

Trajectory of clinical outcomes following hip arthroscopy in female subgroup populations

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ABSTRACT

To describe the recovery trajectory in a group of relatively older borderline dysplastic female femoroacetabular impingement syndrome (FAIS) patients following arthroscopic surgery, to determine if outcomes in this group differs from females with different age and bony morphology characteristics. Four subgroups were created to define (i) older females (>35 years), borderline dysplastic (lateral center edge angle [LCEA] ≤ 25 degrees) and anterior wall index (AWI) deficient (AWI ≤ 0.40) (older, borderline dysplastic, anterior wall deficient [ODD, reference]); (ii) younger (≤ 35 years), borderline dysplastic (LCEA ≤ 25 degrees) and deficient anterior wall (AWI ≤ 0.40) (younger, borderline dysplastic, anterior wall deficient [YDD]); (iii) older (>35 years), non-dysplastic (LCEA > 25 degrees) and non-deficient anterior wall (AWI > 0.40) (older, non-dysplastic, non-deficient anterior wall [ONN]); and (iv) younger (≤ 35 years), non-dysplastic (LCEA > 25 degrees) and non-deficient anterior wall (AWI > 0.40) (younger, non-dysplastic, non-deficient anterior wall [YNN]). One hundred and seventy-three female patients were included. Comparing mean scores, the ODD group reported significantly lower International Hip Outcome Tool (iHOT-12) change scores compared with the ONN group [23.58 ± 9.73 ; $P = 0.03$] at 12 months. ODD group also demonstrated significantly lower iHOT-12 change scores compared with the ONN (27.62 ± 8.22 ; $P < 0.01$) and YNN (25.39 ± 7.68 ; $P < 0.01$) groups at 24 months. Relatively older females with borderline dysplasia and anterior acetabular wall deficiencies had poorer iHOT-12 outcomes at both 12 and 24 months post-operatively compared with other female subgroups. In the absence of hip dysplasia and anterior wall deficiencies, superior iHOT-12 outcomes were observed in both older and younger females post-operatively.

INTRODUCTION

Arthroscopic surgery for femoroacetabular impingement syndrome (FAIS) aims to normalize abnormal morphology of the acetabulum and proximal femur to improve clinical outcomes [1]. Although the prevalence of FAIS surgery continues to increase [2], so has the diversity of the patient population. This surgical procedure was originally reserved for athletic patients; however, a growing number of non-athletic patients are undergoing surgery to manage FAIS symptoms [3]. Surgical intervention has shown to be

effective at improving clinical outcomes in both athletic and non-athletic patients [3–5]. However, recent studies show certain patient subgroups, particularly older and female patients may be at a higher risk for poorer clinical outcomes following surgery [6–8].

Patients undergoing hip arthroscopy for FAIS generally report short-term improvements in perceived and objective measures of physical function [9]. However, patients >40 years of age show poorer clinical outcomes and higher conversion rates to total hip arthroplasty compared with younger

counterparts [9]. Older patients that have undergone hip arthroscopy for management of borderline dysplasia, have also shown poorer clinical outcomes compared with younger adults at 24 months [10]. Additionally, younger patients, particularly <30 years of age, have demonstrated significantly better outcomes compared with older adults [11]. Females have also shown poorer clinical outcomes when compared with male counterparts [7, 8], including longer recovery time [6] and are more likely to undergo a second hip arthroscopy procedure [7]. Several unique personal characteristics are inherent in the older female patient population that likely influence the success of hip arthroscopy, including the presence of arthritis, reduced physical activity and concomitant musculoskeletal conditions [8, 9, 12].

