, by Griffin et al.[5] and Palmer et al.,[6] showed that hip arthroscopy for the treatment of FAI leads to superior outcomes compared with nonoperative measures. Patient management in cases of FAI and labral tears has changed significantly over the past 2 decades. Novel procedures such as labral reconstruction and capsular plication have been developed.[7-9] In addition, specific descriptions of goals such as achieving a spherical femoroplasty have aided in defining the accuracy of FAI treatment.[10]

Surgeon experience has been shown to influence outcomes after hip arthroscopy.[11,12] Kautzner et al.[11] defined the learning curve in hip arthroscopy to be 100 cases, after which they found a reduction in complication rates and an improvement in functional outcomes. Existing literature also supports a smaller threshold, specifically 30 to 60 cases.[12] However, it has also been suggested that there is no end to the learning curve in surgery, and indeed, a surgeon never becomes immune from further learning and improvement.[13-16]

The purpose of this study was to compare the first 200 cases of hip arthroscopy with the last 200 cases of a single surgeon (B.G.D.) regarding patient demographic characteristics, indications for surgery, intraoperative findings, procedures performed, and patient-reported outcomes (PROs). Our hypothesis was that patient demographic characteristics and indications for surgery would be similar in the 2 groups yet, owing to an evolution in surgical technique and surgeon experience, the last 200 cases would exhibit different procedures performed and superior PROs.

Methods

Data were prospectively collected and retrospectively analyzed for the following 2 study periods: between February 2008 and April 2010 (group A) and between October 2015 and August 2016 (group B). Group A consisted of the senior surgeon's first 200 cases and group B consisted of the last 200 cases that were eligible for 2-year follow-up in our hip-preservation registry. Patients were included if they underwent a primary hip arthroscopy performed by the senior surgeon (B.G.D.) and had preoperative scores for the following PROs: modified Harris Hip Score (mHHS), Non-arthritic Hip Score (NAHS), Hip Outcome Score—Sport-Specific Subscale (HOS-SSS), and visual analog scale (VAS) for pain.

Patients with a Tönnis grade of osteoarthritis of 2 or higher, fracture (acetabular or femoral including slipped capital femoral epiphysis), avascular necrosis, Legg-Calvé-Perthes disease, and an inflammatory, connective tissue (Ehler-Danlos syndrome), or neoplastic (pigmented villonodular synovitis) condition were excluded from the analysis. In addition, we excluded patients with Workers' Compensation cases and patients who underwent any previous ipsilateral hip surgery. All patients participated in the American Hip Institute hip-preservation registry. Although this study represents a unique analysis, the data of some patients in this study have been reported in other studies. All data collection and reporting received institutional review board approval.

Imaging and Surgical Indications

All patients underwent a standard preoperative physical examination and radiographic evaluation, which included an anteroposterior pelvic view, a Dunn view, a cross-table lateral view, and a false-profile view. Physical examination and radiographic results were assessed by the senior surgeon (B.G.D.). Radiographic measurements were made using GE Healthcare's picture archiving and communication system (GE-PACS; GE Healthcare, Fairfield, CT). On the anteroposterior pelvic view, the degree of osteoarthritis was assessed with the Tönnis classification,[17] and the lateral center-edge angle was measured by the method of Wiberg.[18] The joint space was measured as the distance between the lateral sourcil and femoral head. The alpha angle was measured on the Dunn view by use of the method delineated by Nötzli et al.[19]

Patients underwent the same radiographic evaluation within 1 month postoperatively. In addition, the preoperative radiographic evaluation included magnetic resonance imaging (MRI) or magnetic resonance arthrography (MRA). Since its introduction to our practice in 2010, delayed gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC) was performed in cases of suspected cartilage damage. The proportion of patients who had generalized chondral damage on MRI, MRA, or dGEMRIC was reported based on radiologist interpretation. In group A, 190 patients had documented MRI findings, with 171 (91.4%) undergoing MRA and 19 (8.6%) undergoing MRI. In group B, 198 patients had documented MRI findings, with 112 (56.6%) undergoing MRA and 31 (15.7%) undergoing MRI. No patients in group A

Table 1. Summary Demographic Characteristics in Groups A and B

	Group a (n = 187)	Group B (n = 189)	*P* Value
Hips included in study			.254
Left	83 (44.4)	96 (50.7)	
Right	104 (55.6)	93 (49.2)	
Sex			.397
Female	124 (66.3)	134 (70.9)	
Male	63 (33.7)	55 (29.1)	
Age at surgery, yr	36.7 ± 13.9	37.2 ± 15.6	.879
BMI	25.3 ± 4.8	25.9 ± 5.2	.112

NOTE. Data are presented as number (percentage) or mean ± standard deviation.

BMI, body mass index.

underwent dGEMRIC, whereas 55 patients (27.8%) in group B underwent dGEMRIC.

All patients underwent conservative management of their symptoms, which included physical therapy, activity modification, and anti-inflammatory medications. Surgery was recommended for patients who did not improve significantly with nonoperative treatment after a minimum of 3 months.

