Arthroscopy and arthrotomy to address intra-articular pathology during PAO for hip dysplasia demonstrates similar short-term outcomes

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ABSTRACT

Periacetabular osteotomy (PAO) remains the gold standard procedure for joint preservation in symptomatic developmental dysplasia of the hip (DDH). Hip arthroscopy (HA) and open arthrotomy have been used to correct intra-articular pathology at the time of PAO, but there is limited data regarding differences in outcomes between these techniques when performed at the time of PAO. The aim of this study was to determine if short-term clinical outcomes differed between patients managed with HA versus arthrotomy to evaluate and treat intra-articular pathology at the time of PAO to discern if one technique is associated with better pain and functional results. Data were retrospectively reviewed from two surgeons at one institution managing DDH patients from September 2013 to December 2015. One surgeon treated patients with PAO and arthrotomy (N = 32), while the other performed PAO and HA (N = 39). There were 87% women, median age was 28 years and mean BMI was 25. Seventy-five percent of all patients received an intra-articular intervention. Patients completed 13 PROs at the pre-operative and 1-year post-operative clinical visits. Pre-operatively, there were no differences in any of the 13 PROs between patients treated with HA versus arthrotomy (P/C210.076). Patients treated with PAO and arthrotomy experienced greater mean improvement in two out of the 13 PROs; the other 11 showed no differences. No treatment effect was observed for any of the 13 PROs using multivariable modelling that accounted for severity of dysplasia and degree of arthritis. Few differences were shown in short-term clinical outcomes between HA and arthrotomy at the time of PAO. This work highlights the need for a high quality randomized clinical trial to provide definitive guidance on whether hip preservation surgeons should address intra-articular pathology at the time of PAO for DDH and which technique best serves this purpose.

INTRODUCTION

The Bernese periacetabular osteotomy (PAO) remains the gold standard for treatment of symptomatic developmental dysplasia of the hip (DDH) in skeletally mature patients. First developed by Ganz in 1984, this technique utilizes four osteotomies to completely mobilize the acetabular fragment [1]. Although a technically demanding procedure, it allows for optimal correction in all planes and maintains integrity of the posterior column, enabling early weight bearing and mobilization. Several groups have confirmed the long-term efficacy of this joint preservation procedure with a recent report from the originating institution documenting survivorship up to 30 years after surgery [2]. Concomitant intra-articular pathology, primarily cartilage and labral damage, occurs with high prevalence in patients with DDH, presumed secondary to the inherent instability and altered biomechanics of the dysplastic hip [3, 4]. In addition, proximal femoral deformity often coexists in patients with dysplasia and may require treatment at the time of PAO to maintain normal range of motion following acetabular re-orientation.

Treatment of intra-articular pathology during PAO was first described with an arthrotomy [5]. This technique is facile and does not add significant time to a case nor does...
it require extra equipment and preparation. However, arthrotomy yields limited exposure to the joint and thus restricts access to appropriately diagnose and treat intra-articular structures. An alternative to arthrotomy is hip arthroscopy (HA), which has recently been described for the management of intra-articular disease during PAO [6]. Arthroscopy allows a comprehensive view of the intra-articular compartment and ability to address disease, but requires specialized training and equipment as well as additional preparation and case time, all while carrying a unique set of potential complications. Both techniques allow for femoral head neck junction osteochondroplasty in order to maintain range of motion after PAO.

Currently, there is insufficient evidence to confirm benefit from assessment and treatment of intra-articular pathology at the time of PAO, whether through open or arthroscopic techniques. Recently, a prospective report of 95 hips undergoing PAO without simultaneous interrogation of the joint showed that 27% of patients returned within 2 years and subsequently underwent arthroscopy to treat labral pathology or cam lesions [7]. Pre-operative magnetic resonance arthrogram (MRA) revealed labral pathology in 94% of all patients in that study, but not all patients required management as more than 70% of the hips did not require subsequent treatment of labral pathology, adding further data to the fact that the PAO is able to provide labral offloading and pain relief even in the presence of a labral tear. However, those that did require treatment after PAO had lower patient-reported outcome (PRO) scores at 2-year follow-up. While intuitive to address structural abnormalities and potential pain generators in patients with DDH, an arthrotomy or HA requires further disruption of the joint and may potentially lead to further instability, iatrogenic damage to intra-articular cartilage, adhesions or heterotopic ossification. It therefore remains unclear which patients are most likely to benefit from treatment of labral or cartilage disease and which technique is best suited for treatment. The aim of this study was to determine if short-term clinical outcomes differed between patients managed with HA versus arthrotomy to evaluate and treat intra-articular pathology at the time of PAO to discern if one technique is associated with better pain and functional results.

MATERIALS AND METHODS
This retrospective cohort study was conducted from September 2013 to December 2015 and was approved by our institutional review board. All patients were treated at Mayo Clinic, Rochester, Minnesota, by 1 of 2 senior hip preservation surgeons (R.T.T. and R.J.S.).

