Combined Periacetabular and Femoral Osteotomies for Severe Hip Deformities

John C. Clohisy MD, Lauren C. St John BS,
Ryan M. Nunley MD, Amanda L. Schutz PhD, MPA,
Perry L. Schoenecker MD

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Abstract Periacetabular osteotomy (PAO) is an effective acetabular reorientation technique for treatment of symptomatic acetabular dysplasia. In hips with severe deformities, an adjunctive femoral osteotomy (PFO) may optimize correction, joint stability, and congruency. We analyzed the clinical and radiographic results of combined PAO/PFO in treating severe hip deformities. Second, we compared the clinical results of patients treated with PAO/PFO with patients treated with isolated PAO for lesser deformities. Twenty-five patients (28 hips) treated with PAO/PFO were reviewed and followed a minimum of 16 months (mean, 44 months). The matched PAO cohort included 25 patients (28 hips). For the PAO/PFO group, the average Harris hip score improved from 60.9 to 86.3. Eighty-nine percent of the patients demonstrated at least a 10-point improvement in the hip score and 75% had a Harris hip score over 80 points. Radiographic evaluation demonstrated consistent deformity correction. The PAO/PFO group had a lower average Harris hip score

preoperatively, yet hip function after surgery was comparable between groups. These data indicate combined PAO/PFO is associated with improved hip function in most patients. These clinical results are comparable to those obtained with isolated PAO for lesser hip deformities.

Level of Evidence: Level III, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

The Bernese periacetabular osteotomy (PAO) was initially introduced by Ganz and colleagues as an acetabular reorientation technique for the treatment of symptomatic acetabular dysplasia [9]. Over the past decade, this versatile osteotomy has been adopted as one of the preferred techniques for acetabular deformity correction. Short- to midterm results have been reported from multiple institutions and demonstrate reduced pain and improved hip function in the majority of patients treated for acetabular dysplasia [2, 5, 7, 14, 17, 19, 20, 23–26, 28].

Despite its noted potential for correcting acetabular deficiency, at times it may be appropriate to combine the PAO with proximal femoral osteotomy (PFO). In severely deformed hips, some authors suggest adjunctive PFO may help to correct the deformities or enhance hip congruency, stability, and function [5, 7, 11]. Although several reports include a subpopulation of patients treated with combined PAO and PFO, we are unaware of any study exclusively reporting the clinical outcomes of this type of reconstruction [5, 7, 11, 26, 28]. With respect to surgical indications for the PFO, Hersche and colleagues [11] retrospectively analyzed radiographic parameters that were associated with the need to perform this adjunctive procedure. They

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J. C. Clohisy (✉), L. C. St John, R. M. Nunley,
A. L. Schutz, P. L. Schoenecker
Department of Orthopaedic Surgery, Washington University
School of Medicine, One Barnes-Jewish Plaza, Suite 11300 West
Pavilion, Campus Box 8233, St Louis, MO 63110, USA
e-mail: clohisj@wudosis.wustl.edu

identified several variables that had an association with the performance of PFO. These included the femoral head extrusion index, acetabular index or neck-shaft angle that was outside normal limits, a deformed femoral head, and osteoarthritis. Joint space height and congruency dependent on femoral head position were also associated with the performance of PFO. Although the authors identified these variables associated with the performance of PFO, the clinical results of the procedures and the prognostic factors influencing the surgical results were not reported. Although several studies include patients with combined PAO and PFO [5, 7, 26, 28], the clinical results of this specific subgroup of patients have not been emphasized.

We have subjectively observed that patients treated with combined PAO/PFO had improved hip function, consistent deformity correction, and preservation of the hip over short- to midterm followup. Additionally, after recovery from surgery, these patients appear to experience hip function similar to patients treated with PAO alone.

To confirm our impressions, we first analyzed hip function, radiographic deformity correction, and osteoarthritis progression associated with combined PAO/PFO in the treatment of severe hip deformities. We then compared hip function and complications of patients with the combined procedure with that of a matched cohort of patients treated with isolated PAO for less severe deformities.

