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Research article

Is combined surgical dislocation and proximal femoral osteotomy a safe procedure for correction of complex hip deformities?

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ABSTRACT

Complex deformities of the hip requiring intra-articular and proximal femoral correction are challenging with regard to surgical access and complication risk. Combined surgical dislocation and proximal femoral osteotomy (SD/PFO) is a surgical strategy that provides unrestricted access to the joint with the capability for adjunctive PFO. Although providing excellent surgical access, concerns over a potentially high risk of postoperative complications remain, and published information on the safety of this technique remain scarce. In this study, we defined the early complication profile of combined surgery across 48 hips with a variety of complex deformities using a standardized, validated complication grading scheme for hip preservation surgery. Patients were mean age 19.1 years 13–33 years and 60% had previous surgery. At the early mean follow-up of 2.9 years, considerable improvement was seen across all outcome scores. Major complications (Grade III or higher) occurred at a rate of 4.2% ($n = 2$). Both were osteotomy non-unions, and both were treated successfully with revision PFO and bone grafting at mean 1.1 years. To our knowledge, the current series of combined SD-PFO surgeries represents the largest to date for which detailed complication data have been reported. Given the complexity of these disorders, a major complication rate of 4.2% is acceptable. Our complication rates were comparable to those reported for isolated SD and PFO procedures. These rates did not vary significantly across morphologic variants or patient-specific characteristics. Additionally, our complication risk profile is consistent with previous, smaller reports, which supports the generalizability of these results among appropriately experienced surgeons.

INTRODUCTION

Complex proximal femoral deformities represent some of the most challenging in hip surgery to comprehensively address. Often, these deformities are sequalae of both treated and untreated developmental deformities and childhood-acquired abnormalities of the hip—slipped capital femoral epiphysis (SCFE), Legg–Calve–Perthes disease (Perthes) and developmental dysplasia of the hip (DDH) [1–4]. Regardless of etiology and primary treatment, a persistence of abnormal proximal femoral morphology can create an environment of multifocal, often severe femoroacetabular impingement (FAI). Features contributing to extra-articular impingement in particular make comprehensive surgical correction in these patients difficult with traditionally less-invasive FAI surgical interventions [5–8].

Open surgical dislocation (SD) has remained a gold standard approach in comprehensive treatment of complex FAI variants and a preferred option for addressing symptomatic impingement less amenable to arthroscopic correction (severe, multifocal and extra-articular) [9–11]. SD permits direct visualization of articular pathology and dynamic assessment of femoroacetabular contact, allowing for more precise diagnosis and comprehensive correction of the underlying deformity. Open SD additionally permits correction of extra-articular impingement confirmed with dynamic examination, through techniques such as trochanteric osteoplasty, relative femoral neck lengthening and trochanteric advancement [12].

In the presence of severe proximal femoral deformity, adequate relief of impingement may additionally require modification to alignment and rotation through proximal femoral osteotomy (PFO) [13, 14]. Although historically two distinct procedures, combined SD-PFO surgery is possible and has seen more frequent use [10, 15–17]. Benefits of combined surgery include not only enhanced access to the proximal femoral deformity, but also the ability to intraoperatively assess both the need for PFO and the corrective aims of the osteotomy, all under guidance of dynamic exam.

Despite these advantages, detailed reports on the safety of this practice remain scarce. While complication rates have been low for both isolated SD [9, 18] and PFO [19, 20], each procedure comes with non-trivial complication risks that may be unsafely compounded in a combined procedure. Avascular

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necrosis (AVN)—especially in the setting of combined SD, PFO and greater trochanteric osteotomy—is a particular concern.

The purpose of this study was to define the early complication profile of SD-PFO surgery performed for comprehensive treatment of complex proximal femoral deformities. A standardized complication grading scheme, validated and previously utilized in hip preservation surgery, was used for this purpose [18, 21].

MATERIALS AND METHODS

A prospective institutional hip preservation repository was reviewed for all patients of a single surgeon (JCC) who underwent SD with combined PFO between 2005 and 2020. Indications for combined surgery were as follows: (i) symptomatic patient <40 years of age with non-operative treatment failure, (ii) presence of complex structural deformity (FAI and/or instability) not amenable to arthroscopic correction and (iii) absence of advanced secondary osteoarthritis (Tonnis Grade <III). Fifty-eight hips (57 patients) were identified, of which 48 (83%) had minimum 1-year follow-up for study inclusion (mean 2.9 years [1–9]).