Surgical Technique

All surgical procedures were performed by the senior surgeon (B.G.D.), a sports fellowship−trained surgeon with a practice focusing on hip preservation. While patients were in the modified supine position, the hip joint was accessed through an anterolateral and a midanterior portal.[20]

A diagnostic arthroscopy was performed in all cases. Intraoperatively, cartilage damage was assessed using the Outerbridge[21] and ALAD (acetabular labrum articular disruption)[22] classification systems. The condition of the labrum was classified according to Seldes et al.,[23] and that of the ligamentum teres was assessed using both the Villar[24] and Domb[25] classifications. Under fluoroscopic guidance, an acetabuloplasty was performed to correct pincer-type impingement and a femoroplasty was performed to correct cam-type impingement.

The management of labral tears has gone through multiple iterations throughout the study period to achieve optimal results. Labral repair techniques and equipment improved over the course of this study, improving our ability to produce anatomic labral repairs with restoration of the seal against the femoral head.[26-30] The reconstruction technique was gradually introduced and developed between 2010 and 2014 and gradually supplanted excision of irreparable labra.[7,31] Microfracture was used to treat patients with acetabular or femoral head Outerbridge grade 4 damage. Capsular treatment was dependent on the patient's range of motion and generalized ligamentous laxity. During the initial study period, capsulotomy alone was often performed, with repair reserved only for select cases. Adapting to advanced biomechanical knowledge, procedures such as routine capsular repair or capsular plication were developed to restore the native anatomy and treat instances of microinstability.[32-34]

Extra-articular, peritrochanteric pathology was also addressed accordingly. Patients who experienced painful external snapping underwent an iliotibial band release. Trochanteric bursitis and gluteus medius tears were treated with endoscopic bursectomy and gluteus medius repair, respectively. Painful internal snapping was treated by iliopsoas fractional lengthening with the method described by Chandrasekaran et al.[35]

Postoperative Rehabilitation

Depending on the procedures performed, patients adhered to a 20-lb flat-foot weight-bearing restriction on the operative side for 2 to 8 weeks. Patients who underwent labral repair began physical therapy on postoperative day 1 and used a hip brace and crutches for 2 weeks. Patients who underwent labral reconstruction or microfracture began physical therapy 6 weeks after surgery. On day 1 after surgery, all patients began using a continuous passive motion machine or recumbent bike. Patients also received a prescription for 325 mg of naproxen twice daily for 4 weeks.

Surgical Outcome Measurement

The following postoperative PROs were analyzed for both groups: mHHS, NAHS, HOS-SSS, and VAS. In addition, satisfaction with surgical results, rated on a scale from 0 to 10, with 10 being the most satisfied, was reported for both groups. For group B, we also

Table 2. Radiographic Measurements in Groups A and B

Radiographic Measure	Group a (n = 187)	Group B (n = 189)	*P* Value
Preoperative Tönnis grade			
0	118 (63.1)	150 (79.3)	<.001
1	69 (36.9)	39 (20.6)	
Preoperative LCEA*			.679
<18°	4 (2.2)	2 (1.1)	
18°-25°	38 (21.0)	41 (21.8)	
>25°	139 (76.8)	145 (77.1)	
Preoperative joint space, cm	0.41 ± 0.10	0.42 ± 0.11	.298
Alpha angle, °			
Preoperatively	60.6 ± 12.4	56.0 ± 11.4	<.001
Postoperatively	45.7 ± 7.9	42.4 ± 6.3	<.001
Preoperative -postoperative *P* value	<.001	<.001	
Delta	−14.8 ± 13.5	−13.6 ± 11.8	<.001
Chondral damage on MRI	53 (28.3)	17 (9.0)	<.001

NOTE. Data are presented as number (percentage) or mean ± standard deviation.

LCEA, lateral center-edge angle; MRI, magnetic resonance imaging.

*The percentages represent the proportions of patients who had LCEA measurements: 181 of the first 200 cases and 188 of the last 200 cases.

Table 3. Intraoperative Findings in Groups A and B

Intraoperative Findings	Group a (n = 187)	Group B (n = 189)	*P* Value
Seldes classification			<.001
0	1 (0.53)	6 (3.2)	
I	65 (34.8)	39 (20.6)	
II	63 (33.7)	43 (22.8)	
I and II	58 (31.0)	101 (53.4)	
ALAD classification			<.001
0	52 (27.8)	21 (11.1)	
1	25 (13.4)	69 (36.5)	
2	36 (19.3)	60 (31.7)	
3	39 (20.9)	31 (16.4)	
4	35 (18.7)	8 (4.2)	
Outerbridge classification for acetabulum			<.001
0	23 (12.3)	19 (10.1)	
1	33 (17.6)	69 (36.5)	
2	40 (21.4)	56 (29.6)	
3	39 (20.9)	30 (15.9)	
4	52 (27.8)	15 (7.9)	
Outerbridge classification for femoral head			<.001
0	99 (52.9)	173 (91.5)	
1	6 (3.2)	0 (0)	
2	18 (9.6)	3 (1.6)	
3	35 (18.7)	8 (4.2)	
4	29 (15.5)	5 (2.6)	
LT percentile classification (Domb classification)			.363
0: 0%	116 (62.0)	126 (66.7)	
1: >0% to <50%	31 (2.7)	34 (18.0)	
2: ≥50% to <100%	34 (18.2)	22 (11.6)	
3: 100%	6 (3.2)	7 (3.7)	
Villar classification of LT			<.001
0: no tear	116 (62.0)	125 (66.1)	
1: complete tear	5 (2.7)	7 (3.7)	
2: partial tear	63 (33.7)	31 (16.4)	
3: degenerative tear	3 (1.6)	26 (13.8)	

