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Lateral shelf acetabuloplasty for severe Legg–Calvé–Perthes disease in patients older than 8 years

A mean eleven-year follow-up

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Abstract

The natural history of Legg–Calvé–Perthes disease (LCPD) in children older than 8 years is usually poor without treatment. The treatment goal is to prevent deformity and incongruity of the hip by achieving a stable spherical femoral head in a deep, congruent, sharp-edged acetabulum, with a good range of hip movement at skeletal maturity. Lateral shelf acetabuloplasty in LCPD can increase the coverage of the femoral head, benefiting the remodeling of the femoral head and acetabulum. The aim of this study was to evaluate the efficacy of lateral shelf acetabuloplasty for severe LCPD in patients older than 8 years.

We evaluated 51 patients with severe LCPD who underwent shelf acetabuloplasty between 1994 and 2005. Clinical and radiological examinations were evaluated preoperatively and over a mean follow-up of 132.35 months (range 102–183 months). According to the Catterall classification, the LCPD was classified as grade II in 11 (21.6%) patients, grade III in 15 (29.4%), and grade IV in 25 (49.0%). According to the Herring classification, there were 12 (23.5%) patients in grade B, 24 (47.1%) in grade B/C, and 15 (29.4%) in grade C. The mean ages at the onset of signs and at surgery were 103.39 months and 110.78 months, respectively.

By the end of follow-up, all patients had a normal passive range of hip movement without pain. The mean Iowa hip score was improved from 69.5 ± 7.28 to 91.6 ± 5.14 ($P < 0.001$). According to the Stulberg classification, 11 (21.6%) hips were classified as grade 1, 19 (37.3%) hips as grade 2, 14 (27.5%) hips as grade 3, and 7 (13.7%) hips as grade 4. The CE angle, Sharp angle, medial joint space ratio, epiphysis height ratio, and percentage of acetabular coverage were significantly improved by shelf acetabuloplasty ($P < 0.001$).

We recommend shelf acetabuloplasty for severe LCPD in patients older than 8 years. The procedure yields a favorable clinical outcome and Stulberg outcome for the hip. Shelf acetabuloplasty can improve femoral head coverage and reduce subluxation of the hip, with a benefit to the biological remodeling of the femoral head within the acetabulum.

Abbreviations: BMP = bone morphogenetic protein, CE = center-edge, LCPD = Legg–Calvé–Perthes disease.

Keywords: child, Legg–Calvé–Perthes disease, Perthes disease, shelf acetabuloplasty

1. Introduction

The optimal treatment goal in Legg–Calvé–Perthes disease (LCPD) is to obtain a spherical femoral head with good congruency to prevent or delay the onset of osteoarthritis after skeletal maturity. There is agreement that patients younger than 5 years with a good remodeling capacity have a particularly excellent prognosis, irrespective of treatment. However, those older than 8 years usually have a poor prognosis, especially without treatment. Apart from the age at diagnosis and surgery, the severity of femoral head flattening and the signs of "head at risk" are also associated with the final clinical outcome.[1] The current surgical treatment options, including proximal femoral varus osteotomy,[2] innominate osteotomy,[3] lateral shelf acetabuloplasty,[4] triple pelvic osteotomy,[5] and Chiari pelvic osteotomy,[6] have proved to be effective in covering the femoral head within the acetabulum. To promote the coverage of the femoral head, shelf acetabuloplasty directly increases the size of the acetabulum by implanting graft bone to the lateral rim.[7,8] When used as salvage surgery, it may provide relief from pain and benefit the involved hip via femoral head flattening, especially in older children.[4,9] It also improves the spherical remodeling of the femoral head and acetabulum by stimulating lateral acetabular growth.[10–12]

Lateral shelf acetabuloplasty is able to increase the coverage of the femoral head, which is an important tissue for remodeling and preventing further femoral head deformation. Since 1994, this surgery has been the conventional treatment for LCPD in our department, especially in patients older than 8 years. The aim of this study was to evaluate the efficacy of lateral shelf acetabuloplasty for the treatment of severe LCPD in patients older than 8 years, over a long-term follow-up.

