Combined Surgical Dislocation and Periacetabular Osteotomy for Complex Residual Legg-Calvé-Perthes Deformities

Intermediate-Term Outcomes

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Background: Residual Legg-Calvé-Perthes (LCP) deformities represent one of the most challenging disorders in hip reconstructive surgery. In complex cases, both instability (acetabular dysplasia) and multifocal femoroacetabular impingement (FAI) (proximal femoral deformities) require correction. We assessed intermediate-term patient-reported outcome measures, radiographic correction, complications, and survivorship for combined surgical dislocation (SD) and periacetabular osteotomy (PAO) for the treatment of complex LCP deformities.

Methods: A retrospective cohort study was performed on 31 hips with complex LCP deformities undergoing combined SD and PAO for concurrent instability and FAI. Treatment included femoral head reshaping, trochanteric advancement and relative femoral neck lengthening, management of intra-articular lesions, and PAO. Twenty-seven hips (87%) had a minimum follow-up of 5 years. The mean age was 19.8 years, 56% of patients were female, and 44% of patients had undergone a previous surgical procedure.

Results: At a mean of 8.4 years, 85% of hips (23 of 27) remained preserved (no conversion to total hip arthroplasty). The survivorship estimates were 93% at 5 years and 85% at 10 years. The median (and interquartile range) increased from 64 points (55, 67 points) to 92 points (70, 97 points) ($p < 0.001$) for the modified Harris hip score (mHHS) and from 60 points (45, 75 points) to 86 points (75, 100 points) ($p = 0.001$) for the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain score. Symptoms (mHHS < 70 points) were reported for an additional 19% of hips (n = 5) at the final follow-up. The University of California Los Angeles (UCLA) activity score increased from a median of 8 points (6, 10 points) to 9 points (7, 10 points) ($p = 0.207$). Structural correction included mean improvement (and standard deviation) of 15.3° ± 7.6° for acetabular inclination, 20.7° ± 10.8° for the lateral center-edge angle, 23.4° ± 16.3° for the anterior center-edge angle, and 18 ± 10 mm for trochanteric height ($p < 0.001$ for all). Complications occurred in 2 hips (7%), including 1 deep wound infection and 1 superficial wound infection. There was 1 reoperation due to complication, but there were no nerve palsies, thromboembolic events, fractures, or nonunions.

Conclusions: At an intermediate follow-up of combined SD and PAO for complex LCP deformities, 85% of hips were preserved. This procedure provides reliable deformity correction, major pain relief, improved function, and acceptable complication and failure rates.

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

Patients with residual Legg-Calvé-Perthes (LCP) deformities may present in adolescence or young adulthood with hip pain and functional limitations. Symptomatology and progressive joint degeneration are commonly due to multifocal femoroacetabular impingement (FAI) and/or hip instability[1-5]. Structural abnormalities typically include a combination of a large aspherical femoral head, short and wide femoral neck, high greater trochanter, and coxa vara, which may predispose to FAI, as well as the variable presence of acetabular dysplasia with joint instability[6-12]. Version abnormalities of both

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJS/G951).

the femur and the acetabulum are variable and need to be considered during evaluation. FAI may include intra-articular and extra-articular components and result in labral and chondral damage[13]. Acetabular dysplasia with structural instability is associated with acetabular rim overloading and labrochondral degeneration[14,15]. These complex structural abnormalities can be very challenging to treat and require a thorough diagnostic evaluation and careful surgical decision-making. In severe cases with both acetabular dysplasia (instability) and FAI, treatment of both sides of the joint may be necessary for comprehensive correction.

Skeletally mature patients presenting with symptomatic LCP deformities without advanced secondary osteoarthritis may be appropriate candidates for hip preservation surgery[6,16-22]. Certain investigators have advocated for a combined surgical dislocation (SD) and periacetabular osteotomy (PAO) for comprehensive deformity correction[6,8,16,18], and others have utilized a staged approach. SD enables wide exposure of the proximal part of the femur and acetabular rim for examination and treatment of any intra-articular abnormalities[23-25]. SD also allows femoral head reshaping, trochanteric advancement, and relative femoral neck lengthening to improve the biomechanical environment of the joint and to prevent impingement[6,16-19,26]. PAO corrects structural instability and/or FAI by reorienting the acetabulum to reduce superolateral acetabular inclination (AI), to improve femoral head coverage, to correct version abnormalities, and to translate the joint center medially[27]. The combined SD and PAO procedures aim to provide sufficient impingement correction and joint stabilization to improve symptoms and preserve the natural hip joint over time. There are few studies reporting on this treatment strategy, and those investigations tend to be relatively small, short-term reports[6,8,16,19,21]. To better assess the efficacy of this intervention, it is critical to evaluate longer-term clinical outcomes.

The purpose of this study was to assess intermediate-term patient-reported outcome measures, radiographic correction, complications, and survivorship for combined SD and PAO for the treatment of complex LCP deformities.

Materials and Methods

A retrospective cohort study was performed of consecutive patients treated for symptomatic, residual LCP deformities with a minimum follow-up of 5 years. We defined LCP deformity as proximal femoral deformity including an aspherical femoral head, short femoral neck, high greater trochanter, and variable secondary acetabular dysplasia[6-12]. During the study period (2006 to 2013), a total of 86 hips underwent surgical treatment (Fig. 1) performed by 1 of the senior authors (J.C.C.). We excluded 55 hips that had undergone treatment other than SD and PAO. The remaining 31 hips treated with combined SD and PAO were the focus of this study. There was a minimum follow-up of 5 years, which excluded 4 hips and included 27 hips (87%); no patients underwent bilateral procedures. Sixteen of the 31 hips were included in a previous publication of short-term results[6]. The prior article on these hips, at a mean follow-up of 1.8 years, indicated a mean modified Harris hip score (mHHS) of 81 points and no major complications or conversion to total hip arthroplasty (THA).