NOTE. Data are presented as number (percentage).
ALAD, acetabular labrum articular disruption; LT, ligamentum teres.

reported minimum 2-year follow-up scores on the International Hip Outcome Tool 12, as well as the physical and mental portions of the Veterans RAND 12-Item Health Survey and physical and mental portions of the Short Form 12 questionnaire. In addition, the proportions of patients who achieved the minimal clinically important difference (MCID) and patient acceptable symptomatic state (PASS) for the mHHS were calculated.[36]

Data Analysis and Statistics

Demographic variables noted for both patient populations were age at surgery, sex, laterality, and body mass index. The preoperative mHHS, HOS-SSS, and VAS score were also reported to provide a baseline for both groups. Our radiographic analysis included the following preoperative and postoperative measurements: Tönnis grade, lateral central-edge angle, alpha angle, and joint space. In addition, intraoperative variables were collected and compared between the 2 groups.

Statistical analysis was performed using Microsoft Excel (Microsoft, Redmond, WA) and the Real Statistics add-in. Continuous variables were assessed for normality with the Shapiro-Wilk test and assessed for equal variances using the *F* test. Normally distributed data were compared using a paired *t* test; non−normally distributed data of equal variance were compared using the Mann-Whitney *U* test, whereas non−normally distributed data of unequal variance were compared using the Welch test. Categorical variables were analyzed with the χ^2 test. The threshold for significance was set at $P < .05$.

Results

Patient Selection

For the first period, of 327 eligible hip arthroscopies performed, 127 were excluded for the following reasons: prior hip surgery (62), prior hip conditions (13), Tönnis grade of 2 or higher (9), Workers' Compensation cases (28), and unwillingness to participate (15). Among the remaining 200 patients, minimum 2-year follow-up was available for 187 (93.5%), and 13 (6.5%) were lost to follow-up. For the second period, of 243 eligible hip arthroscopies performed, 43 were excluded for the

Table 4. Surgical Procedures Performed in Groups A and B

Surgical Procedures	Group a (n = 187)	Group B (n = 189)	*P* Value
Labral treatment			<.001
Debridement	68 (36.4)	9 (4.8)	
Simple repair	76 (40.6)	154 (81.5)	
Base repair	31 (16.6)	1 (0.53)	
Resection	12 (6.4)	0 (0)	
Reconstruction	0 (0)	19 (10.1)	
None	0 (0)	6 (3.2)	
Capsular treatment			<.001
Repair or plication	49 (26.2)	136 (72.0)	
Release	127 (67.9)	47 (24.9)	
Partial capsulotomy	9 (4.8)	0 (0)	
None	2 (1.1)	6 (3.2)	
Acetabuloplasty	151 (80.7)	162 (85.7)	.250
Femoroplasty	130 (69.5)	183 (96.8)	<.001
Acetabular microfracture	16 (8.6)	10 (5.3)	.230
Femoral head microfracture	4 (2.1)	3 (1.6)	.989
Ligamentum teres debridement	71 (38.0)	26 (13.8)	<.001
Trochanteric bursectomy	25 (13.4)	52 (27.5)	.001
Gluteus medius repair	6 (3.2)	34 (18.0)	<.001
Traction time, min	79.4 ± 18.6	53.9 ± 18.1	<.001

NOTE. Data are presented as number (percentage) or mean ± standard deviation.

following reasons: prior hip surgery (21), prior hip conditions (2), Tönnis grade of 2 or higher (1), Workers' Compensation cases (13), and unwillingness to participate (6). Among the remaining 200 patients, minimum 2-year follow-up was available for 189 (94.5%), and 11 (5.5%) were lost to follow-up. As illustrated in Table 1, no significant differences in demographic characteristics were found between the 2 groups.

Preoperative and postoperative radiographic details are presented in Table 2. Tönnis grade 1 was present in 69 patients (36.9%) in group A and 39 patients (20.6%) in group B ($P < .001$). By use of a lateral center-edge angle of 18° to 25° to indicate borderline dysplasia, there were 38 patients (21.0%) with borderline dysplasia in group A and 41 (21.7%) in group B ($P = .679$). MRI, MRA, or dGEMRIC findings of chondral damage were noted in 53 patients (28.3%) in group A and 17 patients (9.0%) in group B ($P < .001$).

