Acetabular Development in the Contralateral Hip in Patients with Unilateral Developmental Dysplasia of the Hip

D. Kobayashi, S. Satsuma, R. Kuroda and M. Kurosaka
J Bone Joint Surg Am. 2010;92:1390-1397. doi:10.2106/JBJS.I.00840

Acetabular Development in the Contralateral Hip in Patients with Unilateral Developmental Dysplasia of the Hip

By D. Kobayashi, MD, S. Satsuma, MD, R. Kuroda, MD, and M. Kurosaka, MD

Investigation performed at Kobe Children's Hospital, Kobe, Japan

Background: Adult patients may present with acetabular dysplasia without a history of developmental dysplasia of the hip. The purpose of the present study was to clarify the development of primary acetabular dysplasia in patients under the age of eighteen years by evaluating the contralateral hip in those with unilateral developmental dysplasia of the hip.

Methods: Radiographs of the contralateral hip of eighty-eight patients with unilateral developmental dysplasia of the hip were reviewed retrospectively. The center-edge angle was measured at the age of eighteen years. The primary acetabular dysplasia group included hips with a center-edge angle of <20°, and the normal group included hips with an angle of ≥20°. The acetabular index at the age of three years, the center-edge angle between the ages of three and eighteen years, and the acetabular angle of Sharp between the ages of six and eighteen years were measured.

Results: According to our classification system, twelve hips (13.6%) were assigned to the primary acetabular dysplasia group. At the age of three years, there were no significant differences between the two groups radiographically. A significant difference in the center-edge angle between the two groups was seen at each evaluation period after the age of six years. However, twenty-two patients in the normal group had poor acetabular coverage and three patients in the primary acetabular dysplasia group had good acetabular coverage at the age of nine years. After the age of nine years, improvements in the center-edge angle and the acetabular angle of Sharp were noted in the normal group, whereas no acetabular growth was seen in the primary acetabular dysplasia group. There was no patient with a center-edge angle of <15° at the age of twelve years in the normal group.

Conclusions: After the age of six years, a difference in acetabular growth develops between patients with primary acetabular dysplasia and those with normal hips. However a final prognosis for acetabular development appears to be difficult to determine until the age of twelve years.

Level of Evidence: Prognostic Level II. See Instructions to Authors for a complete description of levels of evidence.

There is general agreement that acetabular dysplasia is a major risk factor for osteoarthritis of the hip. Acetabular dysplasia is usually classified into two groups: (1) acetabular dysplasia due to a dislocated or subluxated hip in which there is poor congruity between the femoral head and the acetabulum, and (2) acetabular dysplasia due to the inadequate intrinsic growth potential of the acetabulum in a patient without hip dislocation or subluxation. We use the term primary acetabular dysplasia to refer to acetabular dysplasia at skeletal maturity in a patient without a previously dislocated or subluxated hip. The natural course of acetabular development in the dislocated hip after closed or open reduction has been reported previously[1-6]. However, only a few attempts have been made to clearly understand the natural course of primary acetabular dysplasia. The present study used data on the contralateral unaffected hip in patients with unilateral developmental dysplasia of the hip to provide information about the natural history of acetabular development in patients with primary acetabular dysplasia.

Materials and Methods

One hundred and thirty-seven patients without neurological or other musculoskeletal disorders were seen at our institution with an initial diagnosis of unilateral developmental

Disclosure: The authors did not receive any outside funding or grants in support of their research for or preparation of this work. Neither they nor a member of their immediate families received payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity.

TABLE I Center-Edge Angle and Sharp Angle at Eighteen Years of Age

	Center-Edge Angle*	Sharp Angle*
Normal group (n = 76)	28.2° ± 5.2°	42.5° ± 3.0°
Primary acetabular dysplasia group (n = 12)	14.5° ± 4.6°	47.6° ± 3.2°

*The values are given as the mean and the standard deviation.