Few studies have explored what accounts for these outcome differences; however, the hip morphology between sexes is vastly different and likely a major contributor to discrepancies in post-operative outcomes. Arthroscopy in patients with borderline hip dysplasia has shown mixed results in the literature [13]. Gender differences in hip acetabular and femoral morphology may negatively affect interpretation of post-operative outcomes. Variability in defining hip dysplasia specific to radiographic measurements is commonly seen in the literature [13]. Evaluation of acetabular coverage has been relatively simplistic and reported predominately using the lateral center edge angle (LCEA). Classification using cutoff values has helped to categorize into lateral acetabular undercoverage, normal coverage and overcoverage, which has important considerations with respect to degenerative changes of the hip [14]. The LCEA however lacks information regarding 3D coverage of the acetabulum. Recently, acetabular deficiency has included the anterior wall index (AWI) to quantify anterior wall coverage and improve understanding of acetabular pathomorphology [14]. However, implications of the AWI have not been explored in hip arthroscopy, particularly in relation to post-operative clinical outcomes.

Although identifying the effect radiographic measurements and personal characteristics have on clinical outcomes following surgery is important, no study has examined the trajectory of recovery by subgrouping patients based on female sex, age and hip morphology. Understanding why certain subgroups respond better than others may lead to better presurgical decision making and improved health care delivery. Therefore, the purpose of this study was to describe the recovery trajectory in a group of older, borderline dysplastic, female FAIS patients following arthroscopic surgery, to determine if clinical outcomes in this group differs from females with different age and hip morphology characteristics. We hypothesized that older females with acetabular deficiencies would report

poorer outcomes on the International Hip Outcome Tool (iHOT-12) over time compared with other subgroups.

MATERIALS AND METHODS

Study design and participants

This observational study was conducted using a female cohort undergoing primary hip arthroscopy for FAIS between January 2011 and June 2017. Inclusion criteria were female patients, <60 years of age, diagnosed with FAIS and underwent an uncomplicated primary hip arthroscopy procedure from a single board-certified orthopedic surgeon (H.S.W.) within a single healthcare hospital (Murray, UT, USA). Exclusion criteria were patients with missing data of self-reported iHOT-12 outcomes scores, bilateral FAIS surgeries, revision hip arthroscopy or conversion to total hip arthroplasty after primary arthroscopy. The Institutional Review Board at Intermountain Healthcare (IRB#: 1040265) approved this study and the rights of subjects were protected.

Procedures

Subgroup allocation was defined based on (i) age (>35 versus ≤ 35 years), (ii) acetabular coverage (LCEA) (borderline dysplastic ≤ 25 degrees versus non-dysplastic >25 degrees) and (iii) anterior wall coverage (AWI) (deficient ≤ 0.40 versus non-deficient >0.40)] (Table 1). A priori subgroup comparisons of the female patients were identified to minimize the number of comparisons relative to age and hip morphology. Thus, four-group categorical variables were created to define (i) older female (>35 years), borderline dysplastic (LCEA ≤ 25 degrees) and anterior wall deficient (AWI ≤ 0.40) (ODD, reference); (ii) younger (≤ 35 years), borderline dysplastic (LCEA ≤ 25 degrees) and deficient anterior wall (AWI ≤ 0.40) (YDD); (iii) older (>35 years), non-dysplastic (LCEA > 25 degrees) and non-deficient anterior wall (AWI > 0.40) (ONN); and (iv) younger (≤ 35 years), non-dysplastic (LCEA > 25 degrees) and non-deficient anterior wall (AWI > 0.40) (YNN).

The radiographic evaluation of acetabular coverage included LCEA and AWI [14, 15]. Radiographic software (Agfa IMPAX 6.6.1, Mortsels, Belgium) was used to create a circle over the femoral head that best approximated the femoral head shape and center of rotation. The LCEA radiographic measurements were calculated by taking the angle formed by a vertical line and a line originating at the femoral head center with the lateral edge of the acetabular sourcil [14]. The AWI radiographic measurement was performed by bisecting the center of the femoral head and laterally along the middle of the femoral head neck. Two

Table I. Descriptive characteristics of participants based on subgrouping at baseline

