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Research article

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Outcomes of joint preservation surgery: comparison of patients with developmental dysplasia of the hip and femoroacetabular impingement

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ABSTRACT

Femoroacetabular impingement (FAI) and developmental dysplasia of the hip (DDH) are fundamentally and structurally different hip abnormalities yet their clinical presentation can often be very similar. We asked whether adult patients surgically treated for DDH when compared with FAI patients achieve (i) better outcome as reflected by the WOMAC Osteoarthritis Index, (ii) higher physical activity as reflected by the UCLA physical activity scale. Five hundred fifty-six patients treated by periacetabular osteotomy for DDH and 540 patients treated for FAI (cam, pincer, or combined) in nine high-volume centers, between 2008 and 2011 were matched using propensity analysis, based on age and BMI. After exclusions, 144 pairs were evaluated on WOMAC, SF-12 Health Survey, modified Harris Hip Score (mHHS) and UCLA scale at pre and post-operations. At pre-operative evaluation, FAI patients showed lower scores on WOMAC (total, stiffness, function) and SF-12 physical. Statistically significant improvements in the outcome scores were observed from pre to post-operative time points in both treatment groups. Once FAI and DDH patients were compared, FAI patients showed lower scores on most of the outcome measures. However, these differences diminished in time, with only SF-12 mental and mHHS scores remaining significantly lower at 2-year follow-up. Because of more advanced disease at presentation, patients with FAI had an inferior clinical outcome compared with patients with DDH after surgical correction. Further prospective studies are required to better describe the long-term clinical benefits of hip joint preservation surgery.

INTRODUCTION

With the advent of advanced three-dimensional imaging as well as less invasive surgical techniques such as hip arthroscopy, hip preservation surgery has grown in knowledge and in number of advocates over the last decade [1, 2]. The two most common conditions being treated are femoroacetabular impingement (FAI) and developmental dysplasia of the hip (DDH) which are fundamentally and structurally different hip abnormalities yet their clinical presentation can often be very similar [2, 3]. These anatomical variations of the hip joint morphology have been shown to ultimately lead to early secondary osteoarthritis (OA) in the young and active adult population [4–9]. Consequently, proper diagnosis and early intervention can lead to optimized clinical outcome and may be aimed at minimizing the risk of total hip replacement.

Operative treatment is generally recommended in symptomatic adult DDH with corrective periacetabular osteotomy (PAO) that has been shown to provide improvements in the patient's quality of life (QOL) with long-term follow-up [10–12]. Similarly, open and arthroscopic treatments of FAI-related pathologies (i.e. chondro-osteoplasty) for cam correction and reverse PAO for acetabular retroversion have proven to provide consistent early QOL improvements [13, 14]. More importantly, for both conditions, the quality of the cartilage and patient age at presentation, have a significant impact on the clinical outcome of these surgical interventions [15, 16].

In DDH, the cartilage degeneration model suggests an 'inside-out' mechanism [17], resulting from chronic shear stresses caused by the undercoverage of the femoral head namely instability. Some DDH patients may have associated soft tissue laxity and a wide range of hip joint motion affecting cartilage damage. In FAI, Ganz proposed the 'outside-in' cartilage degeneration model [18] with the labral and chondral disease located at the acetabular rim and caused by repetitive mechanical impact of the cam lesion. Typically, FAI patients tend to have stiffer joints and limited hip range of motion in internal rotation. It is unclear if these leading causes of intra-articular hip damage respond similarly to surgical correction and if not should they be approached differently in regards to diagnosis and management. This information becomes critical as we push forward in optimizing the surgical outcome of joint preserving surgery of the hip and consider preventive health measures for degenerative arthritis of the hip.

Accordingly, we questioned whether adult patients undergoing surgical treatment for DDH would achieve (i) better clinical outcomes as reflected by the WOMAC Osteoarthritis Index, (ii) higher physical activity as reflected by the UCLA physical activity scale compared with FAI patients.

