Does Salter Innominate Osteotomy Predispose the Patient to Acetabular Retroversion in Adulthood?

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Abstract

Background Salter innominate osteotomy has been identified as an effective additional surgery for the dysplastic hip. However, because in this procedure, the distal segment of the pelvis is displaced laterally and anteriorly, it may predispose the patient to acetabular retroversion. The degree to which this may be the case, however, remains incompletely characterized.

Questions/purposes We asked, in a group of pediatric patients with acetabular dysplasia who underwent Salter osteotomy, whether the operated hip developed (1) acetabular retroversion compared with contralateral unaffected hips; (2) radiographic evidence of osteoarthritis; or (3)

worse functional scores. (4) In addition, we asked whether femoral head deformity resulting from aseptic necrosis was a risk factor for acetabular retroversion.

Methods Between 1971 and 2001, we performed 213 Salter innominate osteotomies for unilateral pediatric dysplasia, of which 99 hips (47%) in 99 patients were available for review at a mean of 16 years after surgery (range, 12–25 years). Average patient age at surgery was 4 years (range, 2–9 years) and the average age at the most recent followup was 21 years (range, 18–29 years). Acetabular retroversion was diagnosed based on the presence of a positive crossover sign and prominence of the ischial spine sign at the final visit. The center-edge angle, acetabular angle of Sharp, and acetabular index were measured at preoperative and final visits. Contralateral unaffected hips were used as controls, and statistical comparison was made in each patient. Clinical findings, including Harris hip score (HHS) and the anterior impingement sign, were recorded at the final visit.

Results Patients were no more likely to have a positive crossover sign in the surgically treated hips (20 of 99 hips [20%]) than in the contralateral control hips (17 of 99 hips [17%]; $p = 0.584$). In addition, the percentage of positive prominence of the ischial spine sign was not different between treated hips (22 of 99 hips [22%]) and contralateral hips (18 of 99 hips [18%]; $p = 0.256$). Hips that had a positive crossover or prominence of the ischial spine sign in the operated hips were likely also to have a positive crossover sign or prominence of the ischial spine sign in the unaffected hips (16 of 20 hips [80%] crossover sign, 17 of 22 hips [77%] prominence of the ischial spine sign). At the final visit, five hips (5%) showed osteoarthritic change; one of the five hips (20%) showed positive crossover and prominence of the ischial spine signs, and the remaining four hips showed negative crossover and prominence of the

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ischial spine signs. There was no significant difference in HHS between the crossover-positive and crossover-negative patient groups nor in the prominence of the ischial spine-positive and prominence of the ischial spine-negative patient groups (crossover sign, $p = 0.68$; prominence of the ischial spine sign, $p = 0.54$). Hips with femoral head deformity (25 of 99 hips [25%]) were more likely to have acetabular retroversion compared with hips without femoral-head deformity (crossover sign, $p = 0.029$, prominence of the ischial spine sign, $p = 0.013$).

Conclusions Our results suggest that Salter innominate osteotomy does not consistently cause acetabular retroversion in adulthood. We propose that retroversion of the acetabulum is a result of intrinsic development of the pelvis in each patient. A longer-term followup study is needed to determine whether retroverted acetabulum after Slater innominate osteotomy is a true risk factor for early osteoarthritis. Femoral head deformity is a risk factor for subsequent acetabular retroversion.

Level of Evidence Level III, therapeutic study.

Introduction

Femoroacetabular impingement (FAI) is increasingly recognized as an important cause of labral tears, osteochondral lesions, and hip pain in young adults and a leading cause of early osteoarthritis (OA). Reynolds et al. [16] investigated hip pain resulting from retroversion of the acetabulum. In their report, 28 of 43 hips showed acetabular retroversion to be the origin of patient groin pain, which was reproduced by a positive impingement test. Furthermore, Giori and Trousdale [8] reported that the frequency of acetabular retroversion is higher in patients with severe OA than that in the general population and concluded that there is an association between radiographic acetabular retroversion and hip OA. There is a general agreement that the presence of acetabular retroversion is a risk for focal overcoverage, constituting one of the subtypes of pincer-type FAI, which may also be a risk factor for subsequent OA.