Indications for SD and PAO included symptomatic LCP deformities and structural instability (confirmed at the surgical procedure) that did not improve with conservative treatment and the absence of radiographic evidence of advanced osteoarthritis. The goals of the surgical procedure were to relieve femoroacetabular impingement, to stabilize the hip joint, and to treat intra-articular pathology[28] (Figs. 2 through 5). All hips underwent SD[23,24] followed by an intraoperative dynamic examination and a radiographic assessment. The SD (and associated procedure [Table I]) was performed first, followed by the PAO[27-29]. During the SD of the femoral head, reshaping, relative femoral neck lengthening, trochanteric advancement, and management of intra-articular lesions were performed. The SD of the hip allows correction of intra-articular FAI with femoral head osteochondroplasty, relief of extra-articular impingement with trochanteric osteoplasty, trochanteric advancement, and relative femoral neck lengthening. After treatment of intra-articular disease and FAI, the stability of the hip was assessed prior to capsular closure and trochanteric fixation. The presence of instability was determined by direct observation of femoral head subluxation during the dynamic examination[28]. Subluxation observed in any of 3 positions (10° extension and 15° external rotation; 45° flexion, 20° adduction, and 30° internal rotation; 90° flexion and neutral rotation) was considered to indicate instability and the need for PAO[25]. A PAO was performed for radiographic evidence of acetabular dysplasia and documented dynamic instability[28]. In the setting of severe radiographic dysplasia, intraoperative instability is uniformly present. In the setting of mild or moderate radiographic dysplasia without intraoperative instability, no PAO was performed. Adequate hip range of motion (90° of flexion and 20° of abduction) and excellent or good congruity as assessed by intraoperative fluoroscopy were additional criteria for the PAO. The PAO reduction was assessed intraoperatively by radiographic correction and a range-of-motion examination. Care was taken to preserve at least 90° of hip flexion after the PAO to prevent secondary FAI resulting from the PAO. Intraoperative pathology was prospectively recorded[13].

Clinical outcomes were measured preoperatively and at the time of follow-up. Patient-reported outcome measures included the mHHS, the University of California Los Angeles (UCLA) activity score, and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain score. Four hips underwent THA without patient-reported

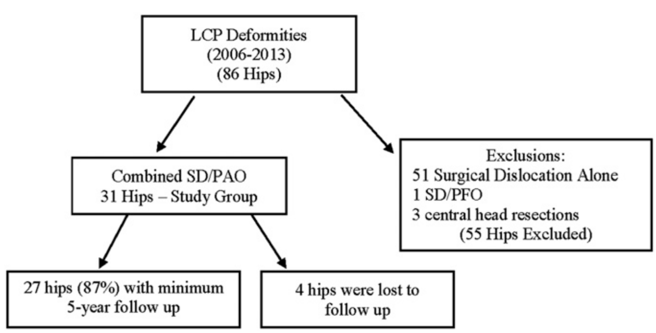

Fig. 1
Study population flowchart. PFO = proximal femoral osteotomy.