At time of surgery, the 48 included hips (47 patients) were mean age 19.1 ± 5.0 years 13–33 years, body mass index (BMI) 23.9 ± 4.7 [15–37] and 50% female. Etiologies of the residual deformities seen across this cohort were diverse and included SCFE (19 hips, 40%), Perthes (10, 21%) and DDH (7, 15%). Complex FAI without recognized developmental hip diagnosis was present in 11 (23%) hips. Post-traumatic AVN without prior developmental diagnosis was the indication for surgery in 1 (2%) hip [Table I].

Prior ipsilateral hip surgery was noted in 29/48 (60%) of the studied hips. Thirteen residual SCFE hips (13/19, 68%) had prior *in situ* pinning. Six residual Perthes hips (6/10, 60%) had either prior PFO (3), pelvic osteotomy (1), shelf procedure (1) or SD with femoral osteochondroplasty (OCP) (1). Three residual DDH hips (4/7, 57%) had either combined pelvic osteotomy and PFO (1), combined SD PFO (1) or arthroscopy (2). Five hips with complex FAI without recognized developmental diagnosis (5/11, 45%) underwent either arthroscopy (4) or pelvic osteotomy (1). The one hip with post-traumatic AVN had previously underwent ORIF for intertrochanteric fracture [Table I].

All patients were indicated for combined SD-PFO surgery as a means of comprehensive deformity correction. Surgical hip dislocation was performed first, as described by Ganz *et al.* [9], and attention turned to the intra-articular morphology. The proximal femur, femoral head, acetabulum and rim structures were assessed for damage of the labrum and articular cartilage. Labral refixation or repair was performed in 23 (48%) cases. Less common procedures included acetabular rim osteoplasty (9, 19%) or chondroplasty (4, 8%) and microfracture of the femoral head (2, 4%) or acetabulum (1, 2%). Femoral head–neck OCP was performed in all cases and guided by intra-operative dynamic assessment of impingement. In many cases, trochanteric advancement (24 hips, 50%)/relative femoral neck lengthening (17, 35%) was additionally performed. In all included cases, the intraoperative decision was made to proceed with intertrochanteric PFO. A no-wedge technique with blade plate fixation was used, with correction dictated by the angles of the plate and its insertion [22]. Care was taken to maintain proximal femoral alignment in anticipation of future hip arthroplasty [23] [Fig. 1].

Six patients (13%) with radiographic evidence of acetabular dysplasia and dynamic instability on intra-operative range-of-motion testing meeting appropriate additional indications (good to excellent joint congruity on intraoperative functional radiographs, hip flexion of at least 90° and abduction of at least 20°) additionally underwent concomitant periacetabular osteotomy (PAO). Instability was defined as femoral head dislocation or subluxation with passive functional intra-operative range-of-motion testing (in any one of three positions: 10° extension/15° external rotation; 45° flexion/20° adduction/30° internal rotation; 90 flexion/neutral) [24].

Mean operative time across all cases was 260 ± 74 min and mean estimated blood loss 563 ± 370 ml.

Retrospective chart review was conducted for each patient to latest follow-up, and all complications noted. Complication was defined as any event causing deviation from expected post-operative course. This extended to radiographic follow-up, which was reviewed for timely osteotomy union and evidence of any post-operative osteonecrosis. When present, heterotopic ossification on most recent anteroposterior standing films was assigned a Brooker Grade [25] and recorded.

Complications were graded in the way proposed by Clavien and Dindo [26], using a modified grading scheme whereby Grades I–V were assigned based upon the required intervention and impact on long-term function and health. This scheme has been validated in hip preservation surgery and used previously to study complications of open preservation procedures [18, 27–29]. Grades were assigned as follows:

Grade I: Complication without deviation from routine recovery requiring no intervention

Grade II: Complication with deviation from routine recovery requiring pharmacologic treatment or close outpatient monitoring

Grade III: Complication with deviation from routine recovery requiring surgical intervention

Grade IV: Complication that cannot be treated with potential for permanent disability

Grade V: Death

Expectable sequelae of the combined surgery were not included for grading by this scheme. Examples include lateral femoral cutaneous nerve sensory deficit (without dysesthesia), minor heterotopic ossification (Brooker Grade II or less), elective hardware removal or conversion to THA with no acute indication other than natural progression of joint degeneration or continued unsatisfactory function.

Chi-square univariate analysis was conducted to explore relationships between categorical patient characteristics and rates of complication (major [Grade III or higher], minor [Grades I–II] and overall [Grade I or higher]). For continuous patient characteristics, logistic regression was used similarly. In both cases, a *P*-value <0.05 was considered significant.

