Intermediate to Long-Term Results Following the Bernese Periacetabular Osteotomy and Predictors of Clinical Outcome

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Background: The Bernese periacetabular osteotomy is a commonly used non-arthroplasty option to treat developmental hip dysplasia in symptomatic younger patients. Predicting which hips will remain preserved and which hips will go on to require arthroplasty following periacetabular osteotomy is a major challenge. In the present study, we assessed the intermediate to long-term results following periacetabular osteotomy to demonstrate the clinical outcomes for patients with varying amounts of dysplasia and arthritis. From these results, a probability-of-failure analysis was conducted to predict the likelihood of hip preservation and to improve surgical decision-making.

Methods: Of the 189 hips (in 157 patients) that were treated with periacetabular osteotomy by a single surgeon from May 1991 to September 1998, thirty-one had diagnoses other than developmental hip dysplasia and twenty-three were lost to follow-up. The remaining 135 hips (in 109 patients) were retrospectively reviewed at an average of nine years. Hips were evaluated with use of the pain subscale of the Western Ontario and McMaster Universities Osteoarthritis Index postoperatively as well as with radiographs that were made preoperatively and at one and more than five years postoperatively. Osteotomy failure was defined as a pain score of ≥10 or the need for total hip arthroplasty.

Results: One hundred and two hips (76%) remained preserved at an average of nine years, with an average Western Ontario and McMaster Universities pain score of 2.4 of 20. Thirty-three hips (24%) met the failure criteria: seventeen underwent arthroplasty at an average of 6.1 years after the osteotomy, and sixteen had a postoperative pain score of ≥10. Kaplan-Meier analysis with arthroplasty as the end point revealed a survival rate of 96% (95% confidence interval, 93% to 99%) at five years and 84% (95% confidence interval, 77% to 90%) at ten years. Complications occurred in twenty hips. Fifteen hips (11%) were treated with a subsequent arthroscopy because of chondral and/or labral lesions at an average of 6.8 years after the osteotomy. Two independent predictors of failure (defined as arthroplasty or a high pain score) were identified: (1) an age of more than thirty-five years and (2) poor or fair preoperative joint congruency. The probability of failure requiring arthroplasty was 14% for hips with no predictors of failure, 36% for those with one predictor (either an age of more than thirty-five years or poor or fair joint congruency), and 95% for those with both predictors.

Conclusions: The Bernese periacetabular osteotomy can be effective for the treatment of painful hip dysplasia, but complications may be expected in as many as 15% of cases. The ideal candidate is the patient who is less than thirty-five years of age and who has good or excellent hip joint congruency.

Level of Evidence: Prognostic Level II. See Instructions to Authors for a complete description of levels of evidence.

Hip dysplasia is one of the most common etiologies of osteoarthritis in the young adult, often leading to arthroplasty long before joint replacement can be considered a lifetime solution[1-6]. Surgical realignment of the congruous dysplastic acetabulum can reduce or eliminate symptoms for years, sometimes indefinitely, in a majority of ap-

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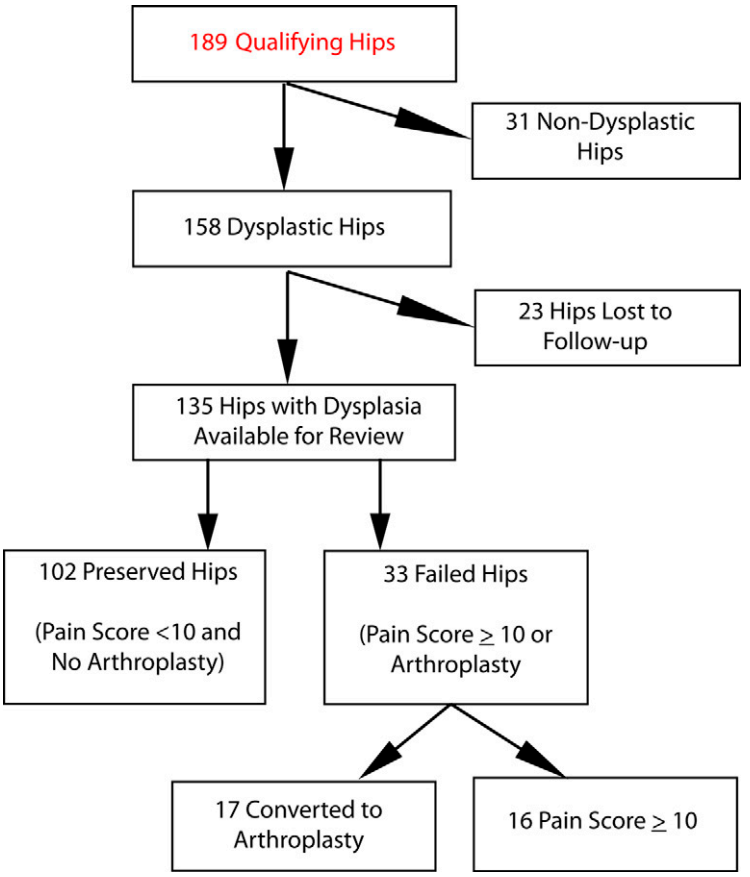

Fig. 1

Flow chart indicating the derivation of the study population.

propriately selected patients, even in those with some degree of preoperative arthritis[7-15].

