Periacetabular osteotomy for the treatment of acetabular dysplasia associated with major aspherical femoral head deformities

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Background: Acetabular dysplasia associated with deformity of the proximal part of the femur can result in hip dysfunction and degenerative arthritis in young adults. The optimal method of surgical correction for these challenging combined deformities remains controversial.

Methods: We retrospectively analyzed twenty-four hips in twenty patients who underwent a Bernese periacetabular osteotomy, which was done with a proximal femoral valgus-producing osteotomy in thirteen hips, for the treatment of acetabular dysplasia associated with proximal femoral structural abnormalities. The average age of the patients at the time of surgery was 22.7 years, and the average duration of clinical follow-up was 4.5 years. The Harris hip score and overall patient satisfaction with surgery were used to assess hip function and clinical results. Plain radiographs were used to assess the correction of the deformity, healing of the osteotomy, and progression of degenerative arthritis.

Results: The mean Harris hip score increased from 68.8 points preoperatively to 91.3 points at the time of the most recent follow-up (p < 0.0001). Sixteen patients (nineteen hips) had an excellent clinical result, and one patient (one hip) had a good result. Two patients (two hips) had a fair result, and one patient (two hips) had a poor result. Twenty-two of the twenty-four hips improved clinically. There was an average improvement of 27.6° in the lateral center-edge angle of Wiberg (p < 0.0001), an average improvement of 33.1° in the anterior center-edge angle of Lequesne and de Seze (p < 0.0001), and an average improvement of 16.5° in the acetabular roof obliquity (p < 0.0001). The hip center was translated medially an average of 6.3 mm (p = 0.0003). The Tönnis osteoarthritis grade was unchanged in twenty hips, progressed one grade in three hips, and progressed two grades in one hip. There were three major technical complications. At the time of the most recent follow-up, none of the hips had required total hip arthroplasty.

Conclusions: The combination of acetabular dysplasia and proximal femoral deformities presents a complex reconstructive problem. The range of motion and radiographic assessment of the hip are major factors in the selection of patients for surgery. In selected patients, the periacetabular osteotomy combined with concurrent femoral procedures, when indicated, can provide comprehensive deformity correction and improved hip function.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

Proximal femoral abnormalities that are characterized by a large aspherical femoral head, a short femoral neck, and so-called trochanteric overgrowth are termed Perthes-like deformities and may be associated with acetabular dysplasia. These combined deformities can result in instability of the hip, femoroacetabular impingement, joint incongruity, abductor in-

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sufficiency, and limb-length inequality. Perthes-like deformities have been associated with the development of degenerative hip disease in several studies\textsuperscript{6-11}, and it is reasonable that joint preservation surgery should be considered for the treatment of symptomatic patients. This combination of acetabular and proximal femoral deformities presents a challenge to the surgeon because correction must achieve a tenuous balance between hip stability achieved by acetabular correction, while avoiding secondary acetabular impingement by the abnormal aspherical femoral head and short femoral neck.

Given the efficacy of the Bernese periacetabular osteotomy in the treatment of symptomatic acetabular dysplasia\textsuperscript{12-16}, we hypothesized that this acetabular reorientation technique would also be effective in the management of selected hips with combined acetabular and proximal femoral deformities. Therefore, over several years, we managed acetabular dysplasia associated with Perthes-like femoral deformities with a reconstructive periacetabular osteotomy. On occasion, the acetabular osteotomy was combined with a proximal femoral osteotomy to achieve congruency, optimize hip range of motion, and minimize femoroacetabular impingement. In this study, we present the early results and complications associated with this type of hip reconstruction.

Materials and Methods

This retrospective study received institutional review board approval. Between 1994 and 2003, the senior authors (J.C.C. and P.L.S.) performed 111 consecutive periacetabular osteotomies for the treatment of acetabular dysplasia. We performed a retrospective radiographic review of all 111 procedures and found that twenty-four hips in twenty patients had features characteristic of a Perthes-like femoral deformity associated with a dysplastic acetabulum (see Appendix). All twenty-four hips had proximal femoral deformities that included an aspherical femoral head, a short femoral neck, and a relatively high greater trochanter (Figs. 1-A through 1-D), consistent with class III of the Stulberg classification system. Hips with major incongruity (Stulberg class IV), advanced secondary osteoarthritis, or marked restriction of flexion (<95°) were not considered candidates for joint preservation surgery.

