

## What Are the Results of Surgical Treatment of Hip Dysplasia With Concomitant Cam Deformity?

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### Abstract

**Background** Periacetabular osteotomy (PAO) is a reliable procedure to correct the deficient acetabular coverage in hips with developmental dysplasia. It is unclear how the presence of additional femoral cam-type deformity might influence the clinical and radiographic treatment results of PAO.

**Questions/purposes** (1) Are there differences in clinical scores (WOMAC, EQ-5D) and examination findings (impingement sign) or radiographic measures of acetabular

orientation and head sphericity after PAO for isolated acetabular dysplasia when compared with the combined pathology of dysplasia and additional femoral cam deformity? (2) Are these clinical and radiographic findings after combined surgical therapy for additional cam deformity influenced by different pathology-adjusted surgical techniques?

**Methods** From July 2005 to December 2010, 86 patients (106 hips) underwent PAO for hip dysplasia. Surgical and outcome data were prospectively collected and retrospectively reviewed in a comparative observational study. Indications for surgery were a lateral center-edge angle less than 25° and hip pain for at least 6 months. The contraindications for surgery were advanced radiographic osteoarthritis (Kellgren-Lawrence Grade 3), incongruency of joint space, and patient age > 50 years. Depending on preoperative hip ROM, impingement test, and presence of a radiographically visible cam deformity, treatment allocation was performed: Group I: isolated PAO in patients without symptomatic asphericity, Group IIa: PAO with subsequent osteochondroplasty through arthrotomy for patients with symptomatic cam deformity and no labrochondral pathology, and Group IIb: arthroscopically assisted osteochondroplasty and additional labrochondral repair with subsequent PAO when patients had labrochondral lesions in addition to a symptomatic cam deformity. Clinical outcome (impingement test, EQ-5D, WOMAC) as well as radiographic parameters (lateral center-edge angle, crossover sign, alpha angle, osteoarthritis grade) were obtained after a mean followup of 63 ± 18 months (range, 31–102 months) and compared with the baseline data. Eleven patients (13%) were lost to followup. With the numbers available, our study had 80% power to detect a difference between Groups I and II of 10 points on the WOMAC scores.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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**Results** There was no difference in the increase of WOMAC scores in patients with PAO alone (Group I; preoperative score  $74 \pm 17$  versus postoperative  $91 \pm 15$ ,  $p = 0.033$ ) when compared with PAO and concurrent osteochondroplasty (Groups II A and B preoperative  $73 \pm 19$  versus postoperative  $90 \pm 13$   $p < 0.001$ ). The mean postoperative alpha angles in Group II ( $38^\circ \pm 6^\circ$ ) improved when compared with preoperative values ( $56^\circ \pm 15^\circ$ ;  $p < 0.001$ ) and were even lower than native offset alpha angles in Group I ( $47^\circ \pm 11^\circ$ ). Clinical scores as well as postoperative radiographic parameters were not different between patients with conventional osteochondroplasty alone (Group IIA) and patients with arthroscopically assisted cam resection and intraarticular labrochondral repair (Group IIB).

**Conclusions** With the numbers available, we detected no differences in outcome scores and radiographic results between patients who had been treated with PAO alone and patients who underwent combined PAO and offset correction for cam deformity. Although arthroscopically assisted treatment of advanced labrochondral lesions together with osteochondroplasty is possible during PAO and the results were not different in this small study when compared with patients with PAO and osteochondroplasty alone, the type and extent of damage that would indicate additional cartilage surgery over cam resection alone remain unclear.

**Level of Evidence** Level III, therapeutic study.

## Introduction

Periacetabular osteotomy (PAO) as initially developed by Ganz [15] has been shown in several long-term studies to be a successful operation for the treatment of hip dysplasia [1, 2, 21, 26, 29, 39, 40]. As a result of a better understanding of hip pathomechanics and the recognition of femoroacetabular impingement (FAI), the surgical technique has evolved. Indications for surgery and selection of appropriate procedures depend not only on acetabular morphology, but also on additional deformities of the proximal femur. Different types of proximal femoral abnormalities can be associated with acetabular dysplasia [9, 40]. In particular, several authors describe a combination of hip dysplasia and cam-type deformities [1, 3, 4, 10, 12, 18, 20, 25, 30, 31, 34, 43] with an occurrence up to 75% in some cohorts.

Early reports of patients with this presentation of dysplasia and cam deformity indicate that treatment results after PAO are influenced by the presence of cam deformities and their correction during initial surgery [6, 43]. It is unclear, however, whether there is an association between clinical outcome and the magnitude of an existing

head-neck asphericity or an already existing intraarticular pathology secondary to this deformity.