Relatively few long-term outcome studies of pelvic osteotomy are available to help to decide between joint preservation and joint replacement. Most of the studies that have assessed the risks for poor outcome following the Bernese periacetabular osteotomy have documented risk factors for the progression of osteoarthritis and the need for additional surgery[8,10]. These risk factors have included increased age, preoperative arthritis, the presence of a labral tear, and an insufficient amount of correction. In addition, while average postoperative pain and functionality assessments have demonstrated significant improvements, all previous studies have demonstrated that several hips had poor or fair pain and function scores postoperatively[7-9,12,15].

We sought to further characterize the outcomes of this procedure and to determine the clinical and radiographic predictors of failure.

Materials and Methods

Institutional review board approval was obtained, and a thorough review of our hospital database and office records as well as Internet search engines was performed to locate all patients who had been managed with periacetabular osteotomy by a single surgeon (M.M.).

All patients who had been managed between May 1991 (the month of the initial periacetabular osteotomy performed at this institution) and September 1998 were eligible for inclusion. All hips had had the index procedure more than five years previously or had undergone total hip arthroplasty. The average duration of follow-up (and standard deviation) was 9 ± 2.2 years. The indications for periacetabular osteotomy included pain and radiographic evidence of femoral head uncovering with a lateral center-edge angle of <20°. Contraindications included osteoarthritis without obvious remaining cartilage to bring into a weight-bearing position. The triradiate cartilage in all patients was closed. Data that were compiled through the initial chart and operative note review included basic demographic information, whether an arthrotomy had been performed, the presence of a full-thickness labral tear at the time of surgery, complications related to surgery, and the need for subsequent surgery.

A total of 189 periacetabular osteotomies were performed in 157 patients during the specified time frame. Thirty-one hips had diagnoses other than developmental dysplasia and were excluded. Twenty-three hips lacked more than five years of follow-up and/or were in patients who could not be reached for evaluation. Preoperative and postoperative radiographs were available for fifteen of those twenty-three hips, and the radiographic measures of dysplasia were similar to

those for the rest of the study group. Pain scores were not obtained for this group of patients. None of the hips that had less than five years of follow-up had undergone an arthroplasty by the time of latest contact.

The remaining 135 hips (in 109 patients) were available for review and, for the purposes of the present study, constituted the group on which all analyses are based (Fig. 1). This group included ninety-five female patients (119 hips) and fourteen male patients (sixteen hips). The average age (and standard deviation) for all patients at the time of surgery was 26.7 ± 9 years. Clinical and radiographic data were analyzed from the routine preoperative, one-year postoperative, and more-than-five-year postoperative time points. When it was impossible for the patient to return for a clinic visit with the senior author (M.M.), questionnaires and radiographs were mailed back for evaluation.

Twenty-seven hips underwent one or more osteotomies before the periacetabular osteotomy, including innominate (Salter) osteotomy (thirteen), intertrochanteric osteotomy (nine), Pemberton osteotomy (three), Chiari osteotomy (one), or shelf osteotomy (one). In addition, twenty-three hips that had undergone a previous osteotomy also underwent closed and/or open reduction with casting, tenotomy, Pavlik harness treatment, or double-diaper bracing.

At the time of follow-up visits, pain was assessed with use of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain subscale, a validated instrument for assessing osteoarthritis[2,16]. Pain over the previous four weeks was rated by the patient in five areas: (1) walking on a flat surface, (2) climbing up or down stairs, (3) lying in bed at night, (4) sitting or lying, and (5) standing upright. The pain was scored as 0 (none), 1 (mild), 2 (moderate), 3 (severe), or 4 (extreme). A total pain score was calculated by summing the scores for all five areas, with a maximum score of 20 indicating extreme symptoms. This instrument was not implemented preoperatively until after the study period, and therefore comparison with the preoperative pain score was not possible for this analysis. Serial pain scores were not available for this evaluation.

Radiographic Measures

Preoperative, postoperative, and more-than-five-year postoperative radiographs (including an anteroposterior view of the pelvis, a false-profile view of the acetabulum, and a von Rosen maximum abduction and internal rotation anteroposterior view with use of standard techniques) were evaluated for several markers, including the lateral center-edge angle of Wiberg, the anterior center-edge angle of Lequesne and de Sèze, the acetabular roof angle described by Tönnis, and the minimum joint space (measured in millimeters)[4,6,17].

Joint congruency was classified into one of four categories as described by Yasunaga et al.[11]: (1) excellent (if the radii of curvature of the acetabulum and the femoral head were almost identical and the joint space was adequately maintained), (2) good (if the radii of curvature of the acetabulum and femoral head were not identical but the joint space was adequately maintained), (3) fair (if the radii of curvature of the femoral head and acetabulum were not identical and partial narrowing of the joint space was present), or (4) poor (if partial disappearance of the joint space had occurred). We assessed preoperative joint congruency and the potential adequacy of postoperative coverage on the von Rosen maximum abduction and internal rotation anteroposterior radiograph of the pelvis and hips. Postoperative congruency was assessed on the standing or supine anteroposterior radiograph of the hip.

Osteoarthritis at the time of surgery and postoperatively was classified according to the criteria of Tönnis[4] as grade 0 (no changes), grade 1 (widened sclerotic zone and minimal osteophyte formation), grade 2 (moderate loss of joint space and cyst formation), or grade 3 (<1 mm of joint space or no joint space).