Salter innominate osteotomy is an effective surgery for residual subluxation of the hip. Several studies [3, 4, 13, 19] have shown, that radiological improvement and avoiding the progression of early onset of OA can be expected after Salter innominate osteotomy; however, the distal segment of the pelvis is displaced laterally and anteriorly during the procedure, possibly predisposing the patient to acetabular retroversion. Although a few studies [2, 5, 17] have sought to clarify the relationship between Salter innominate osteotomy and subsequent acetabular retroversion, there remains considerable disagreement. Potential causes for this may have been small numbers of patients studied, differing

definitions of acetabular retroversion, the control group used for comparison, and the duration of followup.

Therefore, we asked whether a group of pediatric patients with acetabular dysplasia who underwent Salter osteotomy had in the operated hip (1) acetabular retroversion compared with contralateral unaffected hips; (2) radiographic evidence of OA; or (3) worse functional scores. (4) In addition, we asked whether femoral head deformity resulting from aseptic necrosis was a risk factor for acetabular retroversion.

Patients and Methods

Between October 1971 and December 2001 at our hospital, we performed 265 Salter innominate osteotomies in 250 patients for developmental dysplasia of the hip (DDH). We excluded the patients with bilateral DDH, neuromuscular disease, or syndromic disorders. Of the 250 children, 213 patients were identified and 37 patients were excluded as per these criteria. To be considered for this study, clinical and radiographic followup through the age of 18 years was required. This filter left us 99 patients (47% of the original 213), and 114 patients were excluded from our study for inadequate review. Average patient age at pelvic surgery was 4 years (range, 2–9 years), and average patient age at most recent followup was 21 years (range, 18–29 years). The study patients included 90 girls and nine boys. Procedures to reduce the dislocated hip included use of a Pavlik harness (Kinki, Japan) (63 hips), closed reduction with traction (16 hips), closed reduction without traction (13 hips), and open reduction (seven hips).

We have performed Salter innominate osteotomy for residual acetabular dysplasia in patients with DDH as the first choice of additional surgical procedure since 1971. Salter innominate osteotomy was performed as originally described by Salter [18]. Our general indication for Salter osteotomy for residual dysplasia was either an acetabular index (AI) $\geq 30^\circ$ or a center-edge angle (CEA) of Wiberg [26] $\leq 5^\circ$ at 3 to 6 years of age. Ninety-one hips underwent Salter osteotomy only; seven hips underwent Salter osteotomy combined with open reduction, and one hip underwent Salter osteotomy combined with intertrochanteric varus femoral osteotomy. Three hips had intertrochanteric derotational femoral osteotomy 6 to 8 years after Salter innominate osteotomy because of developmental valgus deformity of the femoral head. No surgical procedure was performed on the contralateral control hips.

Acetabular retroversion was diagnosed on the basis of the presence of a positive crossover sign and prominence of the ischial spine sign on AP radiographs of the pelvis at the patient's final visit. The AP radiographs were obtained with