We therefore asked: (1) Are there differences in clinical scores (WOMAC, EQ-5D) and examination findings (impingement sign) or radiographic measures of acetabular orientation and head sphericity after PAO for isolated acetabular dysplasia when compared with the combined pathology of dysplasia and additional femoral cam deformity? (2) Are these clinical and radiographic findings after combined surgical therapy for additional cam deformity influenced by different pathology-adjusted surgical techniques?

## Patients and Methods

After obtaining institutional approval, we performed a retrospective review of prospectively collected data to do a comparative observational study to assess clinical and radiographic outcome after PAO. At our university center, 86 patients (106 hips) could be enrolled from July 2005 to December 2010. All surgical procedures were performed by one experienced surgeon (K-PG).

Patients were offered PAO if acetabular dysplasia with a lateral center-edge (LCE) angle of less than  $25^\circ$  was confirmed by radiographic examination and they reported hip pain for at least 6 months, which did not adequately respond to conservative therapy. Contraindications for this procedure during this study period were advanced radiographic osteoarthritis (Kellgren-Lawrence Grade 3 and 4), incongruency of the joint space on pelvic AP radiographs or abduction view, or patient age  $> 50$  years.

Preoperatively, patients were then allocated to one of two groups based on clinical examination and radiographic morphology as previously described [17]. Group I (53 hips) consisted of patients in whom at least two of the following three criteria were met: painless internal rotation of the hip  $\geq 10^\circ$ , negative anterior impingement test, and no evidence of relevant cam deformity (alpha angle of  $\leq 50^\circ$ ). Patients were assigned to Group II (53 hips) if at least two of the following three criteria were met: internal rotation of the hip  $< 10^\circ$ , positive anterior impingement test, and radiographic proof of cam pathology (alpha angle  $> 50^\circ$ ). In Group II intraoperative osteochondroplasty of the femoral cam deformity in addition to PAO was planned, whereas in Group I, isolated PAO was performed.

Group II was further subdivided into two subgroups depending on the diagnosis of chondrolabral pathology on preoperative MRI investigation. If signs of chondrolabral pathology (ie, labral tears, lesions of the chondrolabral transition zone) were absent, patients were assigned to Subgroup IIa (27 hips). In case of visible chondrolabral pathology, patients were assigned to Group IIb (26 hips).

The intraoperative approach differed between both subgroups. In Group IIa hip arthrotomy and osteochondroplasty were performed after pelvic osteotomy, whereas in Group IIb, surgery started with arthrotomy, arthroscopically assisted hip visualization under traction, consecutive intraarticular surgery if necessary ( $n = 11$  refixation or partial resection of the labrum,  $n = 6$  débridement of damaged acetabular cartilage), and bump resection under hip traction before the osteotomy was performed. Our rationale for performing the intraarticular surgery before the osteotomy in Group 2b was the concern for potential acetabular fragment dislocation through the traction necessary for arthroscopy.

Preoperative imaging consisted of AP pelvic and lateral hip radiographs as well as MRI. Because most patients were referred with MRI investigations performed elsewhere without radial sequences, a standardized assessment measurement of the alpha angle was only performed on lateral hip radiographs.

In all patients a slightly modified technique of the Bernese PAO [15] was performed as previously described by our group [7]. Although osteotomy and fragment fixation follows the Bernese technique [15], the soft tissue exposure is less extensive (reduced incision length, no release of sartorius and rectus femoris muscles). After osteotomy and reorientation, fixation of the acetabular fragment is accomplished. Osteotomy cuts and assessment of final fragment position were done using fluoroscopy control.

Arthrotomy of the hip was performed in all operated cases, but timing as well as technique and additional intraarticular procedures depended on group allocation. In Group I the capsulotomy was very limited, sufficient to control for the absence of impingement, as a result of suboptimal acetabular reorientation or relevant asphericity. In Group IIa arthrotomy together with osteochondroplasty of the head and neck junction was performed after completion of osteotomies and preliminary fragment fixation. In Group IIb surgery started with capsulotomy and inspection of the joint under traction and arthroscopically assisted control, as described by Hartmann and Gunther [19]. Labral and cartilage surgery (ie, resection of degenerated cartilage flaps, microfracturing, labral refixation) and osteochondroplasty can be performed through this approach, before the osteotomy is started.