As the decision to pursue all hip preservation procedures involves a weighing of both risks and benefits, we additionally

Table I. Demographic and complication details by preoperative diagnosis/operative history group

	Patient characteristics						*Complications and grades*		
	n hips	*(%)*	*Age*	*BMI*	*%Female*	*Overall complication*	*I*	*II*	*III*
Full cohort	48		19.1 [13–33]	23.9 [15–37]	50%	7 (14.6%)	3 (6.3%)	2 (4.2%)	2 (4.2%)
No prior surgery	19	(40%)							
Residual SCFE	19	(40%)	16.6 [13–26]	25.5 [20–37]	44%	5 (26.3%)	3 (15.7%)	1 (5.3%)	1 (5.3%)
No prior Surgery	6	(32%)					(1) AVN, (1) HO [III]		
Prior pinning	13	(68%)					(1) HO [IV]	(1) Delayed Union	(1) Nonunion + graft (1.67 years)
Residual Perthes	10	(21%)	18.9 [13–28]	24.4 [18–33]	40%	0	–	–	–
No prior surgery	4	(40%)							
PFO	3	(30%)							
Pelvic osteotomy	1	(10%)							
Shelf procedure	1	(10%)							
SD + OCP	1	(10%)							
Residual DDH	7	(15%)	19.7 [14–31]	22.2 [15–26]	86%	0	–	–	–
No prior surgery	3	(43%)							
Hip Score	2	(29%)							
SD/PFO	1	(14%)							
PAO/PFO	1	(14%)							
Complex FAI w/o Devlp. Dx	11	(23%)	21.1 [19–33]	22.8 [18–27]	55%	2 (18.2%)	–	1 (9.1%)	1 (9.1%)
No prior surgery	6	(55%)						(1) Delayed Union	
Hip scope	4	(36%)							(1) Nonunion + graft (1.67 years)
PAO	1	(9%)							
AVN	1	(2%)	15.7	19.2	0	0	–	–	–
ORIF for Intertroch Fx	1	(100%)							

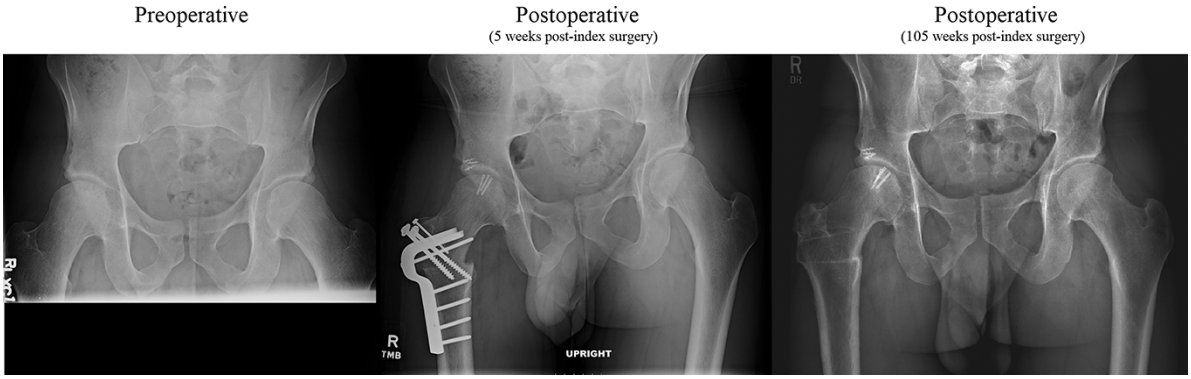

Fig. 1. Preoperative, postoperative and post-hardware removal anteroposterior (AP) radiographs of a 26-year-old male with complex femoroacetabular impingement and mild acetabular dysplasia. The clinical diagnosis was femoroacetabular impingement and major femoral retroversion (9° true retroversion). We treated the rotational deformity and complex impingement with surgical dislocation, proximal femoral derotational osteotomy, femoral head–neck osteoplasty and labral repair. Mosaicplasty was additionally performed to repair an associated full-thickness osteochondral lesion of the femoral head. Hardware was removed at 12 months, with an excellent clinical result at latest follow-up (24 months [mHHS 93]).