Materials and Methods

We retrospectively reviewed all 185 PAOs treated by the senior authors (JCC, PLS) from January 1994 to July 2006. The indications for combined PAO and PFO included a severe hip deformity involving the acetabulum and proximal femur. In these cases, isolated PAO is not adequate to correct structural instability and/or congruency. PAO alone was indicated if the acetabular correction achieved hip stability and congruency. Patient information, surgical details, clinical outcome scores, and complications were obtained by retrospective review of data from the Washington University Hip and Knee Repository, outpatient clinic charts, and hospital records. Twenty-eight of the 185 hips (15%) in 25 patients were treated with combined PAO and PFO (study group) and are the focus of this report. The remaining 157 hips underwent isolated PAO. All patients in both groups had symptomatic acetabular dysplasia as defined by clinical signs and symptoms of hip pain combined with radiographic evidence of deficient acetabular coverage of the femoral head. All hips had one or more radiographic abnormalities, including a lateral center-edge angle less than 20°, an anterior center-edge angle less than 20°, or an acetabular inclination greater than 15°. All hips

had good to excellent congruency [30] as determined by functional radiographs preoperatively. All had at least 90° of hip flexion preoperatively and none had advanced secondary osteoarthritis (Tönnis Grade III) [27].

For the combined PAO/PFO procedures, 28 were performed at one surgery and five were performed in a staged fashion. Staged procedures were performed in these specific cases to avoid excessive blood loss and lengthy procedures. The average time between the first and second stage in patients who underwent a staged reconstruction was 4 to 8 weeks (range, 2–8 weeks). The need for a combined procedure was anticipated preoperatively in all cases. The final decision to do so was made intraoperatively. None of the combined procedures was performed in a delayed fashion as a result of a suboptimal result from a one-stage procedure. The preoperative and intraoperative decision-making process considers several variables when contemplating the need for combined PAO and PFO. Most importantly, varus PFO was performed in the severely dysplastic hip with coxa valga and persistent instability or suboptimal congruency after the PAO (Fig. 1). Valgus PFO was considered in the Perthes-like hip, which is characterized by a large aspheric femoral head, short femoral neck, trochanteric overgrowth, and variable coxa vara [1, 7]. This adjunctive osteotomy is used to enhance congruity, improve clinical abduction motion, advance the trochanter distally, and relieve impingement (Fig. 2). None of the proximal femoral osteotomies were performed for the primary purpose of correcting malrotation, version abnormalities, or limb length inequality.

For the combined PAO/PFO group, 13 patients were female (15 hips) and 12 patients were male (13 hips). The average age at surgery was 22.4 years (range, 11–44 years). The minimum followup was 16 months (mean, 44 months; range, 16–155 months). None of the hips were lost to followup. Twelve of the hips had developmental dysplasia, 10 a Perthes-like hip deformity [1, 7], and three had neuromuscular dysplasia. Sixteen of the hips had valgus-producing PFO. Three of these were to manage iatrogenic coxa vara with a relatively spherical femoral head, whereas 13 were performed to enhance congruity, improve clinical motion, and advance the greater trochanter distally. Twelve had varus-producing osteotomy. An arthrotomy was performed in eight cases to assess for labral disease and secondary femoroacetabular impingement [7]. Addition of the arthrotomy to our surgical procedure became routine over the time period of this study. Five of the hips had a concurrent femoral osteochondroplasty to prevent secondary femoroacetabular impingement, because the hip was judged to be at risk for impingement at the time of arthrotomy. Two hips had psoas tendon lengthening, two adductor release, and two trochanteric advancements (in addition to the intertrochanteric femoral osteotomies).

Fig. 1A–B Anteroposterior pelvic radiographs of an 11-year-old girl with severe bilateral hip dysplasia are shown. In addition to major acetabular deficiency, she has (A) severe bilateral coxa valga. She

was treated with (B) sequential bilateral periacetabular osteotomies and combined varus-producing proximal femoral osteotomies. She had an excellent clinical result bilaterally.

Fig. 2A–B Anteroposterior pelvic views of a 20-year-old woman with a symptomatic Perthes-like deformity of the right hip (A), including moderate acetabular dysplasia, a large aspheric femoral head, short femoral neck, and relatively high greater trochanter. This patient was managed with a combined periacetabular osteotomy and

valgus-producing proximal femoral osteotomy (B). The proximal femoral osteotomy was performed to optimize congruency, advance the trochanter distally, improve clinical abduction motion, and lengthen the extremity. The patient has an excellent clinical result 4 years after surgery.

This study was performed under an Institutional Review Board-approved protocol.