Variable/Subgroups	ODD (n = 24)	YDD (n = 21)	ONN (n = 59)	YNN (n = 69)
Age, years	43.0 (7.1)	28.1 (7.0)	43.3 (5.2)	24.6 (6.2)
Sex, n (% female)	24 (100)	21 (100)	59 (100)	69 (100)
BMI, kg/m ²	26.6 (6.6)	25.8 (7.4)	25.3 (5.1)	24.2 (5.7)
LCEA, degree	20.1 (3.7)	21.1 (2.3)	30.1 (3.7)	30.7 (4.9)
AWI, ratio	0.29 (0.1)	0.29 (0.6)	0.53 (0.1)	0.54 (0.1)
Tegner activity score	5.2 (1.2)	6.8 (2.2)	5.5 (1.7)	6.8 (1.9)
Tonnis grade	0.5 (0.5)	0.3 (0.5)	0.3 (0.4)	0.1 (0.3)
Labral repair, n (%)	15 (62.5)	18 (84.6)	30 (50.9)	34 (49.3)
Labral debridement, n (%)	9 (37.5)	0 (0)	21 (35.6)	21 (30.4)
Femoroplasty, n (%)	18 (75.0)	16 (76.9)	47 (79.7)	48 (69.6)

Values represented as mean (SD), unless otherwise stated. ODD, older female, borderline dysplastic and anterior wall deficient; YDD, younger female, borderline dysplastic and deficient anterior wall; ONN, older female, non-dysplastic and non-deficient anterior wall; YNN, younger female, non-dysplastic and non-deficient anterior wall; BMI, body mass index; LCEA, lateral center edge angle; AWI, anterior wall index; Pre-op, pre-operative; iHOT-12, International Hip Outcome Tool 12 score.

measurements were obtained along this line. First, was the radius taken from the center of the femoral head to the point on the medial femoral head. Second, was the anterior wall starting at the most lateral part of the anterior wall to the medial femoral head. The AWI was calculated by dividing the anterior wall by the radius [14]. Two clinical researchers (D.R.W. and J.D.M.) evaluated all imaging based on standing anteroposterior radiography.

The surgical interventions were performed with specific anterior approach procedures, T-capsulotomy with capsular closure and precautions under general anesthesia. The surgical procedure was performed as follows: In a supine position, standard anterolateral and mid-anterior arthroscopic portals were created to access the anterolateral extracapsular space. A longitudinal capsulotomy was created at the 2 o'clock location from the reflected rectus femoris head proximally to the base of the neck. Limited proximal T-extension capsulotomy both superolaterally and anteromedially was performed at the acetabular attachment only as necessary for exposure. Traction was applied to the surgical limb, visualizing the central compartment and surgical tasks accomplished on the acetabulum as indicated. Traction was then released, and the peripheral compartment inspected with femoroplasty performed as indicated. Throughout the procedure fluoroscopic imaging was utilized to guide and verify satisfactory bone resection. The longitudinal capsulotomy along the length of the femoral neck was closed with multiple interrupted non-absorbable no. 2 sutures. The horizontal portion of the

capsule along the origin of the capsule was not closed secondary to this portion being significantly shorter than the traditional interportal capsulotomy and did not extend medial to the anterior inferior iliac spine, thus not interrupting the majority of the iliofemoral ligament. Capsular closure without plication was performed following conclusion of surgical procedures.

All patients participated in a standard 3-phase rehabilitation protocol at the same facility (Murray, UT, USA). Phase 1 (0–4 weeks) of the rehabilitation protocol consisted of passive, active-assist and active range of motion exercises, stationary bicycling, muscle-activation exercises and modified weight bearing until gait mechanics were normalized. Phase 2 (4–8 weeks) emphasized progressive range of motion and flexibility exercises, muscle strengthening, neuromuscular control training and functional activities. Phase 3 (8–12 weeks) focused on restoring full, symmetric, passive range of motion, muscle strengthening, higher-level neuromuscular control tasks and progressing to higher-level sport or recreational activities as appropriate.