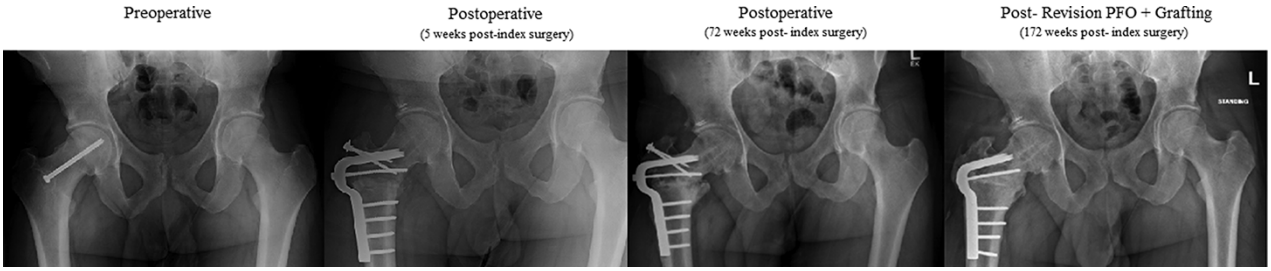

Fig. 2. Preoperative, postoperative, 18-month and 30-month follow-up anteroposterior (AP) radiographs of a 23-year-old male with a BMI of 35. He had prior treatment with *in situ* pinning for slipped capital femoral epiphysis. We treated the major, residual rotational deformity and impingement with surgical dislocation, proximal femoral osteotomy, trochanteric osteoplasty, femoral head–neck osteoplasty and labral repair. He was noncompliant with postoperative weight-bearing recommendations and developed a femoral nonunion. He underwent revision PFO with bone grafting at 18 months with subsequent healing and clinical improvement.

gathered patient reports of post-operative function and satisfaction with combined surgery for inclusion in this study (modified Harris Hip Score (mHHS), UCLA Activity Score (UCLA), Short Form Health Survey (SF-12), Hip Disability and Osteoarthritis Outcome Score (HOOS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)). In patients with reoperation, post-operative scores used were those gathered prior to reoperation. Pre- and postoperative scores were compared with Student's t-tests.

RESULTS

Major complications (Grade III or higher) occurred at a rate of 4.2% across the overall cohort, and minor complications (Grades I–II) at a rate of 10.4%. The two major complications were both non-unions of the femoral osteotomy (Grade III) treated with revision PFO and bone grafting at 0.62 and 1.7 years. Both healed with revision PFO. [Fig. 2] There were no Grade IV or Grade V complications. [Table I].

The five minor complications included three Grade I complications (did not require intervention or monitoring) and two Grade II complications (required monitoring/non-surgical intervention). Grade I complications included one small area of AVN of the central femoral head, which had yet to require intervention at last follow-up (1.5 years postop), one instance of Brooker III heterotopic ossification (HO) and one instance of Brooker IV HO. The two Grade II complications were delayed femoral unions both treated successfully with a bone stimulator (one at 0.27 years and one at 0.65 years). Both were radiographically united by 1-year follow-up and neither required further intervention.

By deformity etiology group, there were no complications of any grade among residual Perthes hips (10 hips, 21% of overall cohort), residual DDH hips (7, 15%) or the post-traumatic AVN hip (1, 2%).

Five of the study's seven complications occurred in the residual SCFE group (19 hips, 40% of overall cohort), for an overall group complication rate of 26.3% (major: 5.3%, minor: 21%). This study's single instance of AVN (Grade I) occurred in a patient without any prior surgery. One delayed union treated with bone stimulation (Grade II) occurred in a patient with prior *in situ* pinning, and one non-union requiring revision PFO and bone grafting (Grade III) occurred in a patient with prior *in situ* pinning. Grade III HO (Grade I complication) was observed in one patient without prior pinning and Grade IV HO (Grade I) in one patient with prior pinning.

The remaining two complications both occurred in the complex FAI without prior developmental diagnosis group (11 hips,

Table II. Patient-reported outcomes

	Outcome scores							
		Preoperative			*Postoperative*			
	n	*Mean*	±*SD*	*Delta*	*Mean*	±*SD*	*n*	*P*
mHHS	46	58.3	±20	+20	78.7	±24	45	<0.005
UCLA	42	5.9	±3	+1.4	7.3	±3	42	0.072
HOOS								
Pain	41	62.6	±22	+18	80.9	±28	38	<0.05
Symptom	42	54.3	±23	+22	76.1	±26	37	<0.05
ADL	42	70.0	±23	+17	87.0	±27	37	<0.05
Sports	41	42.8	±25	+28	71.2	±32	38	<0.005
QOL	41	34.9	±26	+32	66.9	±32	37	<0.005
WOMAC								
Pain	41	67.8	±23	+16	84.2	±27	39	<0.05
Stiffness	42	57.4	±26	+19	76.3	±30	38	<0.05
Function	42	70.0	±23	+17	87.3	±27	38	<0.05
SF-12								
Physical	41	37.6	±11	+11	48.2	±13	38	<0.005
Mental	41	50.6	±12	+5	55.1	±10	38	0.153
		Satisfaction (*n* reporting)			25			
		Extremely satisfied			13	52%		
		Very satisfied			5	20%		
		Somewhat satisfied			3	12%		
		Satisfied			2	8%		
		Somewhat unsatisfied			1	4%		
		Extremely unsatisfied			1	4%		

23% of overall cohort), for an overall group complication rate of 18.2% (major: 9.1%, minor: 9.1%). There was one delayed union treated successfully with bone stimulation (Grade II) in a patient without any prior surgery, and one non-union requiring revision PFO and grafting (Grade III) in a patient with only prior hip scope.