A comparison group of hips (treated only with periacetabular osteotomy) was obtained from the 157 isolated PAOs performed over the same time period. Patient characteristics of the combined PAO/PFO cases were matched to hips treated with isolated PAO by one author (LSJ) who was not involved in the care of the patients. The hips were matched retrospectively to establish pairs with the same gender, age at the time of surgery (within 3 years), and body mass index within two units. We also attempted to match preoperative diagnosis and followup length (Table 1). The clinical outcome of surgery was not considered during the matching process. The comparison group consisted of 11 males (13 hips) and 14 females (15

hips). The average age was 23 years (range, 10–44 years) and the body mass index 24.3 kg/m^2 (range, $19\text{--}33 \text{ kg/m}^2$). Minimum followup was 15 months (mean, 44.8 months; range, 15–143 months). Nineteen of the hips had developmental dysplasia, four a Perthes-like hip deformity, and two had neuromuscular dysplasia. Twelve of the hips had an arthrotomy, seven a femoral head-neck osteochondroplasty, two a partial labral resection, and one a trochanteric advancement. None were treated with PFO.

There was no difference in mean age ($p = 0.808$), body mass index ($p = 0.824$), or followup length ($p = 0.928$) between the study and comparison groups. Similar numbers ($p = 0.355$) of hips in both groups had previous surgery on the affected hip: nine patients in the PAO/PFO group and five in the comparison group. No patients were

Table 1. Patient characteristics and clinical results of the PAO/PFO and PAO patient cohorts

Variable	PAO/PFO	PAO	p value
Number of patients	25	25	
Number of hips	28	28	
Side (left/right)	10/18	15/13	0.1762
Average age (range)	22.4 (10–44)	23 (10–44)	0.808
Gender (male/female)	12/13	11/14	
Average body mass index (kg/m ²)	24.6 (17–32)	24.3 (19–33)	0.824
Previous hip surgery	9 (32%)	4 (14%)	0.1496
Followup (months)	44.1 (16–155)	44.8 (15–143)	0.9288
Preoperative HHS	60.9 (38.5–84.7)	69 (33–95.7)	0.028
Followup HHS	86.3 (58.3–100.1)	89.9 (52.8–100.1)	0.318
Change in HHS	25.3 (–12.1–52.8)	20.9 (–12.1–40.7)	0.248
HHS greater than 30 points	21 (75%)	23 (82%)	0.323
Improvement in HHS 10 points or greater	25 (89%)	23 (82%)	0.4577
Conversion to THA	1 (3.6%)	0 (0%)	
Complications	5 (18%)	3 (11%)	0.457

PAO = periacetabular osteotomy; PFO = femoral osteotomy; HHS = Harris hip score.

lost to followup. All but five patients (five hips) had minimum 2-year followup and all patients had at least 15 months followup.

The surgical technique of PAO was performed as previously described [5–7, 13, 14]. Patients donated two to four units of autologous blood. A modified anterior [21] (two hips) or modified Smith-Petersen [13] (26 hips) surgical approach was used. Intraoperative electromyographic peripheral nerve monitoring and cell saver blood reinfusion were used in all cases. The periacetabular cuts, acetabular fragment reduction, and screw fixation were guided with fluoroscopy. Acetabular fixation was performed with three to five 4.5-mm screws. The overall goals of the surgical procedure were to correct the structural instability of the joint, optimize congruency, avoid overcorrection, and prevent secondary femoroacetabular impingement [22]. Secondary goals included optimizing abductor efficiency (trochanteric height) and leg lengths. A lateral approach to the proximal femur was used for the femoral osteotomies. A no-wedge PFO technique [10] with blade plate fixation was used for hips treated with a combined procedure. The correction was dictated by the angle of the blade plate and angle of blade insertion. Care was taken to maintain proximal femoral alignment for future arthroplasty [8].

Excessive lengthening with valgus osteotomy was avoided by shortening through the osteotomy site. The amount of shortening was determined with preoperative templating. Estimated intraoperative blood loss was 1687 cc (range, 600–3500 cc) in the combined PAO/PFO procedures and 1653 cc in the isolated PAO group.

Preoperative and most recent followup clinical data were obtained for all 50 patients (56 hips). We used a self-reported modified Harris hip score [3] to assess hip function. A hip was classified as clinically improved if the hip score increased by 10 or more points. Additionally, for patients with systemic disease or other joint involvement that decreased overall activity level, a surgical procedure was deemed to have achieved clinical improvement if the preoperative pain completely resolved or if the pain score improved two or more grades. For example, a patient with activity restriction resulting from spastic hemiplegia with hip pain improvement from “moderate” to “none” is considered a good clinical result.