Outcome measures

The shortened version of the iHOT-12, a validated 12-item instrument was used to measure the impact of physical function both pre- and post-operatively [16]. The iHOT-12 survey has excellent agreement with the original iHOT-33 and is shown to be valid, reliable and responsive to change [16, 17]. Scores range from 0 to 100 and is calculated as the mean of all the visual analog scale scores as

measured in millimeters [18]. The iHOT-33 has a minimal clinically important difference (MCID) score of 6.1; however, no MCID has been established for the iHOT-12 [16, 19]. Studies have adapted the iHOT-33 MCID to 2.2 for use with the iHOT-12 [20]. The iHOT-12 measures were collected pre-operatively (-7.0 ± 4.9 months), 3 months (2.7 ± 0.8), 12 months (11.9 ± 1.5) and 24 months (23.1 ± 1.8) post-operatively to evaluate recovery trajectory following surgery. The iHOT-12 measures were collected at routine office visits for pre-operative and 3 month time-points, while 12 and 24 month outcomes were collected by postal mail follow-up.

Statistical analysis

The outcomes at each timepoint were screened for univariate outliers using scatterplots, k-density plots, boxplots and z-scores (using a ± 3.0 z-score cut-point). Sensitivity analyses were performed, omitting identified potential outliers. However, if the parameter estimates did not significantly change, signifying the potential outlier cases were not influential, the outliers were kept in the final analyses.

Multivariable linear regression models with robust standard errors were used and *a priori* selected comparisons were made using Wald post-tests to examine subgroup comparisons on the iHOT-12 change scores after controlling for timing of post-operative assessment at each timepoint [21]. To minimize the number of contrasts performed, the older female, borderline dysplastic and anterior wall deficient (ODD) subgroup was considered the reference group for all analyses. Additionally, the p-values for all pairwise tests were adjusted using Bonferroni multiple comparison procedure [22]. Generalized estimating equations, with an unstructured correlation matrix, were also used to evaluate iHOT-12 measures over time within each subgroup and the appropriate post-estimation commands were used to compare scores between time intervals. Alpha level to test for statistical significance was set at $P \leq 0.05$ and all analyses were carried out using STATA v14.1 statistical software package (College Station, TX, USA). Sample size of $n = 91$ provided 80% power to detect a standardized mean difference (MD) in the repeated measures of 0.30 SD, assuming the two repeated measures have a correlation of $r = 0.50$.

RESULTS

Of the initial 248 health records extracted, 13 records were excluded due to patients undergoing a second surgical procedure shortly after the primary unilateral hip arthroscopy [six patients underwent revision arthroscopy (ODD, 0; YDD, 1; ONN, 2; YNN, 3) and seven patients converted to a total hip replacement (ODD, 3; YDD, 1; ONN, 2;

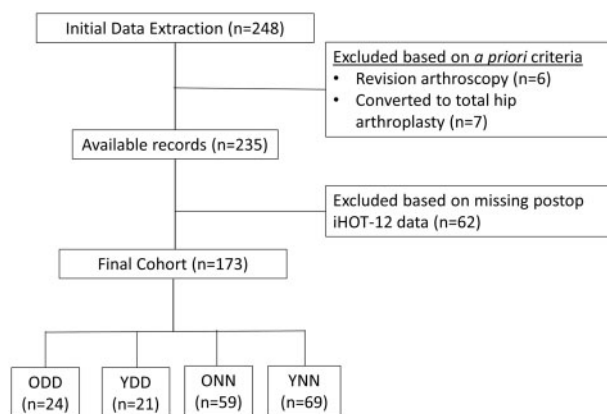


Fig. 1. STROBE flow diagram. ODD, older, borderline dysplastic and anterior wall deficient; YDD, younger, borderline dysplastic and anterior wall deficient; ONN, older, non-dysplastic and non-deficient anterior wall, YNN, younger, non-dysplastic and non-deficient anterior wall.

YNN, 1)]. After exclusion of health records missing iHOT-12 scores ($n = 62$), 173 patients were available for statistical analysis (Fig. 1).

After correction for multiple comparisons and controlling for timing of post-operative assessment, the ODD group demonstrated significantly lower iHOT-12 change scores compared with the ONN group (MD, 23.58 ± 9.73 ; $P = 0.03$) at 12 months (Table II). The ODD group also demonstrated significantly lower iHOT-12 change scores compared with the ONN (MD, 27.62 ± 8.22 ; $P < 0.01$) and YNN (MD, 25.39 ± 7.68 ; $P < 0.01$) groups at 24 months (Table II). No significant between group differences were observed at 3 months post-operatively.