At most recent follow-up, 92% of reporting patients (23/25) were satisfied with the outcome of their surgery (52% extremely satisfied, 20% very satisfied, 8% satisfied and 12% somewhat satisfied), with 8% (2/25) unsatisfied. Significant improvement was seen across all collected patient-reported outcome measures and comprising sub-scores ($P < 0.05$) with the exception of UCLA ($P = 0.07$) and SF-12 mental scores ($P = 0.15$). [Table II] Clinical success defined as mHHS >70 or >15 mHHS improvement from baseline at last follow-up without revision surgery or THA conversion was achieved in 78% of patients at mean follow-up 2.9 years.

Although not considered complications for the purposes of this study, it is worth noting that four patients with relatively advanced radiographic OA at the time of index surgery (100% with Tonnis OA grade $\geq$1, 75% with Tonnis OA grade $\geq$2) underwent conversion to THA (at 0.8, 1.0, 1.4 and 5.2 years). Other than these four performed for progressed OA, there were no additional THAs.

DISCUSSION

The complication profiles of both surgical hip dislocation and PFO as isolated procedures are well-documented. In first describing the SD procedure, Ganz *et al.* reported a major (Grade III or higher) complication rate of 1.4% (3 complications) across 213 hips at minimum 2-year follow-up. All were Grade III complications (three [1.4%] failures of trochanteric fixation requiring reoperation). Minor (Grade II or lower) complications (1.8%) included two (0.9%) sciatic neuropraxias and two (0.9%) cases of Brooker Grade III heterotopic ossification (77 cases Brooker Grades I–II). There were no instances of AVN or infection [9].

In a multi-center cohort of 334 hips that underwent surgical hip dislocation, Sink *et al.* reported a major complication rate of 3.0% (10 complications). These included nine Grade III complications (six [1.8%] trochanteric non-unions, two [0.6%] deep vein thromboses and one [0.3%] deep infection) and one Grade IV complication (one [0.3%] sciatic sensory and motor sciatic nerve paralysis immediately following surgery). Minor complications (1.8%) included two (0.6%) superficial infections, one (0.3%) transient sciatic neurapraxia, two (0.6%) trochanteric delayed unions and one (0.3%) trochanteric fracture sustained in a fall. Similar to the cohort of Ganz *et al.*, there were no instances of AVN [18].

The complications associated with PFO have also been well-defined. Across a cohort of 51 hips treated with intertrochanteric osteotomy (ITO) without osteoplasty for SCFE at 24-year mean follow-up, Schai *et al.* reported a major complication rate of 7.8% (4 complications). All were Grade III complications (two [3.9%] instances of incorrect implant positioning requiring revision osteosynthesis of the ITO, and two [3.9%] cases of osteomyelitis that resolved following hardware removal).

Table III. Studies known to the authors to previously have examined complications with combined surgical dislocation/proximal femoral osteotomy—compared to findings of the current study

Studies reporting complications with combined SD-PFO surgery						
	Patients	*Mean follow-up (years)*	*n (hips)*	*Procedure*	*AVN*	*Other complications*
Rebello	Mixed	3.4	15	ITO + OCP	1 (4.3%)	–
			8	ITO		–
Erickson	SCFE	5.1	19	ITO + OCP	0	1 (5.3%) nonunion of osteotomy site, 1 (5.3%) instrumentation failure
Baraka	SCFE	3.8	23	ITO + OCP	0	1 (4.3%) instrumentation failure
Present Study	Mixed	2.9	48	ITO + OCP	1 (2.1%)	2 (4.2%) non-union, 2 (4.2%) delayed union

Reported minor complications included one (1.9%) instance of partial femoral head osteonecrosis [19]. In 39 hips treated with ITO without osteoplasty for SCFE at 23.4-year mean follow-up, Kartenbender *et al.* reported two (5.1%) instances of femoral head osteonecrosis, one (2.6%) of which required conversion to total hip arthroplasty [20].