Nine patients (nine hips) had a history consistent with Legg-Calvé-Perthes disease; six patients (seven hips) had a Perthes-like deformity considered to be secondary to acetabular dysplasia. One patient (two hips) had dysplasia of both the acetabulum and the proximal part of the femur due to metaphyseal chondroplasia (McKusick type of cartilage-hair hypoplasia). One patient (two hips) presented with acetabular dysplasia and femoral deformity associated with pseudoachondroplasia. One patient (two hips) had atypical dysplasia of the acetabulum (including bilateral retroversion) and proximal femoral deformity associated with static encephalitis. One patient (one hip) had a residual deformity associated with childhood infection, and one patient (one hip) had severe acetabular and femoral deformity associated with a congenitally short femur.

There were nine male and eleven female patients. The average age at the time of surgery was 22.7 years (range, thirteen to forty-four years), and all patients were skeletally mature. The average height of the patients at the time of surgery was 163.7 cm (range, 137 to 183 cm), and the average weight was 65.8 kg (range, 42.5 to 99.9 kg). The average body-mass index was 24.1 (range, 18.4 to 31.6). Twelve hips (50%) had not undergone a previous surgical procedure, and the remaining twelve hips had a total of thirty-three surgical procedures prior to the index periacetabular osteotomy. Two of these hips had one previous procedure, three hips had two, three hips had three, and four hips had four previous procedures. Open reduction of the hip had been performed eleven times in six hips, a varus-producing proximal femoral osteotomy had been performed in seven hips, and an adductor tenotomy had been performed in five hips. Also, a Salter osteotomy, a trochanteric transfer, and incision and drainage for infection had been performed separately in three hips, and seven hips had previously had hardware removed.

All patients had progressive hip pain and hip flexion of ≥95°. None had advanced degenerative joint disease (Tönnis grade-3 osteoarthritis\textsuperscript{17}), and all had adequate congruency, which we defined as a concentric relationship between the acetabular sourcil and the superior portion of the femoral head on an anteroposterior plain radiograph with the hip in flexion.
by the Perthes-like deformities, after completion of the periacetabular osteotomy, we assessed the hip with an anteroposterior flexion-adduction functional radiograph to simulate the correction and congruency that might be obtained with a proximal femoral valgus-producing osteotomy. If there was <20° of hip abduction after acetabular reorientation and if the intraoperative adduction functional radiograph showed maintenance of or improvement in the congruency of the joint, we performed a proximal femoral valgus-producing osteotomy. The goals of performing the femoral osteotomy were to enhance joint congruency, improve clinical abduction, minimize anterolateral femoroacetabular impingement, advance the greater trochanter distally and laterally, and lengthen the extremity (Figs. 1-A through 1-D).

All twenty-four hips were treated with a periacetabular osteotomy\textsuperscript{13,18,19} to correct the acetabular deformity. Twenty-

and abduction. The flexion-adduction radiograph simulates the congruency obtained with the periacetabular osteotomy.

The decision to perform an adjunctive femoral procedure was based on an intraoperative assessment of the hip. Because the preoperative abduction range of motion was limited
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one concurrent femoral osseous or soft-tissue procedures were performed in fifteen hips (63%). These included thirteen proximal femoral valgus-producing osteotomies, one trochanteric advancement, and one isolated osteochondroplasty of the femoral head-neck junction29. An osteochondroplasty was also performed in conjunction with one of the proximal femoral osteotomies. Three hips had an adductor tenotomy, and two of these hips also had a fractional lengthening of the psoas tendon. Three proximal femoral valgus-producing osteotomies were performed as a second stage at six weeks after a technically demanding periacetabular osteotomy.

Surgical Technique

The acetabular osteotomy was performed as previously described by Ganz et al.13,18,19. Electromyographic peripheral nerve monitoring was used in all acetabular procedures2. A Cell Saver (Haemonetics, Braintree, Massachusetts) was utilized for blood collection and reinfusion. A modified anterior25 or modified Smith-Peterson17 approach was used. Periacetabular cuts, acetabular reduction, and screw fixation were monitored intraoperatively with fluoroscopy. The correction of the acetabulum (anterior coverage, lateral coverage, and acetabular inclination) was assessed intraoperatively with anteroposterior and false-profile fluoroscopic images. The acetabular fragment was fixed with three, four, or five 4.5-mm cortical screws. An arthrotomy was not routinely performed in the first twenty-one procedures, but it was performed in three hips later in the series. Two of these three hips demonstrated anterior femoroacetabular impingement, for which a head-neck-junction osteoplasty was performed. At the time of the arthrotomy, impingement was assessed by inspection of the femoral head for an impingement trough that demarcated asphericity and by testing for abutment of the femoral head-neck junction on the acetabular rim with the hip in flexion and internal rotation.