During this time period, a subset of patients scheduled to undergo PAO for DDH were treated with either simultaneous HA or arthrotomy. One surgeon treated all of their patients that met study inclusion criteria with PAO and HA, whereas the other surgeon treated all eligible patients with PAO and arthrotomy. Candidates for PAO had closed triradiate cartilage and symptomatic DDH defined by a lateral center-edge angle (LCEA) as described by Wiberg [8] of $<25^\circ$ and/or an acetabular index as described by Tönnis [9] of $>10^\circ$. An anterior center-edge angle $<25^\circ$ was also considered dysplastic [10]. Patients were further considered if they were $\leq50$ years old and had Grade 0 or Grade 1 degenerative changes according to Tönnis [9]. No patients were included with previous surgery about the hip, isolated acetabular retroversion, neurogenic dysplasia, Legg-Calvé-Perthes or slipped capital femoral epiphysis. During the study period, 87 patients (89 hips) underwent PAO with the aforementioned criteria. PROs were completed both pre-operatively and 1 year post-operatively by 70 patients (71 hips) (80%), which comprised the final cohort.

One surgeon (R.T.T.) treated all eligible patients with a PAO followed by open arthrotomy to address any visible intra-articular pathology ($N=32$ hips) (Fig. 1). The second surgeon (R.J.S.) treated all eligible patients with HA prior to PAO to address any visible intra-articular pathology ($N=39$) (Fig. 2). Patients underwent identical routine perioperative in-hospital care and post-operative follow-up per institutional protocol. The intra-articular treatments included labral repair, labral debridement, osteochondroplasty and acetabular or femoral chondroplasty. For the purposes of classification and sensitivity analyses, labral repair and femoral head–neck junction osteochondroplasty were considered to be ‘major’ interventions, whereas labral debridement and acetabular or femoral chondroplasty were considered to be ‘minor’ interventions. Major and/or minor interventions were performed on 53 hips (75%) overall, 38 hips (97%) in the HA group and 15 hips (47%) in the arthrotomy group (Table 1). Major interventions were performed on 31 hips (44%) overall, 26 hips (67%) in the HA group and 5 hips (16%) in the arthrotomy group (Table 1). A head and neck osteochondroplasty was performed prior to reorientation in 12 hips undergoing PAO and HA and 2 hips undergoing PAO and arthrotomy. All patients with a pre-operative cam deformity or elevated alpha angle had this addressed with osteochondroplasty. Pre-operative MRI was performed on 52 patients and demonstrated evidence of labral pathology in 47 patients (90%). Among those 47 patients, 36 (77%) had subsequent identification and
treatment of the tear intraoperatively with either debridement or formal repair.

Patients filled out 13 PROs at the pre-operative and 1 year post-operative clinical visits as part of a prospectively collected hip preservation registry. PROs included the Harris Hip Score; UCLA Activity Score; all five subcomponents of the Hip Disability and Osteoarthritis Outcome Score (HOOS) [Pain, Symptom, Activities of Daily Living (ADL), Sports and Recreation, Quality of Life]; all four subcomponents of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (Pain, Stiffness, Physical, Total) and both subcomponents of the SF-12 (Physical and Mental).

There were 62 women (87%) and 9 men (13%), median age was 28 years (range 15–42 years) and mean BMI was 25.1 (range 16.9–39.2) (Table I). Four patients (6%) had concomitant acetabular retroversion and DDH (Table I). There were no major differences at the time of surgery between the HA and arthrotomy groups based on age, BMI or gender (Table I). All three radiographic measures, namely LCEA, Tönnis Grade and Tönnis angle differed between the two treatment groups. The open arthrotomy group had a lower mean LCEA (14.6 versus 17.6, \( P = 0.02 \)) and lower Tönnis Grade (Grade 0: 81% versus 59%, \( P = 0.04 \)), and a significantly higher mean Tönnis angle (20.1 versus 14.1 \( P < 0.001 \)) than the HA group (Table II). In order to account for these differences, the association of surgical technique and the pre-operative to post-operative changes in PROs were analysed using multivariable models which included the three above-mentioned radiographic measures as adjusting covariates.

The data are summarized using means and standard deviations for variables comprised of continuous data, and counts and percentages for categorical variables. Comparisons of the PROs between the pre-operative and 1-year follow-up time points for the entire cohort were performed using paired \( t \)-tests. Patients treated with HA were compared with those treated with open arthrotomy with respect to patient characteristics, including age, gender, body mass index and diagnosis (acetabular retroversion versus DDH) using two-sample \( t \)-tests for continuous data and \( \chi^2 \) tests for binary variables. Changes in the PROs from baseline (pre-operative) to 1-year follow-up were compared between the HA and open arthrotomy groups using two-sample \( t \)-tests. Similar analyses were performed to evaluate other factors such as gender, age group, body mass index and presence of acetabular retroversion. Univariate regression analysis was performed to explore relationships between radiographic parameters such as LCEA, Tönnis angle, Tönnis Grade and PROs. Subsequently, multivariable regression analysis was performed in order to account for differences in pre-operative radiographic measures between treatment groups.
Specifically, the association of surgical technique and the pre-operative to 1-year follow-up change in PROs were adjusted for pre-operative LCEA, Tönnis angle and Tönnis Grade. These three radiographic parameters were incorporated into the models as adjusting covariates individually as well as simultaneously. All statistical tests were two-sided and $P$-values <0.05 were considered significant. The analyses were performed using SAS version 9.4 (SAS Institute, Inc., Cary, NC, USA) and R version 3.4.1 (R Core Team, 2017, R Core Team, Vienna, Austria).