dysplasia of the hip between 1973 and 1991. Each child was required to have both clinical and radiographic follow-up from infancy to the age of eighteen years. Forty-seven patients were excluded because they did not have adequate follow-up radiographs for review. All of those patients were lost to follow-up because of personal reasons. We also excluded two patients who presented with subluxation in the uninvolved hip at the first visit. Therefore, all of the hips that were evaluated in the present study were both radiographically and clinically normal at the first visit. Eighty-eight hips in eighty-eight patients with unilateral developmental dysplasia of the hip that was diagnosed during infancy were included in our study and were reviewed retrospectively. The normal hip was the left hip in sixty-two patients and the right hip in twenty-six patients. The study group included eighty-one girls and seven boys with an average age of 3.4 months (range, one month to one year and two months) at the time of the first observation. Procedures to reduce the dislocated hip included the use of a Pavlik harness (forty-five hips), open reduction (twenty-five), closed reduction with traction (eleven), and closed reduction without traction (seven). Additional surgical procedures on the affected hip that were performed after or simultaneously with reduction included four femoral osteotomies and fifteen pelvic osteotomies. No surgical procedure was performed on the normal hip. Two pediatric orthopaedists (D.K. and S.S.) clinically evaluated the patients both initially and throughout the treatment periods.

The hips without developmental dysplasia of the hip (the contralateral hips) were periodically assessed with radiographs. The center-edge angle of the contralateral hip was measured at the ages of three, six, nine, twelve, fifteen, and eighteen years. The center of the femoral head in younger patients was determined with use of the Wiberg method[7]. The acetabular angle of Sharp (the Sharp angle)[8] in the contralateral hip was measured at the ages of six, nine, twelve, fifteen, and eighteen years, and the acetabular index was measured to evaluate the degree of dysplasia at the age of three years because the Sharp angle at this age was considered to be unreliable. In addition, we assessed radiographs to confirm that the secondary ossification center had appeared, with particular attention to the period between the ages of nine and fifteen years. All measurements were made by one investigator (D.K.). At the age of eighteen years, all patients were classified into one of two groups on the basis of the radiographic appearance of the hip: (1) the primary acetabular dysplasia group (center-edge angle, <20°) or (2) the normal group (center-edge angle, ≥20°). The developmental change of the center-edge angle and

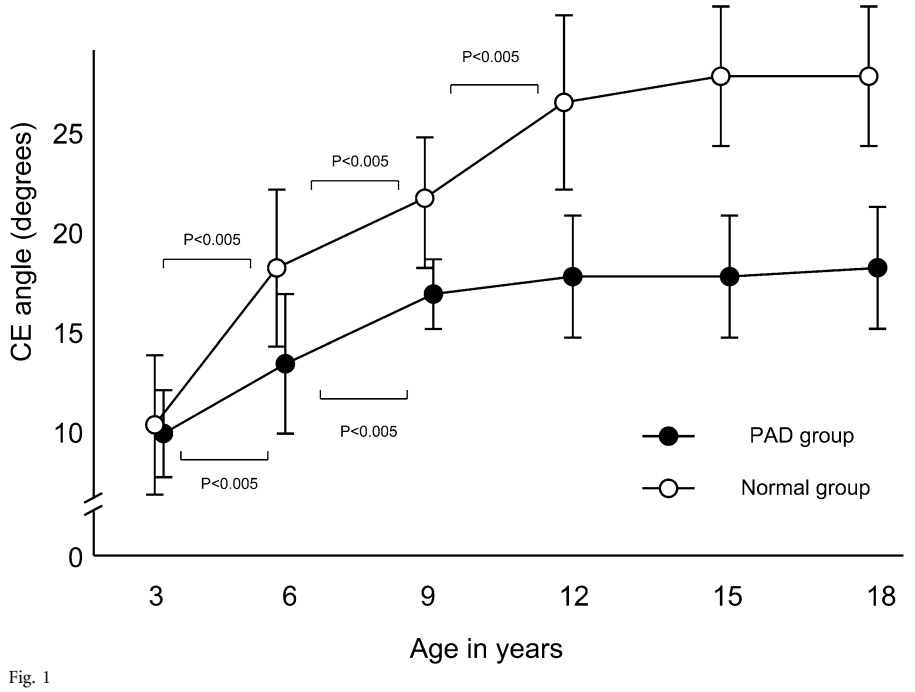

Fig. 1

Line graph illustrating developmental changes in the center-edge (CE) angle in the normal group and the primary acetabular dysplasia (PAD) group.

