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Research article

Short-term patient-reported outcomes following concomitant hip arthroscopy and the endoscopic modified shelf procedure for the treatment of acetabular dysplasia and intra-articular pathology

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ABSTRACT

The shelf procedure is a treatment of acetabular dysplasia, with the aim of increasing weight-bearing acetabular coverage. Although several shelf techniques have been described, the endoscopic procedure with concomitant hip arthroscopy is a new, less invasive alternative. Outcomes following this procedure are scarce. The purpose of this study was to report short-term patient-reported outcomes (PROs) following concomitant hip arthroscopy and endoscopic modified shelf procedure in the setting of acetabular dysplasia and labral tears. Patients that met extraordinarily selective surgical indications and underwent the abovementioned surgery between February 2016 and October 2019 and had minimum 1-year follow-up were included. There were five females with a mean age of 40.18 ± 5.05 years and follow-up of 21.55 ± 8.68 months. The lateral center-edge angle increased from 15.80° to 23.20° ($P = 0.003$), and vertical center-edge angle increased from 16.60° to 23.60° ($P < 0.001$). The Tönnis angle decreased from 15.40° to 3.74° ($P < 0.001$). The alpha angle decreased from 58.46° to 40.70° ($P < 0.001$). PROs demonstrated significant improvement at latest follow-up (modified Harris Hip Score, $P = 0.042$; Non-Arthritic Hip Score, $P < 0.001$; Hip Outcome Score–Sports Specific Subscale, $P = 0.035$; Visual Analog Scale, $P < 0.001$; International Hip Outcome Tool-12, $P = 0.043$), and satisfaction was 8.60 ± 0.89. No secondary surgeries were reported. Concomitant hip arthroscopy and endoscopic modified shelf procedure appears to be a safe and effective procedure for patients with acetabular dysplasia and labral tears yielding favorable outcomes and satisfaction at short-term follow-up.

INTRODUCTION

The prevalence of hip acetabular dysplasia in the general population ranges from 4.0% to 12.8%. Patients with acetabular dysplasia are five times more likely to develop osteoarthritis compared to non-dysplastic patients [1]. Isolated hip arthroscopy in the setting of symptomatic acetabular dysplasia remains controversial [2–5]. The Bernese periacetabular osteotomy (PAO) is the most common treatment for acetabular dysplasia in skeletally mature patients with preserved cartilage [6, 7] and currently remains the gold-standard in this setting [8, 9]. Despite being a technically demanding and invasive surgery, the many advantages of the PAO have led it to be the preferred treatment for many surgeons.

The shelf operation was designed to increase coverage of the femoral head by constructing an extra-articular bony buttress extension on the slope of the acetabulum [10, 11]. Although favorable outcomes have been reported

following the shelf procedure through an open approach [12–14], after the development of the PAO by Reinhold Ganz in 1984, the shelf operation has become much less used [15].

Uchida *et al.* [16] were the first to describe an endoscopic approach for the shelf procedure with concomitant hip arthroscopy. These authors reported significant improvements in short-term patient-reported outcomes (PROs) outcomes in patients with acetabular dysplasia who underwent this approach [17]. To date, only this institution has published outcomes on this minimally invasive procedure.

Accordingly, we undertook this small pilot series with extraordinarily selective indications in order to assess whether favorable outcomes could be reproduced with this procedure at our institution. The purpose of this study was to report short-term PROs following concomitant hip arthroscopy and the endoscopic modified shelf procedure in the setting of acetabular dysplasia and labral tears. It was hypothesized that concomitant hip arthroscopy and the endoscopic modified shelf procedure would result in improvement in PROs and patient satisfaction with a high rate of achieving the minimal clinically important difference (MCID) at short-term follow-up.

MATERIALS AND METHODS

Participation in the American Hip Institute hip preservation registry

All patients included in this study participated in the A.H.I. hip preservation registry. All data collection and reporting received institutional review board approval.

Patient selection

Data in this retrospective case series were drawn from a prospectively maintained institutional database. Patients who underwent concomitant hip arthroscopy and the endoscopic modified shelf procedure by the senior author (B.G.D.) between February 2016 and October 2019 and had minimum 1-year follow-up, were included. There were no exclusion criteria in this study.

Demographics

Six demographic variables: age at surgery, body mass index (BMI), sex, operative side, previous ipsilateral hip surgery and follow-up time were also recorded in the institutional database and were of interest in this study.

Physical examination

Patients underwent a comprehensive physical examination by the senior author (B.G.D) pre- and post-operatively. This examination assessed the range of motion, gait, alignment and strength. To assess hip instability the abduction–hyperextension–external rotation, prone instability and hyperextension–external rotation tests were performed [18]. The Beighton test was used to assess ligamentous laxity [19, 20]. Impingement testing was used to assess concomitant femoroacetabular impingement (FAI) syndrome and labral tear.

Radiographic measurements

Radiographic images were obtained pre-operatively, and post-operatively at the 2-week, 3-month, 1-year, and 2-year points. Radiographic measurements of the hip joint were taken from the anteroposterior, false-profile and Dunn 45° views. Image evaluation was performed with General Electric Healthcare's Picture Archiving Communication System. The institute's radiographic measurements have demonstrated interobserver reliability in previously published studies [21]. The anteroposterior view was used to measure Tönnis grade [22], lateral center-edge angle (LCEA) [23], Tönnis angle [24] and neck-shaft angle (Fig. 1). The Dunn 45° view provided alpha angle and femoral offset (Fig. 2) [25]. The false-profile view provided the vertical center-edge angle (VCEA) (Fig. 2B) [26]. Hip dysplasia was defined as an LCEA $\leq 25°$, being frank acetabular dysplasia in patients with an LCEA $< 18°$, and borderline acetabular dysplasia for patients with an LCEA between 18° and 25° [27]. Additionally, cam-type FAI morphology was defined as alpha angle $> 55°$ [28].