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2. Methods

From January 1994 to December 2005, 51 patients older than 8 years with severe LCPD underwent lateral shelf acetabuloplasty in the Department of Pediatric Orthopedic Surgery of the Chinese People's Liberation Army General Hospital. Informed consent to undergo treatment with lateral shelf acetabuloplasty was obtained from all patients and their parents or guardians. Ethical approval was granted by the hospital's medical ethics committee (reference number 2014–06–248). There were 40 boys and 11 girls. In 32 patients, the left hip was affected and in 19 patients the right. Patients with bilateral LCPD and hinge abduction were excluded from the study. All surgical procedures were led by a single experienced pediatric orthopedic surgeon (Rj, Xu). The age at the onset of signs, the age at surgery, patient's sex, and the side of involvement were noted. We analyzed the clinical history with regard to the onset of symptoms and the presence of pain or limp. In preoperative radiographs, the affected hips were classified according to the Herring and Catterall classifications.

2.1. Lateral shelf acetabuloplasty surgical technique

Before surgery, the center-edge (CE) angle and the preliminary CE angle were determined in preoperative radiographs. Adductor tenotomy was performed as the first surgical step in all cases. A bikini curve incision was made below the iliac crest, passing 1.5 cm below the anterior superior iliac spine to avoid the lateral cutaneous nerve of the thigh. The glutei were stripped from the outer table of the ilium, and the reflected head of the rectus femoris was dissected free from the joint capsule and displaced posteriorly. Iliopsoas muscle tenotomy was performed to reduce the pressure on the femur head. The capsule was thinned by "filleting" with a scalpel. After the exact acetabular edge was identified, a bone trough was made just above the subchondral bone of the acetabulum. Thin strips of cortical and cancellous bone were harvested from the lateral surface of the ilium and placed in the bone trough, extending out over the capsule. A second layer of strips was then placed at 90 degrees below the previous strips. The remaining grafts and artificial bones with bone morphogenetic protein (BMP) were cut into small pieces and packed above the previous grafts. The periosteum and glutei were closed to maintain the grafts in place. A spica cast was worn for 8 weeks and protective weight bearing in a cast was continued for 8 additional weeks.

We obtained postoperative radiographs immediately after the surgery and at final follow-up. The radiographs were analyzed to evaluate the remodeling of the femoral head and the reduction of subluxation of the hip. The radiographic parameters included CE angle, Sharp angle, medial joint space distance (the distance from the deepest point of the teardrop to the medial femoral head), the ratio of the operated hip to the nonoperated hip (a1/a2), the percentage of acetabular coverage (the ratio between the distance from the most lateral point of the acetabulum to the most medial point of the femoral epiphysis and the distance from the most lateral point of the proximal femoral epiphysis to the medial point of the proximal femoral epiphysis) (Fig. 1 and Fig. 2). Apart from the radiographic parameters, the Stulberg classification was determined at the last follow-up. The clinical evaluations were performed at regular intervals until final follow-up. The passive range of hip movement, the presence of pain and limp, Trendelenburg gait, shortening of the lower limbs, and the Iowa hip score were recorded to evaluate the clinical outcome.

Data were analyzed for statistical significance using the paired *t* test. A *P* value of <0.05 was considered significant. SPSS for Windows version 17.0 software (SPSS Inc, Chicago, IL) was used for the statistical analysis.

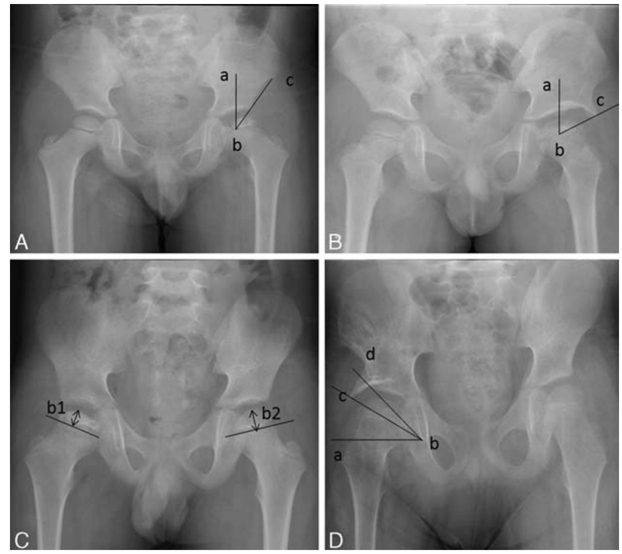

Figure 1. (A) The preoperative Wiberg center–edge angle = ∠abc angle; (B) The postoperative Wiberg center–edge angle = ∠abc angle; (C) Epiphysis height of femoral head ratio between the operated hip versus the contralateral hip (b1/b2); (D) The preoperative Sharp's angle = ∠abc angle, and the postoperative Sharp angle = ∠abd angle.