### RESULTS

Pre-operatively, there were no differences in any of the 13 PROs between patients treated with HA versus arthrotomy ($P \geq 0.076$) (Table III). All PROs with the exception of SF-12 Mental subscale ($P = 0.897$) improved for the entire cohort post-operatively ($P < 0.01$) (Table IV). Patients treated with arthrotomy experienced a greater mean increase from baseline in HOOS Pain and HOOS Quality of Life; the other 11 PROs showed no difference between groups (Table V). Women demonstrated greater mean

| Table I. Demographics and patient characteristics |
|-----------------------------------------------|
| Characteristic | Entire cohort ($N = 71$) | PAO+HA ($N = 39$) | PAO+arthrotome ($N = 32$) | $P$-Value |
| Gender         |                             |                  |                           | 0.968a    |
| Female         | 62 (87%)                    | 34 (87%)         | 28 (88%)                  |           |
| Male           | 9 (13%)                     | 5 (13%)          | 4 (13%)                   |           |
| Age            |                             |                  |                           | 0.798b    |
| Mean (SD)      | 27.3 (7.2)                  | 27.1 (7.4)       | 27.6 (7.1)                |           |
| Median         | 27.8                        | 26.6             | 28.9                      |           |
| Range          | (15.2–41.7)                 | (15.2–41.3)      | (15.3–41.7)               |           |
| Body mass index|                             |                  |                           | 0.428b    |
| Mean (SD)      | 25.1 (4.9)                  | 25.5 (5.1)       | 24.6 (4.7)                |           |
| Median         | 24.3                        | 25.0             | 23.7                      |           |
| Range          | (16.9–39.2)                 | (16.9–38.1)      | (18.3–39.2)               |           |
| Diagnosis      |                             |                  |                           | 0.406a    |
| DDH alone      | 67 (94%)                    | 36 (92%)         | 31 (97%)                  |           |
| DDH+retroversion| 4 (6%)                      | 3 (8%)           | 1 (3%)                    |           |
| Intra-articular intervention |           |                  |                           | <0.001a   |
| Intervention not performed | 18 (25%) | 1 (3%) | 17 (53%) |           |
| Intervention performed | 53 (75%) | 38 (97%) | 15 (47%) |           |
| Majorc and/or minord |                     |                  |                           | <0.0011   |
| No major intervention | 40 (56%) | 13 (33%) | 27 (84%) |           |
| Major intervention | 31 (44%) | 26 (67%) | 5 (16%)  |           |

*a, v².  
bUnequal variance t test.  
cLabral repair, Osteochondroplasty.  
dLabral debridement, Chondroplasty.  
DDH, developmental dysplasia of the hip; PAO, periacetabular osteotomy.
Table II. Radiographic parameters

| Radiographic metric | Entire cohort | PAO+HA | PAO+arthrology | P-Value |
|---------------------|---------------|--------|----------------|---------|
|                     | (N = 71)      | (N = 39) | (N = 32)       |         |
| LCEA (pre-operative)|               |        |                | 0.021<sup>a</sup> |
| N                   | 71            | 39     | 32             |         |
| Mean (SD)           | 16.3 (6.1)    | 17.6 (5.8) | 14.6 (6.2)     |         |
| Median              | 18.0          | 19.0   | 15.0           |         |
| Range               | (-3.0 to 25.0)| (-3.0 to 25.0)| (0.0 to 23.0) |         |
| LCEA (post-operative)|              |        |                | 0.112<sup>a</sup> |
| N                   | 51            | 25     | 26             |         |
| Mean (SD)           | 31.5 (6.1)    | 29.8 (4.9) | 33.2 (6.7)     |         |
| Median              | 30.0          | 30.0   | 33.5           |         |
| Range               | (14.0 to 47.0)| (14.0 to 39.0)| (22.0 to 47.0)|         |
| Tönnis angle (pre-operative)| |        |                | <0.001<sup>a</sup> |
| N                   | 71            | 39     | 32             |         |
| Mean (SD)           | 16.8 (9.6)    | 14.1 (10.6) | 20.1 (7.2)     |         |
| Median              | 14.0          | 11.0   | 20.5           |         |
| Range               | (5.0 to 71.0)| (5.0 to 71.0)| (6.6 to 35.0)|         |
| Tönnis angle (post-operative)| |        |                | <0.001<sup>a</sup> |
| N                   | 51            | 25     | 26             |         |
| Mean (SD)           | 5.5 (5.6)     | 2.2 (3.9)  | 8.7 (5.1)     |         |
| Median              | 5.0           | 0.0    | 8.7            |         |
| Range               | (0.0 to 20.0)| (0.0 to 16.0)| (0.0 to 20.0)|         |
| Tönnis Grade (pre-operative)| |        |                | 0.042<sup>b</sup> |
| 0                   | 49 (69%)      | 23 (59%) | 26 (81%)       |         |
| 1                   | 22 (31%)      | 16 (41%) | 6 (19%)        |         |
| Tönnis Grade (post-operative)| |        |                | 0.189<sup>b</sup> |
| 0                   | 45 (88%)      | 20 (80%) | 25 (96%)       |         |
| 1                   | 6 (12%)       | 5 (20%)  | 1 (4%)         |         |

<sup>a</sup>Wilcoxon.
<sup>b</sup>χ².