Surgical indications

Extraordinarily selective indications were applied for this procedure during the study period. The endoscopic modified shelf procedure was offered for the treatment of acetabular dysplasia only in active adults who did not want to undergo PAO, and otherwise met indications after radiographic imaging, history and physical examination [29]. Indications and contraindications are presented in Table I. Acetabular dysplasia was evaluated radiographically using the LCEA, VCEA and Tönnis angle. Patients were indicated if they had moderate to severe pain, worsened by flexion, joint motion and impingement test, for more than 3 months that was unresponsive to conservative treatment. Clinically, patients had symptomatic FAI, with positive impingement test and evidence of hip instability. Patients underwent magnetic resonance arthrography to identify other intra-articular pathology, such as labral tears. After diagnostic imaging, there was no evidence of osteoarthritis or severe chondral damage. For patients with an LCEA between 12° and 20° who met the indications and did not have any contraindications present, concomitant hip

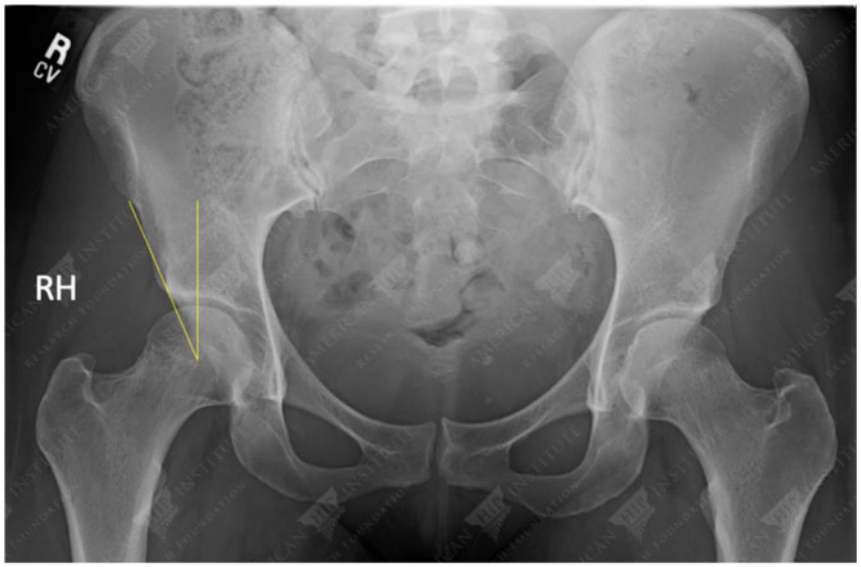

Fig. 1. Anteroposterior pelvis preoperative X-ray. Right hip (RH) with a lateral center-edge angle (yellow lines) of 14°.

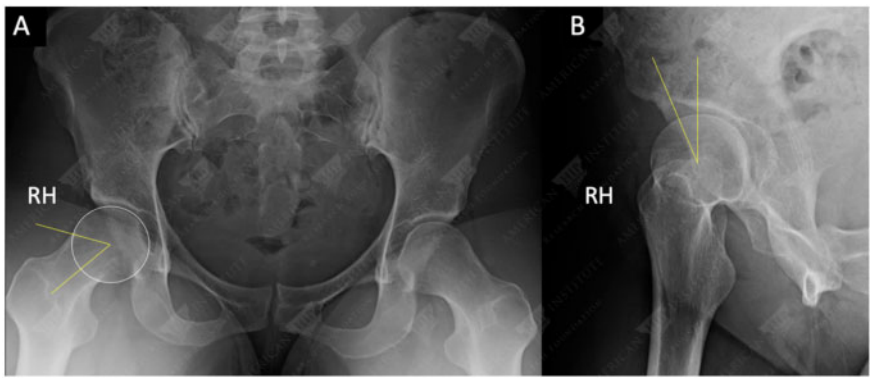

Fig. 2. (**A**) Dunn 45° view preoperative X-ray. Right hip (RH) with an alpha angle over 55° (yellow lines). (**B**) False profile view preoperative X-ray. The vertical center-edge angle demonstrated a value of 15° (yellow lines).

Table I. Surgical indications and contraindications for combined hip arthroscopy and endoscopic modified shelf procedure

Indications	*Contraindications*
Hip pain >3 months	Severe dysplasia, LCEA <12°
	Advanced osteoarthritis, Tönnis grade >1
LCEA between 12° and 20°	Associated severe skeletal abnormalities (perthes, coxa magna and slipped capital femoral epiphysis)
MRA evidence of labral tear	Active infection
No evidence of severe chondral damage on dGEMRIC MRA	Skeletally immature patients (age < 12 years)
Tönnis grade ≤1	Severe chondral damage and subchondral cysts

dGEMRIC, delayed contrast-enhanced magnetic resonance imaging of cartilage; LCEA, lateral center-edge angle; MRA, magnetic resonance arthrography.

Table II. Advantages and disadvantages of combined hip arthroscopy and the endoscopic modified shelf procedure

Advantages	*Disadvantages*
Arthroscopic visualization and fluoroscopy use during case	Steep learning curve
Treatment of concomitant pathologies (labral tear, cam-type FAI)	Meticulous surgical technique
No donor-site morbidity	Not indicated for severely dysplastic hips, LCEA $<12^{\circ}$
Minimally invasive surgery	Risks (extravasation, compartmental syndrome, allograft fracture, non-healing or reabsorption)
Use of cannulated screws for improved graft stabilization	Lack of long-term follow-up

FAI, femoroacetabular impingement; LCEA, lateral center-edge angle.

arthroscopy and the endoscopic modified shelf procedure was offered as an alternative to PAO. The advantages and disadvantages of the procedure are shown in Table II.

Arthroscopic evaluation and surgical technique

All surgeries were performed by the senior author (X.X.X.). Patients received general anesthesia for muscle relaxation. The approach began with patients in the modified supine position on the traction extension table with a well-padded peroneal post in preparation for the hip arthroscopy phase [30].

Under fluoroscopy, the joint seal was broken, and traction was applied as needed. The anterolateral (AL) portal was created under fluoroscopy to vent the joint and was followed by the mid-anterior (MA) and distal anterolateral accessory (DALA) portals [31]. An interportal capsulotomy between the AL and MA portals was performed. A systematic diagnostic arthroscopy was undertaken to make a full assessment of the joint. Ligamentum teres (LT) damage was graded using the Domb and Villar classifications [32, 33]. Labral tears were graded using the Seldes classification system [34]. The chondrolabral junction damage was graded using acetabular labrum articular disruption, while acetabular or femoral head chondral damage was recorded using the Outerbridge classifications.

Treatment of intra-articular pathology was carried out when indicated. Femoral osteoplasty was performed under fluoroscopy to treat cam-type morphology [35]. Based on the extent of labral tearing, size and characteristics, labral pathology was addressed and suction seals were restored by selective debridement, repair, or reconstruction [36]. Labral repairs were conducted through a simple loop technique (Fig. 3) [37]. For labral reconstruction, the knotless pull-through technique with allograft was used (Fig. 4) [38]. LT injuries were debrided with a radiofrequency device and shaver. Capsular plication was performed in all patients [39].