Preoperative antibiotics (1.5 g cefuroxime) were administered as a one-time dose 30 minutes before intervention. After the procedure, patients received nonsteroidal antiinflammatory drugs (600 mg ibuprofen three times daily) for 2 weeks to avoid heterotopic ossification. Weightbearing on the operated hip was restricted to 20 kg for 6 weeks and was allowed without restrictions after 12 weeks postoperatively.

Preoperative as well as followup clinical examinations included the assessment of anterior impingement sign of the operated hip (data not presented). In addition, EQ-5D [16] and WOMAC [41] scores were obtained. Radiographic evaluation before surgery as well as during followup consisted of AP pelvic radiographs carried out by a standardized technique in a supine position and a lateral hip radiograph. The acetabular orientation was assessed by measuring the LCE angle [42] and crossover sign [36]. Although preoperative MRI was performed in a nonstandardized manner, at followup pelvic and hip MRI with calculated radial sequences was obtained. For image acquisition a standard three-dimensional proton density scan using Sampling Perfection with Application optimized Contrasts using different flip angle Evolution (SPACE) with an isotropic voxel of 0.9 mm was customized for optimal field of view and acquisition time. A 1.5-T MRI Scanner (Siemens Somatom Avanto; Siemens HealthCare, Erlangen, Germany) was used. Femoral head sphericity at followup was assessed by measuring the alpha angle in radial MRI using predefined sectors clockwise from anterior to cranial [32].

Evidence of osteoarthritis of the hip before surgery and progression during followup were graded according to the classification system of Kellgren and Lawrence [24]. Sufficient interobserver as well as intraobserver agreement for the Kellgren and Lawrence classification in osteoarthritic hips has been shown in a previous study [17]. Assessment of all pre- and postoperative morphologic features of the acetabulum and femoral head was performed by one trained observer (JG).

#### Statistical Analysis

The Mann-Whitney U test was used for comparison of unpaired data and the Wilcoxon rank-sum test was used to compare paired data without normal distribution. We analyzed differences between unpaired categorical variables with the Fisher's exact or chi-square test and paired categorical variables with the McNemar test. With the numbers available, our study had 80% power to detect a difference between Groups I and II of 10 points on the WOMAC scores ( $G^*$ Power 3.1; Heinrich Heine University, Düsseldorf, Germany).

Although age at operation, body mass index, and prevalence of previous surgery (Table 1) were not different between the groups, they differed for gender distribution (no male patients were operated on in Group I). As a result of bump resection and additional intraarticular surgery when needed, the operation time was significantly longer in Group II than in Group I ( $p = 0.001$ ). We did not find a difference in blood loss,

**Table 1.** Demographic data of patients (Groups I and II)

Parameter	Group I	Group II	p value
Number of patients (hips)	32 (36)	42 (49)	
Age at surgery* (years)	27. ± 11 (14–44)	29 ± 10 (13–47)	0.233
Sex (number [percentage] of male hips)	0 (0)	12 (25)	0.001
Side (number [percentage] of right hips)	17 (47)	27 (55)	0.473
BMI* (kg/m <sup>2</sup> )	23 ± 4 (17–32)	24 ± 4 (18–36)	0.255
Previous hip surgery (%)	1 (3)	3 (6)	0.632
Operation time* (minutes)	130 ± 35 (84–295)	148 ± 29 (95–224)	0.001
Hospitalization after operation (days)	7 ± 1 (5–9)	7 ± 1 (4–10)	0.662
Blood transfusion			
Number (%) of patients receiving transfusion	12 (33)	24 (49)	0.13
Mean amount transfused in units (300 mL)*	1 ± 1 (0–5)	1 ± 1 (0–3)	0.158

\* Values of continuous parameters are expressed as mean ± SD with range in parentheses; BMI = body mass index.