PAO, periacetabular osteotomy; HA, hip arthroscopy.
improvement than men in 7 of 13 PROs; the other 6 PROs showed no difference between groups (Table VI). There was no difference in PROs based on whether intra-articular intervention was performed (Table VII).

Table III. Pre-operative PROs based on treatment algorithm

| Pre-operative score | PAO+HA (N=39) | PAO+arthrotomy (N=32) | P-Value |
|---------------------|---------------|-----------------------|---------|
| UCLA score          |               |                       |         |
| Mean (SD)           | 6.0 (2.7)     | 6.9 (2.7)             | 0.152a  |
| Median              | 6.0           | 7.0                   |         |
| Range               | (2.0 to 10.0) | (3.0 to 10.0)         |         |
| Harris hip score    |               |                       | 0.520a  |
| Mean (SD)           | 59.7 (15.8)   | 62.3 (17.5)           |         |
| Median              | 64.9          | 62.7                  |         |
| Range               | (19.8 to 84.7)| (19.8 to 97.9)        |         |
| HOOS—Pain           |               |                       | 0.941a  |
| Mean (SD)           | 53.8 (17.3)   | 54.2 (22.9)           |         |
| Median              | 60.0          | 57.5                  |         |
| Range               | (5.0 to 85.0) | (12.5 to 92.5)        |         |
| HOOS—Symptom        |               |                       | 0.653a  |
| Mean (SD)           | 51.3 (20.0)   | 53.5 (20.7)           |         |
| Median              | 55.0          | 55.0                  |         |
| Range               | (5.0 to 100.0)| (0.0 to 90.0)         |         |
| HOOS—ADL            |               |                       | 0.926a  |
| Mean (SD)           | 66.1 (20.3)   | 66.6 (24.3)           |         |
| Median              | 68.4          | 72.8                  |         |
| Range               | (13.2 to 95.6)| (23.5 to 100.0)       |         |
| HOOS—Sport/Rec      |               |                       | 0.498a  |
| Mean (SD)           | 37.3 (22.3)   | 41.5 (26.5)           |         |
| Median              | 37.5          | 40.6                  |         |
| Range               | (0.0 to 81.3) | (0.0 to 87.5)         |         |
| HOOS—QOL            |               |                       | 0.909a  |
| Mean (SD)           | 28.5 (18.5)   | 29.0 (18.2)           |         |
| Median              | 25.0          | 31.3                  |         |
| Range               | (0.0 to 62.5) | (0.0 to 62.5)         |         |

(continued)

Table III. (continued)

| Pre-operative score | PAO+HA (N=39) | PAO+arthrotomy (N=32) | P-Value |
|---------------------|---------------|-----------------------|---------|
| WOMAC—Pain          |               |                       | 0.726a  |
| Mean (SD)           | 60.0 (18.5)   | 58.1 (24.2)           |         |
| Median              | 65.0          | 60.0                  |         |
| Range               | (10.0 to 90.0)| (15.0 to 95.0)        |         |
| WOMAC—Stiffness     |               |                       | 0.862a  |
| Mean (SD)           | 51.0 (23.7)   | 52.0 (26.0)           |         |
| Median              | 50.0          | 50.0                  |         |
| Range               | (0.0 to 100.0)| (0.0 to 100.0)        |         |
| WOMAC—Physical      |               |                       | 0.926a  |
| Mean (SD)           | 66.1 (20.3)   | 66.6 (24.3)           |         |
| Median              | 68.4          | 72.8                  |         |
| Range               | (13.2 to 95.6)| (23.5 to 100.0)       |         |
| WOMAC—Total         |               |                       | 0.936a  |
| Mean (SD)           | 63.9 (19.2)   | 63.5 (23.7)           |         |
| Median              | 68.2          | 69.8                  |         |
| Range               | (12.5 to 91.7)| (20.8 to 96.9)        |         |
| SF-12 physical      |               |                       | 0.076a  |
| Mean (SD)           | 35.6 (9.4)    | 40.3 (12.0)           |         |
| Median              | 34.2          | 42.1                  |         |
| Range               | (19.6 to 52.6)| (17.4 to 61.0)        |         |
| SF-12 mental        |               |                       | 0.888a  |
| Mean (SD)           | 52.9 (9.5)    | 53.3 (10.2)           |         |
| Median              | 54.1          | 55.1                  |         |
| Range               | (24.0 to 68.8)| (32.0 to 69.3)        |         |

*aUnequal variance t test.

PAO, periacetabular osteotomy; HA, hip arthroscopy; HOOS, Hip Disability and Osteoarthritis Outcome Score; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; ADL, Activity of Daily Living; QOL, quality of life.
Furthermore, no relationship was shown between the pre-operative and post-operative change in PROs based on the presence of concomitant acetabular retroversion, age or BMI. Multivariable analysis accounting for LCEA, Tönnis angle and Tönnis Grade showed no significant effect of surgical technique for any of the 13 PROs (P ≥ 0.061).

