Comparison of Acetabular Anterior Coverage After Salter Osteotomy and Pemberton Acetabuloplasty: A Long-term Followup

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Abstract

Background The Salter osteotomy and Pemberton acetabuloplasty are common procedures for a deficient acetabulum in patients with developmental dysplasia of the hip. However, the degree of increasing retroversion and anterior acetabular coverage of these two procedures remains unanswered.

Questions/purposes The purpose of this study is to show the change in anterior coverage and relevant parameters in measuring pain and function among patients who have

undergone either a Salter osteotomy or Pemberton acetabuloplasty.

Methods Forty-two patients who underwent either a Salter or Pemberton procedure at one institution between January 1981 and December 2000 and were available for followup at least 10 years later (mean, 18 years; range, 12–28 years) were evaluated retrospectively. This represented 12% of the Salter and Pemberton procedures performed in patients between 12 and 36 months old at our institution during the study period. We measured vertical-center-anterior margin angle, anterior acetabular head index, and weightbearing zone acetabular index, and we made comparisons using the radiographic parameter ratio (the division of each radiographic measurement of the operative side by that of the nonoperated side). All patients completed SF-36 and Harris hip score questionnaires at followup.

Results In the Salter group, there were no differences in vertical-center-anterior margin angle, anterior acetabular head index, or weightbearing zone acetabular index. In the Pemberton group, there was no difference in vertical-center-anterior margin angle or anterior acetabular head index, but the weightbearing zone acetabular index decreased, suggesting increased anterior acetabular coverage (surgically treated side, 6 [95% CI, 4.84, 7.16]; nonoperated side, 12 [95% CI, 10.07, 13.39]; $p < 0.001$). Compared with that in the Salter group, the weightbearing zone acetabular index ratio was smaller in the Pemberton group, which means more acquired anterior coverage after a Pemberton acetabuloplasty (Salter procedure, 0.94 [95% CI, 0.70, 1.17], Pemberton procedure, 0.53 [95% CI, 0.40, 0.65]; $p < 0.001$). Three patients in the Pemberton group had an anterior impingement sign at followup, whereas none in the Salter group did. The SF-36 and Harris hip scores were good and showed no differences between the two groups.

Each author certifies that he or she, or a member of his or her immediate family, has no funding or commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request. Each author certifies that his institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Conclusions Our study suggests the weightbearing zone acetabular index on false profile radiographs of the hip, a parameter focusing on morphologic features of the anterior acetabulum, decreased after Pemberton acetabuloplasty compared with the nonoperated side and after the Salter acetabuloplasty. This suggests that by modifying the shape of the acetabulum with a hinge in the triradiate cartilage, a Pemberton acetabuloplasty may result in increasing acetabular anterior coverage and the risk of hip impingement. However, the functional results with at least 10 years followup were good and similar for both procedures.

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

Introduction

The Salter osteotomy and Pemberton acetabuloplasty are common procedures for a deficient acetabulum in patients with developmental dysplasia of the hip (DDH). A Salter osteotomy is a complete osteotomy to redirect the entire acetabulum to obtain the best possible femoral head-acetabulum relationship [11]. A Pemberton acetabuloplasty is an incomplete osteotomy to modify the shape of the acetabulum by hinging at the horizontal branch of the triradiate cartilage [9]. The objectives of the two surgeries are to improve the anterolateral coverage of the femoral head. Adequate containment and a stable hip allow weightbearing and osseous remodeling of the dysplastic acetabulum.

Fig. 1 The flowchart shows patient selection and exclusion criteria. VCA angle = vertical-center-anterior margin angle; AAHI = anterior acetabular head index; WAI = weightbearing zone acetabular index.

Concerns have been raised that redirection of the acetabulum with the Salter osteotomy may create or increase retroversion or anterior overcoverage [1, 3, 10, 12]. To our knowledge, there has been no study of the change of acetabular version or anterior coverage after a Pemberton acetabuloplasty. However, acetabular retroversion or overcoverage has been implied as a cause of hip pain, impingement, and subsequent osteoarthritis [7].

The purpose of our study is to show the change of anterior coverage after a Salter osteotomy or Pemberton acetabuloplasty and to determine whether the differences had any effect on patients' functional or pain scores. Comparing patients who underwent Salter or Pemberton procedures for unilateral DDH, we specifically sought to evaluate (1) postsurgical radiographic parameters, including comparisons to the contralateral, normal hip, and (2) clinical outcomes pertaining to pain, impingement, function, and general health.