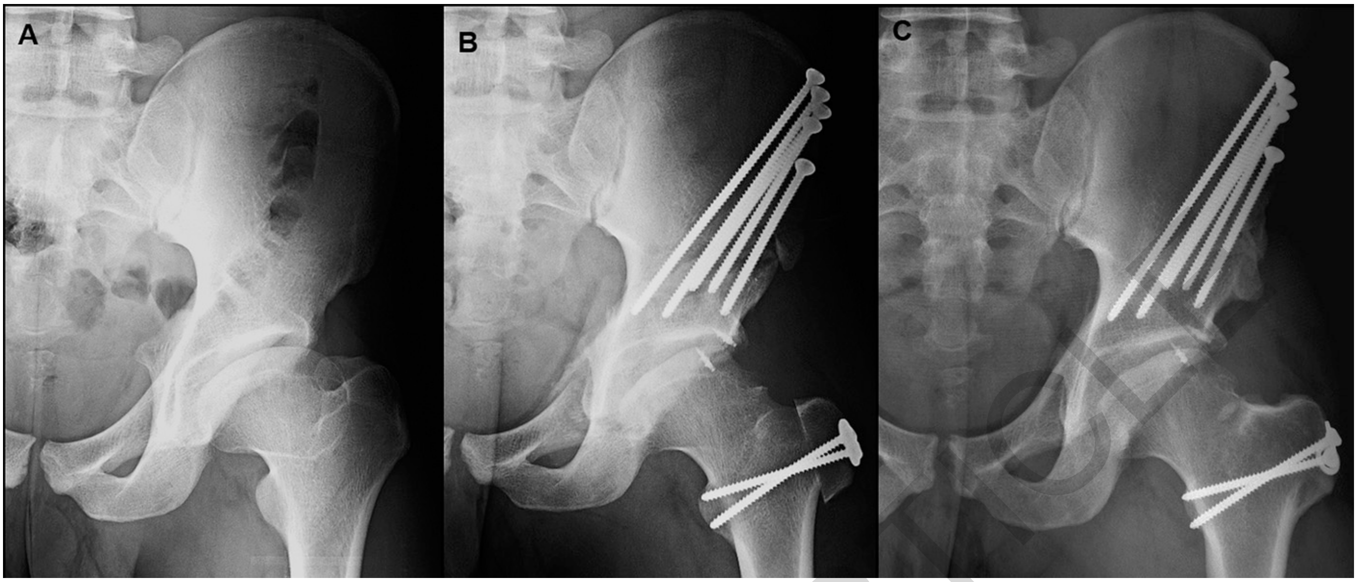

Fig. 2

Figs. 2-A, 2-B, and 2-C Radiographs of a 25-year-old woman with an LCP hip deformity who underwent combined SD and PAO. **Fig. 2-A** Preoperative anteroposterior pelvic radiograph (cropped to focus on left hip) showing an LCP deformity of the proximal part of the femur with an aspherical femoral head, a wide and short femoral neck, and a high greater trochanter. There is associated acetabular dysplasia with retroversion. **Fig. 2-B** Anteroposterior pelvic radiograph made at 1 month postoperatively. **Fig. 2-C** Anteroposterior pelvic radiograph made at 7 years postoperatively showing osseous deformity correction. A combined SD and PAO with femoral head-neck osteochondroplasty, relative femoral neck lengthening, trochanteric advancement, and labral refixation/repair was performed. The femoral head is more spherical and the greater trochanter is positioned more distally. Acetabular correction demonstrates improved coverage, reduced inclination, and improved acetabular anteversion. The patient had an excellent result, with a mHHS of 96 points and a UCLA activity score of 10 points at the 7-year follow-up.

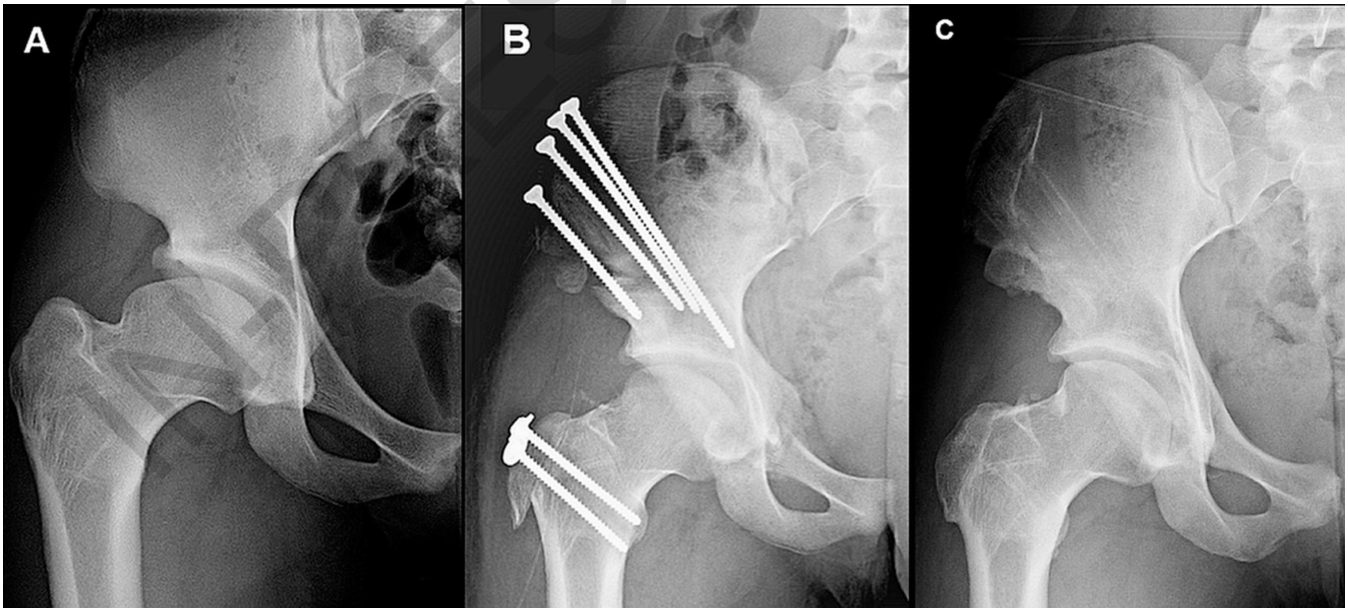

Fig. 3

Fig. 3-A, 3-B, and 3-C Radiographs of a 16-year-old girl treated with combined SD and PAO. Osteochondroplasty, relative femoral neck lengthening with trochanteric advancement, and PAO with improved lateral coverage and version correction were performed. **Fig. 3-A** Preoperative anteroposterior pelvic radiograph (cropped). **Fig. 3-B** Initial postoperative anteroposterior pelvic radiograph. **Fig. 3-C** A 5-year postoperative anteroposterior pelvic radiograph.