**DISCUSSION**

PAO remains the standard of care for managing symptomatic DDH in skeletally mature patients with little or no

### Table IV. Pre-operative versus 1-year follow-up PROs

| PRO metric       | Pre-operative (N = 71) | Post-operative (N = 71) | P-Value |
|------------------|------------------------|-------------------------|---------|
| UCLA score       |                        |                         | 0.006a  |
| Mean (SD)        | 6.4 (2.7)              | 7.3 (2.2)               |         |
| Median           | 6.0                    | 7.0                     |         |
| Range            | (2.0–10.0)             | (3.0–10.0)              |         |
| Harris hip score |                        |                         | <0.001b |
| Mean (SD)        | 60.9 (16.5)            | 84.7 (16.2)             |         |
| Median           | 63.8                   | 91.3                    |         |
| Range            | (19.8–97.9)            | (34.1–100.1)            |         |
| HOOS—Pain        |                        |                         | <0.001b |
| Mean (SD)        | 54.0 (19.7)            | 81.8 (18.9)             |         |
| Median           | 57.5                   | 86.3                    |         |
| Range            | (5.0–92.5)             | (17.5–100.0)            |         |
| HOOS—Symptom     |                        |                         | <0.001b |
| Mean (SD)        | 52.3 (20.2)            | 74.8 (21.1)             |         |
| Median           | 55.0                   | 80.0                    |         |
| Range            | (0.0–100.0)            | (10.0–100.0)            |         |
| HOOS—ADL         |                        |                         | <0.001a |
| Mean (SD)        | 66.3 (22.0)            | 88.0 (16.8)             |         |
| Median           | 69.9                   | 95.6                    |         |
| Range            | (13.2–100.0)           | (32.4–100.0)            |         |
| HOOS—Sports/Rec  |                        |                         | <0.001b |
| Mean (SD)        | 39.2 (24.1)            | 72.4 (27.8)             |         |
| Median           | 37.5                   | 81.3                    |         |
| Range            | (0.0–87.5)             | (0.0–100.0)             |         |
| HOOS—QOL         |                        |                         | <0.001b |
| Mean (SD)        | 28.8 (18.2)            | 67.0 (24.2)             |         |
| Median           | 31.3                   | 68.8                    |         |
| Range            | (0.0–62.5)             | (0.0–100.0)             |         |
| WOMAC—Pain       |                        |                         | <0.001b |
| Mean (SD)        | 59.2 (21.0)            | 85.9 (17.2)             |         |
| Median           | 65.0                   | 90.0                    |         |
| Range            | (10.0–95.0)            | (25.0–100.0)            |         |

(continued)
osteoarthritis. Concomitant intra-articular pathology is common in these patients; however, there is a paucity of data demonstrating whether addressing these abnormalities at the time of PAO is beneficial. Intra-articular pathology can be addressed with HA or arthrotomy at the time of PAO. This study exhibits few differences between patients managed with HA versus arthrotomy, nor was a difference shown between patients who received intra-articular intervention versus those whose joint inspection required no intervention.

This study has a number of limitations. First, all patients had the joint interrogated by either HA or arthrotomy with

Table V. PROs based on surgical technique

|                  | Pre-op to post-op change | PAO+HA (N = 39) | PAO+arthrotomy (N = 32) | P-Value |
|------------------|--------------------------|-----------------|------------------------|---------|
| UCLA score       |                          |                 |                        |         |
| Mean (SD)        | 0.9 (2.7)                | 1.0 (2.4)       | 0.788\(^a\)            |         |
| Median           | 1.0                      | 0.0             |                        |         |
| Range            | (−4.0 to 6.0)            | (−4.0 to 6.0)   |                        |         |
| Harris hip score |                          |                 | 0.351\(^a\)            |         |
| Mean (SD)        | 22.1 (14.7)              | 26.0 (18.6)     |                        |         |
| Median           | 22.0                     | 23.7            |                        |         |
| Range            | (−6.6 to 57.2)           | (0.0 to 64.9)   |                        |         |
| HOOS—Pain        |                          |                 | 0.043\(^a\)            |         |
| Mean (SD)        | 23.6 (19.3)              | 34.7 (21.5)     |                        |         |
| Median           | 25.0                     | 35.0            |                        |         |
| Range            | (−20.0 to 65.0)          | (−10.0 to 72.5)|                        |         |
| HOOS—Symptom     |                          |                 | 0.192\(^a\)            |         |
| Mean (SD)        | 18.4 (24.0)              | 27.1 (18.9)     |                        |         |
| Median           | 20.0                     | 25.0            |                        |         |
| Range            | (−25.0 to 50.0)          | (−10.0 to 70.0)|                        |         |
| HOOS—ADL         |                          |                 | 0.137\(^a\)            |         |
| Mean (SD)        | 17.0 (20.3)              | 24.8 (20.2)     |                        |         |
| Median           | 15.4                     | 22.1            |                        |         |
| Range            | (−42.6 to 50.0)          | (0.0 to 72.1)   |                        |         |
| HOOS—Sport/Rec   |                          |                 | 0.492\(^a\)            |         |
| Mean (SD)        | 29.8 (30.2)              | 35.2 (30.5)     |                        |         |
| Median           | 31.3                     | 37.5            |                        |         |
| Range            | (−31.3 to 93.8)          | (−43.8 to 87.5)|                        |         |
| HOOS—QOL         |                          |                 | 0.043\(^a\)            |         |
| Mean (SD)        | 32.6 (26.0)              | 45.0 (23.0)     |                        |         |
| Median           | 31.3                     | 43.8            |                        |         |
| Range            | (−12.5 to 93.8)          | (6.3 to 93.8)   |                        |         |
| WOMAC—Pain       |                          |                 | 0.056\(^a\)            |         |
| Mean (SD)        | 22.4 (20.4)              | 32.6 (21.1)     |                        |         |
| Median           | 25.0                     | 30.0            |                        |         |
| Range            | (−20.0 to 65.0)          | (0.0 to 75.0)   |                        |         |

(continued)
subsequent treatment of identified pathology. Therefore, we cannot comment on whether addressing intra-articular abnormalities would lead to better outcomes as we do not have a control group where the intra-articular abnormality was left untreated. Furthermore, patients undergoing arthrotomy in the study received fewer interventions. This is certainly related to the inability to examine the entire joint, but not necessarily associated with less pathology in the cohort. These deficiencies will hopefully be addressed by a recently initiated randomized clinical trial at our institution where 50% of patients will receive no further treatment or inspection of the joint at the time of PAO.