Patients and Methods

Between January 1981 and December 2000 at our institution, 554 patients underwent a Salter osteotomy or Pemberton acetabuloplasty for DDH. We excluded patients with bilateral DDH, combined femoral shortening, an associated neuromuscular disorder, syndromic presentation, or who underwent surgeries when they were younger than 12 months or older than 36 months. Three hundred sixty patients were identified. We excluded 223 of the 360 patients because they were unable to attend 10 years of followup. In the remaining 137 patients, 80 were able to be contacted, but 38 declined participation. Our study included the remaining 42 patients (12% of those potentially eligible, 42 of 360, based on our inclusion criteria) who returned for long-term followup at a mean of 18 years (range, 12–28 years) (Fig. 1). The followup for patients in this series who underwent the Salter osteotomy averaged 22 years (range, 18–26 years), and the average followup for the patients who received a Pemberton acetabuloplasty was 16 years (range, 12–28 years). The followup age and duration are longer for patients in the Salter group because more Salter osteotomies were done during the early period of the study (Table 1).

There was differential loss to followup between the study groups. The 14 Salter osteotomies represented 8% (14 of 174) of the procedures done for unilateral DDH in patients between 12 and 36 months old during the study period, whereas the 28 Pemberton acetabuloplasties represented 15% of the procedures during the study period in eligible patients (28 of 186); this difference was significant ($p = 0.04$).

During the earlier part of the study period, the general indications for the Salter osteotomy were DDH discovered

Table 1. Patient demographics

Demographic	Salter osteotomy (95% CI)	Pemberton acetabuloplasty (95% CI)	p value
Number of patients	14	28	
Male: female*	0:14	5:23	0.151
Right: left*	4:10	10:18	0.738
Age at surgery (years) [†]	1.6 (1.37, 1.83)	1.7 (1.49, 1.88)	0.979
Followup age (years) [†]	23 (21.21, 25.07)	18 (15.90, 19.18)	< 0.001
Followup duration (years) [†]	22 (19.71, 23.35)	16 (14.31, 17.38)	< 0.001

* Fisher's exact test; [†]Mann-Whitney test.

at walking age with failed attempts at closed reduction. During the later period, the Pemberton acetabuloplasty was used for the same indication because it does not require internal fixation for stability of the graft. All procedures were performed by one surgeon (SCH).

There were no significant differences between Salter and Pemberton groups in sex, side, and age at surgery (Table 1).

The procedures were performed as originally described by Salter [11] or Pemberton [9]. An anterior iliofemoral approach was used and an iliopsoas tenotomy over the rim was routinely performed. The ligamentum teres was excised and the transverse acetabular ligament was incised. Any soft tissue obstruction in the acetabulum was removed to allow the femoral head to seat deeply into the socket. For the Salter osteotomy, a straight cut was made. It started just above the anteroinferior iliac spine and ended at the greater sciatic notch. For the Pemberton acetabuloplasty, a curved cut was made and extended down to the posterior wing of the triradiate cartilage. The lower fragment after the osteotomy was mobilized downward, outward, and forward. A triangular graft taken from the iliac crest then was placed in the osteotomy site. The graft was fixed with two K-wires in the Salter osteotomy, but this was not necessary in most cases with the Pemberton acetabuloplasty. Postoperatively, all patients wore a 1½-hip spica cast for 6 weeks. Partial weightbearing was started at 6 weeks, and full weightbearing by 3 months after surgery.

During the followup, false profile radiographs of the hip were obtained to evaluate the acetabular anterior coverage. False profile radiographs were taken with the patient in the standing position at an angle of 65° between the pelvis and the film, as described by Lequesne and Laredo [8], to profile the anterosuperomedial edge of the acetabulum. The axis of the ipsilateral foot (second metatarsal bone) is parallel to the film to obtain a true lateral view of the proximal femur (Fig. 2).

Fig. 2 The position of the pelvis for the false profile radiograph is shown. (Reproduced with permission and copyright © of the British Editorial Society of Bone and Joint Surgery from Chosa E, Tajima N. Anterior acetabular head index of the hip on false-profile views: new index of anterior acetabular cover. *J Bone Joint Surg Br.* 2003;85;826–829.)