Clinical Evaluation

Clinical hip function was assessed with the Harris hip score preoperatively and at the time of the follow-up visits. A score of 91 to 100 points indicated excellent function; 81 to 90 points, good function; 71 to 80 points, fair function; and ≤70 points, poor function. All patients returned for a follow-up clinic visit and radiographic examination at a minimum of two years, and the average duration of clinical follow-up was 3.9 years (range, 2.0 to 9.3 years). Telephone interviews2 of all patients who had not been seen in the clinic in the past twelve months were conducted to assess the subjective functional outcome (modified Harris hip score) and to ensure that they had not undergone a total hip arthroplasty or any other surgical procedure on the involved hip(s). The average duration of clinical follow-up, including telephone interviews, was 4.5 years. Patient-reported overall satisfaction with the surgical procedure was also ascertained at the most recent follow-up visit or telephone interview. The patients were asked whether they were satisfied with the result of their surgical treatment. A yes-or-no response was recorded. This information was collected by one of the treating surgeons at the time of the clinical follow-up visits or by an individual who was not a treating surgeon during the telephone interview. No patient was lost to follow-up. All other clinical and operative data were obtained from a retrospective chart review by one of the authors (R.M.N.), who was not involved in the clinical care of the patients.

Radiographic Evaluation

Preoperative and periodic postoperative radiographic analysis was performed in an unblinded fashion for all patients by one senior-level orthopaedic resident (R.M.N.) in conjunction with one attending surgeon (J.C.C.). Standing anteroposterior and false-profile radiographs were made at each clinic visit. The lateral center-edge angle of Wiberg24, anterior center-edge angle of Lequesne and de Seze25, acetabular roof obliquity26,27, and hip center position20,26 were measured, and the preoperative and postoperative values were compared to assess deformity correction. Osseous healing was determined by the presence or absence of consolidation across the osteotomy sites on both the anteroposterior and false-profile radiographs. The ischial, superior pubic ramus, iliac, and posterior column osteotomies were all evaluated for radiographic evidence of healing. Grading of the osteoarthritis was performed with the Tönnis classification system23,24.

Statistical Analysis

Preoperative and follow-up clinical hip scores and radiographic parameters of acetabular position were compared with a paired t test. Significance was determined at a p value of <0.05.

Results

At an average of 4.5 years (range, 2.0 to 9.3 years) postoperatively, nineteen patients (twenty-two hips; 92%) were satisfied with the clinical result of surgery. The Harris hip score had improved in nineteen patients (twenty-two hips; 92%). The average Harris hip score for all patients was 68.8 (range, 44 to 93 points) preoperatively, and it had improved to 91.3 (range, 69 to 100 points) at the most recent clinical evaluation (p < 0.0001). Sixteen patients (nineteen hips) had an excellent clinical result, and one patient (one hip) had a good clinical result. Two patients (two hips) had a fair result, and one patient (two hips) had a poor clinical result. No hip had been converted to a total joint arthroplasty. The pain component of the Harris hip score improved for nineteen patients (twenty-two hips) from a mean score of 21.8 points (range, 10 to 44 points) preoperatively to 38.2 points (range, 20 to 44 points) at the latest follow-up visit (p < 0.0001). At that evaluation, thirteen patients (fifteen hips) had no associated pain, four patients (five hips) had slight occasional pain, one patient (two hips) had mild pain, and two patients (two hips) had moderate pain. No patient reported severe pain. Seventeen patients (twenty hips) had no limp (as reported by the patient), two patients (two hips) had a slight occasional limp, and one patient (two hips) had a moderate limp. Seventeen patients (twenty hips) were able to walk an unlimited distance, while three patients (four hips) were able to walk a limited distance of six blocks or less. Eighteen patients (twenty-one hips) required no assistive device for walking, one patient...
Two of the three additional procedures were performed for
formed in three patients to optimize the hip reconstruction. 
Despite the overall good clinical results, additional procedures
perior pubic ramus. One of those patients was asymptomatic,
patients (two hips) had nonunion of an osteotomy of the su-
hip. None of the hips had advanced degenerative changes
Tönnis grade-3 osteoarthritis) at the most recent follow-up