### Table VI. PROs based on gender

| Pre-op to post-op change | Female (N = 62) | Male (N = 9) | P-Value |
|--------------------------|-----------------|--------------|---------|
| **UCLA Score**           |                 |              |         |
| Mean (SD)                | 1.2 (2.6)       | −0.4 (2.2)   | 0.101a  |
| Median                   | 1.0             | 0.0          |         |
| Range                    | (−4.0 to 6.0)   | (−4.0 to 2.0)|         |
| **Harris hip score**     |                 |              | 0.575b  |
| Mean (SD)                | 24.3 (17.2)     | 20.9 (12.1)  |         |
| Median                   | 23.1            | 15.4         |         |
| Range                    | (−6.6 to 64.9)  | (4.4 to 44.0)|         |
| **HOOS—Pain**            |                 |              | 0.050b  |
| Mean (SD)                | 30.5 (20.9)     | 15.8 (16.1)  |         |
| Median                   | 31.3            | 10.0         |         |
| Range                    | (−20.0 to 72.5) | (−2.5 to 42.5)|         |
| **HOOS—Symptom**         |                 |              | 0.017b  |
| Mean (SD)                | 26.4 (20.4)     | 6.3 (21.7)   |         |
| Median                   | 25.0            | 7.5          |         |
| Range                    | (−25.0 to 70.0) | (−20.0 to 35.0)|       |
| **HOOS—ADL**             |                 |              | 0.110a  |
| Mean (SD)                | 22.9 (19.5)     | 8.3 (22.7)   |         |
| Median                   | 20.6            | 13.2         |         |
| Range                    | (−23.5 to 72.1) | (−42.6 to 44.1)|       |
| **HOOS—Sports/Rec**      |                 |              | 0.037b  |
| Mean (SD)                | 35.8 (28.5)     | 13.2 (34.3)  |         |
| Median                   | 37.5            | 18.8         |         |
| Range                    | (−31.3 to 93.8) | (−43.8 to 75.0)|       |
| **HOOS—QOL**             |                 |              | 0.106b  |
| Mean (SD)                | 40.3 (25.1)     | 25.7 (23.3)  |         |
| Median                   | 43.8            | 25.0         |         |
| Range                    | (−12.5 to 93.8) | (−12.5 to 56.3)|       |
| **WOMAC—Pain**           |                 |              | 0.044b  |
| Mean (SD)                | 29.2 (21.4)     | 13.9 (14.3)  |         |
| Median                   | 30.0            | 10.0         |         |
| Range                    | (−20.0 to 75.0) | (−15.0 to 30.0)|       |

**Table VI. (continued)**

| Pre-op to post-op change | Female (N = 62) | Male (N = 9) | P-Value |
|--------------------------|-----------------|--------------|---------|
| **WOMAC—Stiffness**      |                 |              |         |
| Mean (SD)                | 29.1 (25.0)     | 8.3 (26.5)   | 0.029a  |
| Median                   | 25.0            | 12.5         |         |
| Range                    | (−25.0 to 75.0) | (−50.0 to 37.5)|       |
| **WOMAC—Physical**       |                 |              |         |
| Mean (SD)                | 24.1 (20.3)     | 8.3 (22.7)   |         |
| Median                   | 23.5            | 13.2         |         |
| Range                    | (−23.5 to 72.1) | (−42.6 to 44.1)|       |
| **SF-12 Physical**       |                 |              |         |
| Mean (SD)                | 12.5 (11.1)     | 0.2 (8.3)    |         |
| Median                   | 11.3            | 4.9          |         |
| Range                    | (−18.2 to 39.7) | (−15.3 to 7.8)|       |
| **SF-12 Mental**         |                 |              | 0.344b  |
| Mean (SD)                | −0.7 (12.1)     | 3.4 (11.2)   |         |
| Median                   | −2.6            | 6.4          |         |
| Range                    | (−36.3 to 28.1) | (−18.8 to 14.3)|       |

HOOS, Hip Disability and Osteoarthritis Outcome Score; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; ADL, Activity of Daily Living; QOL, quality of life.