We assessed radiographic measures to compare the groups. Two senior authors (KNK, TMW) reviewed all radiographs, and two junior authors (KWW, CWW) made the radiographic measurements. All radiographs from our institute are stored in Picture Archiving and Communication Systems (PACS) maintained by Agfa HealthCare Company (Mortsel, Belgium). We used the Agfa Orthopaedics Tools in PACS to define the vertical line and femoral head center. We measured vertical-center-anterior margin angle [8], anterior acetabular head index [2], and weightbearing zone acetabular index of the surgically treated and nonoperated sides. Vertical-center-anterior margin angle is composed of a vertical line through the center of the femoral head and a second line through the center of the femoral head and the anterior margin of the acetabulum (Fig. 3). The anterior acetabular head index is determined by three vertical lines. The first line passes through the most posterior aspect of the femoral head, the second through the anterior margin of the acetabulum, and the third through the most anterior aspect of the femoral head. The distance between the first and second lines (A) is divided by the distance between the first and third lines (B) expressed as a percentage (Fig. 4). We designed a weightbearing zone acetabular index measure. First, we drew a vertical line which is tangent to the most posterior aspect of the femoral head, and then we obtained an intersection point of this line and the acetabular roof. Second, we drew a line connecting the intersection point and anterior-inferior margin of the acetabulum. The weightbearing zone acetabular index is defined as an angle between this line and a horizontal line through the

Fig. 3 The diagram shows the vertical-center-anterior margin angle. (Reproduced with permission and copyright © of the British Editorial Society of Bone and Joint Surgery from Chosa E, Tajima N. Anterior acetabular head index of the hip on false-profile views: new index of anterior acetabular cover. *J Bone Joint Surg Br.* 2003;85;826–829.)

Fig. 4 The diagram shows the anterior acetabular head index ($[A/B] \times 100\%$). (Reproduced with permission and copyright © of the British Editorial Society of Bone and Joint Surgery from Chosa E, Tajima N. Anterior acetabular head index of the hip on false-profile views: new index of anterior acetabular cover. *J Bone Joint Surg Br.* 2003;85;826–829.)

intersection point (Fig. 5). For the weightbearing zone acetabular index, the intraobserver reliability interclass correlation coefficient was 0.982 (95% CI, 0.969, 0.989), and the interobserver reliability interclass correlation coefficient was 0.798, (95% CI, 0.705, 0.865). From standing AP radiographs of the pelvis, we evaluated avascular necrosis of the femoral head using the Kalamchi and MacEwen classification [5].

Clinical findings, including any hip pain, limp, or anterior impingement sign, were recorded at the latest followup. The hip pain was quantified by a VAS. The anterior impingement sign of the hip is positive when pain is evoked by a combined flexion and internal rotation test. The patients' postoperative

Fig. 5 The diagram shows the weightbearing zone acetabular index.

performance was evaluated by the Harris hip score and postoperative general health by the SF-36.

The study was approved by the institutional review board at our institution.

Fisher's exact test was used to compare patient demographics and positive symptoms, and the Wilcoxon signed-rank test was used to compare the surgically treated and nonoperated sides in the Salter and Pemberton groups. The Mann-Whitney test was used to compare the Salter and Pemberton groups. A *p* value less than 0.05 was considered significant.

Results

In the Salter group, there were no differences between the surgically treated and nonoperated sides in vertical-center-anterior margin angle, anterior acetabular head index, and weightbearing zone acetabular index. In the Pemberton group, there were no differences between the surgically treated and nonoperated sides in vertical-center-anterior margin angle or anterior acetabular head index, but the weightbearing zone acetabular index was less in the surgically treated hip at latest followup, suggesting that the procedure increased anterior acetabular coverage (surgically treated side, 6 [95% CI, 4.84, 7.16], nonoperated side, 12 [95% CI, 10.07, 13.39]; *p* < 0.001) (Table 2). One female patient underwent a left Pemberton acetabuloplasty at the age of 2 years (Fig. 6). Her followup false profile radiographs obtained 15 years after surgery showed typical increased anterior coverage. There were no differences in vertical-center-anterior margin angle of the surgically treated side, anterior acetabular head index of the surgically treated side, vertical-center-anterior margin angle ratio, or anterior acetabular head index ratio between the Salter and Pemberton groups (Table 3). However, in the