the patient in the supine position. To assess the extent of pelvic inclination, we used the system described by Siebenrock et al. [21]. A crossover sign is positive when the anterior aspect of the acetabular rim is more lateral to the posterior aspect in the proximal part of the acetabulum. A prominence of the ischial spine sign is positive when more than 1 mm of the tip of the ischial spine is visible on AP radiograph as a projection into the pelvic cavity. Radiographic assessments of crossover and prominence of the ischial spine signs were performed three times on different occasions by two observers (DK, MK) and intraobserver and interobserver reliabilities were evaluated. For the crossover sign, the intraobserver reliability of the measurement, evaluated with the use of the interclass correlation coefficient, was 0.843 (range, 0.8421–0.8581) and interobserver reliability was 0.781 (range, 0.7369–0.8299). For the prominence of the ischial spine sign, the intraobserver reliability was 0.854 (range, 0.8100–0.8920), and interobserver reliability was 0.820 (range, 0.7712–0.8540). The CEA was measured at the preoperative and final visits. The center of the femoral head in study patients was determined using the Wiberg method [26]. Acetabular angle of Sharp (the Sharp angle) was measured at the final visit, and AI was measured at the preoperative visit. The grade of aseptic necrosis of the femoral head was classified according to the system of Kalamchi and MacEwen [10] and the severity of OA was evaluated by the system of Tönnis and Heinecke [23]. Patients' contralateral hips were used as controls, and a comparison was made in each patient. Radiographic evaluations except crossover and prominence of the ischial spine signs were performed by a single orthopaedic surgeon (DK).

To evaluate clinical findings, Harris hip score (HHS) and the presence or absence of an anterior impingement sign (discomfort in flexion and internal rotation) in each patient were recorded at the most recent followup by two senior surgeons (DK, SS).

All statistical analyses were performed with JMP software (Version 10; SAS Institute, Inc, Cary, NC, USA). Intraobserver and interobserver reliabilities were evaluated using kappa statistics. To compare the frequency of retroversion in each patient, Fisher's exact test was used. To compare preoperative and final radiographic data between operated hips and contralateral hips, the t-test or Fisher's exact test was used. To compare radiographic parameters between the retroversion and nonretroversion group, the Mann-Whitney U test or Fisher's exact test was used. When the *p* value was < 0.05, the difference was considered to be significant.

Results

Acetabular retroversion was no more likely to be observed in hips that had Salter osteotomies than in the uninvolved

contralateral hips. In addition, patients who developed acetabular retroversion in the hips treated surgically were also likely to have it in the contralateral hip that was not treated surgically.

A positive crossover sign was noted in 20 (20%) of 99 operated hips compared with 17 (17%) of 99 contralateral hips (*p* = 0.584). Hips that had a positive crossover sign in the operated hips were likely also to have a positive crossover sign in the unaffected hips (16 of 20 hips [80%]) (Fig. 1A–C). There were no differences in patient age at operation, preoperative or final CEA, preoperative AI, or

Fig. 1A–C (A) Preoperative AP pelvic radiograph of a female patient revealed unilateral (left) hip dysplasia. (B) At age 3 years 3 months, Salter innominate osteotomy was performed on the left hip. (C) At age 20 years, positive crossover and prominence of the ischial spine signs were noted in both the operated hip (left) and unaffected hip (right).

Table 1. Comparisons of clinical and radiological parameters between crossover-positive and -negative signs in operated hips

Clinical and radiographic data	Crossover-positive (n = 20)	Crossover-negative (n = 79)	p value
Age at the operation, mean months $\pm$ SD (range)	51 $\pm$ 19 (29–103)	48 $\pm$ 19 (24–111)	0.631
Preoperative CEA, mean degrees $\pm$ SD (range)	1.8 $\pm$ 6 (–12 to 10)	–0.9 $\pm$ 9 (–24 to 15)	0.085
Preoperative AI, mean degrees $\pm$ SD (range)	35 $\pm$ 5.6 (25–46)	33 $\pm$ 5.8 (22–44)	0.182
Final CEA, mean degrees $\pm$ SD (range)	28 $\pm$ 10.7 (0–40)	27 $\pm$ 10.1 (–5 to 47)	0.728
Final sharp angle, mean degrees $\pm$ SD (range)	41 $\pm$ 5.2 (32–53)	43 $\pm$ 3.7 (34–53)	0.560
Prominence of the ischial spine-positive	14/20 (70%)	8/79 (10%)	< 0.0001*

* p value significant ($p < 0.05$); CEA = center-edge angle; AI = acetabular index.