Joint subluxation and potentially increased anterior acetabular coverage of the femoral head was assessed radiographically as a break in the Shenton line and a positive crossover sign. A break in the Shenton line was defined as a >5-mm break in a continuous line, drawn on an anteroposterior pelvic radiograph, connecting the inferior border of the superior pubic ramus and the medial border of the ipsilateral femoral neck. A positive crossover sign was defined as an intersection of the anterior and posterior acetabular wall shadows over the femoral head as seen on an anteroposterior pelvic radiograph[18]. The necessity of standardized radiographic positioning to accurately assess acetabular retroversion with a crossover sign has been well documented[19]. Such absolute positioning criteria for radiographs were not defined during the study period. Therefore, a definitive diagnosis of retroversion was not possible for this study.

A senior orthopaedic surgery resident (T.M.) made all radiographic measurements. Intraobserver reliability studies were performed over a one-week interval and demonstrated near-perfect correlations for angular and joint space width measurements. Moderate kappa values were seen for joint congruency and Tönnis grading (kappa = 0.49 and 0.44, respectively), indicating moderate consistency.

Surgical Technique

Initially surgery was performed according to the technique initially described by Ganz et al.[20] (for the first twenty-four procedures), and later (after 1993) it was performed according to an abductor-sparing approach modification as described by Murphy and Millis[21]. Briefly, an anterior surgical approach to the hip was performed, and an osteotomy of the superior pubic ramus and a partial osteotomy of the ischium inferior to the acetabulum were performed. This was followed by an osteotomy bisecting the posterior column between the acetabulum and the sciatic notch, meeting with the inferior acetabular cut. The osteotomy was completed with a cut from just inferior to the anterior-superior iliac spine to the brim of the pelvis, meeting with the posterior column cut. With the use of a Weber bone clamp and a Schanz screw, the acetabular fragment was rotated to attain a horizontal appearance of the weight-bearing acetabulum on the anterior-posterior projection as

TABLE I Comparison of Preserved and Failed Hips

Variable	Preserved Hips (N = 102)	Failed Hips (N = 33)	P Value		Odds Ratio (95% Confidence Interval)†
			Univariate Analysis	Multivariate Analysis*	
Age† *(yr)*	23.9 (10 to 44)	31.3 (12 to 45)	<0.01§		
Age group *(no. of hips)*			<0.01§	<0.01§	6.5 (2.0 to 20.2)
≤35 years	89 (87%)	19 (58%)			
>35 years	13 (13%)	14 (42%)			
Sex *(no. of hips)*			0.36	0.12	
Female	88 (86%)	31 (94%)			
Male	14 (14%)	2 (6%)			
Side *(no. of hips)*			0.84	0.72	
Left	50 (49%)	15 (45%)			
Right	52 (51%)	18 (55%)			
Preop. minimum joint-space width (mean and std. error)# *(mm)*	4.0 ± 1.4	3.2 ± 1.7	0.02§		
Preop. minimum joint-space width# *(no. of hips)*			<0.05§	0.93	
<2 mm	4 (4%)	5 (16%)			
≥2 mm	93 (96%)	26 (84%)			
Preop. joint congruency# *(no. of hips)*			0.02§	0.02§	3.5 (1.3 to 10.4)
Poor or fair	16 (16%)	12 (39%)			
Good or excellent	81 (84%)	19 (61%)			
Labral tear *(no. of hips)*			0.78	0.48	
No	86 (84%)	26 (79%)			
Yes	16 (16%)	7 (21%)			
Preop. crossover sign# *(no. of hips)*	12 (12%)	9 (29%)			
Preop. lateral center-edge angle of Wiberg#** *(deg)*	3 (−5 to 10)	0 (0 to 6)	0.71	0.95	
Preop. anterior center-edge angle of Lequesne#** *(deg)*	6 (0 to 13)	5 (0 to 11)	0.89	0.86	
Preop. Tönnis angle#** *(deg)*	26 (19 to 31)	27 (21 to 30)	0.51	0.98	
Preop. Tönnis grade# *(no. of hips)*			<0.01§	0.38	
0	52 (54%)	10 (32%)			
1	27 (28%)	10 (32%)			
2	18 (19%)	8 (26%)			
3	0 (0%)	3 (10%)			

*Based on multivariate logistic regression analysis with use of a generalized estimating equations approach to account for the within-subjects repeated measure (two hips from the same patient). †For significant multivariate risk factors (an age of more than thirty-five years and poor or fair preoperative joint congruency). ‡The values are given as the median, with the range in parentheses. §Significant. #Seven hips did not have available radiographs. **The values are expressed as the median, with the interquartile range in parentheses.

well as improved femoral head coverage on both the anteroposterior and false-profile projections of the hip with use of intraoperative fluoroscopy. After provisional fixation, passive flexion to at least 90° was confirmed. Fixation was obtained with a combination of 3.5-mm and 4.5-mm cortical screws.

Eighty-two hips (61%) had an arthrotomy at the time of surgery to investigate or treat a suspected labral tear. An unstable, full-thickness labral tear was present and débrided to a stable margin in twenty-two hips (27% of the hips that had an arthrotomy). Prior to September 1994, arthrotomy was not performed.