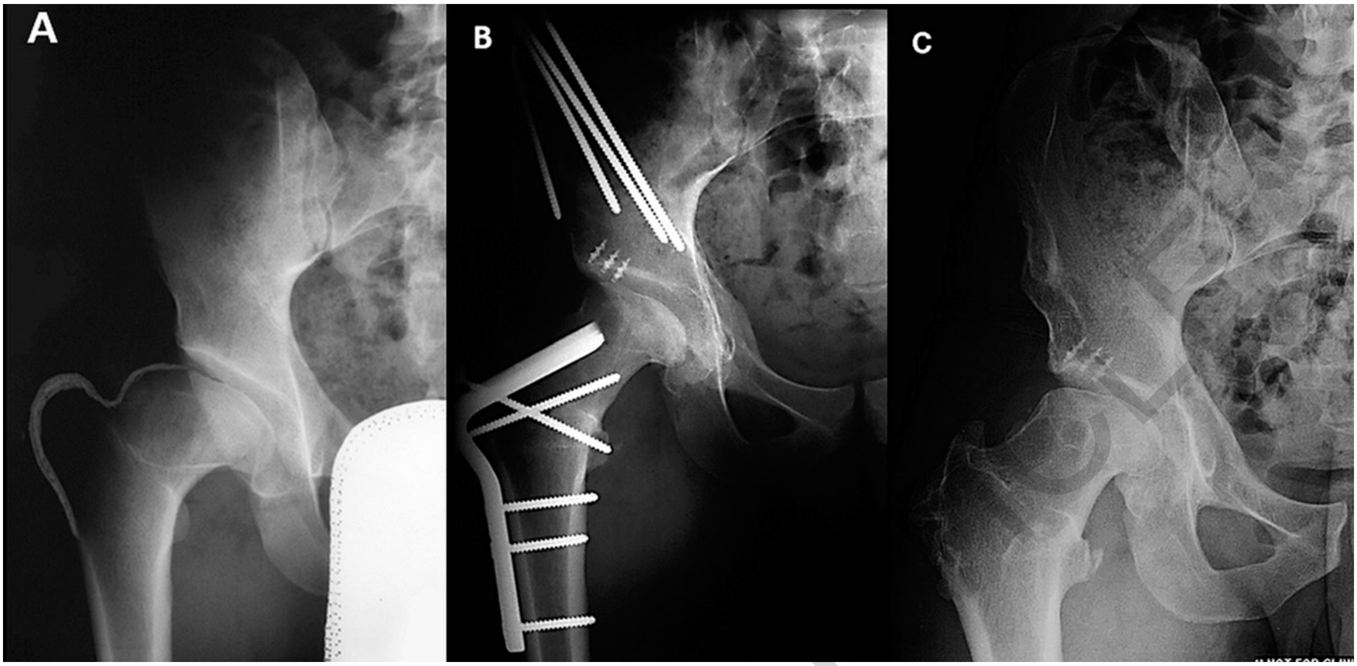

Fig. 4

Figs. 4-A, 4-B, and 4-C Radiographs of a 17-year-old boy with symptomatic, complex, residual LCP deformity. **Fig. 4-A** Preoperative anteroposterior pelvic radiograph (cropped image). **Fig. 4-B** A 1-year postoperative radiograph showing hip dislocation with relative femoral neck lengthening, femoral head-neck osteochondroplasty, trochanteric advancement, labral repair, valgus proximal femoral osteotomy, and PAO. **Fig. 4-C** A 9-year postoperative radiograph showing an excellent clinical result and well-maintained joint space and congruency.

outcome measures being obtained prior to THA, so preoperative and postoperative mHHS were available for 23 (85%) of the 27 hips. WOMAC pain scores were reported for 22 hips (81%). The level of satisfaction with the surgical procedure (extremely satisfied, very satisfied, satisfied, somewhat satisfied, unsatisfied) was assessed[30]. Hips with complications and those with failed treatment were analyzed by reviewing follow-up data and patient surveys. We defined hips as having had failed treatment if they underwent conversion to a THA. Hips were classified as symptomatic if the mHHS was <70 points[31].

Preoperative imaging included anteroposterior pelvic, frog-leg, false profile, and/or 45° Dunn lateral radiographs. Radiographic correction was evaluated by a single reader (G.P.) and included the lateral center-edge angle (LCEA), the anterior center-edge angle (ACEA), AI, the center-to-trochanter distance (CTD), and extrusion index (EI)[13-15,32,33]. Radiographic data for CTD and EI were missing in 2 hips preoperatively and postoperatively. The CTD is the vertical distance from the center of the femoral head to the tip of the greater trochanter along the femoral shaft axis (Fig. 6)[13,33]. Given the femoral head deformity in LCP, the center was defined as the intersection of the longest and shortest diameters of the femoral head[13]. A negative value indicates that the tip of the trochanter is proximal to the center of the femoral head. Values ranging from −1.1 to 1.0 cm are normal[13,33]. The modified Stulberg classification was determined on the basis of preoperative anteroposterior pelvic and frog-leg radiographs[9,10,34]. The degree of osteoarthritis was classified using a modified Tönnis osteoarthritis classification with exclusion of the asphericity component, as all hips had an aspherical head. Advanced imaging, such as computed tomography (CT) and/or magnetic resonance imaging (MRI), was used preoperatively to further evaluate the joint integrity and morphology.

Statistical analysis included comparisons of preoperative and postoperative parameters for the hips that underwent conversion to THA and those that did not. Statistical analysis was performed using the Wilcoxon signed-rank test for continuous variables and the Fisher exact test for categorical variables. Mann-Whitney U tests were used to compare preoperative and postoperative parameters by failure status (THA/THA or mHHS < 70 points). The Fisher exact test was used in place of the chi-square test due to sample limitations. A Kaplan-Meier survival curve was calculated. Significance was set at $p < 0.05$.