Next, with patients still supine, the endoscopic stage for acetabular bony deficiency correction through the shelf technique was performed, as described by Uchida *et al.* and modified by Maldonado *et al.* [16, 29]. An iliac wing bone allograft was selected and prepared to 10-mm-wide and 20-mm-deep, with an additional 3-mm × 7-mm tapered wing wedge created at the superior aspect (Fig. 5). The arthroscope was placed into the extra-capsular space under fluoroscopy. Using a radiofrequency device and shaver, a working space was created between the reflected head of the rectus femoris and the anterior acetabular rim to assist the allograft placement. The bony bed was then decorticated with the bur. A trough measuring ~10 mm wide and 20 mm deep was created and deepened at the superior aspect to create space for the wing wedge fabricated on the allograft bone graft. Two parallel 1.25-mm guidewires were passed through the graft, and the graft itself went through the DALA portal. Adequate position and orientation of the graft was confirmed using arthroscopic and fluoroscopic views. Once confirmed, both guidewires were advanced to the previously created bone slot, and final fixation was achieved with two partially threaded 3.5-mm cannulated screws (Fig. 6). Intraoperative range of motion with and without fluoroscopy was used at the end of every procedure to verify that there was no evidence of bony impingement.

Rehabilitation

After surgery, all patients used crutches with a 20 lb. weight-bearing restriction and were placed in a DonJoy hip brace (DJO Global, Vista, CA, USA) locked at 0° to 90° range of motion for 6–8 weeks. Post-operative day 1, patients began daily use of a continuous passive motion

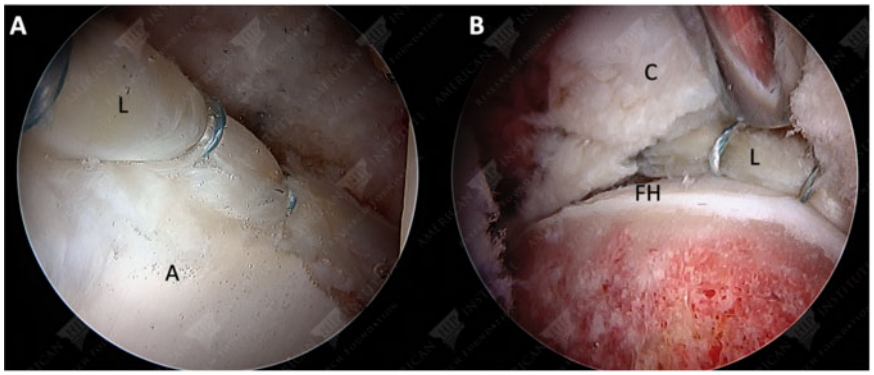

Fig. 3. Right hip corresponding to a dysplastic patient during the arthroscopic phase. (**A**) The labrum (L) has been repaired. (**B**) The suction seal has been restored. A, acetabulum; C, capsule; FH, femoral head.

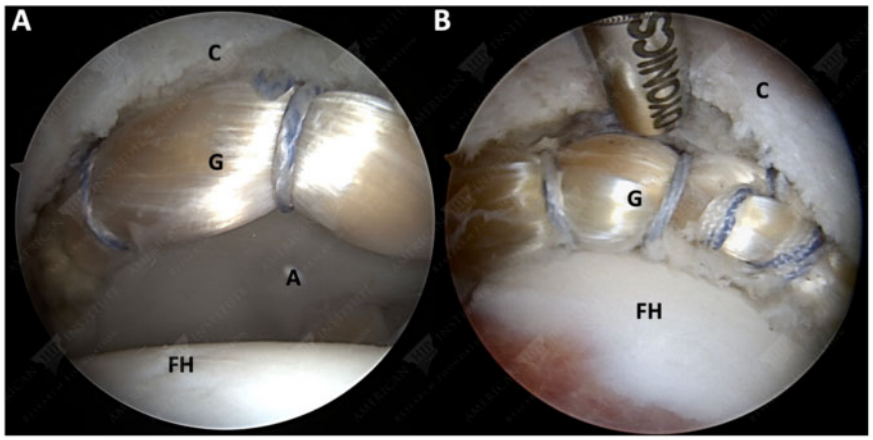

Fig. 4. Intraoperative images depicting labral reconstruction in a right hip of a dysplastic patient during the arthroscopic phase. (**A**) The labrum has been reconstructed using a posterior tibialis allograft (G). (**B**) Traction released to restore the suction seal. A, acetabulum; C, capsule; FH, femoral head.

machine or stationary bike. Formal physical therapy was delayed until 6-week post-operative in order to protect the graft and encourage healing. All patients followed the institution's physical therapy protocol to improve range of motion and strengthen the hip stabilizers and core muscles.

Surgical outcomes

PROs collected for this study included the modified Harris Hip Score (mHHS), Non-Arthritic Hip Score (NAHS), Hip Outcome Score–Sports Specific Subscale (HOS-SSS), Visual Analog Scale (VAS) for pain, International Hip Outcome Tool-12 (iHOT-12) and patient satisfaction (0–10). Any complications, revisions or conversions to total hip arthroplasty were documented. Questionnaires were completed by patients through encrypted email, phone interview, or in clinic preoperatively, and post-operatively at the 3-month, 1-year and 2-year points. Preoperative PROs were utilized to calculate the MCID for the mHHS, NAHS and iHOT-12 using a distribution-based calculation, as reported by Norman *et al.* [40].

Statistical analysis

Descriptive statistics for continuous variables were reported as means and standard deviations. Categorical variables were reported as totals and percentages. Continuous variables were assessed for normality using the Shapiro–Wilk test and assessed for equal variance using the *F*-test. A two-tailed paired *t* test was used to assess normally distributed data sets with equal variance, and the Wilcoxon signed-rank test or Mann–Whitney *U* test was used to analyze nonparametric data. A chi-square analysis was conducted for categorical data. The threshold for statistical significance was set at $P < 0.05$. All statistical analysis was performed using R Studio.

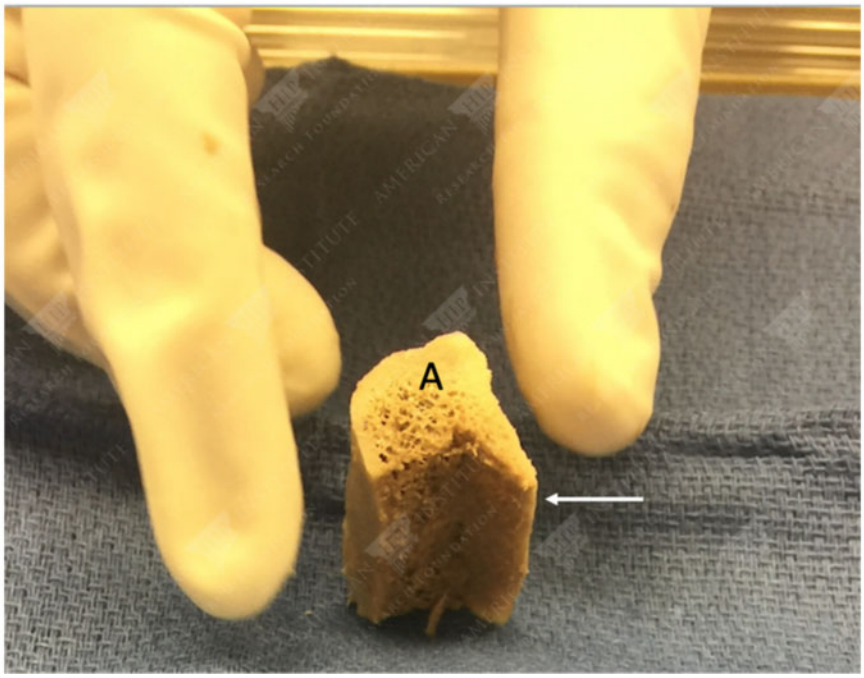

Fig. 5. An iliac wing bone allograft (A) was selected and prepared to 10-mm-wide and 20-mm-deep, with an additional 3-mm × 7-mm tapered wing wedge created at the superior aspect (white arrow). This figure was originally published in the following article: https://doi.org/10.1016/j.eats.2018.03.015.