3. Results

The mean age at the onset of signs was 101.43 ± 10.57 months (range 82–127), and the mean age at surgery was 110.78 ± 11.02 months (95–135). All children presented with a painful limping gait. According to the Catterall classification, 11 (21.6%) patients were in grade II, 15 (29.4%) in grade III, and 25 (49.0%) in grade IV. According to the Herring classification, there were 12 (23.5%) patients in grade B, 24 (47.1%) in grade B/C, and 15 (29.4%) in grade C (Table 1).

Patients were followed up for between 102 months and 183 months after operation, with a mean of 132.35 months (11.02 years). The clinical evaluation at final follow-up showed that 39 patients had a normal passive range of hip movement without pain. Ten patients had a Trendelenburg gait and 15 patients had a

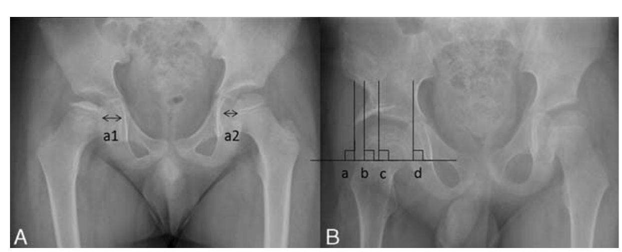

Figure 2. (A) Medial joint space distance (the distance from the deepest point of the teardrop to the medial femoral head) ratio of the operated hip versus the nonoperated hip (a1/a2); (B) Percentage of acetabular coverage (the ratio of the distance between the most lateral point of acetabulum and the most medial point of femoral epiphysis versus that between the most lateral point of proximal femoral epiphysis and medial point of proximal femoral epiphysis), preoperative percentage of acetabular coverage = cd/bd, and postoperative percentage of acetabular coverage = ad/bd.

Table 1

Preoperative parameters of patients in Perthes.

Patient	Sex	Operative age, mo	Follow-up times, mo	Preoperative CE (degress)	Preoperative Herring classification	Preoperative Caterall classification	Postoperative Stulberg classification
1	Male	102	133	15	B/C	II	1
2	Male	98	105	9	C	IV	3
3	Female	101	118	25	B	II	1
4	Female	135	103	15	C	IV	2
5	Male	129	143	26	C	IV	4
6	Male	108	129	30	B/C	III	2
7	Male	107	131	16	B	IV	3
8	Male	110	158	7	C	IV	3
9	Male	113	124	32	C	IV	2
10	Female	100	141	21	B/C	IV	3
11	Male	103	157	10	C	IV	2
12	Male	99	141	31	B/C	III	1
13	Male	97	183	14	B	II	2
14	Female	110	158	25	B	II	1
15	Male	113	135	10	B/C	III	2
16	Male	116	130	20	C	IV	3
17	Male	129	149	27	B/C	IV	4
18	Female	134	146	17	B	III	2
19	Male	139	118	26	B/C	III	1
20	Female	115	129	23	B/C	IV	3
21	Male	114	124	30	C	IV	4
22	Male	95	142	29	C	IV	2
23	Male	97	134	15	C	III	2
24	Male	102	127	24	B	II	1
25	Male	127	130	24	B/C	II	2
26	Male	99	157	35	B/C	III	2
27	Male	99	114	37	B/C	IV	4
28	Female	103	104	25	C	IV	3
29	Male	107	138	16	B	III	1
30	Male	120	149	30	B/C	III	2
31	Male	127	139	28	B	II	1
32	Male	100	124	28	C	IV	3
33	Male	101	119	21	B/C	IV	2
34	Female	102	113	21	B/C	III	2
35	Male	114	136	36	B/C	IV	4
36	Male	120	125	14	B	II	1
37	Male	107	119	15	B	III	2
38	Male	102	113	21	B/C	III	1
39	Male	106	153	25	B	II	2
40	Male	116	141	33	C	IV	3
41	Female	117	132	30	B/C	IV	3
42	Male	120	151	36	B/C	II	2
43	Female	120	157	19	B/C	IV	3
44	Male	118	140	23	B/C	IV	3
45	Male	107	135	15	B/C	IV	4
46	Male	100	102	27	C	III	2
47	Male	120	114	30	B/C	IV	3
48	Male	117	139	20	B	II	1
49	Female	110	131	29	B/C	III	2
50	Male	99	115	18	C	IV	4
51	Male	106	102	21	B/C	III	3