To date, however, detailed reports of complications following combined surgery remain limited. In a mixed cohort of patients (SCFE, Perthes, osteonecrosis and DDH) undergoing SD for treatment of complex deformities. Rebello *et al.* reported on a 23-hip subgroup that underwent concomitant ITO (15 with head–neck OCP, 8 without) at 3.4-year mean follow-up. The only reported complication was one (4.3%) minor complication (mild anterior segmental osteonecrosis managed non-operatively). There were no other complications reported in this group. Of note in a different study subgroup with PFOs instead performed at the level of the femoral neck (all without OCP) was an osteonecrosis rate of 60% (3/5) [10].

Among a cohort of 19 SCFE hips that underwent combined SD-ITO (all with head–neck OCP) at 5.1-year mean follow-up, Erickson *et al.* reported a major complication rate of 10.6% (2 complications). Both were Grade III complications (one [5.3%] non-union of the ITO and one [5.3%] instrumentation failure within two post-operative weeks that required revision surgery). There were no instances of post-operative osteonecrosis or chondrolysis at 5.1-year mean follow-up, and no other complications were reported [17].

Similarly, there were no instances of osteonecrosis among 23 SCFE hips that underwent combined SD-ITO (all with head–neck OCP) in a report by Baraka *et al.* at mean follow-up 3.8 years. The only reported complication was one (4.3%) major (Grade III) complication (loss of fixation and instrumentation failure at 2 post-operative weeks) [16].

To the knowledge of the authors, the current series of combined SD-PFO surgeries represents the largest reported to date for which detailed complication data have been made available. Rates of the more serious complications typically associated with SD or PFO surgery were found to be no higher with combined surgery. Most pertinently, this was true of the studied cohort's 2.1% AVN rate (literature range 0–5.1% following isolated SD/PFO) and 4.2% non-union rate (0–5.3%). These rates also appear consistent with those across previous reports of combined surgery (AVN 0–4.3% and non-union 0–5.3%) [Table III].

The current study's 4.2% major (Grade III or higher) complication rate was within the 4.0–10.8% summed literature major complication rate ranges for isolated SD (1.4–3.0%) and isolated PFO (2.6–7.8%). This rate was also consistent with the major complication rates reported across the few studies to previously have examined outcomes of combined surgery (0–10.6%) [Table III] Together, these observations support an acceptability of the complication profile associated with combined surgery and suggest that similarly low rates can be achieved across appropriately experienced surgeons.

No significant associations were apparent between complication incidence and any of the examined patient characteristics—including age, sex, BMI and pre-arthritic hip diagnosis. This was true for both major (Grade III or higher) and minor (Grades I–II) complications, as well as for Grade-I-only, Grade II–IV and Grade I–IV complications. [Table IV] There was a trend toward significance in the relationship between pre-arthritic diagnosis of residual SCFE and occurrence of minor (Grades I–II) complications ($P = 0.051$), which was reflected in the trend for any (Grades I–IV) complication ($P = 0.062$). This trend was not observed with respect to major (Grade III or higher) complications ($P = 0.76$).

There are several limitations to the current study. Among the studies from which literature rate ranges were derived, only one rigorously reported complications through a well-defined grading scheme (isolated SD). Exhaustive complication data were not available across prior studies of isolated PFO or combined SD-PFO surgery outcomes, and these studies' reporting standards for less serious complications (Grade I ± II) appeared to vary. Because of this—and because of their greater immediate clinical relevance—major (Grade III or higher) complications were the primary focus of this study.

However, reliance on major complication rate as the primary comparative outcome measure may impact the degree to which the comparisons made in this study capture or reflect clinical course differences more apparent in the longer term. While there were only two instances of Brooker III or greater HO in the study cohort, Brooker I–II HO was observed in 18 (37.5%) patients (16 Grade I and 2 Grade II) in whom no HO had been apparent preoperatively. This contrasts with the 5.4% (18/334) following isolated SD reported by Sink *et al.* The significance of this to longer-term clinical course differences (HO progression, effect on survival and revision FAI/conversion THA outcomes) is unclear. This may similarly apply to AVN—the only instance

Table IV. Univariate analysis of association of patient factors with complication occurrence—by complication grade(s)