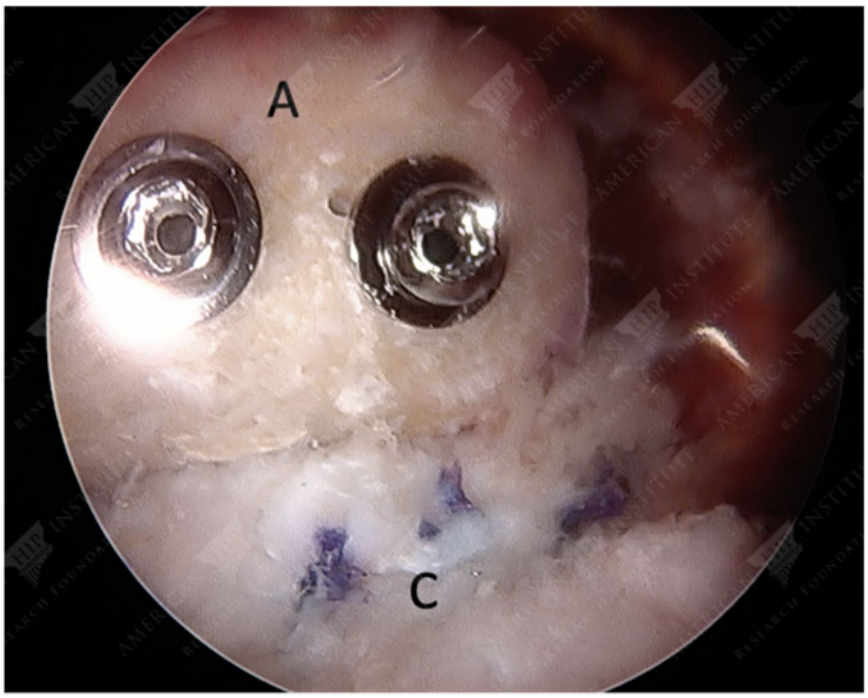

Fig. 6. The image corresponded to a right hip with the final modified shelf endoscopic construct with the iliac wing bone allograft (A) fixated with two cannulate screws. The plication of the capsule (C) can be noticed. The article was published under the terms of https://creativecommons.org/licenses/by-nc-nd/4.0/.

RESULTS

Demographics

There were five eligible patients (five hips) that underwent an endoscopic modified shelf procedure by the senior author (B.G.D.) during the study period, all of whom had a minimum 1-year follow-up. The cohort consisted of five females with a mean age of 40.18 ± 5.05 years, BMI of 23.84 ± 2.29 kg/m^2 and follow-up of 21.55 ± 8.68 months. Two patients were operated on the left hip, and three on the right. One patient had a previous ipsilateral hip arthroscopy, and the rest had no previous hip surgery before the concomitant hip arthroscopy and shelf procedure. Demographics are presented in Table III.

Radiographic measurements

All pre-operative radiographs were Tönnis grade 0, and there was no progression of arthritis in radiographs taken at the latest clinical follow-up. The LCEA increased from 15.80 ± 1.64° to 23.20 ± 2.28° ($P = 0.003$), and VCEA increased from 16.60 ± 2.07° to 23.60 ± 1.82° ($P < 0.001$). The Tönnis angle of acetabular inclination decreased from 15.40 ± 2.30° to 3.74 ± 2.27° ($P < 0.001$). The alpha angle decreased from 58.46 ± 4.34° to 40.70 ± 1.58° ($P < 0.001$). Table IV shows the pre- to post-operative radiographic measurements for this study group.

Table III. Patient demographics

Age at surgery, years	40.18 ± 5.05
BMI	23.84 ± 2.29
Sex	
Male	0 (0.0)
Female	5 (100.0)
Operative side	
Left	2 (40.0)
Right	3 (60.0)
Previous ipsilateral hip surgery	
Yes	1 (20.0)
No	4 (80.0)
Follow-up, months	21.55 ± 8.68
Beighton score	
0	1 (20.0)
2	2 (40.0)
4	1 (20.0)
9	1 (20.0)

Values are presented as mean ± standard deviation or *n* (%).
BMI, body mass index.

Table IV. Pre- and post-operative radiographic measurements

	Pre-operative	*≥1-year follow-up*	P-*value*
Tönnis grade 0	5 (100.0)	5 (100.0)	—
LCEA, °	15.80 ± 1.64	23.20 ± 2.28	**0.004**
VCEA, °	16.60 ± 2.07	23.60 ± 1.82	**<0.001**
Tönnis angle, °	15.40 ± 2.30	3.74 ± 2.27	**<0.001**
Alpha angle, °	58.46 ± 4.34	40.70 ± 1.58	**<0.001**
Femoral offset, cm	0.64 ± 0.05	1.29 ± 0.72	0.062
Neck shaft angle, °	133.20 ± 10.38	131.72 ± 5.52	0.711

Values are presented as mean ± standard deviation or *n* (%). Bold values indicate statistical significance ($P < 0.05$).
LCEA, lateral center-edge angle; VCEA, vertical center-edge angle.

Intraoperative findings and procedures

All patients were found to have labral tears. Three patients were treated with labral repair, one patient with labral selective debridement and one patient with segmental labral reconstruction. Femoroplasty was performed in four patients. Intraoperative findings and surgical procedures can be found in Tables V and VI, respectively.

Surgical outcomes

For the entire cohort, PROs demonstrated significant improvement at minimum 1-year follow-up when compared with preoperative levels (mHHS, $P = 0.042$; NAHS, $P < 0.001$; HOS-SSS, $P = 0.035$; VAS, $P < 0.001$; iHOT-12, $P = 0.043$). The mean patient satisfaction was 8.60 ± 0.89. Additionally, 100% of patients met the MCID for mHHS, NAHS and iHOT-12. Pre- and post-operative PROs are presented in Table VII.