*aWilcoxon.*

*bEqual variance t test.*

(continued)
### Table VII. PROs based on performance of intra-articular intervention

| Pre-op to post-op change | Major \(^a\) and/or Minor \(^b\) | | Major \(^a\) Only | |
|--------------------------|----------------------------------|------------------|-------------------|------------------|
|                          | Intervention (N = 53) | No intervention (N = 18) | P-Value | Intervention (N = 31) | No intervention (N = 40) | P-Value |
| UCLA score               | 0.912 \(^c\) | 0.444 \(^c\) | | | | |
| Mean (SD)                | 0.9 (2.6) | 1.0 (2.5) | | 0.7 (2.8) | 1.2 (2.3) | |
| Median                   | 1.0 | 0.0 | | 1.0 | 1.0 | |
| Range                    | (-4.0 to 6.0) | (-4.0 to 6.0) | | (-4.0 to 6.0) | (-4.0 to 6.0) | |
| Harris hip score         | 0.844 \(^c\) | 0.488 \(^c\) | | | | |
| Mean (SD)                | 24.1 (15.7) | 23.0 (19.4) | | 25.4 (15.7) | 22.6 (17.3) | |
| Median                   | 22.0 | 22.0 | | 23.1 | 22.0 | |
| Range                    | (-6.6 to 64.9) | (0.0 to 64.9) | | (-6.6 to 64.9) | (-1.1 to 64.9) | |
| HOOS—Pain                | 0.995 \(^c\) | 0.408 \(^c\) | | | | |
| Mean (SD)                | 28.4 (20.7) | 28.4 (22.0) | | 25.8 (21.0) | 30.3 (20.8) | |
| Median                   | 30.0 | 30.0 | | 25.0 | 32.5 | |
| Range                    | (-20.0 to 72.5) | (-10.0 to 67.5) | | (-17.5 to 65.0) | (-20.0 to 72.5) | |
| HOOS—Symptom             | 0.440 \(^c\) | 0.599 \(^c\) | | | | |
| Mean (SD)                | 21.2 (21.3) | 28.3 (24.5) | | 20.8 (23.1) | 24.3 (21.1) | |
| Median                   | 20.0 | 30.0 | | 20.0 | 25.0 | |
| Range                    | (-25.0 to 50.0) | (-10.0 to 70.0) | | (-20.0 to 50.0) | (-25.0 to 70.0) | |
| HOOS—ADL                 | 0.841 \(^c\) | 0.619 \(^c\) | | | | |
| Mean (SD)                | 20.4 (20.5) | 21.6 (20.9) | | 19.1 (22.2) | 21.9 (19.4) | |
| Median                   | 20.6 | 11.8 | | 16.2 | 20.6 | |
| Range                    | (-42.6 to 52.9) | (0.0 to 72.1) | | (-42.6 to 152.9) | (-17.6 to 72.1) | |
| HOOS—Sport/Rec           | 0.614 \(^c\) | 0.296 \(^c\) | | | | |
| Mean (SD)                | 31.3 (31.3) | 35.4 (28.2) | | 37.0 (29.7) | 28.9 (30.6) | |
| Median                   | 31.3 | 37.5 | | 37.5 | 31.3 | |
| Range                    | (-31.3 to 93.8) | (-43.8 to 75.0) | | (-25.0 to 93.8) | (-43.8 to 75.0) | |
| HOOS—QOL                 | 0.336 \(^c\) | 0.425 \(^c\) | | | | |
| Mean (SD)                | 36.7 (26.8) | 42.7 (20.4) | | 35.3 (29.3) | 40.5 (21.9) | |
| Median                   | 37.5 | 43.8 | | 40.6 | 37.5 | |
| Range                    | (-12.5 to 93.8) | (6.3 to 75.0) | | (-12.5 to 93.8) | (6.3 to 93.8) | |

(continued)
Second, each treatment algorithm was performed solely by one surgeon. As such differences in patient selection and technique may play a role as confounding variables. For example, patients treated with HA tended to have less severe dysplasia and more severe degenerative changes at baseline. However, these parameters were accounted for in the multivariable regression which showed no statistically significant differences in the PRO changes between surgical
technique groups and as such, we believe this limitation is
at least partially mitigated. Third, the short-term follow-up
precludes analysis of how treating intra-articular disease
may or may not alter the natural history of the dysplastic
hip following PAO. The primary intent of this investigation
was to determine patient function at a 1-year time point
when post-operative healing is expected to be near comple-
tion. Nevertheless, longitudinal follow-up of the cohort is
mandatory and further research regarding mid- to long-
term outcomes is necessary.

Our study did not find a difference in 1 year PRO im-
provement following PAO between patients who had
intra-articular assessment via HA or arthroscopy. Likewise,
no difference was identified between patients who received
intervention versus inspection alone. Siebenrock et al.
showed in a previous report that patients with labral tears
had worse performance after PAO [11]. In another study
from Pitto et al., 37 patients that had labral tears at the
time of PAO were treated as follows: 12 cases had labral
repair, 21 had damaged labrum excised and 4 had labral de-
bridement. There was no difference in observed outcomes
between these groups and the surgeons concluded that
treatment of the labrum may not be necessary as PAO
unloads the chondrolabral junction, providing an improved
environment for the labrum to heal [12]. The present
study did not show a difference between those that had la-
bral tears that were treated and those that did not have
identified tears at the time of arthroscopy or arthroscopy.