Procedures Performed

Tables 3 and 4 detail intraoperative findings and procedures performed, respectively, for both patient populations. Regarding labral tears, a significant difference in the distribution of tear type was found between the 2 groups, with group B having more combined type I and type II tears ($P < .001$). In both cohorts, the most common labral treatment was simple repair. No reconstructions were performed in group A, whereas 19 reconstructions (10.1%) were performed in group B.

Patients with ALAD (acetabular labrum articular disruption) cartilage damage of grade 3 or greater comprised 39.6% of group A and 20.6% of group B ($P < .001$). Grade 4 acetabular Outerbridge defects were found in 52 cases (27.8%) in group A and 15 cases (7.9%) in group B ($P < .001$). Femoroplasty was performed in significantly more patients in group B (183 vs 130, $P < .001$). Group B had significantly lower preoperative and postoperative alpha angles than group A (56.0° ± 11.4° vs 60.6° ± 12.4° and 45.7° ± 7.9° vs 42.4° ± 6.3°, respectively; $P < .001$) (Table 2).

Capsular release (67.9%) was the most commonly performed capsular treatment in group A, whereas capsular repair or plication (72.0%) was the most commonly performed capsular treatment in group B ($P < .001$). Gluteus medius repair was performed in 6 patients in group A and 34 patients in group B ($P < .001$). Finally, the traction time was significantly lower in group B than in group A (53.9 ± 18.1 minutes vs 79.4 ± 18.6 minutes, $P < .001$).

Surgical Outcomes

On average, patients showed significant improvements postoperatively with respect to the mHHS, NAHS, HOS-SSS, and VAS score (Table 5). No statistically significant differences in preoperative mHHS and HOS-SSS were found between the 2 groups; however, patients in group B had a significantly higher preoperative NAHS than patients in group A ($P < .01$) (Fig 1A). In addition, patients in group B experienced less pain preoperatively than patients in group A ($P < .01$) (Fig 1B).

Table 5. Patient-Reported Outcomes in Groups A and B

Patient-Reported Outcomes	Group a (n = 187)	Group B (n = 189)	*P* Value
mHHS			
Pre	61.3 ± 15.3	61.8 ± 15.6	.721
2 yr post	83.2 ± 15.9	86.1 ± 16.6	.013
Pre-post *P* value	<.001	<.001	
Delta	21.6 ± 19.9	23.8 ± 18.4	.256
NAHS			
Pre	57.7 ± 17.4	63.4 ± 16.4	<.001
2 yr post	81.6 ± 16.7	86.8 ± 16.1	<.001
Pre-post *P* value	<.001	<.001	
Delta	23.0 ± 19.4	23.1 ± 17.1	.962
HOS-SSS			
Pre	42.2 ± 25.0	40.9 ± 22.9	.583
2 yr post	71.4 ± 26.0	76.5 ± 25.5	.029
Pre-post *P* value	<.001	<.001	
Delta	28.6 ± 32.5	33.9 ± 26.7	.129
VAS score			
Pre	6.4 ± 1.8	4.9 ± 2.2	<.001
2 yr post	2.9 ± 2.5	2.0 ± 2.4	<.001
Pre-post *P* value	<.001	<.001	
Delta	−3.4 ± 3	−2.8 ± 2.8	.053
Patient satisfaction	8.0 ± 2.1	8.2 ± 2.2	.129

NOTE. Data are presented as mean ± standard deviation.

Pre, preoperative; post, postoperative; mHHS, modified Harris Hip Score; NAHS, Non-arthritic Hip Score; HOS-SSS, Hip Outcome Score−Sport-Specific Subscale; VAS, visual analog pain scale.