			Complication incidence in relation to patient factors															
			Major (III–IV) complications			*Minor (I–II) complications*			*All (I–IV) complications*			*Grade I complications*			*Grade II–IV complications*			
Factor	*nhips*	*(%)*	*n*	*(%)*	*P*	*n*	*(%)*	*P*	*n*	*(%)*	*P*	*n*	*(%)*	*P*	*n*	*(%)*	*P*	
Sex																		
Male	24	(50%)	1	(4.2%)	0.99	2	(8.3%)	0.63	3	(12.5%)	0.68	2	(8.4%)	0.55	1	(4.2%)	0.30	
Female	24	(50%)	1	(4.2%)	0.99	3	(12.5%)	0.63	4	(16.7%)	0.68	1	(4.2%)	0.55	3	(12.5%)	0.30	
Age					0.11			0.25			0.98			0.12			0.13	
BMI					0.18			0.27			0.89			0.58			0.75	
Diagnosis																		
ResidualSCFE	19	(40%)	1	(5.3%)	0.76	4	(21.1%)	0.051	5	(26.3%)	0.062	3	(15.7%)	–	2	(10.5%)	0.66	
ResidualPerthes	10	(21%)		–			–			–			–			–		
ResidualDDH	7	(15%)		–			–			–			–			–		
ComplexFAI	11	(23%)	1	(9.1%)	0.35	1	(9.1%)	0.87	2	(18.2%)	0.70		–		2	(18.2%)	0.18	
AVN	1	(2%)		–			–			–			–			–		

of which, in this study, was graded as a Grade I complication, as it had not affected clinical course or required intervention at time of last follow-up.

Although the current series appears to be the largest to date for which detailed complication has been made available, additional confidence in the reported rates afforded by a larger sample size would have been of benefit to this study. Additionally, all included surgeries were performed by a surgeon with significant experience with open hip preservation surgery and patient selection for these procedures. This may limit the generalizability of results. Finally, although data for this study were prospectively entered into a hip preservation repository, compilation of comprehensive complication information relied on retrospective review. When combined with the fact that many patients traveled from a distance for treatment, it is possible that some complications—more likely those not requiring surgical re-intervention or close monitoring (Grade I)—were not captured.

CONCLUSION

To our knowledge, the current series of combined SD-PFO surgeries represents the largest to date for which detailed complication data have been reported. Given the complexity of these disorders, a major complication rate of 4.2% is acceptable. Our complication rates were comparable to those reported in the literature for isolated SD and PFO procedures. These rates did not vary significantly across morphologic variants or patient-specific characteristics. Additionally, our complication risk profile is consistent with previous, smaller reports and supports the generalizability of these results across appropriately experienced surgeons.

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CONFLICT OF INTEREST STATEMENT

Nepple: Arthroscopy: Editorial or governing board; Pediatric Research in Sports Medicine Society: Board or committee member; Responsive: IP royalties; Responsive Arthroscopy: Paid consultant; Smith & Nephew: Paid consultant; Paid presenter or speaker; Research support; Zimmer: Research support Pashos: GlaxoSmithKline: Stock or stock Options Schoenecker: Clinical Orthopaedics and Related Research: Editorial or governing board; Journal of Bone and Joint Surgery - American: Editorial or governing board; Journal of Children's Orthopaedics: Editorial or governing board; Journal of Pediatric Orthopedics: Editorial or governing board; Orthopediatrics: Stock or stock Options; Pediatric Orthopaedic Society of North America: Board or committee member Clohisy: Department of Defense grant: Research

support; Hip Society: Board or committee member; International Society for Hip Arthroscopy: Board or committee member; Microport: IP royalties; Microport Orthopedics, Inc.: Paid consultant; Wolters Kluwer Health - Lippincott Williams & Wilkins: Publishing royalties, financial or material support; Zimmer: Paid consultant; Research support.