Trajectory of recovery across all subgroups combined, after correcting for multiple comparisons, resulted in significant improvements in iHOT-12 from baseline (pre-operative visit) to 3 months ($\beta = 36.4$, 95% CI 31.5, 41.2, $P < 0.01$; Fig. 2) and from 3 to 12 months ($\beta = 10.1$, 95% CI 5.2, 14.9, $P < 0.01$; Fig. 2) post-operatively. No significant differences were observed from 12 to 24 months ($P > 0.05$) post-operatively.

Trajectory of recovery for each subgroup, after correcting for multiple comparisons, resulted in significant improvements in iHOT-12 from baseline and 3 month visits for each subgroup (ODD: $\beta = 30.1$, 95% CI 15.1, 45.1, $P < 0.01$ | YDD: $\beta = 44.8$, 95% CI 22.2, 67.3, $P < 0.01$ | ONN: $\beta = 38.8$, 95% CI 30.3, 47.4, $P < 0.01$ | YNN: $\beta = 39.3$, 95% CI 31.3, 47.5, $P < 0.01$; Fig. 3). Significant differences were also observed between the 3 and 12 month visits for the ONN group ($\beta = 14.6$, 95% CI 6.1, 23.2, $P < 0.01$; Fig. 3). No significant differences

Table II. Multivariable regression models with robust standard errors on iHOT-12 change scores over time

Time/Group	B ^a	SE	β^b	P-value ^c	95% CI
3 months					
ODD	REF	—	—	—	—
YDD	-4.04	7.87	-0.05	1.00	-19.62, 11.53
ONN	3.56	5.62	0.08	1.00	-7.54, 14.67
YNN	3.92	5.58	0.08	1.00	-7.11, 14.96
12 months					
ODD	REF	—	—	—	—
YDD	21.26	12.79	0.20	0.27	-4.03, 46.56
ONN	23.58	9.73	0.42	0.03	4.32, 42.83
YNN	17.82	9.66	0.33	0.18	-1.29, 36.94
24 months					
ODD	REF	—	—	—	—
YDD	7.85	18.72	0.07	1.00	29.37, -45.08
ONN	27.62	8.22	0.51	<0.01	11.28, 43.96
YNN	25.39	7.68	0.46	<0.01	10.11, 43.96

ODD, older female, borderline dysplastic and anterior wall deficient (reference); YDD, younger female, borderline dysplastic and deficient anterior wall; ONN, older female, non-dysplastic and non-deficient anterior wall; YNN, younger female, non-dysplastic and non-deficient anterior wall. ^aUnstandardized regression coefficient. ^bStandardized regression coefficient. ^cAdjusted for multiple comparison using Bonferroni procedure.

were observed between the 12 and 24 month visits for any of subgroups.

DISCUSSION

The purpose of this study was to describe the recovery trajectory in a group of relatively older borderline dysplastic female FAIS patients following arthroscopic hip surgery, to determine if clinical outcomes in this group differs from females with other age and hip morphology characteristics. Our data shows, as a cohort, patients' demonstrated significant improvement in iHOT-12 scores compared with baseline and continued improvement up to 12 months following surgery. Further findings show, when patients were classified based on subgroup allocation, older non-dysplastic and non-anterior wall deficient females demonstrated approximately a 24- (12 months) and 28-point (24 months) improved iHOT-12 change score compared to the older borderline dysplasia and anterior wall deficient

females. Younger non-dysplastic and non-anterior wall deficient females demonstrated approximately a 25-point improved iHOT-12 change score compared to the older borderline dysplasia and anterior wall deficient females 24 months post-operatively. Younger borderline dysplasia and anterior wall deficient females showed no differences in clinical outcomes compared to older borderline dysplasia and anterior wall deficient females at all timepoints.