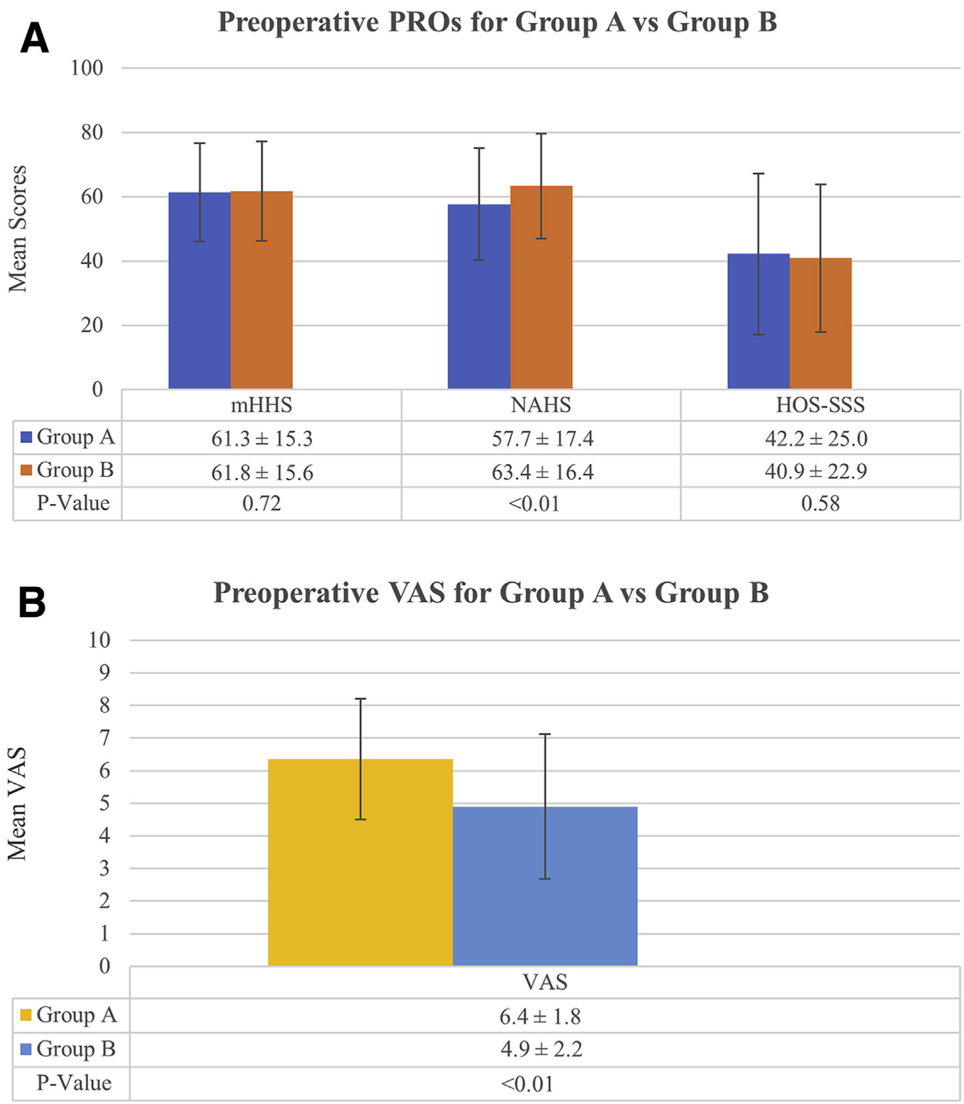


Fig 1. (A) Mean preoperative patient-reported outcomes comparing groups A and B. (HOS-SSS, Hip Outcome Score—Sport-Specific Subscale; mHHS, modified Harris Hip Score; NAHS, Non-arthritic Hip Score.) (B) Mean preoperative pain score on visual analog scale (VAS) (from 0 to 10, with 10 being the most pain) in groups A and B. The error bars indicate standard deviations.

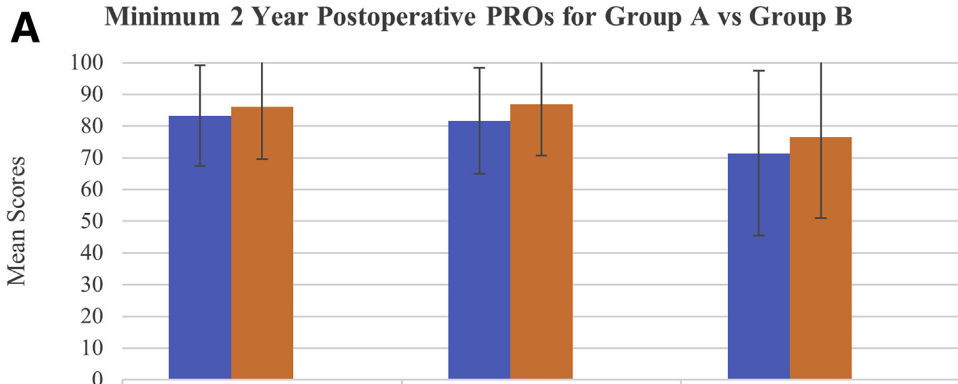
Postoperatively, patients in group B exhibited a significantly higher mHHS, NAHS, and HOS-SSS than patients in group A (Fig 2A) ($P < .05$). Furthermore, patients in group B experienced significantly less pain at a minimum of 2 years postoperatively (Fig 2B) ($P < .05$). The mean rating for satisfaction with surgery in groups A and B was 8.0 and 8.2, respectively ($P = .13$). Patients in group B showed significant improvements in the scores for all the following outcomes at a minimum of 2 years postoperatively: International Hip Outcome Tool 12, physical and mental portions of the Veterans RAND 12-Item Health Survey, and physical and mental portions of the Short Form 12 questionnaire (Table 6).

There was a significant increase in patients who achieved the MCID and PASS for the mHHS at 2 years postoperatively ($P < .05$) (Table 7). Figure 3 illustrates the trend in outcomes for group A at the following time points: preoperatively, minimum of 2 years postoperatively, and minimum of 5 of years postoperatively.