There was one superficial wound complication, which was resolved with antibiotics. At one patient's 6-month follow-up visit, a broken distal screw was noted on radiographic imaging. However, the broken hardware was stable with no evidence of subsidence or loosening. There were no other complications recorded. No secondary surgeries were reported.

Table V. Intraoperative findings

Seldes	
I	0 (0.0)
II	2 (40.0)
Combined I and II	3 (60.0)
ALAD	
0	0 (0.0)
1	4 (80.0)
2	0 (0.0)
3	1 (20.0)
4	0 (0.0)
Outerbridge (acetabulum)	
0	0 (0.0)
1	4 (80.0)
2	0 (0.0)
3	1 (20.0)
4	0 (0.0)
Outerbridge (femoral head)	
0	5 (100.0)
1	0 (0.0)
2	0 (0.0)
3	0 (0.0)
4	0 (0.0)
LT percentile class (domb)	
0: 0%	2 (40.0)
1: 0% to <50%	1 (20.0)
2: 50% to <100%	1 (20.0)
3: 100%	1 (20.0)
LT villar class	
0: no tear	2 (40.0)
1: full-thickness tear	1 (20.0)
2: partial thickness tear	0 (0.0)
3: degenerative tear	2 (40.0)

Values are presented as *n* (%).
ALAD, acetabular labrum articular disruption; LT, ligamentum teres.

DISCUSSION

This study demonstrated that concomitant hip arthroscopy and the endoscopic modified shelf procedure for the treatment of acetabular dysplasia and labral tears resulted in significant improvement in PROs and high satisfaction at short-term follow-up. Similar findings have been previously reported. In a retrospective investigation of 32 dysplastic patients (36 hips, 11 males and 21 females) who underwent concomitant hip arthroscopy and shelf procedure with minimum 2-year follow-up, Uchida *et al.* [17] concluded that promising clinical outcomes and return to sports-related activity is attained by active patients with acetabular dysplasia.

The concept of the shelf procedure to correct acetabular dysplasia in patients with lateral bone coverage defect of the acetabulum is not new. Favorable long-term results have been established using an open approach [12, 13], with a survival probability of 50% after 25 years [41]. The shelf procedure is considered to be one of the least invasive options for the management of acetabular dysplasia in young active adults. The advantages of the open technique include the prevention of osteonecrosis development in the acetabulum and maintenance of the pelvic ring [10]; however, one main concern of the open technique is damage to the abductors which can be avoided with the minimally invasive endoscopic approach [16]. Yet, for both approaches, the weight-bearing area of hyaline cartilage over the femoral head cannot be increased and the acetabular medialization of the joint cannot be performed, unlike the PAO. Therefore, the severity of dysplasia that can be treated with open or endoscopic measures is controversial [14].

Table VI. Concomitant arthroscopic procedures

Labral treatment	
Selective debridement	1 (20.0)
Repair	3 (60.0)
Reconstruction	1 (20.0)
Femoroplasty	4 (80.0)
LT debridement	3 (60.0)
Capsular treatment	
Plication	5 (100.0)
Interportal capsulotomy without closure	0 (0.0)

Values are presented as *n* (%).
LT, ligamentum teres.

Table VII. Pre- and post-operative patient-reported outcomes

PRO	*Pre-operative*	*≥1-year follow-up*	P-*value*
mHHS	72.33 ± 5.40	89.80 ± 9.42	**0.042**
NAHS	67.92 ± 3.68	91.00 ± 8.63	**<0.001**
HOS-SSS	44.21 ± 20.15	86.31 ± 19.21	**0.035**
VAS	7.91 ± 0.73	1.40 ± 1.39	**<0.001**
iHOT-12	42.72 ± 11.30	84.30 ± 21.08	**0.043**
Satisfaction	—	8.60 ± 0.89	—

Values are presented as mean ± standard deviation (SD). Bold values indicate statistical significance ($P < 0.05$).

mHHS, modified Harris Hip Score; NAHS, Non-Arthritic Hip Scope; HOS-SSS, Hip Outcome Score, Sport-Specific Subscale; VAS, Visual-Analog Scale; iHOT-12, international Hip Outcome Tool-12.

Acetabular dysplasia and cam-type FAI often coexist [42]. Goronzy *et al.* [43] reported a 53.8% incidence of femoroplasty due to cam-type FAI morphology during PAO surgery. In this study, 80.0% of the patients required a neck–head junction morphology correction that was performed in a reproducible manner [35].

Hip arthroscopy is a powerful tool for intra-articular joint inspection at the time of acetabular dysplasia surgery [44] It provides full access to the joint for the evaluation and treatment of intra-articular pathology. The prevalence of labral tears during diagnostic arthroscopy in the setting of acetabular dysplasia has been reported to be as high as 84.0% [45]. The importance of the labrum in hip biomechanics has been previously established [46, 47], and labral tears could adversely affect clinical outcomes in dysplastic patients after the shelf procedure. Berton *et al.* [12] recommended labral repair during shelf arthroplasty to prevent a potential source of residual pain. In the present investigation, a restoration of the labral suction seal through selective labral debridement [48], labral repair and labral reconstruction was achieved [36].

While data on outcomes following concomitant hip arthroscopy and endoscopic modified shelf procedure is scarce, this study is one of the first to report PROs following this procedure for the surgical management of acetabular dysplasia. Additionally, the inclusion of multiple validated functional hip outcomes scores in this study leads to more generalizable results. While the PAO remains the gold-standard treatment for acetabular dysplasia in skeletally mature patients with preserved cartilage [8], concomitant hip arthroscopy and the endoscopic shelf procedure is a less invasive alternative that can be offered to young, active, adult patients with acetabular dysplasia who do not want or qualify for PAO (Figs 7–10).

This study has limitations, one being that this was a retrospective investigation on prospectively collected data.