PATIENTS AND METHODS

This was a retrospective study of prospectively collected data of patients treated in nine expert hip centers (12 surgeons) across North America for DDH or FAI hip pathologies from 2008 to 2011. Institutional review board approval was obtained prior to the initiation of the study. Patients locally consented to allow the participating centers to enter the patient's data in the Academic Network of Conservation Hip Outcome Research (ANCHOR) joint preservation database (Washington University, St Louis, MO, USA). A total of 556 patients treated by PAO for DDH and 540 patients treated for FAI via open and arthroscopic surgery (cam, pincer, or combined) were matched using propensity analysis, based on age and BMI. Matching by gender was impossible due to the female dominance in the DDH group. Before the matching process, the minimum 2 years follow-up was 49.0% in FAI patients (265 out of 540) and 63.8% in DDH patients (355 out of 556). For the matching process, patients with the diagnosis of Legg-Calvé-Perthes disease, any neuromuscular disorders, bilateral procedures, joint space narrowing of >2 mm, unavailable for 2-year follow-up and concomitant femoral corrective osteotomy were subsequently excluded, resulting in 144 matched pairs (288 patients in total). After matching, the resulting minimum 2 years follow-up was 86.1% in FAI patients (124 out of 144) and 82.6% in DDH patients (119 out of 144).

Clinical outcome measures

These patients were evaluated on four patient-reported outcome measures consisting of Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) [19], Short-Form 12-item Health Survey (SF-12), mHHS and UCLA Physical Activity Scale at the following time points; pre-operation, 1- and 2-year post-operation.

Radiographic measurements

Pre-operative radiographic evaluations including the Tönnis OA grade [20], minimum joint space on standing pelvic AP, lateral center-edge angle of Wiberg [21], Tönnis angle [20], anterior center-edge angle on the false-profile view [22] and alpha angle [23] on Dunn view were analysed from both group of patients.

Surgical procedures

All patients with DDH (LCEA <25 degrees and/or Tonnis angle >10 degrees) underwent a PAO and 48.5% underwent concomitant femoral neck osteochondroplasty. The FAI subgroup included 46% cam (alpha angle > 50 degrees), 7% pincer (cross-over sign and/or ischial spine sign) and 47% mixed morphologies. FAI treatment was completed by hip arthroscopy in 55% of patients and by open surgical dislocation in 37% of patients. The remaining 8% of FAI patients could not be divided as either arthroscopic or open surgical dislocation due to incomplete data. Surgical techniques and post-operative management were proper to each center and surgeons involved in this study. No attempts were made to standardize those protocols as the presenting patient population was of interest.

Statistical analysis

A priori power analysis using G*Power software [24] with an alpha-level of 0.05 and 80% power based on the published mean WOMAC pain scores of the two groups [25] resulted in a required sample size of 112 per group. In order to account for possible study attrition, a sample of 300 patients (150 per group) was targeted. A propensity analysis was used to match the patients based on age and BMI. Descriptive statistics were used to present

Table I. *Demographic and surgical information of the matched groups*

	DDH group	*FAI group*
Demographics [range]		
Number (n)	144	144
Gender (M:F)	26: 118	98: 46
Side (Left: Right)	65: 79	80: 64
Age (years)	26.4 [14.5–45.7]	26.7 [14.3–45.7]
BMI (kg/m^2)	24.0 [18.2–36.2]	23.5 [17.2–35.6]
Surgical procedures		
Periacetabular Osteotomy	94.1%	6%
Osteotomy and femoral head/ neck osteochondroplasty	45.8%	—
Surgical hip dislocation	1.7%	37.0%
Hip arthroscopy	22.0%	55.3%
femoral head/neck osteochondroplasty	49.0%	93.8%
Acetabular chondroplasty		57.7%

demographic and clinical data. Shapiro-Wilk test was used to determine goodness of fit of each variable and nonparametric tests were used when necessary. Analysis with generalized linear model with Greenhouse-Geiser correction for repeated measures were used to delineate differences in clinical presentations and outcome measures between the two groups of patients. Relationships among morphological features and functional outcomes were investigated using Pearson's correlation (r) coefficient and an absolute r value of >.4 were considered clinically significant and reported. A P values of < 0.05 was considered statistically significant. All statistical analyses were performed using SPSS 22 (IBM, Armonk, New York)

RESULTS

Table I summarizes the demographic data and the surgical procedures from each group. The DDH group was female gender dominant while the FAI group was male gender dominant. Baseline outcome scores showed worse clinical scores at pre-operative evaluation (Table II) of the FAI patients in WOMAC (total, stiffness, and function) and