Complications and Reoperations

Details regarding revision surgery in both cohorts are shown in Table 8. In group A, 12 patients (6.4%) underwent a revision arthroscopy and 11 patients (5.8%) required a total hip replacement within 2 years of the index surgical procedure. In group B, 8 patients (4.2%) underwent a revision arthroscopy and 7 patients (3.7%) required a total hip replacement within 2 years. In addition, 1 complication (0.5%) occurred in group A (fracture) and 1 complication (0.5%) occurred in group B (infection).

The proportions of revision arthroscopies and conversions to total hip arthroplasty (THA) were higher in group A; however, these did not reach significant levels ($P = .475$ and $P = .455$, respectively). For conversion to THA in group A, survivorship analysis showed 94.5%,



	mHHS	NAHS	HOS-SSS
Group A	83.2 ± 15.9	81.6 ± 16.7	71.4 ± 26.0
Group B	86.1 ± 16.6	86.8 ± 16.1	76.5 ± 25.5
P-Value	0.01	<0.01	0.03

	VAS	Satisfaction
Group A	2.9 ± 2.5	8.0 ± 2.1
Group B	2.0 ± 2.4	8.2 ± 2.2
P-Value	<0.01	0.13

Fig 2. (A) Mean postoperative patient-reported outcomes comparing groups A and B. (HOS-SSS, Hip Outcome Score—Sport-Specific Subscale; mHHS, modified Harris Hip Score; NAHS, Non-arthritic Hip Score.) (B) Mean preoperative pain score on visual analog scale (VAS) (from 0 to 10) and mean satisfaction rating (from 0 to 10, with 10 being the most satisfied with surgical results) in groups A and B. The error bars indicate standard deviations.

89%, and 80.49% rates of survivorship at 24, 60, and 120 months, respectively.

Discussion

This analysis reflects the noteworthy evolution in a single surgeon's practice of hip arthroscopy that has occurred since 2008. In particular, 3 main domains warrant further discussion: patient selection, surgical procedures, and surgical outcomes. Preoperative imaging showed a significantly ($P < .001$) higher proportion of patients in group A with radiographic signs of arthritis (Tönnis grade 1, 36.9% vs 20.6%; chondral damage on MRI, 28.3% vs 9.0%). In addition, group A patients had, on average, larger preoperative and postoperative alpha angles (60.6° vs 56° and 45.7° vs 42.4°, respectively). Patients in group A also showed a higher prevalence of intraoperatively diagnosed cartilage damage (Outerbridge grades 3 and 4) of the femoral head and the acetabulum. More patients in group B underwent labral repair and reconstruction, capsular plication, and femoroplasty, and on average, group B patients spent less time in traction. Regarding patient selection, we found that group A consisted of significantly ($P < .001$) more patients with radiographic and MRI evidence of early-stage arthritis. In group B, there were significantly ($P < .001$) more labral reconstructions and capsular closures. Finally, group B patients had significantly higher PRO scores at 2-year follow-up, and greater proportions of group B patients achieved the MCID and PASS for the mHHS.

The most significant changes evident in our study regarding patient selection reflect (1) the improved understanding that hip arthroscopy should be limited to nonarthritic patients and (2) more advanced technology that allows us to detect patients with initial stages of arthritis, even prior to the appearance of arthritic changes on plain radiography. In our cohorts, the proportion of patients with Tönnis grade 1 was

Table 6. Additional Outcomes for Group B (n = 189)

Patient-Reported Outcome	Preoperatively	2 yr Postoperatively	*P* Value
IHOT-12 score	36.0 ± 19.7	77.4 ± 24.1	<.001
SF-12M score	52.1 ± 10.4	55.8 ± 7.8	<.001
SF-12P score	37.1 ± 8.8	49.2 ± 9.6	<.001
VR-12M score	54.9 ± 9.9	60.5 ± 7.8	<.001
VR-12P score	39.2 ± 14.0	50.6 ± 9.3	<.001

NOTE. Data are presented as mean ± standard deviation.

iHOT-12, International Hip Outcome Tool; SF-12M, Short Form 12 mental portion; SF-12P, Short Form 12 physical portion; VR-12M, Veterans RAND 12-Item Health Survey mental portion; VR-12P, Veterans RAND 12-Item Health Survey physical portion.

significantly greater in group A than in group B ($P < .001$). In addition, during the first period, a higher proportion of patients had chondral damage on preoperative MRI (28.3% vs 9.0%). These findings coincide with the 2 previously mentioned paradigm shifts in hip arthroscopy. Numerous studies have shown inferior outcomes and higher revision rates in arthritic patients.[37-41] Such findings have also been shown in large-scale registry studies,[42,43] as well as systematic reviews and meta-analyses.[44-46] Higher-resolution MRI with stronger magnetic fields, as well as the emergence of dGEMRIC, has helped clinicians decipher which patients will not benefit from hip arthroscopy by identifying early pre-radiographic stages of arthritis.[47-50] Palmer et al.[51] were able to show a correlation between baseline dGEMRIC values and 5-year joint space narrowing, and Chandrasekaran et al.[52] found significantly better outcomes in patients with a dGEMRIC index of 323 milliseconds or greater.