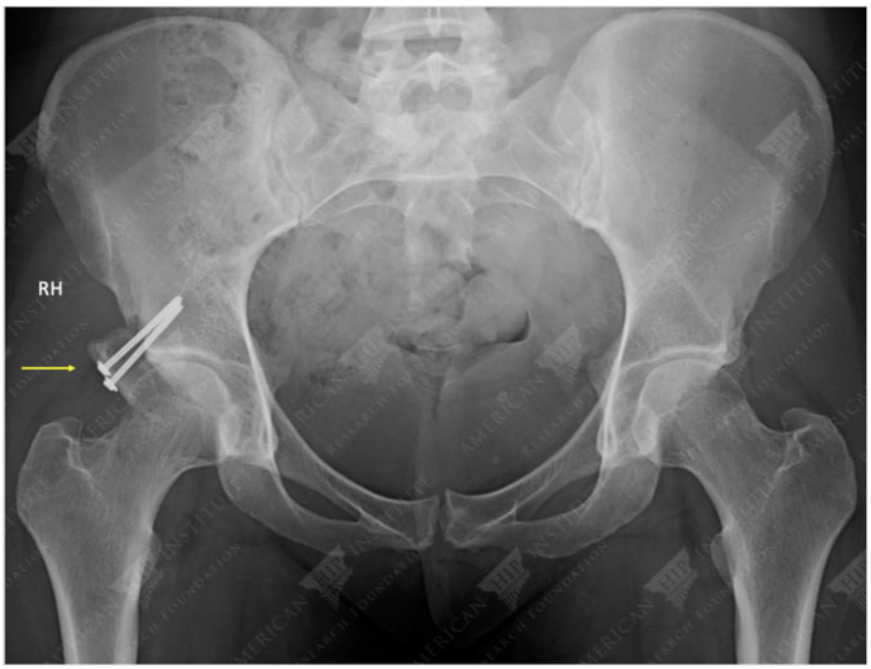

Fig. 7. Anteroposterior pelvis post-operative X-ray showing final result in the right hip (RH). The iliac bone allograft is marked (yellow arrow).

Fig. 8. False profile view post-operative X-ray showing final construct (yellow arrow) and correction of the cam-type femoroacetabular morphology (white arrow) in the right hip (RH).

Fig. 9. Anteroposterior pelvis X-ray at 1-year post-operative showing final construct in the right hip (RH). The iliac bone allograft is marked (yellow arrow).

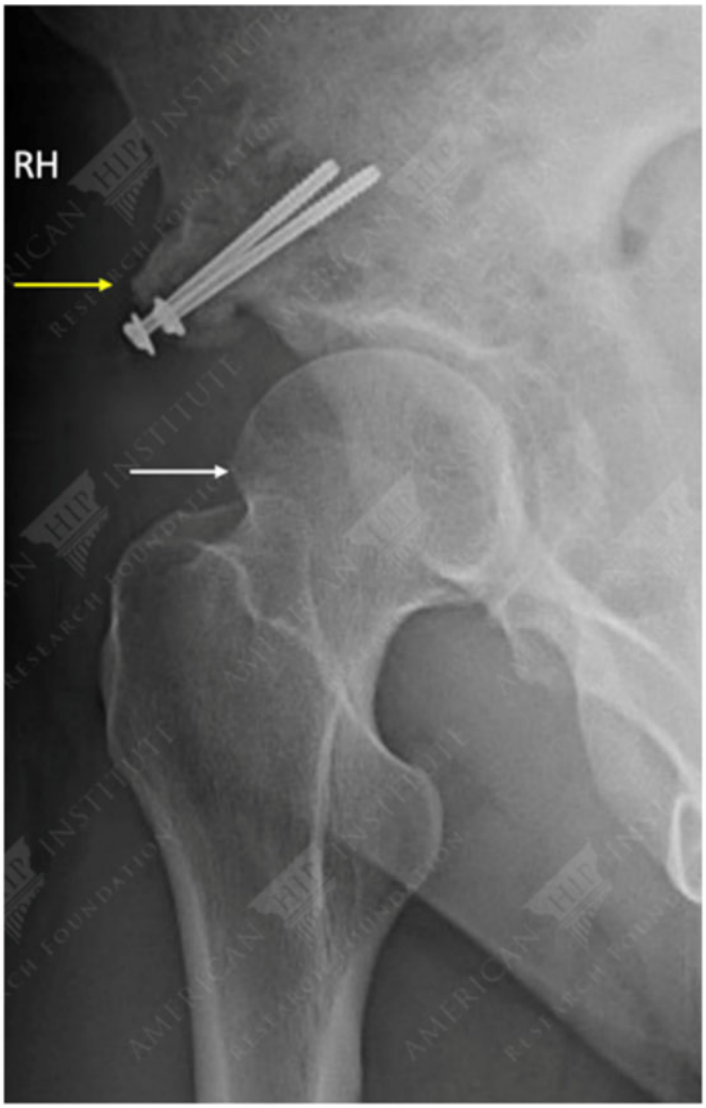

Fig. 10. False profile view X-ray at 1-year post-operative showing final construct (yellow arrow) and correction of the cam-type femoroacetabular morphology (white arrow) in the right hip (RH).

Moreover, there was no control or comparison to other procedures, such as PAO. The authors of the present investigation acknowledge PAO with or without concomitant hip arthroscopy as the best treatment option for acetabular dysplasia in young adults. Concomitant hip arthroscopy and the endoscopic modified shelf procedure is offered as an alternative treatment for patients who meet indications and do not want to undergo PAO. The sample size was also small, limiting the generalizability of the results. Further, this was an analysis of a single surgeon database. Acetabular dysplasia is a complex tridimensional structural pathology and isolated assessment based solely on LCEA may be oversimplistic. The classification of acetabular dysplasia as frank or borderline based on LCEA measurements alone is controversial [49]. Finally, this study reported short-term outcomes, longer follow-up is needed to determine the durability of the results.

CONCLUSION

Concomitant hip arthroscopy and endoscopic modified shelf procedure appears to be a safe and effective procedure for patients with acetabular dysplasia and labral tears yielding significant improvement in PROs and patient satisfaction at short-term follow-up.

ETHICAL APPROVAL

This study was performed in accordance with the ethical standards in the 1964 Declaration of Helsinki. This study was carried out in accordance with relevant regulations of the US Health Insurance Portability and Accountability Act (HIPAA). Details that might disclose the identity of the subjects under study have been omitted. This study was approved by the IRB (IRB ID: 5276).

DATA AVAILABILTY

The data analyzed during the current study will be shared by the corresponding author upon reasonable request.

CONFLICT OF INTEREST STATEMENT

Dr. Domb reports grants and other from American Orthopedic Foundation, during the conduct of the study; personal fees from Adventist Hinsdale Hospital, personal fees and non-financial support from Amplitude, grants, personal fees and non-financial support from Arthrex, personal fees and non-financial support from DJO Global, grants from Kaufman Foundation, grants, personal fees, non-financial support, from Medacta, grants, personal fees, non-financial support and other from Pacira Pharmaceuticals, grants, personal fees, non-financial support and other from Stryker, grants from Breg, personal fees from Orthomerica, grants, personal fees, non-financial support and other from Mako Surgical Corp, grants and non-financial support from Medwest Associates, grants from ATI Physical Therapy, grants, personal fees and non-financial support from St. Alexius Medical Center, grants from Ossur, outside the submitted work; In addition, Dr. Domb has a patent 8920497 - Method and instrumentation for acetabular labrum reconstruction with royalties paid to Arthrex, a patent 8708941 - Adjustable multi-component hip orthosis with royalties paid to Orthomerica and DJO Global, and a patent 9737292 - Knotless suture anchors and methods of tissue repair with royalties paid to Arthrex and Dr. Domb is the Medical Director of Hip Preservation at St. Alexius Medical Center, the Clinical Instructor at the University of Illinois College of Medicine, a board member for the American Hip Institute Research Foundation, AANA Learning Center Committee, the Journal of Hip Preservation Surgery, the Journal of Arthroscopy; has had ownership interests in the American Hip Institute, Hinsdale Orthopedic Associates, Hinsdale Orthopedic Imaging, SCD#3, North Shore Surgical Suites, and Munster Specialty Surgery Center.