**Table 2.** Clinical and radiographic data for Groups I and II

Parameter	Group I		Group II	
	Preoperative	Followup Mean time 72 ± 19 (39–102) months <sup>†</sup>	Preoperative	Followup Mean time 57 ± 15 (31–90) months
WOMAC*	74 ± 17 (39–100)	91 ± 15 (50–100) <sup>‡</sup>	72.9 ± 18.8 (27.1–100)	90.2 ± 12.8 (42.7–100) <sup>‡</sup>
EQ-5D*	10 ± 2 (7–13)	8 ± 2 (6–13) <sup>‡</sup>	10 ± 2 (6–14)	8 ± 2 (6–12) <sup>‡</sup>
EQ-5D VAS* (%)	67 ± 9 (50–80)	81 ± 16 (50–100)	63 ± 20 (25–98)	81 ± 17 (20–100) <sup>‡</sup>
Positive impingement test (%)	8/19 (42) <sup>†</sup>	4/30 (13)	22/29 (76)	7/38 (18) <sup>‡</sup>
Conversion to THA (%)		1 (3)		2 (4)
Osteoarthritis (%) (Kellgren and Lawrence) <sup>‡</sup>				
Grade 0	24/29 (83)	18/29 (62)	33/37 (89)	20/37 (54)
Grade 1	5/29 (17)	7/29 (24)	3/37 (8)	13/37 (35)
Grade 2	0	3/29 (10)	1/37(3)	4/37 (10)
Grade 3	0	1/29 (3)	0	0
Grade 4	0	0	0	0
Progression of osteoarthritis grades* (post- minus preoperative)		0.4 ± 0.7 (0–2)		0.4 ± 0.6 (0–2)
Lateral center-edge angle* (°)	14 ± 7 (–6 to 23)	32 ± 8 (16–43) <sup>‡</sup>	16.3 ± 5.8 (5.4–26.6)	32.4 ± 5.7 (21.3–42.3) <sup>‡</sup>
Crossover sign (% positive)	10/29 (35)	4/29 (14) <sup>†,‡</sup>	13/37 (35)	0/37 (0) <sup>‡</sup>
Alpha angle axial radiograph*	50 ± 13.5 (33.1–80.7)	46.7 ± 11.4 (28.3–77.9) <sup>†</sup>	55.8 ± 14.9 (32.5 – 90.2)	38.2 ± 5.8 (27.7–57.6) <sup>‡</sup>
MRI alpha angle*				
12 o'clock		35.5 ± 5.4 (24.7–49.6)		37.4 ± 4.9 (29.8–46.2)
13 o'clock		35.5 ± 4.9 (25.4–47.3)		37.7 ± 10.3 (27.8–91.4)
14 o'clock		40 ± 10 (25.4–62.2)		35.9 ± 5.8 (26.3–47.7)
15 o'clock		39.8 ± 12.3 (21.7–81.7)		35.9 ± 7.3 (25–58.9)

\* Values of continuous parameters are expressed as mean ± SD with range in parentheses; <sup>†</sup>significant difference compared with Group II; <sup>‡</sup>significant difference compared with preoperative status; VAS = visual analog scale.

however. In terms of clinical factors, the prevalence of a positive impingement test was increased in Group II (Table 2), but we did not observe any difference ( $p = 0.395$ ) in the mean preoperative WOMAC and EQ-5D scores. In both groups, the prevalence of hips with no osteoarthritis or osteoarthritis Grade 1, according to

Kellgren and Lawrence, was similar (Table 3). Two patients in Group II but no patients in Group I showed Grade 2 osteoarthritis preoperatively. We did not find statistical differences for preoperative acetabular morphologic features (Table 2); however, the alpha angle was lower in Group I ( $50^\circ \pm 14^\circ$ ) than in Group II ( $56^\circ \pm 15^\circ$ ).

**Table 3.** Demographic data of patients (Groups IIa and IIb)

Parameter	Group IIa	Group IIb	p value
Number of patients (hips)	21 (24)	22 (25)	
Age at surgery* (years)	30 ± 10 (13–47)	27 ± 9 (17–46)	0.395
Sex (number [percentage] of all male hips)	6 (25)	6 (24)	0.935
Side (number [percentage] of right hips)	13 (54)	14 (56)	0.897
BMI* (kg/m <sup>2</sup> )	25 ± 5 (19–36)	24 ± 3 (18–33)	0.810
Previous hip surgery (%)	2 (8)	1 (4)	0.609
Operation time* (minutes)	136 ± 21 (103–207)	160 ± 31 (95–224)	0.002
Length of hospitalization after operation (days)	6 ± 2 (4–10)	7 ± 1 (4–9)	0.272
Blood transfusion			
Number (%) of patients receiving a transfusion	12 (50)	12 (48)	0.882
Mean amount transfused in units (300 mL)*	1 ± 1 (0–2)	1 ± 1 (0–3)	0.981

\* Values of continuous parameters are expressed as mean ± SD with range in parentheses; BMI = body mass index.

The preoperative clinical examination showed differences in the prevalence of a positive impingement test (higher prevalence in Group II). In terms of radiographic factors, LCE angle, prevalence of positive crossover sign, and alpha angle were significantly higher in Group IIb than in Group IIa (Table 4). Operation time was significantly shorter in Group IIa than in Group IIb (138 ± 22 minutes versus 159 ± 31 minutes; Table 3).