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Results

Twenty-seven hips (27 patients) undergoing combined SD and PAO for complex LCP deformities were assessed at a

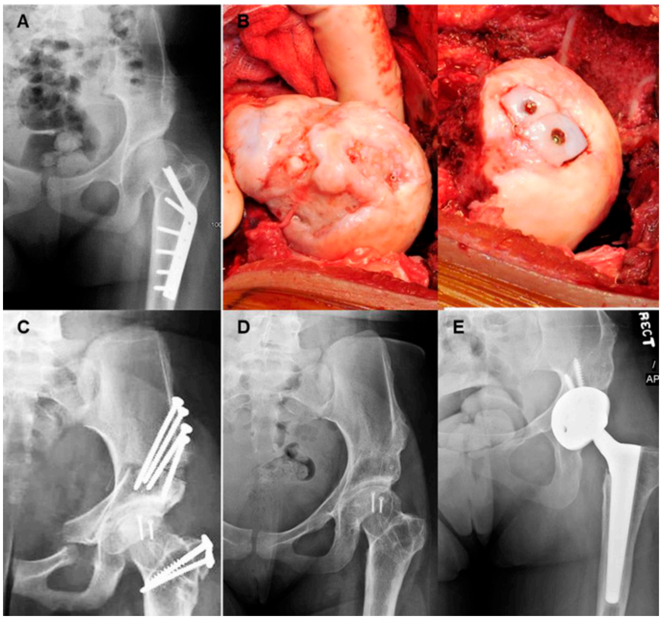


Fig. 5

Figs. 5-A through 5-E Images of a 13-year-old girl with severe residual LCP deformity. **Fig. 5-A** Preoperative anteroposterior pelvic radiograph (cropped image). **Fig. 5-B** Intraoperative photographs of the femoral head before (*left*) and after (*right*) autogenous osteochondral grafting. **Fig. 5-C** Initial postoperative anteroposterior pelvic radiograph made after SD with femoral head-neck osteochondroplasty, osteochondral grafting, relative femoral neck lengthening with trochanteric advancement, and PAO. **Fig. 5-D** Radiograph made at 3.5 years after combined SD and PAO; the patient had persistent symptoms. **Fig. 5-E** Radiograph made at 3 years after THA; the patient had pain relief.

mean follow-up of 8.4 years (range, 5.8 to 11.7 years). The modified Stulberg classification included 1 hip (4%) in Class 2, 23 hips (85%) in Class 3, and 3 hips (11%) in Class 4. Fifty-six percent of hips (15 hips) were in female patients, and the mean age (and standard deviation) at the time of the surgical procedure was 19.8 ± 6.3 years (range, 13 to 36 years). The preoperative Tönnis grades were 0 in 13 hips (48%), 1 in 13 hips (48%), and 2 in 1 hip (4%). The mean preoperative values were 9.7° ± 9.4° for LCEA, 6.7° ± 18° for ACEA, 23.4° ± 7° for AI, and −25 ± 10 mm for CTD.

Overall, 12 patients (44%) had ≥1 previous surgical procedures, including 5 pelvic osteotomies, 6 proximal femoral osteotomies, 1 osteochondroma removal, 1 epiphysiodesis of the greater trochanter, 1 trochanteric transfer, 1 hip arthroscopy, and 2 (7%) adductor tenotomies or casting.

Intra-Articular Pathology

Intra-articular pathology was present in all hips (Table II). The acetabular labral morphology was uniformly (100%) hypertrophied. Twenty-two hips (81%) had a complete or partial labral detachment or tear, with 11 hips (41%) undergoing labral repair and 8 hips (30%) undergoing partial labral resections. Three hips (11%) were treated with chondroplasty for partial-thickness acetabular chondromalacia. Three hips (11%) had full-thickness acetabular cartilage defects requiring microfracture. Eighteen hips (67%) had chondromalacia of the femoral head, including 2 full-thickness femoral head defects, 1 of which was treated with autogenous femoral head osteochondral grafting (Fig. 5). Femoral head chondromalacia with unstable edges was treated with chondroplasty (n = 2) and stable chondromalacia was left in situ.

Clinical and Radiographic Outcomes

At the time of follow-up, 85% of hips remained preserved (no THA) and 4 (15%) had undergone THA at a mean time of 6.3 years. The survivorship estimates were 93% at 5 years and 85% at 10 years (Fig. 7). The surviving 23 hips had a median mHHS increase (and interquartile range) from 64 points (55, 67 points) to 92 points (70, 97 points) ($p < 0.001$) (Fig. 8). Persistent symptoms (mHHS < 70 points) were reported for 5 (22%) of these hips. The median WOMAC pain scores improved from 60 points (45, 75 points) to 86 points (75, 100 points) ($p = 0.001$), and the median UCLA activity score improved 8 points (6, 10 points) to 9 points (7, 10 points) ($p = 0.207$) (Fig. 9). Patient satisfaction data were available for 24 of the 27 hips: 20 hips that were preserved and 4 hips that underwent THA conversions. Eighteen of the 23 patients with surviving hips had satisfaction data available: 16 patients (89%) were satisfied (9 extremely satisfied, 5 very satisfied, 2 satisfied), and 2 patients (11%) were somewhat satisfied. Radiographic analysis demonstrated consistent deformity correction (Table III). Structural correction included mean improvement (and standard deviation) of 15.3° ± 7.6° for AI, 20.7° ± 10.8° for the LCEA, 23.4° ± 16.3° for the ACEA, and 18 ± 10 mm for trochanteric height ($p < 0.001$ for all).

TABLE I Procedures Performed Concurrently with SD and PAO

Concurrent Procedures	No. of Hips* (N = 27)
Femoral head osteochondroplasty	27 (100%)
Ligamentum teres excision	27 (100%)
Relative femoral neck lengthening	25 (93%)
Trochanteric advancement	25 (93%)
Labral repair or resection	19 (70%)
Trochanteric osteoplasty	5 (19%)
Intertrochanteric osteotomy	3 (11%)
Acetabular microfracture	3 (11%)
Acetabular chondroplasty	3 (11%)
Acetabular rim osteoplasty	2 (7%)
Psoas tendon lengthening	2 (7%)
Femoral head articular autogenous grafting	1 (4%)
Femoral head chondroplasty	2 (7%)

*The values are given as the number of hips, with the percentage in parentheses.