Preoperative and intraoperative assessment of the need for an additional proximal femoral intertrochanteric osteotomy was also conducted with use of standard anteroposterior,

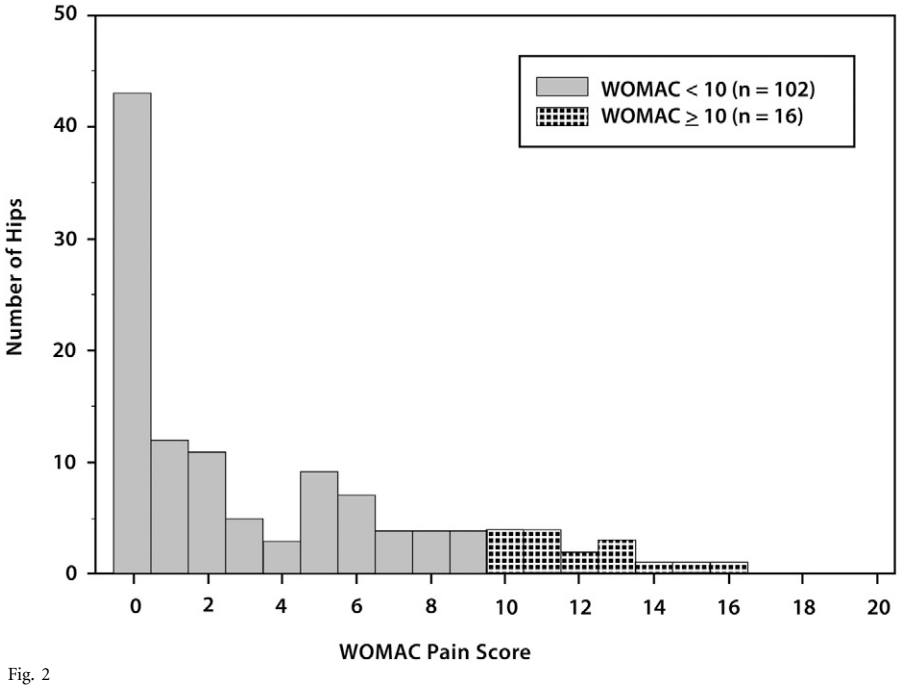

Fig. 2

Histogram demonstrating the distribution of Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain scores for hips that did not undergo arthroplasty.

false-profile, and fluoroscopic radiographs. An additional osteotomy was performed if deemed necessary to further improve the femoral head coverage and/or congruency with the newly positioned acetabulum. Femoral osteotomy sites were fixed with standard, adult blade plates.

Postoperative Care

Postoperative pain was treated with intravenous and/or epidural analgesia, which was converted to oral medication prior to hospital discharge. Partial weight-bearing was continued for six to ten weeks (or until there was radiographic evidence of bone healing), and then progressive weight-bearing and increased range of motion were allowed. This routine was utilized for all hips, including those that underwent an intertrochanteric osteotomy. Patients were discharged by the seventh day. Weight-bearing and range-of-motion exercises were taught to all patients by a physical therapist prior to surgery. Patients who were more than sixteen years of age at the time of surgery were managed with either Coumadin (warfarin) or aspirin for prophylaxis against deep-vein thrombosis for one month postoperatively. Prophylaxis against heterotopic ossification was not routinely administered. Implants were routinely removed within twelve months after surgery.

Patients were seen for follow-up clinical and radiographic examinations either at the hospital of the primary surgeon or by their local orthopaedic surgeon (with the radiographs being mailed to the primary surgeon for periodic review). Complications in the immediate postoperative period were assessed by the primary surgeon and were documented. Delayed findings (e.g., heterotopic ossification and delayed union) were assessed radiographically by the primary surgeon during the follow-up period.

Criteria for Failure of Periacetabular Osteotomy

The periacetabular osteotomy was considered to have failed if the patient had gone on to have a total hip arthroplasty or if the latest WOMAC pain score was 10 (indicating an average of "moderate" pain) or greater.

Statistical Analysis

Univariate tests that were used to compare hips that had a failure (defined as total hip arthroplasty or a WOMAC pain score of ≥10) with hips that remained preserved included the two-sample Student t test for age, joint space width, and Tönnis angle; the Fisher exact test for sex, side, and the presence of a labral tear; and the Pearson chi-square test for joint congruency and Tönnis grade. The nonparametric Mann-Whitney U test was used to compare lateral and anterior center-edge angles as these variables departed from a normal distribution and are expressed in terms of the median and range. Survivorship analysis was performed with use of the Kaplan-Meier product-limit method to account for censoring, and 95% confidence intervals around the survivorship curve were calculated with use of the Greenwood formula[22]. Multivariate logistic regression analysis with use of backward selection with a p value of 0.01 for removal was conducted to control for confounding variables and to determine independent predictors of failure (defined as arthroplasty or a pain score of ≥10). The generalized estimated equations approach was used to control for the possible effect of bilateral hip

TABLE II Radiographic Evaluation*

	Preserved Hips (N = 97)†	Failed Hips (N = 31)††
Preoperative evaluation		
Lateral center-edge angle *(deg)*	3 (−5 to 10)	0 (0 to 6)
Anterior center-edge angle *(deg)*	6 (0 to 13)	5 (0 to 11)
Tönnis angle *(deg)*	26 (19 to 31)	27 (21 to 30)
>5-year follow-up evaluation		
Lateral center-edge angle *(deg)*	26 (10 to 48)	25 (−3 to 44)
Anterior center-edge angle *(deg)*	27 (−7 to 50)	24 (−20 to 40)
Tönnis angle *(deg)*	7 (−7 to 30)	8 (−3 to 23)

*Seven hips lacked complete preoperative and postoperative radiographs for comparison. †The values are presented as the median, with the interquartile range in parentheses. ††Failed hips included those treated with arthroplasty and those with a pain score of ≥10.

procedures performed at different times. Odds ratios, 95% confidence intervals, and the estimated probability of failure were determined for the combination of independent predictors[23,24]. Significance was established at the two-tailed 0.05 alpha level. A receiver operating characteristic curve was constructed to assess the diagnostic performance of the group of multivariate predictors in identifying which hips would have a failure (that is, which hips would be treated with an arthroplasty or would have a high pain score) following periacetabular osteotomy[25].