The initial study population consisted of 106 hips (86 patients) in which PAO was performed. Seven hips (six patients) in patients < 18 years were not contacted for followup as a result of restriction of ethics approval to adult patients only. Using our records and contacting patients by phone, we identified three hips (three patients) with known conversions to THA. Twenty patients were operated on both hips and seven of these patients were allocated for one side to Group I and for the other side to Group II. A complete clinical as well as radiographic and MRI investigation in our institution at final followup was performed on 66 (51 patients) of the remaining 96 hips (77 patients). In 16 hips (15 patients) who declined clinical and radiographic followup investigation, as a result of traveling distance, we obtained telephone interviews and completed questionnaires. Fourteen hips (11 patients) were lost to followup for different reasons (Fig. 1).

Followup investigations were performed at a mean duration of 63 ± 18 months (range, 31–102 months; Group I: 72 ± 19 months; Group II: 57 ± 15 months) postoperatively.

## Results

Neither conversion rate to THA nor results of clinical scores or prevalence of positive impingement signs showed statistical or clinically relevant differences between Groups I

and II at final followup. Compared with the preoperative values, the postoperative WOMAC as well EQ-5D scores (Table 2) increased in both groups. Before intervention, Group I had less patients with a positive impingement sign than Group II. With the numbers available there were no differences between Groups I and II at final followup in terms of the presence of an anterior impingement test (four of 30 [13%] versus seven of 38 [18%];  $p = 0.747$ ). Radiographic measures of femoral morphology were not different in both groups at followup. Development of radiographic osteoarthritis was not different between the groups. Before intervention the mean alpha angle (Table 2) was 50° ± 14° for cases without and 56° ± 15° for cases with correction of an additional femoral cam deformity ( $p = 0.169$ ). After intervention the mean alpha angle was 47° ± 11° for cases without correction and 38° ± 6° for cases with femoral neck offset correction ( $p = 0.001$ ). Radial MRI sequences performed at followup showed no significant differences between Group I and Group II measuring the alpha angle in the anterior cranial quadrant of the femoral head-neck junction in 30° steps. Regarding acetabular coverage (Table 3), only three patients showed a positive crossover sign at followup in both groups. The LCE angle increased significantly from 14° ± 7° (–6° to 23°) preoperatively to 32° ± 8° (16°–43°) ( $p < 0.001$ ) in Group I and from 16° ± 6° (5°–27°) to 32° ± 6° (21°–42°) in Group II ( $p < 0.001$ ), respectively.

There was no difference in conversion rate to THA, results of clinical scores, and prevalence of postoperative impingement signs at latest followup between the different surgical approaches analyzed in Groups IIA and IIB. Both groups showed similar increases of WOMAC and EQ-5D scores from preoperatively (74 ± 17 in Group IIa versus 72 ± 20 in Group IIb,  $p = 0.989$ ) to followup investigation (92 ± 13 versus 89 ± 12,  $p = 0.117$ ). Preoperatively, the prevalence of a positive anterior impingement test was



**Table 4.** Clinical and radiographic data for Groups IIa and IIb

Parameter	Group IIa		Group IIb	
	Preoperative	Followup Mean time 56 ± 14 (35–87) months	Preoperative	Followup Mean time 59 ± 16 (31–90) months
WOMAC*	74 ± 17 (43–98)	92 ± 13 (43–100) <sup>‡</sup>	72 ± 21 (27–100)	90 ± 12 (46–100) <sup>‡</sup>
EQ-5D*	10 ± 2 (7–13)	8 ± 2 (6–12) <sup>‡</sup>	11 ± 2 (6–14)	8 ± 2 (6–12) <sup>‡</sup>
EQ-5D VAS* (%)	66 ± 16 (35–90)	82 ± 16 (40–100) <sup>‡</sup>	61 ± 22 (25–98)	80 ± 19 (20–100) <sup>‡</sup>
Positive impingement test (%)	6/11 (55)	4/20 (20) <sup>‡</sup>	16/18 (88)	3/18 (17) <sup>‡</sup>
Conversion to THA (%)		1 (4)		1 (4)
Osteoarthritis (%) (Kellgren and Lawrence)				
Grade 0	18/19 (95)	12/19 (63)	15/18 (83)	8/18 (44)
Grade 1	1/19 (5)	5/19 (26)	2/18 (11)	8/18 (44)
Grade 2	0	2/19 (11)	1/18 (5)	2/18 (11)
Grade 3	0	0	0	0
Grade 4	0	0	0	0
Progression of osteoarthritis grades* (post- minus preoperative)		0.4 ± 0.6 (0–2)		0.4 ± 0.6 (0–2)
Lateral center-edge angle*	14 ± 6 (5–24) <sup>†</sup>	33 ± 6 (21–42) <sup>‡</sup>	19 ± 5 (9–27)	32 ± 6 (21–41) <sup>‡</sup>
Crossover sign (% positive)	4/19 (21.1) <sup>†</sup>	0/19 (0) <sup>‡</sup>	9/18 (50)	0/18 (0) <sup>‡</sup>
Alpha angle axial radiograph*	49 ± 12 (33–69) <sup>†</sup>	39 ± 5 (28–50) <sup>‡</sup>	63 ± 15 (38–90)	37 ± 6 (29–58) <sup>‡</sup>
MRI alpha angle*				
12 o'clock		38 ± 14 (32–46)		37 ± 5 (30–46)
13 o'clock		40 ± 4 (28–91)		36 ± 4 (31–36)
14 o'clock		37 ± 5 (28–48)		34 ± 6 (26–27)
15 o'clock		35 ± 6 (25–48)		37 ± 8 (27–59)