Table 2. Comparison of surgical and nonoperated sides

Procedure	Surgically treated side (95% CI)	Nonoperated side (95% CI)	<i>p</i> value*
Salter osteotomy (14 patients)			
VCA angle (degrees)	44 (37.14, 50.98)	42 (36.31, 47.40)	0.551
AAHI (%)	86 (81.49, 90.84)	88 (83.19, 92.60)	0.379
WAI (degrees)	12 (9.26, 15.07)	13 (10.83, 16.14)	0.209
Pemberton acetabuloplasty (28 patients)			
VCA angle (degrees)	43 (37.65, 48.11)	43 (38.61, 47.62)	0.955
AAHI (%)	86 (82.44, 88.82)	88 (85.18, 90.77)	0.096
WAI (degrees)	6 (4.84, 7.16)	12 (10.07, 13.39)	< 0.001

* Wilcoxon signed-rank test; VCA angle = vertical-center-anterior margin angle; AAHI = anterior acetabular head index; WAI = weightbearing zone acetabular index.

Pemberton group, the weightbearing zone acetabular index of the surgically treated side and the weightbearing zone acetabular index ratio were smaller (Salter osteotomy, 12 [95% CI, 9.26, 15.07]; Pemberton acetabuloplasty, 6 [95% CI, 4.84, 7.16], *p* = 0.001); (Salter osteotomy, 0.94 [95% CI, 0.70, 1.17], Pemberton acetabuloplasty, 0.53 [95% CI, 0.40, 0.65], *p* < 0.001) (Table 3). This suggests that the Pemberton acetabuloplasty afforded greater anterior acetabular coverage.

The functional scores we evaluated (Harris hip score, SF-36, SF-36 physical health dimension or mental health dimension) after the Salter osteotomy and Pemberton acetabuloplasty were good and revealed no differences between the procedures. Among 14 patients who underwent the Salter osteotomy, one (7%) had intermittent tenderness over the lateral hip (VAS 4), and among the 28 patients who underwent the Pemberton acetabuloplasty, three (11%) had intermittent hip soreness, especially after exercise (VAS 2, 3, 3). Despite symptoms, the patients still obtained high Harris hip scores (100, 96, 96, and 100, respectively). No patient in the Salter group had an anterior impingement sign, and only three (11%) in the Pemberton group had a mild anterior impingement sign. In these three patients, the vertical-center-anterior margin angle and anterior acetabular head index of the surgically treated side were not different compared with the nonoperated side (vertical-center-anterior margin angle ratios/anterior acetabular head index ratios, 0.65/0.87, 0.91/0.94, and 1.01/0.93), but in these three patients, the weightbearing zone acetabular index was smaller, which means more acetabular anterior coverage of the surgically treated side when compared with that of the contralateral nonoperated side (weightbearing zone acetabular index ratios, 0.32, 0.88, and 0.75) (Table 3).

Fig. 6A–F A female patient underwent a Pemberton acetabuloplasty on the left side at the age of 2 years. Her false profile radiographs obtained 15 years after surgery showed typical increased anterior coverage. Shown are the (A) vertical-center-anterior margin angle, (B) anterior acetabular head index, and (C) weightbearing zone

acetabular index of the right hip, which was the nonoperated side, and the (D) vertical-center-anterior margin angle, (E) anterior acetabular head index, and (F) weightbearing zone acetabular index of the left hip which was the surgically treated side.

Discussion

Only several studies have focused on the correction after a Salter osteotomy in the sagittal plane, acetabular version, and anterior coverage [1, 3, 10, 12]. To our knowledge, there has been no study regarding the change in the sagittal plane after a Pemberton acetabuloplasty. How anterior coverage of acetabular change after a Salter osteotomy or Pemberton acetabuloplasty affects eventual clinical outcomes remains unanswered. In our study, we found that a Pemberton acetabuloplasty had more increased anterior coverage and also can have the risk of anterior impingement as compared with a Salter osteotomy. However, the clinical functional scores showed no differences between the two procedures during followups of our patients.