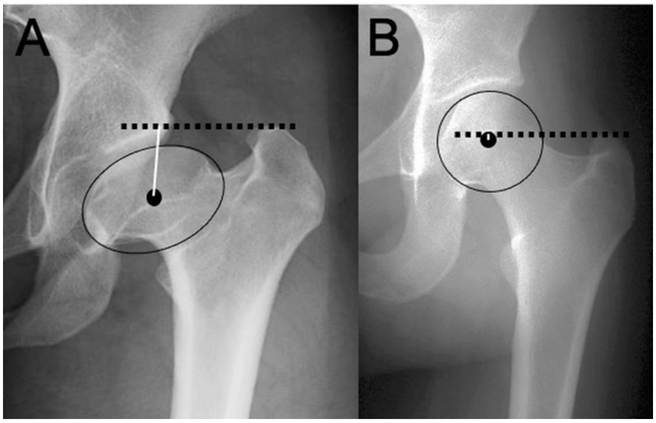


Fig. 6

Figs. 6-A and 6-B Radiographs showing the CTD, the vertical distance from the center of the femoral head to the tip of the greater trochanter along the femoral shaft axis. **Fig. 6-A** The CTD, indicated by the white line, is −27 mm in the hip with residual LCP deformity. **Fig. 6-B** The CTD is −2 mm in the normal hip.

Complications, Reoperations, and Failures

Four hips required THA at mean time of 6.3 ± 4.3 years (Fig. 7). One THA was due to a major complication (infection), and the others were due to osteoarthritis progression. When comparing hips that had undergone failed treatment with surviving hips, there was a significant difference (p = 0.03) in the preoperative mean CTD at −47 ± 12 mm compared with −23 ± 8 mm (Table IV). There was a significant difference (p = 0.01) in the postoperative mean ACEA between successes (31.9° ± 8.1°) and failures (14.7° ± 3.9°), indicating less postoperative anterior coverage in failures (Table V). The revision surgical procedure included 1 hip arthroscopy at 1.4 years for a labral tear, with slight improvement in symptoms.

Two hips (7%) had major complications, including 1 deep infection (noted above). This hip eventually went on to THA at 3 years. Another patient had a superficial wound infection treated nonoperatively. There were no nerve palsies, thromboembolic events, fractures, or nonunions.

Discussion

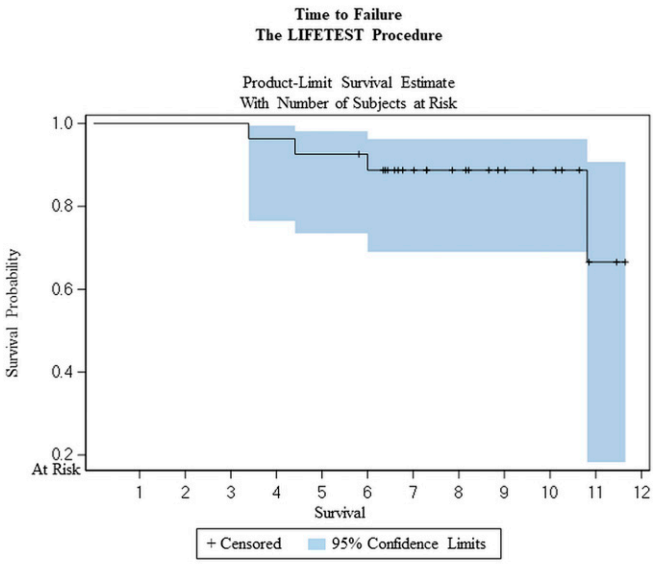
Although treating residual LCP deformities is challenging, the current study demonstrates preserved hips in 85% of patients undergoing SD and PAO at a mean follow-up of >8 years. The survivorship estimates were 93% at 5 years and 85% at 10 years (Fig. 7). It is important to note that, despite the young age of our patients (mean, 19.8 years), preoperative hip pain and dysfunction were substantial (median mHHS, 64 points). The natural history of this selected, symptomatic group of patients is not known. When considering all patients diagnosed with LCP disease, the long-term prognosis has been investigated. McAndrew and Weinstein[2] reported on 37 hips followed for a mean time of 48 years, with 15 hips (41%) requiring total hip replacement between the third and sixth decades. Anthony et al.[35] recently reported on 61 patients with residual LCP disease undergoing THA. The mean age was 42 years, with only 26% of these patients having had a previous surgical procedure.

SD is a reliable method to assess and treat intra-articular and proximal femoral abnormalities[8,22-24]. Acetabular dysplasia is a common finding in LCP deformities and may be associated with instability, yet including PAO in the surgical strategy for treating LCP deformities is controversial. PAO is the standard treatment for classic acetabular dysplasia with associated structural instability and an LCEA of <20°[27,31,36]. Determination of the need for acetabular reorientation should include preoperative radiographs, intraoperative assessment of joint stability, joint congruity, and hip range of motion[17,28]. Our final determination is made on the basis of an intraoperative evaluation that includes direct assessment and visualization for subluxation. In the setting of severe radiographic dysplasia, intraoperative instability is uniformly present; in the setting of moderate radiographic dysplasia, it is often present; and, in the setting of mild radiographic dysplasia, it is sometimes

TABLE II Hip Pathology

Characteristic	No. of Hips* (N = 27)
Labrum	
Normal labrum†	5 (19%)
Labral detachment or degeneration	20 (74%)
Full-thickness labral tear	2 (7%)
Acetabulum	
Normal acetabulum	12 (44%)
Acetabular chondromalacia	8 (30%)
Acetabular debonding	2 (7%)
Acetabular cleavage or defect	4 (15%)
Unable to visualize	1 (4%)
Femoral cartilage	
Normal femoral cartilage	9 (33%)
Femoral chondromalacia	9 (33%)
Femoral head cleavage or defect	9 (33%)
Tönnis grade	
0	13 (48%)
1	13 (48%)
2	1 (4%)
Stulberg class	
2	1 (4%)
3	23 (85%)
4	3 (11%)

*The values are given as the number of hips, with the percentage in parentheses. †All labra were noted to be hypertrophic; normal indicates a hypertrophic labrum without apparent pathology.