\* Values of continuous parameters are expressed as mean ± SD with range in parentheses; <sup>†</sup>significant difference compared with Group II except for Kellgren and Lawrence grades; <sup>‡</sup>significant difference compared with preoperative status except for Kellgren and Lawrence grades; VAS = visual analog scale.

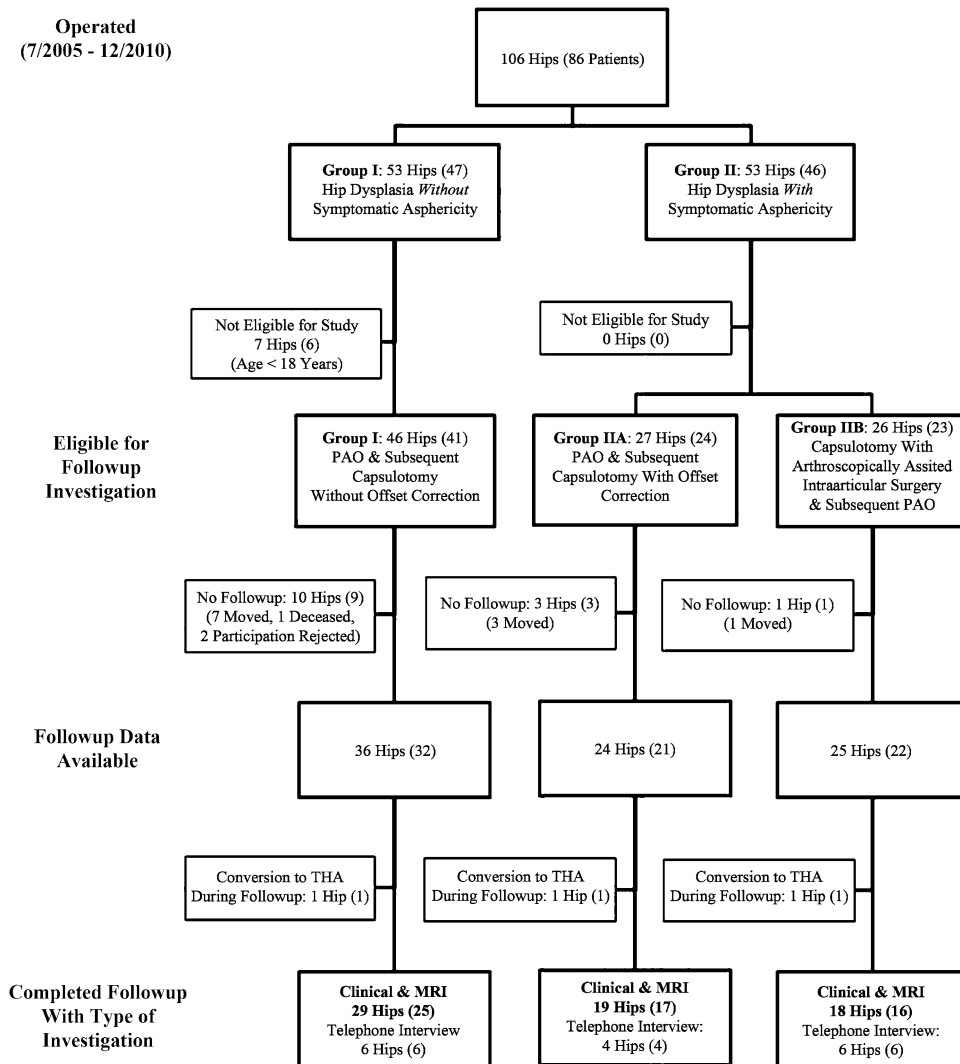
lower in Group IIa (six of 11 [55%] versus 16 of 18 [88%];  $p = 0.071$ ), but postoperatively the prevalence was similar (four of 20 [20%] versus three of 18 [15%];  $p = 1$ ). Radiographic measures of acetabular and femoral morphology were also comparable in both Groups IIA and IIB at followup. Development of radiographic osteoarthritis was not significantly different in both groups. Regarding postoperative radiographic measurement, the LCE angle was similar in both groups ( $33^\circ \pm 6^\circ$  versus  $32^\circ \pm 6^\circ$ ;  $p = 0.753$ ) and no patient in any group showed a crossover sign. Although the preoperative alpha angle was different ( $49^\circ \pm 12^\circ$  versus  $63^\circ \pm 15^\circ$ ;  $p = 0.009$ ), there was no difference for the postoperative alpha angle ( $39^\circ \pm 5^\circ$  versus  $37^\circ \pm 6^\circ$ ;  $p = 0.134$ ).