There are several limitations of our study. First, there was considerable loss to followup, as one might expect after

nearly two decades. We successfully contacted 22% of potentially eligible patients (80 of 360 patients) by phone and 53% (42) of them returned for completed followups. For the remaining 47%, the patients cited good functional results, the distance for traveling, and busy at work as reasons for not returning for followups, but no one cited clinical failures. Therefore, we do not think many patients with poor hip scores or radiographic results were missed, and therefore loss to followup may not have had a substantial influence on our outcome interpretation. Second, the followup duration of the Salter group (22 years) is longer than that of Pemberton group (16 years). In addition, there was a discrepancy in the numbers of Salter osteotomies (14) and Pemberton acetabuloplasties (28) at the final followup. The Salter osteotomy was performed during the earlier part of the study, therefore most of the patients who had this procedure had graduated from school and were

Table 3. Comparison of Salter and Pemberton groups

Clinical and radiographic findings	Salter osteotomy (95% CI)	Pemberton acetabuloplasty (95% CI)	p value
Symptoms [†] (pain, soreness, discomfort of surgically treated hip)	1/14 (7%)	3/28 (11%)	1.000
	Relative risk ratio, 0.67 (0.08, 5.84)		
Anterior impingement sign [†]	0/14 (0%)	3/28 (11%)	0.539
	Relative risk ratio, 0		
VCA angle (degrees)*	44 (37.14, 50.98)	43 (37.65, 48.11)	0.885
AAHI (%)*	86 (81.49, 90.84)	86 (82.44, 88.82)	0.906
WAI (degrees)*	12 (9.26, 15.07)	6 (4.84, 7.16)	0.001
VCA angle ratio*	1.06 (0.92, 1.21)	1.00 (0.91, 1.09)	0.609
AAHI ratio*	0.98 (0.93, 1.02)	0.97 (0.94, 1.00)	0.932
WAI ratio*	0.94 (0.70, 1.17)	0.53 (0.40, 0.65)	< 0.001
Kalamchi classification			
No avascular necrosis	0	5	
Group I	3	3	
Group II	7	13	
Group III	4	7	
Group IV	0	0	
Harris hip score*	99 (97.77, 99.94)	99 (99.08, 100.06)	0.362
SF-36*	83 (76.54, 89.03)	85 (80.86, 89.07)	0.468
SF-36 (physical health dimension)*	82 (75.81, 88.34)	87 (83.23, 90.62)	0.198
SF-36 (mental health dimension)*	78 (70.39, 85.32)	79 (73.77, 84.38)	0.742

* Mann-Whitney test; [†]Fisher's exact test; VCA angle = vertical-center- anterior margin angle; AAHI = anterior acetabular head index; WAI = weightbearing zone acetabular index; relative risk ratio of all parameters is the value of the surgically treated side divided by that of the nonoperated side.

employed. In contrast, the Pemberton acetabuloplasty was performed later during the study period, therefore the patients who had this procedure were still students and were more readily available to return for followups. We think the results of the 42 patients who completed their followups could represent the clinical course for patients in each group. Robb et al. [10] measured acetabular retroversion of 17 skeletally mature hips after Salter osteotomies. Only two (12%) showed retroversion and they believed that acetabular remodeling might occur after the Salter osteotomy. Barnes et al. [1] measured anterior coverage in 26 hips at 40 years followup after the Salter osteotomy. There were no significant differences in anterior coverage among surgically treated hips, contralateral hips, and normal age-matched hips. They suggested that performing the Salter osteotomy before the patient is 5 years old did not consistently cause acetabular retroversion that persisted to adulthood. Among the four studies [1, 3, 10, 12] regarding anterior acetabular coverage after Salter osteotomy, the two studies reporting a remodeling effect were those with longer followups (Table 4). Our patients underwent surgeries when they were between 12 to 36 months old, which is

younger than patients in other studies [1, 3, 10, 12]. They may have more remodeling potential. Compatible with other studies [1, 10], the change in anterior acetabular coverage in the Salter group in our study was not significant after an average of 22 years of followup. For the Pemberton group, we cannot conclude that remodeling continues and the weightbearing zone acetabular index would be restored after a longer followup. Third, if there is femoral neck angulation or femoral head deformity as a result of avascular necrosis even to a minimal degree, the eccentric center of the femoral head or increased head width would affect measurement of the vertical-center-anterior margin angle and anterior acetabular head index. We think these two radiographic parameters may be less reliable in describing the change of acetabulum anterior coverage. In our study, there were some degrees of femoral neck angulation or femoral head deformity in 88% of patients (37 of 42). Therefore we designed the weightbearing zone acetabular index, which could show the change of acetabular anterior coverage without referring to head center or width.