moderate limp. There were 17 patients with leg length discrepancy, ranging from 0.5 to 2.0 cm. Mean Iowa hip score improved from 69.53 ± 7.28 to 91.62 ± 5.14 ($P < 0.001$). Three patients required additional surgery because of the residual greater trochanter and coxa vara.

The containment of the femoral head increased significantly postoperatively. There was a significant increase in the CE angle, from 23.02 ± 7.47 degree preoperatively to 46.33 ± 6.02 degree at final follow-up ($P < 0.001$). There was a noticeable increase in percentage of acetabular coverage from $75.90\% \pm 7.64\%$ to $113.73\% \pm 7.19\%$ ($P < 0.001$) (Table 2). Shelf acetabuloplasty significantly reduced the subluxation of the femoral head. Medial joint space ratio (a1/a2) decreased from $164.82\% \pm 8.39\%$ to $116.25\% \pm 7.85\%$ at final follow-up ($P < 0.001$). Sharp angle decreased from 57.61 ± 4.21 degree preoperatively to 44.37 ± 3.55 degree ($P < 0.001$). Epiphysis height ratio (b1/b2) improved

Table 2

Descriptive analysis of radiographic parameters and Iowa Hip Score.

Measure	Preoperative		1 year postoperative		Last follow-up	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
CE angle	23.02	7.47	62.27*	7.72	46.33†	6.02
Sharp angle	57.61	4.21	35.18*	4.95	44.37†	3.55
Percentage of acetabular coverage	75.90	7.64	130.94*	8.74	113.73†	7.19
Epiphysis height ratio	56.16	10.37	63.49	8.51	86.04†	6.39
Medial joint space ratio	164.82	8.39	145.12*	8.09	116.25†	7.85
Iowa Hip Score	69.53	7.28	73.46	6.25	91.62†	5.14

* There was significant difference between preoperative and 1 year postoperative.
† There was significant difference between preoperative and last follow-up.

from 56.16% ± 10.37% to 86.04% ± 6.39% ($P < 0.001$). According to the Stulberg classification, 11 (21.6%) hips were classified as grade 1, 19 (37.3%) as grade 2, 14 (27.5%) as grade 3, and 7 (13.7%) as grade 4. No hip was aspherical and incongruent (grade 5). Statistical analysis of the radiographic parameters showed a significant improvement, with spherical remodeling of the femoral head (Fig. 3 and Fig. 4).

4. Discussion

LCPD, a childhood precursor to osteoarthritis of the hip, is an idiopathic avascular necrosis of the femoral head in children. The etiology of LCPD in theory includes exposure to tobacco smoke, overweight, hyperactivity, undetermined coagulopathy, and dietary deficiencies. However, none of these etiologies has been specifically implicated. The biologic sequelae of LCPD comprise a chain of events with eventual revascularization of the femoral head, which is followed by femoral head shape change, flattening, and even subluxation. Various treatment strategies have been reported in the literature, including symptomatic treatment methods (skin traction, nonsteroidal anti-inflammatory drugs, and crutches) and early surgical treatment of mild clinical symptoms (pain or limp) or before the signs and symptoms of the risk factors become apparent.[12–15]

The aim of lateral shelf acetabuloplasty is to promote the concentric reduction of the femoral head into the acetabulum without restriction on hip motions. Innominate osteotomy can alter the natural process of LCPD and benefit femoral head remodeling during remaining growth.[3] Park et al and Yavuz et al[16,17] also indicated that Salter osteotomy could improve the sphericity of the femoral head. Salter osteotomy is an effective method of surgical treatment for LCPD in patients younger than 8 years. However, the clinical outcome tends to decline as the pubic symphysis gradually stabilizes in patients older than 8 years.[18] Salter et al[19] also reported that surgery was suitable for early phases of LCPD, as the femoral head is rather large and deformed during the fragmentation phase. Terjesen et al[2] reported that proximal femoral varus osteotomy can improve the sphericity of the femoral head in severe forms of LCPD, mainly in