Several studies have shown patients demonstrate marked improvement in clinical outcomes when compared with baseline and continue to improve up to 12 months following surgery [5, 7, 12, 23]. However, no study has compared clinical outcomes based on subgrouping patients on known influential personal characteristics to determine a more specific understanding of trajectory of recovery following hip arthroscopy. Our study is the first to compare the trajectory of recovery by subgrouping female patients based on age and hip morphology following arthroscopy for FAIS. Our results suggest anterior and superior acetabular hip morphology deficiencies leads to poorer iHOT-12 change scores, independent of age, compared with those without acetabular deficiencies. Patients with borderline dysplasia and anterior wall deficiency plateaued at 3 months with no continual improvement observed at 12 months post-operatively. Similar findings have showed patients following hip arthroscopy maximize iHOT-33 and Harris Hip scores within the first 6 months with no significant additional gain observed at 24 months following surgery [12]. Further data showed these patients demonstrated trends, although non-significant, toward poorer iHOT-12 change scores at 24 months post-operatively. This variation in self-reported outcomes may be important in identifying the most appropriate surgical candidates and/or setting realistic patient expectations in functional recovery for those undergoing surgery with hip morphology deficiencies.

Prior studies have shown the presence of hip dysplasia leads to inferior outcomes [24], with higher risk of conversion to periacetabular osteotomy and a contributing factor to total hip arthroplasty [25, 26]. These studies have used the LCEA to define hip dysplasia; however, it has been shown that 3D coverage of the acetabulum requires additional measurements to determine true joint coverage [27–29]. As first proposed by Siebenrock *et al.* [14], the AWI provides necessary information about anterior acetabular wall coverage and proposed normative values to identify deficient coverage. The combination of both radiographic measurements provides a more accurate assessment of acetabular coverage deficiencies and may be more informative at identifying higher risk patients. Our results demonstrate that acetabular deficiencies, more so