Only a few studies focused on anterior coverage change or retroversion after a Salter osteotomy [1, 3, 10, 12]

Table 4. Studies of acetabular anterior coverage after Salter osteotomy

Variable	Takashi et al. [12]	Dora et al. [3]	Robb et al. [10]	Barnes et al. [1]	Current study
Type of surgery	Salter osteotomy	Salter osteotomy, triple pelvic osteotomy	Salter osteotomy	Salter osteotomy	Salter osteotomy, Pemberton acetabuloplasty
Number of hips/patients	30 / 30	90 / 73	17 / 16	36 / 30	42 / 42
Mean age of patients at surgery (years)	6	4.8	5	2.8	1.6
Mean followup (years)	10.4	11.5	15	> 40	17.7
Measurement method	AP radiograph, computer program [6]	AP radiograph, Hefti template [4]	AP radiograph, Hefti template [4]	AP radiograph, Hefti template [4]	False profile radiograph, direct measurement
Radiographic results	Anterior-half coverage of the involved side was greater than the values for the unaffected side; anterior inclination of the distal fragment obtained by Salter osteotomy continues until bone maturation.	Anterior overcoverage after Salter and triple pelvic osteotomy was frequent; acetabular remodeling during growth seems not to be sufficient to correct this malalignment until maturity.	Only 2 patients (12%) showed retroversion; acetabular remodeling may occur with age.	No significant difference between anterior coverage; Salter osteotomy before the age of 5 years did not consistently cause acetabular retroversion that persisted into adulthood.	Acetabular anterior coverage increased after Pemberton acetabuloplasty compared with the nonoperated side and after the Salter acetabuloplasty.
Functional results	No functional results were provided.	Only 6 of 26 hips showing anterior overcoverage were available for clinical examination; only one patient reported spontaneously about pain in groin after physical activity.	The mean average Harris hip score was 85; neither of the 2 patients with retroversion had signs of impingement.	No functional results were provided.	The Harris hip score and SF-36 with at least 10 years followup were good and similar for Salter and Pemberton procedures.

(Table 4) and no study after Pemberton acetabuloplasty. These studies used the Hefti template [4] or a computer program [6] to measure acetabular anterior coverage on an AP radiograph of the pelvis. The results were heterogeneous. We evaluated the acetabular anterior coverage by false profile radiographs of the hip, which are useful in evaluating postoperative femoral head coverage and also in investigating the natural history of osteoarthritis of the hip by the amount of anterior coverage. Measurements of anterior coverage were easy and straightforward with high intraobserver and interobserver reliabilities. We found no differences in the vertical-center-anterior margin angle and anterior acetabular head index, but the weightbearing zone acetabular index ratio was significantly different between hips that had the Pemberton acetabuloplasty and the nonoperated control hips and also between the hips that had Pemberton and Salter procedures. The lower weightbearing zone acetabular index in the Pemberton group is the result of reshaping the acetabulum by hinging the triradiate

cartilage anteriorly and laterally, and reflects improved anterior acetabulum coverage after the procedure (Table 3).

Although a deficient acetabulum is treated in different ways with the Salter osteotomy and Pemberton acetabuloplasty, in our study, there were no differences between the functional results. The postoperative Harris hip scores and SF-36 scores were good, and only a few patients had symptoms or the impingement sign. Among four previous studies regarding anterior acetabular coverage change after a Salter osteotomy [1, 3, 10, 12], only two provided clinical or functional results [3, 10] (Table 4). Only six of 73 patients were available for clinical examination and only one reported hip pain according to Dora et al. [3]. Robb et al. [10] reported a mean average Harris hip score of 85. According to these studies and our study, the clinical importance of anterior acetabular coverage and how much overcoverage can cause symptoms or impingement remain unanswered.

At a mean followup of 18 years, neither the Salter osteotomy nor the Pemberton acetabuloplasty increases the

vertical-center-anterior margin angle and anterior acetabular head index on false profile radiographs of the hip. There is no definite answer regarding how anterior coverage increases in both procedures, therefore, by measuring the weightbearing zone acetabular index, we found the index in the Pemberton group decreased compared with that on the nonoperated side or on the surgically treated side in the Salter group. This implies that by modifying the shape of the acetabulum with a hinge in the triradiate cartilage, a Pemberton acetabuloplasty may cause an increase in acetabular anterior coverage, which may increase the risk of impingement. Longer followup is needed to determine whether the differences in anterior acetabular coverage between the procedures will result in more patients presenting with femoroacetabular impingement or premature osteoarthritic changes.

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