Summary of the Number of Censored and Uncensored Values			
Total	Failed	Censored	Percent Censored
27	4	23	85.19

Fig. 7
Kaplan-Meier survival curve for conversion to THA as the end point, demonstrating the years of survival of the 27 hips. The survivorship was 93% at 5 years and 85% at 10 years. As indicated by the size of the confidence interval, the results beyond 10 years in the curve are unstable due to the small number of patients with >10-year follow-up.

present. The hip congruency, as determined by intraoperative fluoroscopic evaluation, must be adequate and the range of motion must be sufficient, with flexion of >90° and abduction of >20°, to tolerate acetabular reorientation[28]. With this surgical technique and decision-making process, we have observed clinical improvement for most patients and continue to use this approach.

There were limitations in this study. First, there was no natural history or control group for comparison. The young patients in this study (mean age, <20 years) had severe symptoms as characterized by a median preoperative mHHS of 64 points. The goals of the surgical procedure emphasize pain relief, improved function, and preservation of the hip. Second, performing multiple procedures in a single hip makes it difficult to determine the role of each portion of the procedure relative to clinical outcomes. Third, given the relatively small sample size, we were unable to assess the role of less common factors in the outcome in this population. For example, the advanced femoral head cartilage changes were present in 1 hip treated with autogenous grafting that subsequently underwent THA. This may indicate that advanced femoral head cartilage changes negatively affect the long-term outcome of this procedure, but they were not common enough to assess this factor. Additionally, the senior authors do have considerable experience in patient selection and the surgical treatment of these patients. The generalizability of our results therefore remains unclear. Defining structural instability in hips with LCP disease is subjective; we have previously published our criteria[6] and have found this methodology to produce positive clinical outcomes. Finally, our clinical outcomes were reported at the final follow-up and the study therefore had limitations in that the effects of aging and changing lifestyle throughout the follow-up period were not considered.

Previous short-term studies demonstrated consistent radiographic correction and favorable clinical outcomes after SD and PAO for LCP hip deformities. Clohisy et al. reported major clinical improvement with low complication rates in a short-term evaluation of 16 patients[6]. The current study included an expanded cohort. Clinical failures increased at the intermediate-term follow-

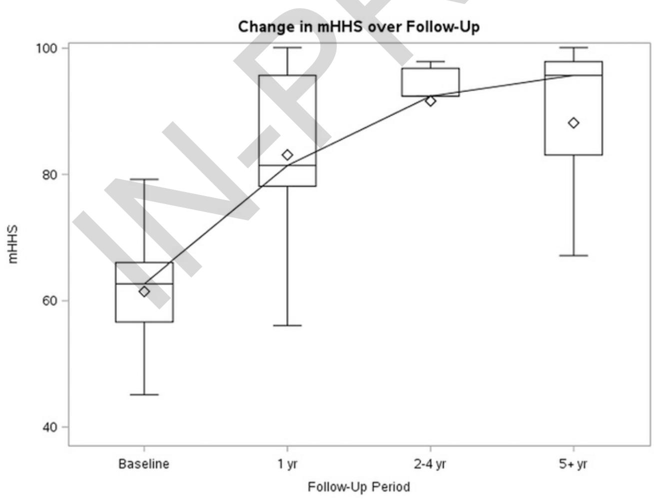


Fig. 8

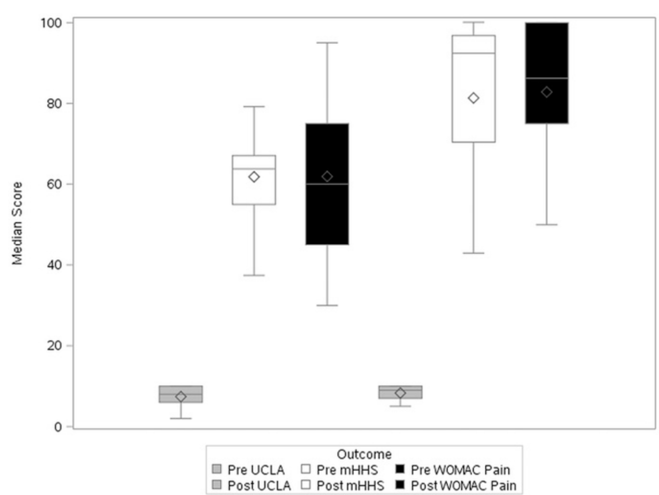


Fig. 9

Fig. 8 Box plot of the change in mHHS for combined SD and PAO over time. The line within the box represents the median and the diamonds represent the mean. The box represents the interquartile range, and the whiskers represent the range. **Fig. 9** Box plot of UCLA activity scores, mHHS, and WOMAC pain scores for combined SD and PAO. The line within the box represents the median and the diamonds represent the mean. The box represents the interquartile range, and the whiskers represent the range.