Source of Funding
There were no external sources of funding for this retrospective review.

Results

One hundred and two hips (76%) remained preserved and did not meet any failure criteria. Thirty-three hips (24%) met the failure criteria (conversion to total hip arthroplasty or a WOMAC pain score of ≥10); specifically, seventeen (13%) of 135 hips later underwent total hip arthroplasty at an average of 6.1 years after surgery, and sixteen hips (12%) were rated as having a pain score of ≥10 (average, 12 ± 1.9) at an average of 9.7 years after surgery.

Outcomes for Preserved Hips

The average age of the patients with preserved hips was 23.9 ± 8.4 years. Demographic and radiographic data are presented in Table I. The pain scores for the involved hips represented the average symptoms over the previous four weeks. Patients with preserved hips following the periacetabular osteotomy had an average pain score of 2.4 ± 2.8 (Fig. 2). Within the group of preserved hips, seventy-five (74%) had a pain score of between 0 and 4 (average, 0.9 ± 1.2) and twenty-seven (26%) had a score of between 5 and 9 (average, 6.5 ± 1.4).

Preoperative and more-than-five-year postoperative radiographs were available for review for ninety-seven (95%) of the 102 preserved hips (Table II). Seventy-nine hips (81%) had had grade-0 or 1 signs of osteoarthritis before surgery, and eighteen (19%) had had grade-2 or 3 signs of osteoarthritis before surgery. In comparison, seventy-one hips (70%) had grade-0 to 1 changes at the time of the most recent follow-up visit. Twenty-four hips (24%) had progression in terms of the osteoarthritis grade (with eighteen hips advancing from grade 0 to grade 1). Eleven hips (11%) demonstrated radiographic regression of osteoarthritis by at least one grade.

Two hips had a postoperative crossover sign. As stated, the criteria for correct positioning of the pelvis were not in place during the study period and it is therefore difficult to accurately judge the importance of this finding. One hip lacked a follow-up false-profile radiograph to assess anterior coverage, and the other hip had an anterior center-edge angle of 40°, which may explain the appearance of this crossover sign. Both hips had a negative Tönnis angle, indicating lateral overcoverage as well. However, at an average of ten years after surgery, both patients rated the pain in that hip as 0 (no pain).

Within this group of preserved hips, fifty-seven hips (59%) had had a preoperative minimum joint space of <2 mm, a Tönnis grade of 2 or 3, and/or poor or fair congruency. The average postoperative pain score for these hips was 2.2 at an average of nine years after the periacetabular osteotomy.

Outcomes for Hips with Failure of Periacetabular Osteotomy

Thirty-three hips (24%) had a failure according to the combined criteria. The average age of the patients in this group was 31.3 ± 8.8 years. Demographic and radiographic data are presented in Table I.

Preoperative and more-than-five-year postoperative radiographs were available for review for thirty-one (94%) of the thirty-three hips that had a failure (Table II). Seventeen hips (55%) had had grade-0 or 1 signs of osteoarthritis before surgery, and fourteen (45%) had had grade-2 or 3 signs of osteoarthritis before surgery. In comparison, twelve hips (39%) had grade-0 or 1 changes at the time of the most recent follow-up visit. Thirteen hips (42%) had progression of the osteoarthritis grade (with ten hips advancing from grade 0 to grade 1). Five hips (16%) demonstrated radiographic regression of the osteoarthritis by one grade.