All patients had a supine anteroposterior pelvis, false profile, and functional (abduction/adduction) view preoperatively. All measurements were performed by one author (JCC). Preoperative and the most recent followup anteroposterior pelvis and false profile radiographs were available for 53 of the 56 hips. Two patients (two hips) in the PAO/PFO group and one patient (one hip) in the control group were missing preoperative false profile radiographs. On the anteroposterior pelvis, we measured the lateral center-edge angle of Wiberg [29], acetabular roof obliquity [15, 16], and the horizontal position of the hip center [4, 16]. Osteoarthritis grade was evaluated with a previously reported modification of the Tönnis classification [18, 27]. The anterior center-edge angle of Lequesne and de Seze [12] was determined on the false profile radiograph.

We analyzed clinical and radiographic results of the two patient groups using paired t-tests for continuous variables (modified Harris hip score, lateral center-edge angle, anterior center-edge angle, acetabular roof obliquity, horizontal position of hip center) and Fisher’s exact test on categorical variables (occurrence of complications).

Results

Patients treated with combined PAO/PFO demonstrated improved hip function and experienced reduction in pain in response to surgery. The mean Harris hip score improved 25.4 points at average 44 months after surgery (including the score for the patient who went on to subsequent THA). Twenty-five (89%) of the 28 hips improved 10 or more points. One patient with initial improvement for 5 years experienced progressive symptoms after 5 years and

Fig. 3A–E A failed combined PAO/PFO in a 44 year-old man is shown. **(A)** This patient had a Perthes-like deformity of the left hip with severe superolateral inclination of the acetabular articular cartilage, an aspherical femoral head, short, wide femoral neck, and relatively high greater trochanter. **(B)** The patient also had severe lack of femoral head coverage anteriorly. **(C)** This patient was treated with a combined periacetabular osteotomy (PAO) and proximal femoral valgus osteotomy (PFO). **(D)** The patient had improved hip function for 5 years and then had rapid deterioration of the hip joint associated with severe radiographic osteoarthritis. **(E)** At 5½ years after the initial surgery, the patient was treated with THA.

underwent THA 67 months after the index PAO/PFO (Fig. 3).

Radiographic evaluation of the PAO/PFO study group demonstrated deformity correction, osteotomy healing, and no osteoarthritis progression in the majority of cases. Significant improvement in the average lateral center-edge angle, acetabular inclination anterior center-edge angle, and medial translation of the hip center were observed (Table 2). The Tönnis osteoarthritis grade was improved (10) or unchanged (11) in 21 (75%) of the 28 hips. Six hips

demonstrated osteoarthritis progression of one grade and one hip had progression of two grades.

Patients with combined PAO/PFO and PAO alone had similar improvements in hip function after surgical intervention (Table 1). The study cohort had a lower ($p = 0.02$) average preoperative hip score (60.9 versus 69.0), but the final followup average scores (86.3 versus 89.9, $p = 0.32$) and average change in scores (25.3 versus 20.9) were similar ($p = 0.25$). The preoperative limp portion of the Harris hip score was lower ($p = 0.0003$) in the study

Table 2. Summary of radiographic correction and osteoarthritis progression for PAO/PFO group

Hip variable	Radiographic findings*		p Value
	Preoperative	Postoperative	
Lateral center-edge angle (degrees)	−3.1 (−29 to 24)	23.3 (8 to 39)	0.000000027
Anterior center-edge angle (degrees)	−7 (−45 to 22)	28.2 (12 to 48)	0.0000000082
Acetabular inclination (degrees)	30.3 (13 to 48)	9.8 (−5 to 24)	0.000000019
Horizontal position of hip center†	17.8 (8 to 32)	9.7 (−4 to 25)	0.000000015
Tönnis grade (number of hips)			
0	8	16	
1	19	7	
2	1	3	
3	0	2	

PAO = periacetabular osteotomy; PFO = femoral osteotomy; * the values are given as the mean with the range in parentheses; †horizontal position of the hip center = distance from medial aspect of the femoral head to the ilioischial line [4].

cohort, but the postoperative limp was similar ($p = 0.16$) in the two groups. The preoperative and postoperative measures of pain, need for a supportive device, and walking distance were similar in the two groups. We observed no differences ($p = 0.417$) in frequency of postoperative complications between the two groups. Assessment of complications revealed that in the PAO/PFO group there was one ischial nonunion, two transient nerve palsies, one delayed femoral union, and one superior pubic ramus nonunion. The PAO alone comparison group had one ischial nonunion and one wound dehiscence. Hardware was removed from 12 hips in the PAO group and from 16 hips in PAO only.