TABLE III Changes in Radiographic Parameters from Preoperatively to Postoperatively*

Radiographic Parameter	Preoperative† (N = 27)	Postoperative† (N = 27)	P Value
LCEA *(deg)*	9.7 ± 9.4 (−12 to 34)	30.4 ± 7.1 (11 to 45)	<0.001
ACEA *(deg)*	6.7 ± 18 (−32 to 40)	30.1 ± 9.2 (11 to 47)	<0.001
Extrusion index *(%)*	43.0 ± 19.1 (5.4 to 100)	21.8 ± 29.7 (0 to 100)	<0.001
CTD *(mm)*	−25 ± 10 (−55 to −6)	−7 ± 11 (−25 to 15)	<0.001
AI *(deg)*	23.4 ± 7.0 (11 to 37)	8.1 ± 5.3 (0 to 19)	<0.001

*Reported on the cohort of 27 hips (including those that underwent THA). †The values are given as the mean and the standard deviation, with the range in parentheses.

up to 33% (15% [4 hips] THA and 19% [5 hips] mHHS < 70 points). Our clinical outcomes indicate major improvement for most patients but also suggest that the reconstruction of hips with LCP disease may not be as predictable as for hips with classic acetabular dysplasia[31,36]. Our results do appear to be similar to those of other reports in the literature. Albers et al. reported a minimum 5-year follow-up of 11 patients with residual LCP disease undergoing SD and PAO and reported survival rates of 86% at 5 years and 61% at 8 years[16]. In another study, Albers et al. reported a conversion rate to THA of 10% at a mean time of 5 years after relative femoral neck lengthening (without PAO) primarily for LCP deformities[17]. These reports are supportive of this treatment strategy, but indications for a surgical procedure should be strict. We now refrain from a combined procedure in patients ≥25 years of age, and established secondary osteoarthritis (Tönnis grade 2 or 3) is a strong contraindication to a surgical procedure. Additionally, we do not endorse arthroscopic treatment for patients with complex residual LCP deformities. SD is preferred as this technique allows unrestricted access to treat intra-articular pathology (femoral and acetabular), to correct intra-articular and extra-articular impingement, and to provide direct visualization during the dynamic examination to assess both impingement and instability, thereby informing our impingement correction and decision to perform the PAO.

We compared the preoperative and postoperative variables between successes and failures to identify predictors of failure. We identified 2 factors associated with failure, including a greater preoperative CTD, with hips that underwent failed treatment measuring −47 mm compared with −23 mm in surviving hips (Table IV). This difference is substantial and may be an indicator of deformity severity at baseline, which may limit the clinical outcome. Additionally, lower postoperative ACEA was present in hips undergoing THA, indicating less postoperative anterior coverage (Table V). This finding suggests that adequate anterior coverage may play a role in clinical outcomes and is a potential target as a modifiable variable. In these hips, the

TABLE IV Preoperative Predictors of Conversion to THA

Preoperative Variable	No THA (N = 23)	THA (N = 4)	P Value
Age* *(yr)*	20.9 ± 6.3	21.4 ± 7.2	0.92
mHHS* *(points)*	61.8 ± 9.8	60.5 ± 12.5	0.59
UCLA activity score* *(points)*	7.4 ± 2.4	6.8 ± 3.2	0.69
UCLA activity score ≥ 9†	10 (43%)	2 (50%)	0.99
Tönnis grade†			0.12
0	15 (65%)	0 (0%)	
1	7 (30%)	4 (100%)	
2	1 (%)	0 (0%)	
LCEA* *(deg)*	9.9 ± 10.0	5.6 ± 4.9	0.19
Tönnis angle**(deg)*	22.5 ± 6.4	29.9 ± 7.8	0.11
ACEA* *(deg)*	7.9 ± 16.6	−1.0 ± 29.3	0.41
Extrusion index* *(%)*	37.6 ± 10.7	44.6 ± 3.4‡	0.23
CTD* *(mm)*	−23 ± 8	−47 ± 12‡	0.03§

*The values are given as the mean and the standard deviation. †The values are given as the number of hips, with the percentage in parentheses. ‡There were missing values for 2 hips. §Significant.

TABLE V Postoperative Radiographic Predictors of Conversion to THA

Variable	No THA* (N = 23)	THA* (N = 4)	P Value
LCEA *(deg)*	31.4 ± 6.3	21.0 ± 9.4	0.06
AI *(deg)*	8.2 ± 4.9	13.4 ± 2.6	0.07
ACEA *(deg)*	31.9 ± 8.1	14.7 ± 3.9	0.01†
CTD *(mm)*	−5.6 ± 10.7	−16.0 ± 12.7‡	0.17
Extrusion index *(%)*	14.4 ± 9.0	28.5 ± 20.5‡	0.17

*The values are given as the mean and the standard deviation. †Significant as determined with use of the Wilcoxon signed rank test. ‡There were missing values for 2 hips.

acetabular reduction is challenging due to potential joint incongruity, limited range of motion, and potential for secondary FAI. We tend to be less aggressive with acetabular reduction in LCP deformities for these reasons, but increased attention to anterior coverage in the future seems prudent, given these findings.

At the intermediate-term follow-up, SD and PAO for complex LCP deformities preserved 85% of hips and provided reliable deformity correction, major pain relief, and improved function, with acceptable complication and failure rates. Intermediate-term outcomes of combined SD and PAO for symptomatic, residual LCP deformities are encouraging; however, long-term studies with larger sample sizes are needed. Future studies will investigate and improve our understanding of the most appropriate indications, optimal surgical techniques, and specific predictors of clinical outcomes in this challenging patient population. ■

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