REFERENCES

1. Ross J, Nepple J, Baca G *et al.* Intraarticular abnormalities in residual Perthes and Perthes-like hip deformities. *Clin Orthop Relat Res* 2012; **470**: 2968–77.
2. Eijer H, Podeszwa DA, Ganz R *et al.* Evaluation and treatment of young adults with femoro-acetabular impingement secondary to Perthes' disease. *Hip Int* 2006; **16**: 273–80.
3. Rab G. The geometry of slipped capital femoral epiphysis: implications for movement, impingement and corrective osteotomy. *J Pediatr Orthop* 1999; **19**: 419–24.
4. Mamisch TC, Kim YJ, Richolt JA *et al.* Femoral morphology due to impingement influences the range of motion in slipped capital femoral epiphysis. *Clin Orthop Relat Res* 2009; **467**: 692–8.
5. Bedi A, Kelly BT, Khanduja V. Arthroscopic hip preservation surgery: current concepts and perspective. *Bone Joint J* 2013; **95-B**: 10–9.
6. Larson CM, Stone RM. Current concepts and trends for operative treatment of FAI: hip arthroscopy. *Curr Rev Musculoskelet Med* 2013; **6**: 242–9.
7. Jayakumar P, Ramachandran M, Youm T *et al.* Arthroscopy of the hip for paediatric and adolescent disorders: current concepts. *J Bone Joint Surg Br* 2012; **94**: 290–6.
8. Dukas AG, Gupta AS, Peters CL *et al.* Surgical treatment for FAI: arthroscopic and open techniques for osteoplasty. *Curr Rev Musculoskelet Med* 2019; **12**: 281–90.
9. Ganz R, Gill TJ, Gautier E *et al.* Surgical dislocation of the adult hip a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. *J Bone Joint Surg Br* 2001; **83**: 1119–24.
10. Rebello G, Spencer S, Millis MB *et al.* Surgical dislocation in the management of pediatric and adolescent hip deformity. *Clin Orthop Relat Res* 2009; **467**: 724–31.
11. Zhang D, Chen L, Wang G. Hip arthroscopy versus open surgical dislocation for femoroacetabular impingement: a systematic review and meta-analysis. *Medicine (Baltimore)* 2016; **95**: e5122.
12. Albers CE, Steppacher SD, Schwab JM *et al.* Relative femoral neck lengthening improves pain and hip function in proximal femoral deformities with a high-riding trochanter. *Clin Orthop Relat Res* 2015; **473**: 1378–87.
13. Ganz R, Horowitz K, Leunig M. Algorithm for femoral and periacetabular osteotomies in complex hip deformities. *Clin Orthop Relat Res* 2010; **468**: 3168–80.
14. Aprato A, Pellegrino P, Kain MS *et al.* Do osteotomies of the proximal femur still have a role? *Curr Rev Musculoskelet Med* 2014; **7**: 323–9.
15. Mcclincy M, Bosch P. Combined surgical dislocation and proximal femoral osteotomy for correction of SCFE-induced femoroacetabular impingement. *Oper Tech Orthop* 2013; **23**: 140–5.
16. Baraka MM, Hefny HM, Thakeb MF *et al.* Combined Imhauser osteotomy and osteochondroplasty in slipped capital femoral epiphysis through surgical hip dislocation approach. *J Child Orthop* 2020; **14**: 190–200.
17. Erickson JB, Samora WP, Klingele KE. Treatment of chronic, stable slipped capital femoral epiphysis via surgical hip dislocation with combined osteochondroplasty and Imhauser osteotomy. *J Child Orthop* 2017; **11**: 284–8.
18. Sink EL, Beaulé PE, Sucato D *et al.* Multicenter study of complications following surgical dislocation of the hip. *J Bone Joint Surg Am* 2011; **93**: 1132–6.
19. Schai PA, Exner GU. Corrective Imhäuser intertrochanteric osteotomy. *Oper Orthop Traumatol* 2007; **19**: 368–88.
20. Kartenbender K, Cordier W, Katthagen BD. Long-term follow-up study after corrective Imhäuser osteotomy for severe slipped capital femoral epiphysis. *J Pediatr Orthop* 2000; **20**: 749–56.
21. Sink EL, Leunig M, Zaltz I *et al.* Reliability of a complication classification system for orthopaedic surgery. *Clin Orthop Relat Res* 2012; **470**: 2220–6.
22. Ganz R, MacDonald SJ. Indications and modern techniques of proximal femoral osteotomies in the adult. *Semin Arthroplasty* 1997; **8**: 38–50.
23. Clohisy JC, Schoenecker PL. Proximal femoral osteotomy. In: Callaghan JJ, Rosenberg AG, Rubash H (eds.) *The Adult Hip*. 2nd edn. Philadelphia, PA: Lippincott Williams & Wilkins, 2004.
24. Clohisy JC, Nepple JJ, Ross JR *et al.* Does surgical hip dislocation and periacetabular osteotomy improve pain in patients with Perthes-like deformities and acetabular dysplasia? *Clin Orthop Relat Res* 2015; **473**: 1370–7.
25. Brooker AF, Bowerman JW, Robinson RA *et al.* Ectopic ossification following total hip replacement. Incidence and a method of classification. *J Bone Joint Surg Am* 1973; **55**: 1629–32.
26. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 2004; **240**: 205–13.
27. Wells J, Schoenecker P, Petrie J *et al.* Are complications after the bernese periacetabular osteotomy associated with subsequent outcomes scores? *Clin Orthop Relat Res* 2019; **477**: 1157–63.
28. Edelstein AI, Duncan ST, Akers S *et al.* Complications associated with combined surgical hip dislocation and periacetabular osteotomy for complex hip deformities. *J Hip Preserv Surg* 2019; **6**: 117–23.
29. 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* 2021; **7**: 764–76.