Dr. Lall reports grants, personal fees and non-financial support from Arthrex, non-financial support from Iroko, non-financial support from Medwest, non-financial support from Smith & Nephew, grants and non-financial support from Stryker, non-financial support from Vericel, non-financial support from Zimmer Biomet, personal fees from Graymont Medical, outside the submitted work; and Dr. Lall is the Co-Medical Director of Hip Preservation at St. Alexius Medical Center, the Clinical Instructor at the University of Illinois College of Medicine, and member of the AANA Learning Center Committee.

Dr. Maldonado reports non-financial support from Arthrex, non-financial support from Stryker, non-financial support from Smith & Nephew, non-financial support from Ossur, outside the submitted work; and Dr. Maldonado is an editorial board member of the Journal of Arthroscopy.

Dr. Saks reports grants from Arthrex, personal fees from DJO Global, outside the submitted work.

REFERENCES

1. Wilkin GP, Poitras S, Clohisy J *et al.* Periacetabular osteotomy with or without arthroscopic management in patients with hip dysplasia: study protocol for a multicenter randomized controlled trial. *Trials* 2020; **21**: 725.
2. Edelstein AI, Nepple JJ, Abu-Amer W *et al.* What mid-term patient-reported outcome measure scores, reoperations, and complications are associated with concurrent hip arthroscopy and periacetabular osteotomy to treat dysplasia with associated intra-articular abnormalities? *Clin Orthop* 2020; **479**: 1068–1077.
3. Uchida S, Utsunomiya H, Mori T *et al.* Clinical and radiographic predictors for worsened clinical outcomes after hip arthroscopic labral preservation and capsular closure in developmental dysplasia of the hip. *Am J Sports Med* 2016; **44**: 28–38.
4. Wyles CC, Hevesi M, Bartels DW *et al.* Arthroscopy and arthrotomy to address intra-articular pathology during PAO for hip dysplasia demonstrates similar short-term outcomes. *J Hip Preserv Surg* 2018; **5**: 282–95.
5. Thanacharoenpanich S, Boyle MJ, Murphy RF *et al.* Periacetabular osteotomy for developmental hip dysplasia with labral tears: is arthrotomy or arthroscopy required? *J Hip Preserv Surg* 2018; **5**: 23–33.
6. Wyles CC, Vargas JS, Heidenreich MJ *et al.* Natural history of the dysplastic hip following modern periacetabular osteotomy. *J Bone Joint Surg Am* 2019; **101**: 932–8.
7. Novais EN, Coobs BR, Nepple JJ *et al.*; ANCHOR Study Group. Previous failed hip arthroscopy negatively impacts early patient-reported outcomes of the periacetabular osteotomy: an ANCHOR Matched Cohort Study. *J Hip Preserv Surg* 2018; **5**: 370–7.
8. Wyles CC, Vargas JS, Heidenreich MJ *et al.* Hitting the target: natural history of the hip based on achieving an acetabular safe zone following periacetabular osteotomy. *J Bone Joint Surg Am* 2020; **102**: 1734–40.
9. Beck EC, Gowd AK, Paul K *et al.* Pelvic osteotomies for acetabular dysplasia: are there outcomes, survivorship and complication