Table II. *Mean baseline scores of patients in each group*

	DDH group	*FAI group*	P *values*
mHarris hip score	64.0 (14.6)	60.8 (14.4)	0.09
WOMAC total	68.5 (19.4)	63.4 (19.7)	0.04
WOMAC pain	64.7 (20.3)	60.4 (20.7)	0.10
WOMAC stiffness	61.9 (22.9)	55.0 (23.1)	0.02
WOMAC function	70.5 (20.2)	65.1 (20.7)	0.04
UCLA activity score	6.9 (2.4)	6.7 (2.6)	0.45
SF-12 mental	51.5 (9.9)	53.4 (10.6)	0.14
SF-12 physical	41.1(9.9)	38.2 (10.2)	0.02

SF-12 physical scores. Radiological parameters differed greatly as expected between groups pre-operatively, and were corrected adequately after surgery (Table III). The evaluation of alpha angle in both groups showed a median angle value of 43.0° in DDH and 46.0° in FAI ($P = 0.366$). Postoperative minimal AP joint space measurement was significantly smaller in the FAI group (3.5 versus 4.0 mm in DDH, $P < 0.001$). Tönnis OA grade distribution was similar in both groups: Grade 0 in 50.5% of DDH and 51.3% in FAI; Grade 1 in 44.7% of both groups; Grade 2 in 3.7% of DDH and 3.9% of FAI; and Grade 3 in 1.1% of DDH and represented a contraindication for surgery in the FAI group. As for the relationship between Tönnis OA grade classification and minimum joint space, higher OA grade was associated with smaller joint space in both groups ($P = 0.001$).

Patient-reported outcomes

Statistically significant improvements in the clinical outcome scores were observed from pre-operative to 1- and 2-year post-operative time points in both treatment groups (Table IV). FAI patients fared worse at 1-year post-operative on all outcome measures except the SF-12 mental score at 1 year compared with DDH patients. At the 2-year mark, FAI patients experienced similar outcome to the DDH group on most scores except continuing to be worse on the mHHS and being significantly worse on the SF-12 mental scale. Functional outcome scores comparisons between FAI and DDH, when stratified for Tönnis OA grade 0, showed significantly better scores in the DDH group at baseline and 1 year but most of these differences disappeared at the 2-year mark (Table IV). For Tönnis OA grade 1 patients, DDH patients showed significantly greater improvements on WOMAC total and pain scores at the 2-year follow-up (Table IV).

Table III. ***Pre- and Post-operative radiographical parameters of patient in each group***

	DDH			*FAI*			P *values (DDH versus FAI)*	
	Pre	*Post*	P *values*	*Pre*	*Post*	P *values*	*Pre*	*Post*
Lateral Center-edge Angle (°)	12.0 (−19.0 −65.0)	29.8 (4.3 −41.0)	<0.001	22.5 (−12.0 −44.0)	29.0 (16.2 −45.0)	<0.001	<0.001	0.885
Anterior Center-Edge Angle (°)	11.0 (−19.0 −72.0)	30.0 (8.3 −67.0)	<0.001	21.1 (−28.1 −43.5)	29.7 (14.7 −62.0)	0.001	<0.001	0.805
Alpha angle (°)	54.9 (28.0 −88.3)	43.0 (5.2 −123.4)	0.866	52.0 (35.4 −85.3)	46.0 (34.0 −80.1)	0.778	0.907	0.366
Acetabular Inclination (°)	20.0 (4.0 −50.0)	6.0 (−7.3 −25.0)	<0.001	11.5 (−7.1 −90.0)	5.0 (−16.0 −24.0)	<0.001	<0 .001	0.121
AP Minimum Joint space(mm)	4.2 (1.0 −9.0)	4.0 (0.9 −22.4)	0.073	4.0 (1.6 −9.0)	3.5 (0.4 −6.0)	0.002	0.008	<0.001

Median and range are indicated for each parameter

Relationship between morphological features and outcomes

No clinically relevant correlations were found between morphological features and outcomes in either group.

DISCUSSION

We have compared two matched cohorts of FAI and DDH patients treated in high-volume centers and have demonstrated that both groups show significant improvements in post-operative functional outcomes. Although the functional scores of DDH patients were higher at baseline and 1-year post-operation, this difference is substantially diminished at the 2-year follow-up. A better understanding of hip morphologies, their natural history and relative evolution within patient populations are critical for optimization of patient care. DDH and FAI are recognized as the commonest cause of hip pain and secondary arthritis in the young patients but, little has been done to systematically compare the two entities. In both DDH and FAI, intra-articular lesions of the labrum and acetabular cartilage are the cause of pain with open [10, 18, 26] or arthroscopic approaches [17, 22, 27–29] advocated to treat these lesions. FAI and DDH are hip morphologies presenting different cartilage damage profiles and prognosis.