Figure 3. Radiographs of a 10-year-old boy, with a history of pain in the left hip and limp. There was no history of injury and his general health was otherwise normal. (A) Anteroposterior radiographs of the pelvis at the time of diagnosis with the hip in Herring B and Catterall group II. (B) Anteroposterior radiographs immediately after a shelf acetabuloplasty. (C) Anteroposterior radiograph at follow-up showing that the hip was classified as Herring B/C and Catterall group IV. (D) Anteroposterior radiographs at the follow-up of 9 years indicating that there was a good remodeling of the femoral head with the hip classified as Stulberg II.

Figure 4. Radiographs of an 8-year-old boy, with a 10-month history of pain in the left hip and increasing limp. There was no history of injury and his general health was otherwise normal. (A) Anteroposterior radiographs of the pelvis at the time of diagnosis with the hip classified as Herring C and Catterall group IV; there was significant loss of epiphyseal height and widening of the medial joint space of the hip. (B) Anteroposterior radiographs immediately after shelf acetabuloplasty. (C) Anteroposterior radiograph showing that a significant increase in coverage of femoral head and CE angle. (D) Anteroposterior radiographs at 10-year follow-up indicating the remodeling of the femoral head with the hip classified as Stulberg 4.

children younger than 9 years. In the study of Herring et al,[1] the number of patients older than 8 years with surgical treatment was too small for meaningful statistical analysis. Aksoy et al[20] reported that the femoral head in young children gained markedly better sphericity remodeling compared with children older than 9 years; similar results were also reported by Friedlander for femoral varus osteotomy.[21] There was an upper age limit above which surgical treatment no longer gave better femoral head sphericity.

In our study, lateral shelf acetabuloplasty was able to promote the containment of femoral head in the acetabulum, which is a significant factor during growth. The percentage of acetabular coverage of the femoral head increased from 75.90% ± 7.64% to 113.73% ± 7.19%, a result that is consistent with those of another study that reported an increase from 74% to 98%.[9] Herring et al[22] reported an improvement in the coverage of the femoral head from 66% to 110%. Furthermore, the CE angle increased from 23.02 ± 7.47 degree to 46.33 ± 6.02 degree ($P < 0.001$). The increase in femoral head coverage and CE angle could provide better containment in the hip for remodeling of a new femoral head. Medial joint space ratio (a1/a2) decreased from 164.82% ± 8.39% to 116.25% ± 7.85% at the final follow-up ($P < 0.001$), which is comparable with the results of Chang et al.[9] Dimitriou et al and Huang et al[23,24] also noted a significant decrease in the medial joint space ratio of the femoral head. In addition, the mean Sharp angle decreased from 57.61 ± 4.21 degree to 44.37 ± 3.55 degree. According to the above statistical parameters, shelf acetabuloplasty could improve subluxation of the femoral head.

There were 11 (21.6%) hips classified as Stulberg grade 1, 19 (37.3%) as grade 2, 14 (27.5%) as grade 3, and 7 (13.7%) as grade 4. Chang et al[9] achieved a Stulberg classification of 1–2 in 33.3% of cases and 3 in 38.1%. Daly et al[25] reported that Stulberg grade 1–3 was achieved in 81.4% of patients, a similar result to ours (85.1%). In a study by Jacobs et al,[8] 81% of 43 hips had Stulberg grade 1–3, representing a fair outcome. The results for Stulberg grade 1–3 were comparable to those of other studies, with 67% to 86% for femoral osteotomy and 78% for Salter osteotomy.[21,26,27] Epiphysis height ratio (b1/b2) improved from 56.16% ± 10.37% to 86.04% ± 6.39% ($P < 0.001$). We observed that the spherical remodeling of the femoral head improved as the femoral head coverage was increased by shelf acetabuloplasty. Kadhim et al[28] also reported that shelf acetabuloplasty provided a good or fair Stulberg outcome in LCPD. David et al[4] reported that the benefit of the shelf procedure was in reducing the number of aspherical incongruent hips in comparison with conservative treatment.