Of note, nearly 30% of the population in group A received a diagnosis of grade IV acetabular cartilage damage during arthroscopy. Because many of these patients also presented with femoral head cartilage damage or generalized chondral damage, microfracture was only performed in a minority of these cases (16 of 52, 30.7%).

The second important domain in which significant changes have occurred is surgical procedures. Hip arthroscopy has been described as a field "still in its infancy"[53]; thus, surgical procedures and surgical experience have been developing rapidly over the past decade. Our study showed a significant decrease in traction time between the 2 periods examined (79.4 minutes vs 53.9 minutes, $P < .001$). A possible explanation for this finding may be the development of surgical techniques as well as dedicated surgical equipment. Another contributing factor may be that with added surgical experience, it is reasonable that surgery times would also show a significant decrease.

We found significant changes in labral treatment, femoroplasty, and capsular closure. Initially, labral debridement and resection were performed in over 40% of cases. A growing understanding of the function and importance of the labrum in maintaining the suction seal of the hip joint and its contribution to joint stability has led to increased diligence in preserving the labrum.[54-56] The introduction of knotless anchors has led to improvement in the ability to expeditiously perform anatomic labral repairs.[30] These factors, as well as gained experience, have likely led to an increased tendency to repair rather than debride reparable labra. As reconstruction techniques have developed and studies have shown excellent postoperative outcomes after labral reconstruction, there has been a substantial increase in its incidence for irreparable labra. This is exemplified in our patient population, with the senior surgeon performing 0 labral reconstructions in group A and nearly 20 in group B.

Matsuda et al.[57] coined the term "critical corner" to describe residual impingement not resected during routine anterolateral femoroplasty. Residual cam lesions have been shown to lead to inferior outcomes[58] and have commonly been implicated in revision hip arthroscopies in previous studies.[59,60] These studies and others contributed to the development of the "spherical femoroplasty" as an attempt to minimize residual cam lesions and simultaneously avoid over-resection.[10] As the technique and accuracy of femoroplasty improved, even small deformities were treated with femoroplasty. This is shown in our analysis: Although group B had lower preoperative alpha angles, there was still an increase in femoroplasties performed and a lower mean postoperative alpha angle. This finding also shows the continual refinement of surgical technique and capabilities, often described as the "learning curve."

Over the past decade, the idea of microinstability of the hip has emerged, proving the importance of preservation of the hip joint stabilizers.[61] During the first period in our study, 67.9% of patients underwent a capsular release, and during the second period, 72.0% underwent either repair or plication of the capsule. Finally, recognition of and advancements in the ability to treat associated extra-articular pathology such as a gluteus medius tear are evident in the approximately 500% increase in its incidence in our study, with 6 gluteus medius repairs in group A and 34 in group B.

Table 7. Proportion of Patients Achieving MCID and PASS for mHHS in Groups A and B

Threshold for mHHS	Group a	Group B	*P* Value
MCID of 8	137 of 187 (73.3)	157 of 189 (83.1)	.029
PASS of 74	133 of 187 (71.1)	152 of 189 (80.4)	.047

NOTE. Data are presented as number (percentage). For MCID, the percentage is calculated based on the proportion of the patient population that had both preoperative and 2-year postoperative data. For PASS, the percentage is calculated based on the proportion of the patient population that had postoperative data.

mHHS, modified Harris Hip Score; MCID, minimal clinically important difference; PASS, patient acceptable symptomatic state.

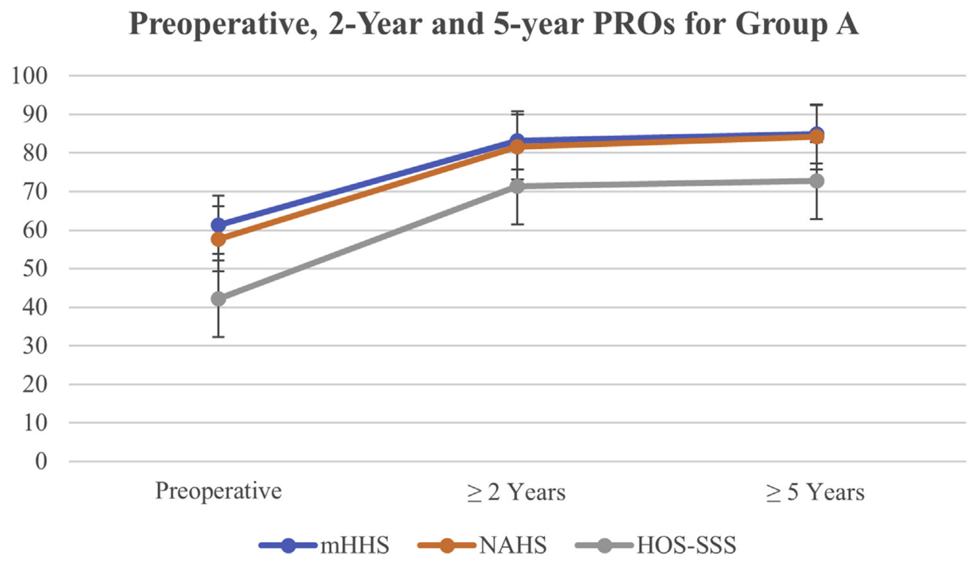


Fig 3. Comparison of patient-reported outcome scores preoperatively, at minimum 2-year follow-up, and at minimum 5-year follow-up in group A. (HOS-SSS, Hip Outcome Score—Sport-Specific Subscale; mHHS, modified Harris Hip Score; NAHS, Non-arthritic Hip Score.)