Table 2. Preoperative and final radiographic data in operated and contralateral hips

Radiographic data	Operated hips	Contralateral hips	p value
Preoperative CEA, mean degrees $\pm$ SD (range)	–0.76 $\pm$ 8 (–24 to 15)	11 $\pm$ 5 (3–22)	< 0.0001*
Preoperative AI, mean degrees $\pm$ SD (range)	33 $\pm$ 6 (22–46)	25 $\pm$ 4.5 (18–32)	< 0.0001*
Final CEA, mean degrees $\pm$ SD (range)	27 $\pm$ 10 (–5 to 47)	25 $\pm$ 8 (9–40)	0.184
Final sharp angle, mean degrees $\pm$ SD (range)	42 $\pm$ 4.0 (32–53)	43 $\pm$ 4.3 (34–54)	0.182
Femoral head deformity, number/Number (%) (Kalamuchi II, III, IV)	25/99 (25)	0/99 (0)	< 0.0001*

* p value significant ($p < 0.05$); CEA = center-edge angle; AI = acetabular index.

final Sharp angle between the crossover-positive and crossover-negative groups for the operated hips (Table 1).

A positive prominence of the ischial spine sign was noted in 22 (22%) of the 99 operated hips and in 18 (18%) of the 99 contralateral hips ($p = 0.479$). Compared with the prevalence of a positive prominence of the ischial spine sign in the 22 operated hips, the prevalence of the sign was 77% (17 hips) in the contralateral hips. There were no differences in patient age at operation, preoperative or final CEA, preoperative AI, or final Sharp angle between the prominence of the ischial spine-positive and prominence of the ischial spine-negative groups for the operated hips. Fourteen (70%) of 20 operated hips with a positive crossover sign had a positive prominence of the ischial spine sign, and only eight (10%) of 79 hips with a negative crossover sign had a positive prominence of the ischial spine sign ($p < 0.001$) (Table 1). Furthermore, 15 (75%) of 20 contralateral hips with a positive crossover sign showed a positive prominence of the ischial spine sign, and 74 (94%) of 79 contralateral hips with a negative crossover sign showed a negative prominence of the ischial spine sign. The presence or absence of a prominence of the ischial spine sign was correlated ($p < 0.001$) with the presence or absence of crossover in both operated and contralateral hip groups. The preoperative CEA in operative hips was smaller than those in contralateral hips (operated hips -0.76° , 95% confidence intervals [CIs], -2.43 to 0.926 ; contralateral hips 11° , 95% CIs, 9.01 – 13.30 , $p < 0.001$; Table 2). The preoperative AI in operated hips was larger than those in contralateral hips

(operated hips 33° , 95% CIs, 31.8 – 34.2 ; contralateral hips 25° , 95% CIs, 23.1 – 26.8 , $p < 0.001$; Table 2).

At the final visit, five hips (5%) showed sclerotic change of the acetabulum, and two of the five hips showed slight joint space narrowing. All five hips were categorized as Grade I according to the Tönnis classification [23]. One of the five hips (20%) showed positive crossover and prominence of the ischial spine signs, and the remaining four hips showed negative crossover and prominence of the ischial spine signs.

Four patients had mild hip pain with no effect on average activities, and 17 patients had occasional slight hip pain at the final followup visit. The mean HHS in the operated hips was 98 ± 4.2 (range, 83–100). The incidence of positive symptoms did not differ between patients with and without positive crossover or prominence of the ischial spine signs (Table 3). Despite symptoms, the patients still had high HHS scores. There was no difference in HHS between the crossover-positive and crossover-negative patient groups nor in the prominence of the ischial spine-positive and prominence of the ischial spine-negative patient groups (crossover, $p = 0.684$, prominence of the ischial spine, $p = 0.536$). No patient had a positive anterior impingement sign.