## Discussion

Recent studies suggest a higher than previously recognized coincidence of symptomatic acetabular dysplasia and femoral cam deformities [1, 3, 10, 12, 18, 20, 31, 34, 43].

Some authors have shown that improper surgical treatment of impingement has a negative impact on the clinical outcome [1, 6, 28, 40, 43]. To our knowledge, however, no investigation has been performed in which the treatment results of patients with and without femoral neck osteochondroplasty during PAO for symptomatic acetabular dysplasia are compared. In addition, the appropriate surgical technique to address a concomitant deformity on the femoral side is unclear. In this prospective evaluation of patients undergoing PAO for treatment of hip dysplasia, the clinical outcome at midterm followup showed no difference with the numbers available between a group without relevant clinical or morphologic signs of hip impingement preoperatively and a group in which osteochondroplasty has been performed. MRI investigation at followup similarly showed no difference in values of native alpha angles in the group without cam resection and alpha angles after surgical correction in the osteochondroplasty group. In addition, clinical as well as radiographic results revealed no difference in two subgroups with different techniques for bump resection (through conventional open arthroscopy

**Fig. 1** The STROBE diagram of operated hips (patients) and cases with completed followup is shown.



after osteotomy versus arthroscopically assisted resection before osteotomy).

This study has obvious limitations. First, we allocated the hips to two main study groups as well as subgroups based on a combination of clinical findings (degree of painless internal rotation of the hip, positive or negative impingement test) and structural parameters (alpha angle, MRI signs indicative for chondrolabral pathology). It is well known, however, that clinical findings in hip dysplasia and FAI are difficult to distinguish [22]. In addition, validity and reliability of clinical investigations in FAI are not very high [33, 35]. Preoperative MRI investigations were not performed in a standardized manner, because many patients had been referred to surgery after externally provided examinations and did not want to repeat them again. Therefore, we decided to measure preoperative alpha angles on standardized radiographs, although the limitations of reproducible cam deformity assessment by

conventional radiography are well known [14]. Being aware of this problem, we decided to perform capsulotomy in all patients of Group I to avoid a potential mechanical conflict, which had not been recognized during allocation. However, patient allocation to a specific treatment group with regard to addressing a cam deformity may or may not have been biased by the uncertainties mentioned. Nonetheless, by categorizing our results into several indications for differentiated surgical treatment approaches.

Although our study is not underpowered for the main study question, the overall number of patients as well as the size of our subgroups is relatively small. Therefore, potential differences between the treatments could appear with larger sample size. In addition, we note that 11 of our 80 patients were lost to followup at 5 years and the proportion lost was unevenly distributed over the three cohorts.

It is possible that these patients have had reoperations or conversions to THA done elsewhere. In a young patient group with considerable geographic mobility, a complete followup rate is rarely achieved. In those patients in whom clinical and radiographic investigation was not possible, we obtained information through telephone interviews and standardized questionnaires. Also, even in the patients who could be contacted, the minimum followup is still relatively short, and our conclusions regarding clinical outcome and osteoarthritis progression must be considered preliminary. Nevertheless, the number of long-term studies on PAO is limited [2, 21, 26, 29, 39, 40] and none of them has addressed the questions on which we focused. In addition, the correlation between morphologic deformity correction and patient outcome scores can be assessed, even during this medium-term followup. We must also acknowledge that the clinical parameters were assessed by different observers preoperatively and at followup. This potential source of error is difficult to avoid in a prospective study spanning over more than 5 years. The results of impingement tests may also be biased and, hence, we also included validated clinical scores based on patient-related outcome dimensions independent of investigators' assessment. Finally, all operations were performed at a single center by a single surgeon with many years' experience in pelvic osteotomies. This may affect the generalizability of our results, but the findings may at least be representative for high-volume subspecialty hip preservation surgeons.