More stringent patient selection and advances in surgical techniques may have contributed to improved outcomes and lower revision and conversion rates in group B. An important consideration should be the baseline characteristics of the 2 groups. Preoperatively, group B showed similar mHHS and HOS-SSS values but a significantly higher NAHS and significantly lower VAS score for pain. This may have been one of the reasons for improved outcomes in this patient population. The proportions of patients achieving the MCID and PASS for the mHHS were significantly higher in group B. The importance of attaining these score benchmarks lies in the clinical relevance to the individual patient.[62]

In addition to patient selection and technological developments, surgical experience may contribute to the improved outcomes found in the latter cohort. This has been shown in previous registry studies evaluating a cross-sectional group of surgeons[42,43] and is in line with previous literature that has shown lower complication rates for higher-volume surgeons, even amongst those with over 100 annual cases.[42]

Although not statistically significant, a lower revision rate and lower rate of conversion to THA were found in the latter cohort. The lack of statistical significance can be attributed to the relatively low rates of conversion in both groups. A post hoc power analysis revealed that our study was underpowered with respect to the rate of revision and the rate of conversion to THA and showed that, to detect a difference, more than 1,000 patients would be required in each group.

Finally, although some studies have evaluated the suggested learning curve of hip arthroscopy,[11,12,63] others have stressed that, especially in complex surgical procedures such as hip arthroscopy, learning and improvement are evident long after reaching the theoretical plateau of the learning curve.[13] In this study, we have shown continued improvement in both surgical decision making (as evidenced by improved patient selection) and surgical techniques (as evidenced by continued refinement of labral, capsular, and osteoplasty techniques).

As the 12th-century physician-philosopher Maimonides commented on the physician, “Today he can discover his errors of yesterday and tomorrow he can obtain a new light on what he thinks himself sure of today.”[64] The process of learning—and relearning—is clearly evident in the field of hip preservation, in which we are on a constant path of discovery and innovation. Some of the procedures and perceptions

Table 8. Reoperations Within 2 Years of Index Surgery

Surgery	Group a (n = 187)	Group B (n = 189)	*P* Value
Revision arthroscopy	12 (6.4)	8 (4.2)	.475
Time to secondary arthroscopy, mo	12.1 ± 6.9 (0.8-22.1)	11.0 ± 6.7 (2.1-20.7)	.720
Hip arthroplasty	11 (5.9)	7 (3.7)	.455
Time to total hip replacement, mo	15.9 ± 7.5 (3.0-24.0)	11.1 ± 6.6 (0.2-19.2)	.178

NOTE. Data are presented as number (percentage) or mean ± standard deviation (range).

that we may consider dogma today, may prove to be inaccurate or insufficient in the future.

A major strength of this study was that our analyzed cohort is pulled from a data registry with data being collected since 2008, which allows us to examine trends in procedures and outcomes as performed by a large-volume surgeon. By analyzing a single surgeon's cases, we eliminate any confounding variables related to differences between surgeons. In addition, we report a multitude of validated functional hip outcome scores for both groups with minimum 2-year follow-up. Furthermore, we include MCID and PASS analysis to provide clinical context for the reported outcomes.

Limitations

One limitation of this study is its retrospective nature, which may introduce selection bias. Although the high rate of follow-up (>90% for both groups) hopefully minimizes this type of bias, if the patients lost to follow-up would be considered the worse-case scenario, they would dramatically influence the revision and conversion rates. In addition, our patient cohort underwent a heterogeneous mix of procedures ranging from labral reconstruction to gluteus medius repair. Moreover, the patients in group A had higher rates of cartilage damage, as well as lower scores on some of the preoperative PROs, which introduces selection bias. Therefore, although we found superior outcomes in group B, we acknowledge that a direct causation link between procedures and outcomes cannot be inferred and superior outcomes may be the consequence of improved patient selection. Finally, the ability to generalize these results to other centers is limited by the fact that all procedures analyzed in this study were performed by a single surgeon.

Conclusions

This study shows the noteworthy evolution in the management of the prearthritic adult hip occurring between 2008 and 2016. This includes improvements in preoperative patient evaluation and patient selection. In addition, the proportion of patients undergoing labral reconstruction, capsular plication, and femoroplasty has increased significantly. These developments, as well as increased surgical experience, may have contributed to improved surgical outcomes.

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