Aseptic necrosis of the femoral head was noted in 43 hips (43%). Using the Kalamchi and MacEwen classification system [10], 18 hips were classified as Group I, 14 as Group II, 10 as Group III, and one as Group IV. We categorized the 25 hips in Groups II, III, and IV as having femoral head deformity (femoral head deformity group),

Table 3. Comparison of clinical findings between crossover-positive and -negative and prominence of the ischial spine-positive and -negative groups

Clinical findings	Crossover-positive (n = 20)	Crossover-negative (n = 79)	p value	Prominence of the ischial spine-positive (n = 22)	Prominence of the ischial spine-negative (n = 77)	p value
Symptoms of operated hips, number/Number (%)						
None	16/20 (80)	60/79 (76)	0.5372	18/22 (82)	58/77 (75)	0.6895
Occasional slight hip pain	3/20 (15)	14/79 (18)	0.8200	3/22 (14)	14/77 (18)	0.5198
Mild hip pain	1/20 (5)	5/79 (6)	0.8735	1/22 (4)	5/77 (7)	0.7275
Harris hip score (mean $\pm$ SD, range)	99 $\pm$ 3 (86–100)	98 $\pm$ 4 (83–100)	0.6845	99 $\pm$ 3 (86–100)	98 $\pm$ 4 (83–100)	0.5361
Anterior impingement sign, number/Number (%)	0/20 (0)	0/79 (0)	1.00	0/22 (0)	0/77 (0)	1.000

Significant difference $p < 0.05$.

where a positive crossover sign was noted in nine (36%) of 25 hips, and a positive prominence of the ischial spine sign was noted in 10 (40%) of 25 hips (Fig. 2). In the no femoral head deformity group, a positive crossover sign was noted in 13 hips (17%) and a positive prominence of the ischial spine sign was noted in 13 hips (17%). The prevalence of retroversion in the two groups showed a significant difference according to the crossover ($p = 0.0292$) and prominence of the ischial spine ($p = 0.0134$) signs.

Discussion

In recent years, there has been a renewed interest in the relationship between pelvic osteotomy and subsequent acetabular retroversion [1, 2, 5, 17, 24, 27]. Ziebarth et al. [27] observed a high postoperative rate of clinical signs of FAI and acetabular retroversion (19 of 46 hips) after Bernese periacetabular osteotomy performed at an average patient age of 23.5 years despite the normalization of acetabular coverage. Akiyama et al. [1] demonstrated the presence of acetabular retroversion in 37.5% of hips after Pemberton osteotomy compared with 10% of hips treated by a Pavlik harness at skeletal maturity. It seems reasonable to conclude that pelvic osteotomy has a risk of predisposing the operated hip to acetabular retroversion in adulthood. Robb et al. [17] investigated acetabular retroversion after Salter innominate osteotomy at an average patient followup age of 20 years. In their series, only two of 16 patients (12.5%) showed acetabular retroversion, suggesting long-term anterior overcoverage and retroversion with this procedure were unfounded. Barnes et al. [2] noted no difference in anterior coverage among 26 hips after Salter innominate osteotomy compared with 20 contralateral hips. Results from both Robb et al. and Barnes et al. were similar to those of our study despite the small number of patients they studied. Dora et al. [5] investigated anterior

overcoverage after 85 Salter innominate osteotomies and 10 triple osteotomies and concluded that acetabular retroversion after pelvic osteotomy is frequent (60% of cases after triple osteotomy; 24% of cases after Salter innominate osteotomy); however, the control group used for comparison in their study was unclear. We believe that a comparison with the contralateral hip in each patient provides the most reliable information for evaluating the contribution of Salter osteotomy to acetabular retroversion, although the contralateral hip may prove to have minor degrees of dysplasia at skeletal maturity. The coexistence and prevalence of acetabular retroversion in operated and contralateral hips suggest that Salter innominate osteotomy is not a risk factor for retroverted acetabulum. The most likely explanation is that retroversion of the pelvis is instead caused by the intrinsic pelvic development of each patient. Retroversion is less frequent in patients who have undergone Salter innominate osteotomy than in those with other pelvic osteotomies because of the younger age at which Salter osteotomy is performed. Patients in our study underwent Salter osteotomy at an average age of 4 years, and even the oldest patient was only 9.2 years old. Morphologic remodeling of the pelvis may progress during skeletal maturation.