two requiring surgery. All three complications occurred in the
first eleven procedures that we performed; all three patients
had previous procedures on the hip. One patient who had a
proximal femoral varus-producing osteotomy and adductor release had excessive limb-lengthening, which was
associated with the combined periacetabular osteotomy and proximal femoral varus-producing osteotomy, and she had a
transient peroneal nerve palsy. Five days postoperatively, the
patient underwent femoral shortening through the osteotomy.
The symptoms worsened over time, and seven years after the
index procedure, the patient underwent open labral débride-
ment, osteoplasty of the acetabular rim, osteoplasty of the
femoral head-neck junction, and trochanteric advancement. 
Five months after this second procedure, the patient was as-

table 1 summary of radiographic correction and osteoarthritis progression

<table>
<thead>
<tr>
<th>Radiographic Findings*</th>
<th>Preop.</th>
<th>Postop.</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral center-edge angle (deg)</td>
<td>2.9 (--28 to 19)</td>
<td>30.5 (15 to 51)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Anterior center-edge angle (deg)</td>
<td>-3.96 (--32 to 19)</td>
<td>29.2 (--25 to 52)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Acetabular roof obliquity (deg)</td>
<td>25.2 (15 to 45)</td>
<td>8.7 (--5 to 21)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Hip joint medialization (mm)</td>
<td>16.1 (9 to 24)</td>
<td>9.8 (0 to 23)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Tönnis grade (no. of hips)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>19</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>7</td>
<td></td>
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<tr>
<td>2</td>
<td>1</td>
<td>2</td>
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<td>3</td>
<td>0</td>
<td>0</td>
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*The values are given as the mean, with the range in parentheses.

(two hips) required use of a cane for long distances, and one pa-
tient (one hip) used a cane at all times.

One patient (two hips) was not satisfied. This patient had atypical dysplasia associated with static encephalitis. The patient was limited by the underlying neuromuscular disor-
der, and symptoms recurred in the hip after isolated periace-
tabular osteotomies. Two patients (two hips) had a fair clinical
result, yet they were satisfied with the improvement from sur-
gery. One patient with a fair result after treatment with a peri-
acetabular osteotomy and trochanteric advancement reported intermittent pain on the lateral aspect of the hip at the time of
the most recent follow-up at four years postoperatively. The
second patient with a fair result had had severe acetabular and
femoral deformities associated with a congenitally short fe-
mur, had multiple previous surgeries on the extremity, and
had a major limb-length discrepancy. Although hip congru-
ency and femoral head coverage were improved with the sur-
gery, the patient continued to have activity-related hip pain.

Radiographic analysis demonstrated consistent deform-
ity correction and significant improvements in the lateral
center-edge angle (mean, 27.6°; p < 0.0001), the anterior cen-
ter-edge angle (mean, 33.1°; p < 0.0001), the acetabular roof
obliquity (mean, 16.5°; p < 0.0001), and hip joint medializa-
tion (mean, 6.3 mm; p = 0.0003) (Table I). The Tönnis os-
teoarthritis grade was unchanged in twenty hips, it progressed
one grade in three hips, and it progressed two grades in one
hip. None of the hips had advanced degenerative changes
(Tönnis grade-3 osteoarthritis) at the most recent follow-up
evaluation. All of the major osteotomies healed, although two
patients (two hips) had nonunion of an osteotomy of the su-
perior pubic ramus. One of those patients was asymptomatic,
and one was treated surgically (see below).

Additional Procedures and Complications

Despite the overall good clinical results, additional procedures
(with the exclusion of elective hardware removal) were per-
formed in three patients to optimize the hip reconstruction. 
Two of the three additional procedures were performed for
persistent hip symptoms related to secondary anterior femo-
roacetabular impingement. One patient underwent open re-
duction and internal fixation with iliac crest bone-grafting for
nonunion at the site of a superior pubic ramus osteotomy and
had no relief of symptoms. Subsequently, this hip was treated
with combined arthroscopic labral débridement and a limited
open femoral head-neck junction osteoplasty for anterior
impingement. The patient did well after that procedure. He
was satisfied with the overall result and had a Harris hip score
of 92 points at the time of the four-year follow-up. The second
patient had hip symptoms recur five years postoperatively be-
cause of residual anterior femoroacetabular impingement. The
symptoms worsened over time, and seven years after the
index procedure, the patient underwent open labral débride-
ment, osteoplasty of the acetabular rim, osteoplasty of the
femoral head-neck junction, and trochanteric advancement.
Five months after this second procedure, the patient was as-
ymptomatic except for a slight limp and she had a Harris hip
score of 96 points. The third patient underwent screw ex-
change one month following periacetabular osteotomy be-
cause of a concern for intra-articular penetration.