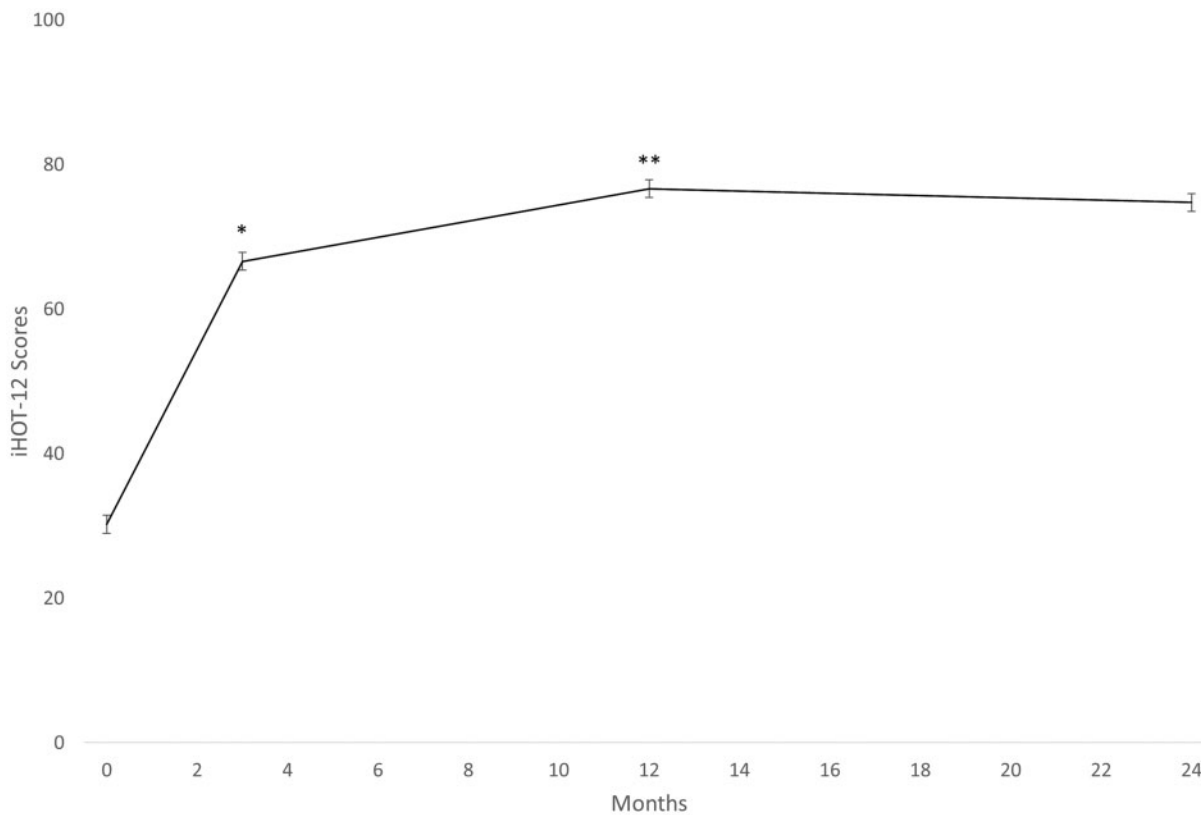


Fig. 2. Graphic display of iHOT-12 results of females undergoing hip arthroscopy for FAIS across all subgroups combined. * $P < 0.05$ (pre-operative to 3 months post-operative visits); ** $P < 0.05$ (3–12 months post-operative visit).

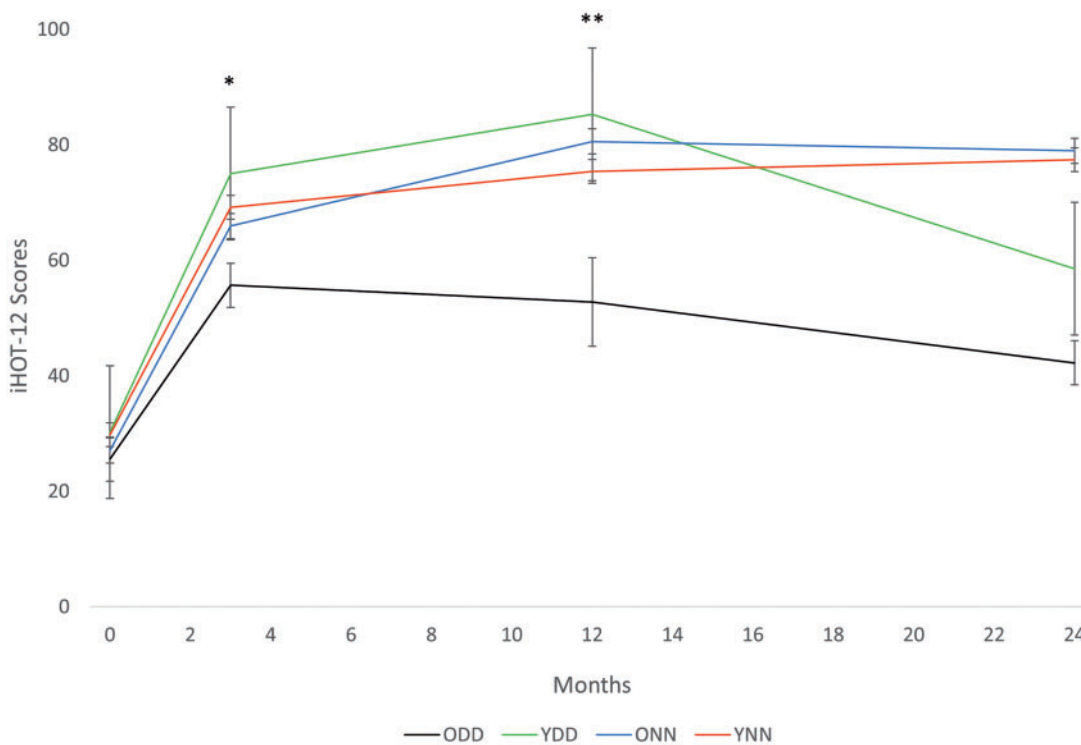


Fig. 3. Graphic display of iHOT-12 results of females undergoing hip arthroscopy for FAIS across each subgroup combined. ODD, older, borderline dysplastic and anterior wall deficient; YDD, younger, borderline dysplastic and anterior wall deficient; ONN, older, non-dysplastic and non-deficient anterior wall, YNN, younger, non-dysplastic and non-deficient anterior wall. * $P < 0.05$ (pre-operative to 3 months post-operative visits, significant difference found in all groups); ** $P < 0.05$ (3–12 months post-operative visit, significant difference found only in the ONN group).