There are several limitations to our study. First, although we are presenting long-term followup on these operations, the patients remain quite young, and so the contribution of retroverted acetabulum to OA could not be fully characterized. The number of osteoarthritic hips simply was too small to evaluate in our study for us to reliably infer a relationship between acetabular retroversion after Salter innominate osteotomy and subsequent early onset of OA. Second, the proportion of avascular necrosis (AVN) in this study was relatively high (AVN 43%, femoral head deformity 25%). These findings may have influenced final radiological or clinical outcomes. Third, we used crossover and prominence of the ischial spine signs for defining

Fig. 2 The prevalence of crossover and prominence of the ischial spine signs between the femoral head deformity group and no femoral head deformity group is shown. Significant differences were observed in the prevalence of crossover and prominence of the ischial spine

signs between patient groups with and without femoral head deformity. CO = crossover; PRIS = prominence of the ischial spine.

retroverted acetabulum. Given that both signs can be obtained by AP radiography, they are convenient and minimally invasive indicators for evaluating the presence of acetabular retroversion and have accordingly been used in many studies [1, 6–8, 11, 12, 15, 16, 20–22, 26, 27]. However, some recent studies stated that the crossover sign is not a reliable indicator for the assessment of acetabular retroversion. A comparison of plain radiographs and CT images by Wassilew et al. [25] led them to report that a positive crossover sign is strongly correlated with pelvic tilt, and the authors suggested that the crossover sign determined from AP radiographs is considerably limited by pelvic tilt and inherent limitations of radiographs. An analysis using CT or MRI would be necessary for a more detailed understanding of acetabulum morphology, and future studies might consider these questions. Fourth, this study may include some potential selection or assessment biases. Because our observer (DK) was one of the osteotomy surgeons and performed both clinical and radiological assessments, unintentional bias may have influenced the results of the radiological and clinical assessments. In addition, the radiological and functional outcome data were also limited because this cohort represents 47% of the study population. However, these 47% of patients in our study showed good functional outcomes. No one had severe hip pain and received THA or other pelvic surgery. Therefore, loss to followup may not have a substantial influence on our conclusions. Despite these potential biases, we believe our data are reasonable.

Our study revealed that clinical features at the final patient followup visit were not different between retroverted and nonretroverted hips. In addition, clinical signs of FAI were not observed. These results suggested that

positive crossover or prominence of the ischial spine signs are not a pathologic indicator clinically. This observation contradicts Reynolds et al.'s proposal [16] that all the symptomatic hips with acetabular retroversion have a positive anterior impingement. The comparison study between Salter and Pemberton osteotomy by Wang et al. [24] showed no patient displayed a positive anterior impingement sign in the patients after Salter osteotomy compared with 11% of patients showing a positive sign after Pemberton osteotomy. Their study showed less frequency of clinical sign of FAI after Salter osteotomy and was consistent with ours. However, because patient clinical features in early adult stages (average patient followup age, 21 years) could not be reliably evaluated, we cannot be certain of this theory in this study. Damage of the labrum or osteochondral lesion may not have been correctly evaluated. Patients must be followed carefully with attention to positive anterior impingement signs. A longer followup period is required to determine whether acetabular retroversion observed after Salter innominate osteotomy is a truly pathological feature or a clinically acceptable finding.