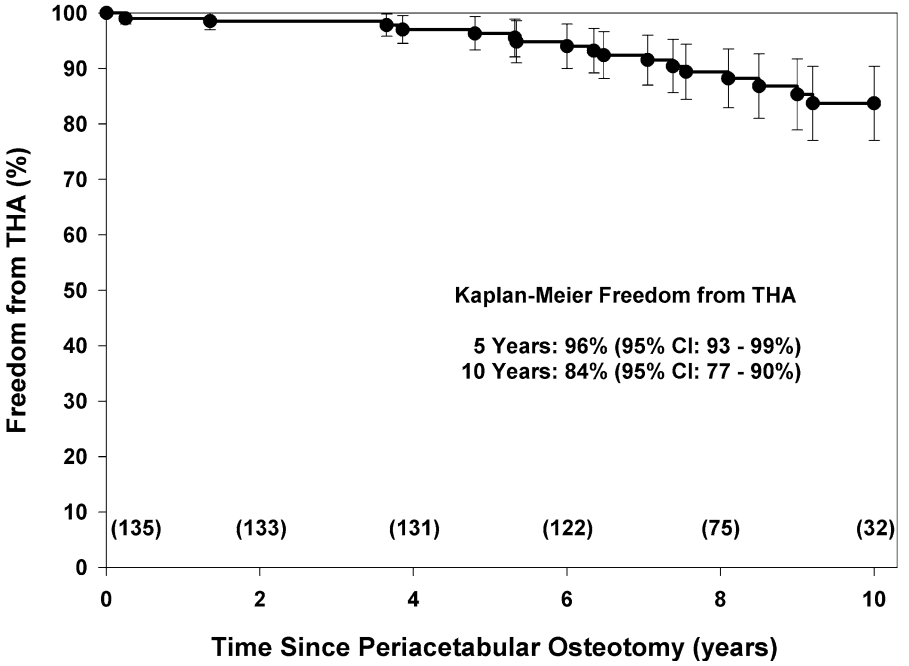

Fig. 3

Kaplan-Meier survivorship curve demonstrating the number of preserved hips following periacetabular osteotomy. Each decrease in the curve corresponds to osteotomy failure and subsequent treatment with arthroplasty. The error bars indicate 95% confidence intervals (CI). THA = total hip arthroplasty.

Seven hips (21%) had diagnosis and treatment of a labral tear at the time of the osteotomy. No hip had a crossover sign postoperatively. Two hips had a break in the Shenton line. In both cases, the Tönnis angle was <10°. The lateral and anterior center-edge angles in those two hips were 25° to 28°, with no radiographic signs of subluxation.

Within this group of hips that had a failure, we also found that thirteen hips (42%) had had good or excellent joint congruency, seventeen (55%) had had a Tönnis osteoarthritis grade of 0 or 1, and twenty-seven (87%) had had ≥2 mm of joint space preoperatively.

As previous studies had evaluated conversion to total hip arthroplasty as the primary mode of osteotomy failure, we assessed the seventeen hips that fell into this category. The average age in this group was 34.4 ± 6.3 years. Kaplan-Meier analysis with arthroplasty as the end point revealed an estimated survival rate of 96% (95% confidence interval, 93% to 99%) at five years and 84% (95% confidence interval, 77% to 90%) at ten years (Fig. 3).

An average WOMAC pain score of 10 indicated moderate pain and discomfort and was set as a marker for failure. At the time of the most recent review, sixteen hips had a pain score of ≥10 (Fig. 2). The average age at the time of surgery for this group was 27.7 ± 9.5 years. The Kaplan-Meier estimated survival rate with failure due to a pain score of ≥10 as the end point could not be accurately calculated as we did not have serial evaluations to determine the exact time to this type of failure.

Predictors of Osteotomy Failure

Univariate and multivariate analyses were performed to determine predictors of periacetabular osteotomy failure. Preserved and failed hips were found to be similar with regard to patient sex, the side of surgery, and the amount of dysplasia (based on the center-edge and Tönnis angles) (Table I). We did not find that the presence of a labral tear predicted failure as has been noted by other authors[8,11]. Univariate predictors for failure included an age of more than thirty-five years at the time of surgery, <2 mm of joint space, preoperative poor or fair joint congruency indicating a mismatch in the radii of curvature with at least partial loss of joint space, and a higher Tönnis osteoarthritis grade. However, only an age of more than thirty-five years and preoperative poor or fair congruency

TABLE III Multivariate Predictors of Failure

No. of Predictors*	Probability of Failure	95% Confidence Interval
0	14%	8% to 20%
1	36%	24% to 48%
2	95%	90% to 100%

*Multivariate predictors included an age of more than thirty-five years and poor or fair preoperative joint congruency.

were found to be independently predictive of failure on multivariate analysis. A simplified probability-of-failure table (Table III) was constructed to estimate the probability of failure of the osteotomy because of either a higher pain score (≥10) or total hip arthroplasty on the basis of the number of independent preoperative predictors. This table can be summarized as follows: the probability of failure of the osteotomy, defined as an arthroplasty (at an average of six years) or moderate or worse pain (at an average of nine years), was 14% if no predictors were present, 36% if one predictor was present, and 95% if both predictors were present. The relationship of these predictors was examined with receiver operating characteristic analysis. The area under this curve was 0.80, indicating good to excellent diagnostic performance of these two predictors.

Additional Intertrochanteric Osteotomy

A simultaneous intertrochanteric osteotomy was performed in twenty-five (19%) of the 135 hips following periacetabular osteotomy. Twenty-three varus derotational osteotomies were performed for the treatment of coxa valga (two with shortening), and two valgus-producing osteotomies were performed for the treatment of mild coxa vara to improve joint congruency. These procedures were evenly spread throughout this initial experience. No complications were associated with the performance of the femoral osteotomy or with the implants. There were no clinical or radiographic predictors of the need for an additional intertrochanteric osteotomy.

Arthroscopy Following Osteotomy

Fifteen hips (11%) underwent arthroscopic débridement of either painful labral or chondral lesions at an average of 6.8 ± 2.9 years following the periacetabular osteotomy. All but one hip had had an arthrotomy at the time of the osteotomy, and three had had a full-thickness labral tear that was débrided to a stable margin. The preoperative evaluation demonstrated an average Tönnis score of 0.3, an average joint space width of 3.9 mm, and good to excellent congruency on the average. No patient had a magnetic resonance imaging before the osteotomy.