The findings of our study indicate that systematic resection of clinically relevant cam deformities during PAO can produce the same clinical and radiographic results as isolated osteotomy when no major concurrent head-neck asphericity exists. It may be difficult, however, to determine which type of femoral deformity needs to be addressed. Some authors propose intraoperative dynamic assessment of hip motion through arthrotomy [30, 38]. Most authors agree that an alpha angle greater than  $50^\circ$  to  $55^\circ$  reflects a characteristic of cam FAI [5, 10, 11, 20, 23, 32]. There is also evidence that reduced internal rotation of the hip during clinical examination and a positive impingement test are indicative of the presence of reduced femoral offset [8]. Therefore, we used a combination of all of these to allocate patients to groups with or without planned cam correction: if two of three combined clinical and radiographic criteria were positive ( $< 10^\circ$  of internal rotation, positive anterior impingement test, alpha angle  $> 50^\circ$ ), we scheduled concomitant osteochondroplasty during PAO. Despite being aware of the preliminary and unvalidated character of this decision aid, we also decided to perform arthrotomy in cases allocated to the group without planned cam surgery. Because dynamic investigation of hip mobility after PAO in these patients showed that no additional cam deformity had to be addressed, intraoperative capsulotomy may not be

necessary in patients who do not have painful internal rotation or major radiographic cam deformity. Potential drawbacks of capsulotomy (heterotopic ossification, stiffness and inadvertent cartilage injury to the femoral head) could then be avoided, but with the obvious tradeoff that assessment for possible intraarticular fracture (presence of joint hematoma) and iatrogenic impingement secondary to inadvertent retroversion or overcoverage is no longer possible.

Our study revealed no relevant clinical or statistical differences between the different surgical approaches analyzed in Groups IIA and IIB. We do not know to what extent additional repair for chondrolabral lesions contributes to overall treatment results in PAO and what degree of damage is necessary to justify additional surgery. Our allocation to either conventional chondroplasty through capsulotomy alone (Group IIA) or additional procedures under arthroscopic assistance before osteotomy (Group IIB) was based on preoperative MRI investigations without proper standardization and the number of treated patients is too small to allow adjustment of results for severity of damage. We could find no other studies in which conventional chondroplasty and arthroscopic or arthroscopically assisted techniques have been directly compared in this setting. One recent multicenter study reports the results of 972 patients with PAO, where 53% had an additional anterior arthrotomy and 20% had a hip arthroscopy to either perform osteochondroplasty or to address labral pathologic changes, but outcomes of the different cohorts are not compared [37]. Most studies only assess the outcomes after anterior arthrotomy and bump resection after osteotomy [1, 6, 38]. Domb et al. [12, 13], however, believe that concomitant arthroscopy at the time of a PAO allows more complete visualization and improved ability to address intraarticular pathology than does anterior arthrotomy alone. If arthroscopy or arthroscopically assisted techniques as published earlier [9, 11, 19, 27] are applied during PAO, potential drawbacks must be considered. Operation time may be longer and intraoperative radiographic assessment of proper acetabular reorientation is impaired, because most conventional traction tables only allow fluoroscopic control without the possibility of a full radiographic pelvic view. Finally, it is not clear which patients will profit from additional cartilage or labrum surgery through arthroscopic or arthroscopically assisted techniques during PAO. Therefore, we cannot recommend this procedure as routine at the present time.

In conclusion, with the numbers of patients available, we detected no differences in outcome scores and radiographic results between patients with combined hip dysplasia and FAI, who underwent PAO together with cam resection and patients with PAO alone performed for



isolated dysplasia. Our results also show that arthroscopically assisted cam resection and labrochondral repair through a miniarthrotomy before osteotomy is possible. Although this approach or even arthroscopic techniques alone may be a helpful adjunct to PAO in patients with combined pathology, the limitations of our investigation do not allow us to recommend its routine use in clinical practice. Larger studies, ideally multicenter studies, will be needed to validate our preliminary observations.

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