differences between different osteotomy techniques? *J Hip Preserv Surg* 2020; **7**: 764–76.
10. Shibata KR, Matsuda S, Safran MR. Open treatment of dysplasia—other than PAO: does it have to be a PAO? *J Hip Preserv Surg* 2017; **4**: 131–44.
11. Kanezaki S, Nakashima H, Hatakeyama A *et al.* Endoscopic shelf acetabuloplasty after failed hip arthroscopic labral repair and capsular closure in patients with developmental dysplasia of the hip. *J Hip Preserv Surg*. 2016; **3**(hnw030.033). doi:10.1093/jhps/hnw030.033.
12. Berton C, Bocquet D, Krantz N *et al.* Shelf arthroplasties long-term outcome: influence of labral tears. A prospective study at a minimal 16 years' follows up. *Orthop Traumatol Surg Res* 2010; **96**: 753–9.
13. Hirose S, Otsuka H, Morishima T, Sato K. Long-term outcomes of shelf acetabuloplasty for developmental dysplasia of the hip in adults: a minimum 20-year follow-up study. *J Orthop Sci* 2011; **16**: 698–703.
14. Migaud H, Chantelot C, Giraud F *et al.* Long-term survivorship of hip shelf arthroplasty and Chiari osteotomy in adults. *Clin Orthop* 2004; **418**: 81–6.
15. Ziran N, Varcadipane J, Kadri O *et al.* Ten- and 20-year survivorship of the hip after periacetabular osteotomy for acetabular dysplasia. *J Am Acad Orthop Surg* 2019; **27**: 247–55.
16. Uchida S, Wada T, Sakoda S *et al.* Endoscopic shelf acetabuloplasty combined with labral repair, cam osteochondroplasty, and capsular plication for treating developmental hip dysplasia. *Arthrosc Tech* 2014; **3**: e185–91.
17. Uchida S, Hatakeyama A, Kanezaki S *et al.* Endoscopic shelf acetabuloplasty can improve clinical outcomes and achieve return to sports-related activity in active patients with hip dysplasia. *Knee Surg Sports Traumatol Arthrosc* 2018; **26**: 3165–77.
18. Hoppe DJ, Truntzer JN, Shapiro LM *et al.* Diagnostic accuracy of 3 physical examination tests in the assessment of hip microinstability. *Orthop J Sports Med*. 2017; **5**: 2325967117740121.
19. Maldonado DR, Chen JW, Yelton MJ *et al.* Achieving successful outcomes of hip arthroscopy in the setting of generalized ligamentous laxity with labral preservation and appropriate capsular management: a propensity matched controlled study. *Am J Sports Med* 2020; **48**: 1625–35.
20. Saadat AA, Lall AC, Battaglia MR *et al.* Prevalence of generalized ligamentous laxity in patients undergoing hip arthroscopy: a prospective study of patients' clinical presentation, physical examination, intraoperative findings, and surgical procedures. *Am J Sports Med* 2019; **47**: 885–93.
21. Domb BG, Chen SL, Go CC *et al.* Predictors of clinical outcomes after hip arthroscopy: 5-year follow-up analysis of 1038 patients. *Am J Sports Med* 2020; **49**: 112–20.
22. Domb BG, Chaharbakhshi EO, Rybalko D *et al.* Outcomes of hip arthroscopic surgery in patients with Tonnis grade 1 osteoarthritis at a minimum 5-year follow-up: a matched-pair comparison with a Tonnis grade 0 control group. *Am J Sports Med* 2017; **45**: 2294–302.
23. Ogata S, Moriya H, Tsuchiya K *et al.* Acetabular cover in congenital dislocation of the hip. *J Bone Joint Surg Br*. 1990; **72**: 190–6.
24. Clohisy JC, Carlisle JC, Beaulé PE *et al.* A systematic approach to the plain radiographic evaluation of the young adult hip. *J Bone Joint Surg Am* 2008; **90 (Suppl 4)**: 47–66.
25. Mansor Y, Perets I, Close MR *et al.* In search of the spherical femoroplasty: cam overresection leads to inferior functional scores before and after revision hip arthroscopic surgery. *Am J Sports Med* 2018; **46**: 2061–71.
26. Sakai T, Nishii T, Sugamoto K *et al.* Is vertical-center-anterior angle equivalent to anterior coverage of the hip? *Clin Orthop* 2009; **467**: 2865–71.
27. Maldonado DR, Kyin C, Shapira J *et al.* Revision hip arthroscopy in the borderline dysplastic population: reporting outcomes with minimum 2-year follow-up, with a subanalysis against a propensity-matched nondysplastic control group. *Am J Sports Med* 2020; **49**: 66–75.
28. Domb BG, Annin S, Chen JW *et al.* Optimal treatment of cam morphology may change the natural history of femoroacetabular impingement. *Am J Sports Med* 2020; **48**: 2887–96.
29. Maldonado DR, Ortiz-Declet V, Chen AW *et al.* Modified shelf acetabuloplasty endoscopic procedure with allograft for developmental hip dysplasia treatment. *Arthrosc Tech*. 2018; **7**: e779–84.
30. Lall AC, Saadat AA, Battaglia MR *et al.* Perineal pressure during hip arthroscopy is reduced by use of trendelenburg: a prospective study with randomized order of positioning. *Clin Orthop* 2019; **477**: 1851–1857.
31. Maldonado DR, Chen JW, Walker-Santiago R *et al.* Forget the greater trochanter! Hip joint access with the 12 o'clock portal in hip arthroscopy. *Arthrosc Tech* 2019; **8**: e575–84.
32. Maldonado DR, Chen SL, Walker-Santiago R *et al.* An intact ligamentum teres predicts a superior prognosis in patients with borderline dysplasia: a matched-pair controlled study with minimum 5-year outcomes after hip arthroscopic surgery. *Am J Sports Med* 2020; **48**: 673–81.
33. Gray AJ, Villar RN. The ligamentum teres of the hip: an arthroscopic classification of its pathology. *Arthrosc J Arthrosc Relat Surg* 1997; **13**: 575–78.
34. Seldes RM, Tan V, Hunt J *et al.* Anatomy, histologic features, and vascularity of the adult acetabular labrum. *Clin Orthop*. 2001; **382**: 232–40.
35. Lall AC, Annin S, Chen JW *et al.* Achieving a perfectly spherical femoroplasty: pearls, pitfalls, and optimal surgical technique. *Arthrosc Tech* 2020; **9**: e303–13.
36. Domb BG, Hartigan DE, Perets I. Decision making for labral treatment in the hip: repair versus débridement versus reconstruction. *J Am Acad Orthop Surg* 2017; **25**: e53–e62.
37. Maldonado DR, Chen SL, Chen JW *et al.* Prospective analysis of arthroscopic hip anatomic labral repair utilizing knotless suture anchor technology: the controlled-tension anatomic technique at minimum 2-year follow-up. *Orthop J Sports Med* 2020; **8**: 232596712093507.
38. Perets I, Hartigan DE, Chaharbakhshi EO *et al.* Circumferential labral reconstruction using the knotless pull-through technique-surgical technique. *Arthrosc Tech* 2017; **6**: e695–8.
39. Maldonado DR, Perets I, Mu BH *et al.* Arthroscopic capsular plication in patients with labral tears and borderline dysplasia of the hip: analysis of risk factors for failure. *Am J Sports Med* 2018; **46**: 3446–53.

40. Norman GR, Sloan JA, Wyrwich KW. Interpretation of changes in health-related quality of life: the remarkable universality of half a standard deviation. *Med Care* 2003; **41**: 582–92.
41. Rosset P, Heudel B, Laulan J *et al.* [Long-term evolution following shelf procedure for hip dysplasia in adults. Shelf survival analysis in 68 cases and retrospective review of 44 with at least 26 years follow-up]. *Acta Orthop Belg*. 1999; **65**: 315–26.
42. Maldonado DR, LaReau JM, Perets I *et al.* Outcomes of hip arthroscopy with concomitant periacetabular osteotomy, minimum 5-year follow-up. *Arthrosc J* 2019; **35**: 826–34.
43. Goronzy J, Franken L, Hartmann A *et al.* What are the results of surgical treatment of hip dysplasia with concomitant cam deformity? *Clin Orthop* 2017; **475**: 1128–37.
44. Jo S, Lee SH, Wang SI *et al.* The role of arthroscopy in the dysplastic hip—a systematic review of the intra-articular findings, and the outcomes utilizing hip arthroscopic surgery. *J Hip Preserv Surg* 2016; **3**: 171–80.
45. Redmond JM, Gupta A, Stake CE, Domb BG. The prevalence of hip labral and chondral lesions identified by method of detection during periacetabular osteotomy: arthroscopy versus arthrotomy. *Arthrosc J Arthrosc Relat Surg*. 2014; **30**: 382–8.
46. Storaci HW, Utsunomiya H, Kemler BR *et al.* The hip suction seal, part I: the role of acetabular labral height on hip distractive stability. *Am J Sports Med* 2020; **48**: 2726–32.
47. Utsunomiya H, Storaci HW, Rosenberg SI *et al.* The hip suction seal, part II: the effect of rim trimming, chondrolabral junction separation, and labral repair/refixation on hip distractive stability. *Am J Sports Med* 2020; **48**: 2733–9.
48. Chen AW, Yuen LC, Ortiz-Declet V *et al.* Selective debridement with labral preservation using narrow indications in the hip: minimum 5-year outcomes with a matched-pair labral repair control group. *Am J Sports Med* 2018; **46**: 297–304.
49. Vaudreuil NJ, McClincy MP. Evaluation and treatment of borderline dysplasia: moving beyond the lateral center edge angle. *Curr Rev Musculoskelet Med*. 2020; **13**: 28–37.