Discussion

The Bernese PAO has been established as an effective surgical technique for the correction of acetabular deformities [2, 5, 7, 14, 17, 19, 20, 23–26, 28], yet in severely dysplastic hips, optimal reconstruction may require an adjunctive proximal femoral osteotomy [11]. Nevertheless, the documented clinical results of combined PAO/PFO are limited and, to our knowledge, there are no studies focused on this combination of procedures. We performed this study to determine hip function, radiographic deformity correction, and osteoarthritis progression associated with combined PAO/PFO procedures. Additionally, we compared hip function and complications of combined PAO/PFO procedures with isolated PAO procedures.

We acknowledge several limitations of our study. This is a relatively small group of patients treated by two surgeons, and the clinical results are only short- to midterm. Because this is a relatively uncommon procedure, future studies with longer-term followup and larger patient cohorts may be best accomplished with a multicenter study design. The comparison group in this study has fundamental differences in the severity of the deformities and, therefore, has limitations as a “control” group. Nevertheless, this comparison cohort was established to determine if the final clinical result was compromised by the PFO. The data indicate that despite having lower Harris hip scores preoperatively, the combined PAO/PFO procedures yielded comparable hip scores at followup. Similarly, limp severity was worse in the PAO/PFO group preoperatively but was equivalent at latest followup.

Our findings suggest that despite more severe deformities and hip dysfunction before surgery, the PAO/PFO cases were associated with outcomes similar to those of less deformed hips treated with isolated PAO. Defining the specific indications for PFO in conjunction with PAO is difficult as a result of the heterogeneous nature of severe hip deformities and as a result of multiple variables

influencing the decision-making process. We take into account both preoperative and intraoperative information in making these decisions. Standard radiographic views, functional views, hip range of motion, and joint assessment at the time of arthrotomy can all provide unique information regarding the need for PFO. With these observations, we analyze joint stability/subluxation, congruency, intra-articular and extraarticular impingement, and joint space width. We currently do an arthrotomy in all cases. Femoral head stability within the acetabulum is assessed with dynamic examination, and impingement of the femoral head, femoral neck, and greater trochanter are inspected with functional hip motion. Instability and impingement mechanics are visualized directly through the arthrotomy and with fluoroscopy. This is performed through a complete range of motion and visualized with both the anteroposterior and faux profile-like views. This assessment is particularly important in hips with an aspheric femoral head in which obtaining stability without impingement can be more difficult. We contemplate adjunctive PFO in two clinical situations. First, in the severely dysplastic hip with coxa valga (neck-shaft angle greater than 140°) and persistent instability and/or suboptimal congruency after the PAO, we consider a varus PFO (Fig. 1). In most cases, the final decision to proceed with the femoral-sided procedure is determined by an intraoperative abduction functional view. If femoral head coverage and joint congruency are improved, and joint space width remains the same or widens with the functional position, proximal femoral varus-producing osteotomy is performed. A varus correction of 10° to 20° is most common. Flexion/extension, rotation correction, and shortening can be integrated into the osteotomy on a case-by-case basis. Trochanteric advancement may be performed for varus corrections greater than 20° . When correcting coxa valga, the proximal femoral procedure may be performed before or after the PAO and typically at the same surgery. With severe femoral deformities (typically coxa valga with subluxation), we may perform the femoral procedure first to facilitate achieving an optimal acetabular correction. In lesser femoral deformities, the PAO is performed first and the hip is then assessed with a functional abduction view and joint inspection through an arthrotomy.

The second main indicator for a proximal femoral osteotomy is a varus deformity or “Perthes-like” abnormality of the proximal femur (Figs. 2, 3). These hips may have a combination of structural and clinical problems, including an aspheric femoral head, short, wide femoral neck, high greater trochanter, limited abduction motion, and leg length discrepancy. Factors supporting a valgus PFO to optimize the reconstruction include enhanced congruency with the adduction functional view and adequate adduction motion to tolerate a valgus-producing

osteotomy. A relatively high greater trochanter, limited clinical abduction motion (less than 20°), and intraarticular or extraarticular impingement are additional reasons to perform valgus osteotomy. Leg length discrepancy is a secondary consideration and is not an independent factor needing correction. The valgus correction performed is usually between 10° and 20°. Care must be taken to avoid excessive valgus correction and associated recurrent instability.

The data in this report indicate the majority of patients treated with combined PAO/PFO for severe hip deformities have improved hip function at short- to midterm followup. The PFO does not seem to compromise the final clinical result and, therefore, should be considered in patients with residual instability, suboptimal congruency, excessively high greater trochanter, and/or impingement after acetabular reorientation. Clearly, studies with larger patient numbers and longer-term followup are essential to definitively demonstrate the appropriate indications and long-term clinical efficacy of this reconstructive procedure.

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