Postoperative radiographic evaluation demonstrated no radiographic predictors of later surgery. One hip had an anterior center-edge angle of 41°. However, the remainder of the hips in this group had average anterior and lateral center-edge angles of 28.5° ± 9.4° and 28.5° ± 8.6°, respectively. All patients presented with mechanical symptoms of locking and/or catching and had pain with flexion, adduction, and internal rotation of the hip. Pre-arthroscopy magnetic resonance imaging was performed for all hips, and either direct or indirect arthrography was performed for five.

Magnetic resonance imaging accurately predicted the arthroscopic findings for both labral and articular cartilage lesions in four hips. In the remaining eleven hips, discrepancies were found between the imaging findings and the arthroscopic assessment of the articular cartilage. At the time of arthroscopy, thirteen hips had at least partial-thickness loss of femoral weight-bearing cartilage and, of these, four had a full-thickness cartilage defect. Two hips had intact acetabular articular cartilage, and the remaining thirteen had at least partial loss of cartilage, primarily in the weight-bearing zone. Three hips had full-thickness cartilage loss, two at the anterior acetabular rim and one more medially in the weight-bearing zone opposite a chondral lesion of the femoral head. All had a labral tear that was débrided back to a stable margin.

Four hips had a pain score of ≥10. One of those hips was treated with arthroplasty within two years. The other three hips had an average post-arthroscopy pain score of 12. For the remaining hips that underwent arthroscopy, the average post-arthroscopy pain score was 1.7. We could find no preoperative clinical or radiographic predictors of subsequent cartilage pathology requiring arthroscopic débridement.

Patients Lost to Follow-up

Twenty-three hips in twenty-two patients were not found for evaluation. Radiographs of fifteen of these hips were available for review. No pain scores were obtained for this group. The average age for this group (27.1 years) was similar to that for the study group. The preoperative and one-year postoperative radiographic results that were available for these hips did not differ from those for hips that had more than five years of follow-up. None of the fifteen hips that had one year of follow-up had gone on to arthroplasty at the time of that evaluation.

Complications

Twenty patients (twenty hips) experienced complications related to the periacetabular osteotomy that were evaluated during the first year after surgery. The most common complication was a transient peroneal nerve palsy (nine hips; 6.7%), followed by a wound hematoma requiring surgical drainage (six hips; 4.4%). Of the wound hematomas, two demonstrated growth of organisms on culture and were subsequently reclassified as infections and were treated with appropriate antibiotics until resolution. Two patients (two hips) had an asymptomatic nonunion of the superior pubic ramus osteotomy site. Two hips had development of Brooker class-3 heterotopic ossification[26]. One patient presented with an intrapelvic abscess two months after surgery and was managed with surgical drainage.

Discussion

The present report on 135 hips with varying degrees of developmental dysplasia describes the early experience and initial learning curve of a single surgeon with the use of the Bernese periacetabular osteotomy at our institution. Seventy-six percent of the hips remained preserved with little or no pain at an average of nine years after the osteotomy, and 24% of the hips had a failure according to our criteria.

Previous reports on the intermediate and long-term results of reorienting acetabular osteotomies for the treatment of hip dysplasia have shown good to excellent survival rates and

improvement in clinical outcomes. Van Hellemondt et al. reported that 88% of fifty-one triple pelvic osteotomies were preserved at an average of fifteen years, with improvement of the Merle d'Aubigné and Postel clinical score from 12.9 preoperatively to 13.3 postoperatively[15]. Trousdale et al., in a report on the intermediate-term results of periacetabular osteotomy in forty-two patients who had an average duration of follow-up of four years, noted that the Harris hip score improved from 62 preoperatively to 86 postoperatively[9]. Siebenrock et al. reported that 82% of seventy-one hips were preserved at an average of 11.3 years after a Bernese periacetabular osteotomy, with significant improvement in the Merle d'Aubigné and Postel clinical score from 14.6 preoperatively to 16.3 postoperatively[8]. They also noted several prognostic factors that were independently associated with a negative outcome following the periacetabular osteotomy. Significant variables included an older age at the time of surgery, the presence and grade of arthritis, the presence of a labral lesion, and failure to attain complete coverage of the femoral head. Poorer outcomes included conversion to total hip arthroplasty (twelve of seventy-one hips), conversion to arthrodesis (one hip), and a "fair" Merle d'Aubigné and Postel rating (six of fifty-eight preserved hips). More recently, this same group of patients was reviewed at a minimum of nineteen years after osteotomy[27]. Once again, predictors of poor outcome included an older age (more than thirty years) at the time of surgery, worse preoperative arthritis, and the presence of a preoperative limp or a positive anterior impingement test.

While all of those studies demonstrated improved average pain and function scores in association with periacetabular osteotomy, each study included patients who experienced substantial pain in the hip and/or loss of function postoperatively. Siebenrock et al. reported "fair" clinical results in 10% of hips[8]. Similarly, in the present study, sixteen hips (12%) had pain that was rated as ≥10 (moderate to extreme) on this scale.

We considered this amount of postoperative pain to be a clinical failure. These hips were then combined with the seventeen hips that underwent conversion to arthroplasty in an effort to describe what we believe to be a more accurate representation of periacetabular osteotomy failure. Univariate and multivariate analyses involving this combined criterion of higher postoperative pain or conversion to arthroplasty demonstrated that an age of more than thirty-five years at the time of surgery and preoperative poor or fair joint congruency were independently predictive of periacetabular osteotomy failure. To further aid in assessing the risk of failure, we constructed a simplified analysis for the probability of failure (Table III), which demonstrated good to excellent diagnostic performance in predicting failure after osteotomy. This prediction rule based on independent multivariate predictors may be a useful guide to the surgeon and the patient for decision-making when considering periacetabular osteotomy as a joint-preserving procedure.