Although our study provides a concrete comparison of DDH and FAI patients presenting for surgical treatment, it has limitations. First, the fact that FAI patients were considered as a single group without subdividing them into morphological types or surgical approach may have influenced our results. Differences in FAI treatment outcome may exist between subgroups may be blended in the average outcome of the FAI group. Second, this study is a short-term glance on outcomes of both pathologies. No direct conclusions can be drawn on the prognosis of either affectation after 2 years of follow-up. With the ultimate objective to guide the clinician in the decision-making process in mind, a similar comparative analysis on the long-term (10 years) outcomes of DDH and FAI surgeries would better support advices for preventive or earlier surgical interventions.

The current study has strong points while remaining very close to published work on the subject. Our cohorts are comparable to literature in regards to female preponderance

Table IV. ***Outcome score comparison between the two groups at 1- and 2-year post-operation***

All Patients	*DDH group*		*FAI group*	
Mean (SD)	*1 year*	*2 years*	*1 year*	*2 years*
WOMAC total	90.2 (12.7)	71.7 (32.1)	83.1 (17.9)*	72.7 (32.1)
WOMAC pain	88.3 (15.1)	69.2 (35.0)	81.3 (18.5)*	69.2 (35.0)
WOMAC stiffness	83.0 (16.7)	66.1 (38.7)	72.5 (21.8)*	62.7 (34.7)
WOMAC function	91.5 (12.7)	71.9 (38.9)	85.1 (18.5)*	72.4 (34.2)
SF-12 mental	52.7 (9.2)	54.5 (7.6)	52.5 (9.2)	51.2 (10.4)*
SF-12 physical	51.2 (9.1)	49.8 (9.0)	46.1 (11.8)*	47.8 (11.2)
Mhhs	86.4 (12.5)	87.4 (12.5)	79.6 (14.5)*	80.0 (17.4)*
UCLA Tonnis = 0 only	7.4 (2.2)	7.6 (2.2)	7.1 (2.4)	7.3 (2.5)
WOMAC total	91.1 (12.4)	90.1 (14.7)	83.9 (15.2)*	85.4 (15.0)
WOMAC pain	90.4 (12.7)	88.5 (15.4)	80.0 (19.2)*	82.7 (16.7)
WOMAC stiffness	84.1 (17.8)	83.5 (18.5)	74.7 (18.9)*	76.2 (23.0)
WOMAC function	92.0 (13.2)	91.2 (15.2)	86.1 (15.0)*	87.4 (14.7)
SF-12 mental	52.7 (9.2)	54.2 (7.2)	52.3 (9.5)	50.3 (11.0)
SF-12 physical	51.4 (7.6)	51.4 (8.8)	46.2 (10.9)*	49.3 (10.1)*
mHHS	87.4 (13.4)	88.4 (11.4)	78.4 (13.9)*	80.5 (15.0)*
UCLA	7.4 (2.4)	7.9 (2.2)	7.3 (2.2)	7.7 (2.5)
Tonnis = 1 only				
WOMAC total	91.1 (10.8)	90.4 (13.5)	84.3 (19.7)*	82.9 (20.8)*
WOMAC pain	89.0 (13.6)	88.7 (15.5)	83.6 (20.2)*	82.0 (21.7)
WOMAC stiffness	83.3 (16.0)	83.0 (20.0)	75.5 (22.3)*	77.4 (23.6)
WOMAC function	92.6 (10.6)	91.8 (13.3)	85.7 (20.4)*	83.4 (21.4)*
SF-12 mental	54.0 (8.4)	53.8 (8.4)	51.9 (9.4)	51.8 (9.5)
SF-12 physical	51.0 (8.2)	48.2 (9.6)	47.6 (11.5)	46.0 (13.1)
mHHS	86.4 (12.0)	86.2 (13.8)	82.9 (14.9)	77.8 (21.4)*
UCLA	7.5 (2.2)	7.4(2.1)	7.0 (2.3)	6.7 (2.6)