Our study of lateral shelf acetabuloplasty in LCPD differs from other studies in several ways. First, there is agreement that patients older than 8 years usually have a poor prognosis, with a flat, broad femoral head. Jacobs et al[8] reported that shelf acetabuloplasty could be considered as an appropriate surgical treatment for children older than 5 years of age with LCPD. Another study reported that patients with a mean age of 7.4 years (range 3.9–15.3) were treated with shelf acetabuloplasty.[10] Catterall[29] reported that >50% of patients aged >8 years who were treated non-operatively had a poor outcome regarding clinical symptoms. Several series of patients aged >8 years who underwent varus femoral osteotomies and innominate osteotomies had poor outcomes. Sponseller et al[30] reported that 7 (38.9%) of 18 patients older than 8 years were classified as Stulberg 4 or 5 with treatment of varus osteotomy. This was broadly similar to the results of Kitakoji et al,[31] who reported a rate of 17% for Stulberg 4 and 5. Noonan et al[32] also reported that 8 (44.4%) of 18 hips had Stulberg 4 or 5 following varus osteotomy for LCPD in patients older than 9 years. In our study, we had a good Stulberg outcome: 11 (21.6%) hips as grade 1, 19 (37.3%) hips as grade 2, 14 (27.5%) hips as grade 3, and 7 (13.7%) hips as grade 4. In summary, lateral acetabuloplasty in patients with LCPD older than 8 years could improve the biological remodeling of the femoral head within the acetabulum, with favorable Stulberg outcomes.

Second, the resorption of bone graft has been a challenging problem in shelf acetabuloplasty. Cancellous bone in lateral acetabuloplasty was not completely fused with the acetabulum, which may have a negative effect on femoral head coverage. In our study, artificial bone with BMP was mixed with autogenous bone to reduce the process of absorption in the margin of the acetabulum. BMP could improve the fusion of graft bone and acetabulum. The lateral shelf procedure can reduce the physiological forces on the femoral head and improve biological remodeling. In our study, the lateral shelf was placed just above the growth plate of the acetabulum to accomplish the fusion of graft bone and pelvis and stimulate the growth of the lateral plate of the acetabulum. Marcin et al[11] also reported that additional lateral growth of true acetabulum was stimulated by surgery, hypothesizing that remodeling of an excessive osseous graft may be beneficial and prevent acetabular rim impingement. The remodeling of the acetabulum increased as a result of growth at the periphery of the acetabular growth plate and the formation of graft bone in the lateral pelvic wall.

Third, in our study, adductor tenotomy and iliopsoas muscle tenotomy were performed in all cases. The release of soft tissue contracture was a significant procedure in the treatment of LCPD. The adduction contracture in LCPD kept the hip in a position of adduction as a result of the subluxation of the femoral head. Adductor tenotomy releases the hip in the neutral position, allowing recovery of hip movement. The percutaneous adductor tenotomy under sterile conditions was performed for adduction contracture. The iliopsoas muscle tends to be contracted in LCPD, which increases the pressure on the femoral head and prevents the biological remodeling of femoral head and acetabulum. The iliopsoas muscle of contracture may keep the femoral head in subluxation, and iliopsoas muscle tenotomy could reduce the subluxation of the femoral head.

There are several limitations to our study. First, it was a retrospective study of the treatment of LCPD, which may not provide full clinical data for the patients. However, we evaluated a consecutive cohort of patients older than 8 years who were treated with lateral shelf acetabuloplasty by the single surgeon in our department. Second, the radiological parameters, including CE angle and Sharp angle, were based on anterior-posterior plain radiography. Although the radiograph is inadequate to provide complete information about the three-dimensional sphericity of the femoral head and acetabulum, the clinical data were sufficient to indicate the effects of lateral acetabuloplasty.

5. Conclusion

Lateral shelf acetabuloplasty seems to be best indicated for severe LCPD in patients older than 8 years. It results in favorable clinical function of the hip and good Stulberg outcomes. Shelf acetabuloplasty increases the femoral head coverage to promote biological remodeling of the femoral head within the acetabulum. In addition, this surgical approach represents a containment procedure that helps to reduce subluxation of the femoral head, thereby helping to restore the biomechanical function of the hip joint.

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