Labral symptoms requiring operative treatment occur in some hips following otherwise successful acetabular realignment surgery. Our analysis did not demonstrate that the presence of a labral tear at the time of osteotomy was an independent predictor of failure, nor did it predict which hips would later have development of a torn labrum. Arthrotomy was not routinely performed early in this series, and it was performed in only eighty-two (61%) of the 135 reviewed hips. This may account for our inability to document a preoperative labral tear as a predictor of poor outcome. The contribution of acetabular retroversion to hip arthritis has been described[18]. A lack of standardized radiographs during the study period prevented us from making a definitive statement regarding retroversion and its potential contribution to outcomes in the present study.

In the present study, fifteen (11%) of the 135 hips later underwent arthroscopic débridement of torn labral or articular cartilage. Four of these hips had a postoperative pain score of ≥10, one of which underwent arthroplasty two years after arthroscopy. The remaining eleven hips regained nearly pain-free states, with an average pain score of 1.7. We identified no preoperative variable to predict which hips were at risk for the development of a painful labral or articular lesion following osteotomy. Preoperative magnetic resonance imaging was not performed in this patient cohort. However, magnetic resonance imaging has proved to be more effective than plain radiography for assessing the health of cartilage before surgery and for predicting which joints will still be painful postoperatively[28].

Despite the association of arthritis with osteotomy failure, in many hips the preoperative assessment did not correlate with the postoperative outcome. Nine (53%) of the seventeen hips that underwent arthroplasty and eight (50%) of the sixteen hips that had a pain score of ≥10 had had little or no preoperative radiographic evidence of arthritis (Tönnis grade 0 to 1). Conversely, eighteen (19%) of the ninety-seven preserved hips with radiographs available for review had had obvious preoperative radiographic signs of arthritis (Tönnis grade 2 to 3). Eleven (11%) of these ninety-seven preserved hips demonstrated improvement in the Tönnis grade. These interesting and somewhat counterintuitive results emphasize the shortcomings of plain radiography and of this grading system in assessing and predicting the response of articular cartilage in dysplastic hips to joint-preserving surgery. Currently, we are employing the delayed gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC) technique preoperatively and postoperatively to assess the health of articular cartilage over time[28].

While we found no significant difference between the preserved and failed hips with regard to preoperative or postoperative radiographic measurements of dysplasia (the center-edge and Tönnis angles), we believe that the final positioning of the acetabular fragment is a critical step in periacetabular osteotomy. Undercorrection or overcorrection leads to overloading of the acetabular rim, with negative consequences[29-31]. Given that the preserved and failed hips were equally corrected, additional factors must also be important in determining the outcome following this osteotomy.

The present study demonstrated a 15% complication rate, with transient nerve palsy being the most frequent complication. Trousdale et al. described a 45% complication rate in their first forty-two hips that were treated with periacetabular osteotomy[9]. In a follow-up study of seventy-five hips undergoing periacetabular osteotomy, Siebenrock et al. noted a lower complication rate of 20%[8]. Subsequently, Trousdale and Cabanela reported a complication rate of 11% in a study of 250 periacetabular osteotomies, with neurapraxia of the lateral femoral cutaneous nerve being common[32]. Nerve palsy following the pelvic osteotomy has been reported previously[7-9,15,33]. The most common complication in the present study was peroneal nerve palsy (6.7%). This finding is consistent with previously published electromyographic data acquired by Pring et al. during periacetabular osteotomy[33]. In the present study, all nine patients (nine hips) with this complication had recovered full nerve function by one year. While previous reports seem to demonstrate a general decrease in complication rates with increasing experience, there remains a relatively high risk of complications in association with this procedure, with the majority of complications being transient.

The limitations of the present study included the lack of comparative preoperative and postoperative pain assessment; the lack of scoring of hip function; the lack of a similar control group; the moderate kappa values for the Yasunaga system for the classification of congruency; and the incompletely characterized natural history of developmental hip dysplasia. In addition, as is common to retrospective studies, our inability to locate and/or completely review all patients and their radiographs may have confounded our results, including the overall osteotomy survival rate.

In summary, our analysis of periacetabular osteotomy for the treatment of painful dysplasia in 135 hips with a mean duration of follow-up of nine years demonstrated that 76% of the hips were still preserved and had little or no pain. While radiographic correction of dysplasia is possible with the Bernese periacetabular osteotomy, the amount of intra-articular pathology at the time of surgery is often difficult to accurately assess preoperatively. As with other initial series, there was a substantial rate of complications (15%) in this early experience, with the majority of complications being transient. We were unable to find predictors of the need for subsequent surgery. However, we identified two independent predictors of failure resulting in a high pain score or total hip arthroplasty: an age of more than thirty-five years and poor or fair joint-space congruency. Validation of our prediction model and advances in imaging modalities will likely improve patient selection and decrease the rate of failure. Additional improvement in outcomes is expected as a result of refinements in surgical technique that have been incorporated since the beginning of the experience reported here, including improved assessment of intra-articular pathology and optimization of acetabular fragment placement. ■

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