A significant future area for PAO research is the estab-
lishment of procedure-specific minimum clinically import-
ant differences (MCIDs) for this procedure. While these
have been relatively well-established for commonly used
PRO measures in HA, especially in the case of HOOS
Sports/Rec and mHHS, with conservative estimates of
25.0 and 9.0 points, respectively [13], such cutoffs are not
readily available in the PAO literature. On the basis of the
established values in the arthroscopy literature, both the
PAO with HA and PAO with arthroscopy groups well-
surpassed the MCIDs for mHHS and HOOS Sports/Rec
between pre- and post-operative assessments. It is note-
worthy that the differences in mHHS and HOOS Sports/
Rec observed between the two intervention cohorts were
neither statistically significant, nor did the point estimates
for the differences between the groups meet MCID.
Further comparisons between the two groups employing a
prospective, randomized controlled study design are
needed to investigate potential differences while minimiz-
ing the confounders present in retrospective analyses.

The results presented in this study are very similar to a
recent report from Goronyz et al. who followed three
groups of patients for a mean of 63 months: PAO alone for
isolated DDH; PAO and osteochondroplasty via arthroto-
my for DDH and cam lesions; PAO and osteochondro-
plasty and labral repair via HA for DDH with cam lesions
and labral tears. They demonstrated no differences in post-
operative PROs between all three groups [14]. This study
shares an important limitation with the current work; in
both, it remains unclear if the patients with intra-articular
pathology would have done worse had their labral tears or
cam lesions been ignored. Indeed, delineating sources of
pain generation in DDH is a clinical challenge as concomi-
tant intra-articular pathology is extremely common in these
patients. Hartig-Andreasen et al. in a recent prospective
study of 95 hips showed that labral disease was identified
in 94% of patients on pre-operative MRA before PAO [7].
However, MRA should be interpreted with caution. In a re-
cent conference abstract, our group showed poor concor-
dance between pre-operative MRA and intraoperative HA
with 55% agreement for labral pathology and 30% agree-
ment for acetabular cartilage pathology [15]. MRA is an
important tool, but is not reliable in determining what type
of labral pathology would require fixation or repair, unless
the MRI clearly shows a chondrolabral disruption. Intra-
substance degeneration of the labrum, e.g. may be inter-
preted on MRI as a tear, but not require treatment at the
time of HA. In addition, normal variants, such as a sulcus
between the chondral and labral junction may be inter-
preted as a tear. Identifying what chondrolabral pathology
requires treatment would help identify patients that should
undergo HA or arthroscopy at the time of PAO. A pro-
spective, randomized study that takes into account pre-
operative MRI findings is necessary.

Hartig-Andreasen et al. perform a minimally invasive trans-
sartorial approach for PAO and do not inspect the joint at
the time of surgery [16]. Although 94% of patients had pre-
operative MRA-diagnosed labral disease, only 27% returned
within 2 years for subsequent HA to address persistent symp-
toms that were attributed in part to labral disease. At 2-year
follow-up, patients that underwent subsequent HA had infe-
rior outcomes to patients undergoing PAO alone, which
would support identifying patients with labral disease or char-
aristics that lead to failure of the PAO alone [7]. The
authors reported that those with pre-operative borderline dys-
plasia, acetabular retroversion and complete labral detach-
ment had a higher likelihood of requiring subsequent surgery.
Our historical experience would indicate that <10% of
patients return for intra-articular intervention, however, we
routinely perform either HA or arthroscopy in almost every
patient. It remains unclear whether existent intra-articular
damage that is not treated may progress after appropriate re-
orientation of the acetabulum or if an incompetent labrum
poses an elevated risk for subsequent cartilage degeneration.
Mechlenburg et al. demonstrated unchanged cartilage status more than 2 years after PAO regardless of whether there was concomitant labral damage [17]. Matheney et al. also showed that a labral tear at the time of PAO did not increase the risk for THA at long-term follow-up [18]. Further follow-up is needed to determine the differences in radiographic progression and natural history between groups and how this compares to the untreated dysplastic hip [19].

We showed that age and BMI did not have an impact on early PROs. This is not surprising as 66% were <30 years, 96% were <40 years and 86% were <30 BMI. Furthermore, relative advanced age and elevated BMI have been associated with inferior outcomes after PAO at later follow-up time points [2,20]. Although numbers were limited (n = 4), we did not observe an association between concomitant acetabular retroversion and PRO outcomes. Presence of dysplasia with retroversion needs to be taken into account at the time of correction in order to prevent iatrogenic impingement [5]. Albers et al. have reported residual impingement in any plane after PAO adversely affects outcomes at 10 years [21]. In the present study, 14 hips underwent osteochondroplasty; however, their post-operative PROs were no different than those that did not. We did find that women had superior PRO outcomes to men with almost all metrics; 7 of the 13 were significantly improved. The vast majority of patients (87%) were women, which is representative of most DDH practices. Previous studies have shown that men have more severe forms of dysplasia and abnormal head neck junctions, potentially creating an environment for a more difficult correction [18]. This finding could also be related to the discrepant sample size; however, there was no difference in intra-articular intervention between men and women.

In conclusion, this study further confirms the ability of PAO to drastically improve symptoms and hip function in patients with DDH. Treating patients with HA as opposed to arthroscopy for intra-articular pathology did not demonstrate added benefit in this cohort of patients. Women showed greater clinical improvement than men regardless of which treatment algorithm was applied. This work highlights the need for high quality randomized clinical trials and larger cohort studies to provide definitive guidance on whether hip preservation surgeons should address intra-articular pathology at the time of PAO for DDH and which technique is best suited for this purpose.

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CONFLICT OF INTEREST STATEMENT

Each author certifies that he or she has no commercial associations (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 waived approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

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