Score of all patients and those stratified according to Tönnis classifications 0 and 1 are reported. * indicates significant between-groups differences ($P < 0.05$)

in DDH and males in FAI. Our data have comprehensive outcome assessments with the mHHS, WOMAC, SF-12 and UCLA physical activity score unlike most studies published. The heterogeneity of study designs published to date on FAI treatment precludes direct comparisons of the clinical impact of any given treatment. Our data show similar amplitude in the favourable clinical response to surgery for FAI as others [4, 5, 30–33]. But the mean alpha angle in our FAI cohort is small at 52° when compared with pre-op values of other series [16, 34]. This may have biased our analyses to judge FAI patients better than the usual cases of FAI seen elsewhere. Different factors may have contributed to this low alpha-angle value for the FAI cohort. First, choosing the anterior alpha-angle as seen on the Dunn's lateral view instead of using maximal alpha angle from CT images may minimise its mean value. Second, high-volume centers may be treating FAI patients with subtler cam deformities than published literature would suggest. As for our DDH cohort, pre-operative descriptive radiological parameters faired very similar to published cohorts [10, 25, 35, 36] but were not as severe as in the typical pediatric cohorts [37, 38]. The clinical response to surgical treatment of DDH as measured with contemporary outcome measures proved comparable improvements [10, 39–41].

This study confirms the concomitant existence of DDH and FAI. In a group of patients presenting with DDH treated by PAO with concomitant hip arthroscopy, Domb *et al.* [27] observed that 10 out of 16 hips had a cam deformity requiring osteo-chondroplasty. Also, when analyzing reasons for secondary hip surgeries, Clohisy *et al.* [42] found that dysplasia patients required additional femoral head neck osteochondroplasty in 65% of adult and only 59% in pediatrics. Mid to long-term publications reveal residual impingement after PAO in close to 30% of well-corrected hips [26, 31, 36, 43]. In our patients undergoing PAOs, 49% of patients required some form of femoral head neck osteochondroplasty which is similar to some authors [44, 45] but higher than most reports [12, 43, 46, 47]. Comparison with older literature may not be fair since the recognition that FAI may co-exist in DDH is recent as witnessed by experts doing more arthrotomies or arthroscopies during PAOs over time and as experience grows [27, 48–50]. To illustrate this, Tibor *et al.* [51] evaluated 96 patients (112 hips) presenting with hip pain with MR arthrography, and noticed two or more impingement parameters in 66% of hips and two or more instability parameters in 51% of hips. Recognition of any impingement parameters in DDH is important since PAO will provide improved anterior and lateral coverage yet will worsen impingement in deep flexion and internal rotation [11, 26, 36, 43] as it may also affect long-term outcome [44].

Despite our matching efforts taking into consideration age and BMI, the FAI patients presented worse baseline scores on most outcome measures**.** It is unsure why this difference exists but an attempt to guide our comprehension could be the sex dominance in both groups. It is possible that females present earlier symptoms in DDH due to a lower muscle mass protecting the hip, and also possibly being more attuned to the instability than the loss of motion and end of motion hip pain seen in males with FAI. Moreover, following the appropriate surgical management, FAI patients continued to fair worse than DDH patients up to 2 years post-operative. Since our data show that at equal Tönnis OA grade, FAI patients are not expected to respond as well as DDH patients after the appropriate surgery, the clinician should aim at downgrading the patient expectation from surgical treatment in FAI compared with DDH. FAI may in fact be a worse cartilage disease either biologically or biomechanically. In addition, because the cartilage fails first in FAI due to the outside-in damage pattern compared with earlier labral involvement in DDH, the absence of pain fibers in the hyaline cartilage may then explain the damage to the articular cartilage without the patient exhibiting hip symptoms in the FAI patient population. In comparing patients undergoing surgical correction of DDH to FAI at short-term follow-up, both groups demonstrated significant improvements from baseline. However, these clinical benefits from surgery appear to decrease with time, as shown by the decreasing trend in the 2-year follow-up functional scores. Our follow-up is too short to provide hints of an answer on how the relation between FAI and DDH clinical benefits from surgery will evolve over time. The fact that FAI patients presented for their initial consultation with clinically worse outcome scores than DDH patients is an important finding to consider as it may reflect on the patient's healing potential. Further prospective studies are required to better describe the long-term clinical benefits of hip joint preservation surgery.

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CONFLICT OF INTEREST STATEMENT

Each author certifies that he or she has no commercial association (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangements etc.) that might pose a conflict of interest in connection with the submitted article. Each author certifies that his or her institution approved the human protocol for this investigation, and that all investigations were conducted in conformity with ethical principles of research.

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