The relationship between femoral head deformity and acetabular retroversion is interesting. Several studies [6, 12, 20] have revealed a high prevalence of acetabular retroversion in patients with Legg-Calvé-Perthes disease. Kawahara et al. [12] noted that acetabular retroversion appeared in 49.5% of hips with this disease and that positive retroversion was significantly correlated with the severity of the femoral-head deformity. Sankar and Flynn [20] investigated the prevalence of acetabular retroversion in patients with Legg-Calvé-Perthes disease during and after skeletal maturity and reported that the prevalence of

acetabular retroversion before skeletal maturity (1.8%) was rare compared with that after skeletal maturity (31%). They accordingly suggested that the high prevalence of acetabular retroversion was not the cause of Legg-Calvé-Perthes disease but showed a cause-and-effect relationship with femoral head deformity. In our study, hips with femoral head deformity were more likely to have acetabular retroversion compared with hips without femoral head deformity. To our knowledge, ours is the first report describing a relationship between acetabular retroversion and femoral head deformity after aseptic necrosis in patients with DDH. We speculate that the same morphological changes that occur with Legg-Calvé-Perthes disease ensue in the affected pelvis as a result of femoral head deformity. Femoral head deformity resulting from aseptic necrosis is a risk factor for subsequent acetabular retroversion.

It is important for us to examine how often acetabular retroversion is noted in the normal population given that in our study, we used the contralateral hip in patients with unilateral DDH as a control. On radiographic evaluation of healthy adult volunteers, Ezoe et al. [6] noted acetabular retroversion in only seven (6%) of 112 hips. In contrast to the low rate of acetabular retroversion in the normal population, the ratio of retroversion in patients with DDH was high. In a review of the literature, Fujii et al. [7] reported an incidence of 17.7% of retroverted acetabulum in 96 patients with DDH compared with 4% in normal hips. Li and Ganz [15] reported that acetabular retroversion was found in 40 (17.2%) of 232 hips with DDH. The incidence of acetabular retroversion in our study—which showed 20% crossover-positive and 22% prominence of the ischial spine-positive operated hips and 17% crossover-positive and 18% prominence of the ischial spine-positive contralateral hips—was higher than the incidences for the same in the normal population and similar to those in patients with DDH. The reason why the contralateral hip in patients with unilateral DDH showed a high prevalence of acetabular retroversion remains unknown. We previously reported a relatively high rate (13%) of acetabular dysplasia ($\text{CEA} < 20^\circ$) at skeletal maturity in the contralateral hip in patients with unilateral DDH [14]. In addition, Jacobsen et al. [9] reported that 34% of patients with unilateral dislocation of the hip developed contralateral acetabular dysplasia, confirming that patients with unilateral DDH are at risk of developing contralateral dysplastic malformation. These data and our results suggest that contralateral hips in patients with unilateral DDH are not true normal hips when three-dimensional pelvic imaging and frontal plain radiograph are used for evaluation.

In conclusion, we note that in our study, a positive crossover sign was observed in 20% of patients and a positive prominence of the ischial spine sign was observed in 22% of patients who underwent Salter innominate

osteotomy once the children reached skeletal maturity. However, hips contralateral to those with retroversion after Salter osteotomy showed a high prevalence of acetabular retroversion. Our results thus suggest that Salter osteotomy does not consistently cause acetabular retroversion in adulthood. We propose that retroversion of the acetabulum is a result of intrinsic development of the pelvis in each patient. In our study, prevalence of acetabular retroversion in patients with femoral head deformity was significantly higher than in patients without such deformity. Aseptic necrosis after DDH treatment presented a risk of predisposing the pelvis to subsequent acetabular retroversion. The prevalence of acetabular retroversion of the contralateral hip in patients with unilateral DDH was more frequent than that in the normal population. We do not know why the frequency of retroverted acetabulum appeared not only in the affected hip, but also in the contralateral unaffected hip. A longer-term followup study, using a large patient sample, is needed to determine whether retroverted acetabulum after Slater innominate osteotomy is a true risk factor for early OA.

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