than age, may contribute more to inferior clinical outcomes post-operatively. We found no difference between the older and younger subgroups who demonstrated acetabular deficiencies at the 24 month follow-up. This highlights the importance of examining hip morphology within the FAIS population, in addition to demographics. Although this study did not serve to examine the causal inference of these poorer outcomes, it may be possible that the decreased anterior bony support and shallow hip socket in these non-arthritic patients leads to poorer clinical outcomes due to iatrogenic instability and/or soft tissue overload.

Relatively older patients have shown inferior clinical outcomes in the FAIS surgical population [10, 24]. Females older than 45 years have shown significantly poorer clinical outcomes compared with females younger than 30 and between 30 and 45 years of age [11]. Other studies have shown patients older than 38 years of age undergoing FAIS arthroscopy with the presence of hip dysplasia showed inferior clinical outcomes post-operatively and showed nearly a six time greater risk of surgical failure [24]. Our findings demonstrate the trajectory of recovery was less dependent on age and more dependent on the pre-operative hip morphology. We did not examine the relationship of age on iHOT-12 scores independently; however, the descriptive trends observed at each timepoint did not appear to show differences between the relatively older and younger subgroups.

A more refined shared decision-making model can be achieved by better understanding how hip morphology features and age influence clinical outcomes and timing of post-operative recovery in female patients following hip arthroscopy. Although our results certainly warrant further investigation into the role of subgroup allocation of patients, it appears doing so may lead to more appropriate surgical candidate selection. The role of conservative management within the FAIS population remains understudied; however, is a growing focus of research [30, 31]. As this continues to be explored it appears subgroup allocation of patients may allow surgeons to identify those that will benefit from surgical intervention and consider alternative non-surgical treatment options for the less optimal surgical candidates. As the frequency of hip arthroscopy for FAIS continues to increase, it is imperative that more attention is drawn to the pathoanatomical variants of the hip joint and the relation to clinical outcomes. Identification of subgroup allocation following FAIS arthroscopy in the female population highlights differences in recovery trajectory.

This study should be interpreted in light of several limitations. Our study included the use of retrospective data limiting any causal inferences of these results. The iHOT-

12 outcomes at both 12 and 24 months were obtained via postal mail services, which could have led to possible selection bias. Subgroup allocations were classified based on relatively arbitrary definitions, leading to smaller sample sizes and while conservative alpha level corrections were conducted to minimize the risk of making a Type 1 error, larger sample sizes examining these relationships are needed. Additionally, future work should consider data-driven subgroup allocation approaches to better understand the influence female sex, age and hip morphology have on functional recovery. Exclusion of patients that underwent a revision surgery, related to injury or failure to improve, or conversion to total hip arthroplasty was performed to provide a more homogenous cohort of patients that completed the 24 month follow-up. Future studies should evaluate subgroup characteristics and their influence on post-operative complications. Last, alternative confounding variables (e.g. surgical technique, labral involvement, etc.) could have influenced our results and were not accounted for in this study.

CONCLUSION

Relatively older females with borderline dysplasia and anterior acetabular wall deficiencies had poorer iHOT-12 outcomes at both 12 and 24 months post-operatively compared with other female subgroups. In the absence of hip dysplasia and anterior wall deficiencies, superior iHOT-12 outcomes were observed in both older and younger females post-operatively. It is important to understand the impact age and acetabular deficiencies have on the recovery trajectory to better assist surgical decision making in advising patients on expected clinical outcomes.

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CONFLICT OF INTEREST STATEMENT

None declared.

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