Major complications occurred in three patients, with
two requiring surgery. All three complications occurred in the
first eleven procedures that we performed; all three patients
had previous procedures on the hip. One patient who had a
previous proximal femoral varus-producing osteotomy and
adductor release had excessive limb-lengthening, which was
associated with the combined periacetabular osteotomy and
proximal femoral varus-producing osteotomy, and she had a
transient peroneal nerve palsy. Five days postoperatively, the
patient underwent femoral shortening through the osteotomy.
At forty-four months postoperatively, she had an excellent
clinical result with a Harris hip score of 96 points. The patient
had a full recovery of motor function with slightly decreased
sensation over the distal lateral aspect of the calf that was not a
problem. Another patient had a transient femoral nerve palsy
develop following an isolated periacetabular osteotomy. Elec-
tromyographic monitoring had not detected femoral nerve
stiffness during the surgical procedure. This patient had a history of two open hip reductions in childhood and a previous proximal femoral varus-producing osteotomy for the treatment of developmental dysplasia of the hip. The patient had full motor recovery with slightly decreased sensation over the anteromedial aspect of the thigh that was not a problem. At sixty-seven months, the patient had an excellent clinical result with a Harris hip score of 93 points. One patient (who had two previous open reductions, an adductor release, and a proximal femoral osteotomy) reported continued pain in the groin and the lateral aspect of the hip for several months following the combined periacetabular osteotomy and proximal femoral valgus-producing osteotomy. On the basis of the radiographs, we suspected a delayed union of the intertrochanteric osteotomy at eleven months. The patient underwent exploration and was found to have a partial union that was treated with iliac crest bone-grafting. The osteotomy went on to heal by six months, and she had a hip score of 97 points at the time of the last visit (sixty-three months postoperatively).

One additional complication included the development of heterotopic ossification (Brooker class II) in one hip that was associated with an excellent clinical result and a Harris hip score of 92 points at the two-year evaluation. No patient had a major, persistent neurovascular injury, an intra-articular fracture, or a thromboembolic complication, and no hip had a total hip arthroplasty.

Discussion

Perthes-like hip deformities in skeletally mature patients are known to be associated with a substantial risk for subsequent degenerative osteoarthritis in the fifth and sixth decades of life. To date, the optimal method(s) and timing of surgical intervention in these patients remain controversial. Perhaps the most challenging clinical scenario occurs when a Perthes-like deformity of the proximal part of the femur is associated with substantial acetabular dysplasia. In this circumstance, we have used the periacetabular osteotomy for deformity correction on the acetabular side combined, in selected patients, with a valgus-producing proximal femoral osteotomy. Our results demonstrate substantial improvements in clinical hip function and a high rate of patient satisfaction at a mean follow-up of 4.5 years. Similarly, one of the innovators of the periacetabular osteotomy reported good to excellent results in 88% of twenty-seven Perthes-like hips followed for thirty-six months. Our radiographic analysis revealed significant improvement in the radiographic parameters of acetabular dysplasia and reliable healing of the acetabular osteotomy.

We also observed a relatively high risk for perioperative complications and reoperations. This is likely due to several factors that increase the complexity of these procedures. First and most importantly, many of these procedures were performed early in our experience with the periacetabular osteotomy. Secondly, many of these patients had severe deformities and had previous surgical procedures on the involved hip, both of which may have contributed to a higher risk of perioperative complications.
these patients with unique combinations of deformities. Finally, identifying an appropriate control group for this patient cohort is difficult. Even historical cohorts followed in natural history studies\(^ {1,5-10} \) are of limited value because of the substantial heterogeneity of Perthes-like deformities in terms of the pathoanatomy, associated acetabular abnormalities, and clinical manifestation of the structural disease. The cohort we analyzed is unique in that it represents a consecutive series of patients who all had a symptomatic hip, Perthes-like disease of the proximal part of the femur, and associated acetabular dysplasia.

In summary, we emphasize that surgical treatment of acetabular dysplasia associated with Perthes-like femoral deformities is complex, and the entire pathoanatomy of the hip must be taken into account. Our results suggest that periacetabular osteotomy combined with appropriate femoral correction, when indicated, is associated with good clinical results at short-term to mid-term follow-up. Continued clinical and radiographic evaluation at longer-term follow-up is essential to assess the efficacy of this surgical strategy.

### References