TABLE II Percentage of Patients with an Abnormal Center-Edge Angle (<20°) in Each Period

	3 Years	6 Years	9 Years	12 Years	15 Years
Normal group (n = 76)	94.7%	39.5%	28.9%	6.6%	1.3%
Primary acetabular dysplasia group (n = 12)	100%	91.7%	75%	83.3%	91.7%

the Sharp angle in each group was evaluated and compared at each period.

Statistical Analysis

Data were analyzed statistically with use of the Student t test. Paired analysis was performed for comparisons of developmental growth in individual patients, and unpaired analysis was performed for comparisons between groups. The level of significance was set at $p < 0.05$.

Source of Funding

There was no external funding source in this investigation.

Results

Final Evaluation of Contralateral Hips

The mean center-edge angle (and standard deviation) of the contralateral hip at the age of eighteen years was 25.9° ± 7.4° (range, 7° to 42°), and the mean Sharp angle at the age of eighteen years was 43.3° ± 3.5° (range, 36° to 52°). No femoral deformity (osteonecrosis or proximal femoral growth arrest) and no signs of osteoarthritis were found in any of the contralateral hips. Of the eighty-eight hips in our study, twelve (13.6%) were assigned to the primary acetabular dysplasia group (Table I). In the primary acetabular dysplasia group, the average center-edge angle was 14.5° ± 4.6° (range, 6° to 19°) and the average Sharp angle was 47.6° ± 3.2° (range, 43° to 52°). In the normal group, the procedures for reducing the dislocated hip included a Pavlik harness (forty hips), open reduction (twenty-two), closed reduction with traction (nine), and closed reduction without traction (five). In the primary acetabular dysplasia group, the procedures for reducing the dislocated hip included a Pavlik harness (five hips), open reduction (three), closed reduction with traction (two), and closed reduction without traction (two).

Acetabular Index and Center-Edge Angle at the Age of Three Years

The mean acetabular index at the age of three years was 26.3° ± 4.6° (range, 17° to 35°) in the primary acetabular dysplasia group and 24.1° ± 4.1° (range, 18° to 32°) in the normal group; with the numbers studied, this difference was not significantly different. Only two hips in the primary acetabular dysplasia group had an acetabular index of >30° at this age.

The mean center-edge angle at the age of three years was 10.0° ± 5.2° (range, 1° to 17°) in the primary acetabular dysplasia group and 11.4° ± 6.0° (range, −5° to 20°) in the normal

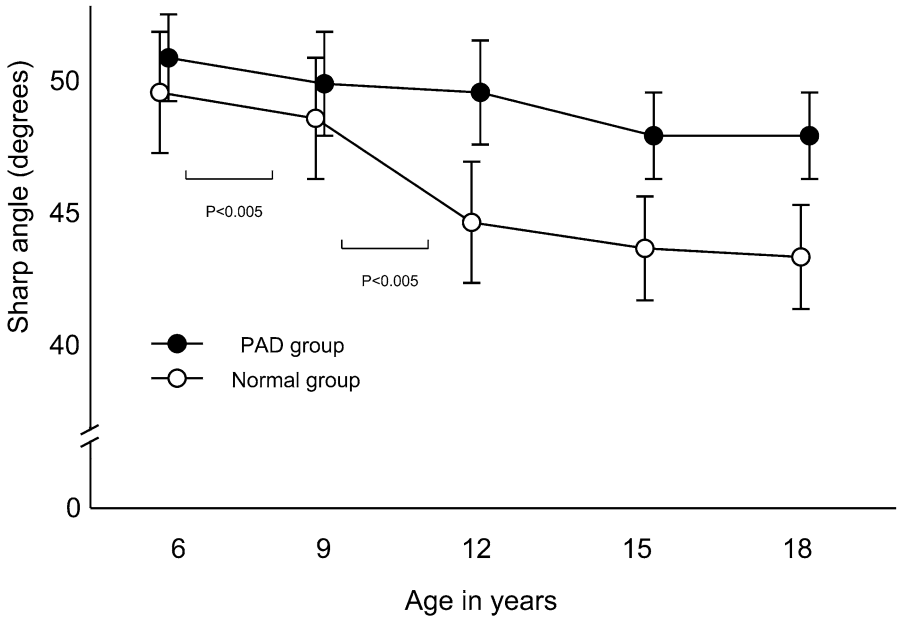

Fig. 2

Line graph illustrating developmental changes in the Sharp angle in the normal group and the primary acetabular dysplasia (PAD) group.

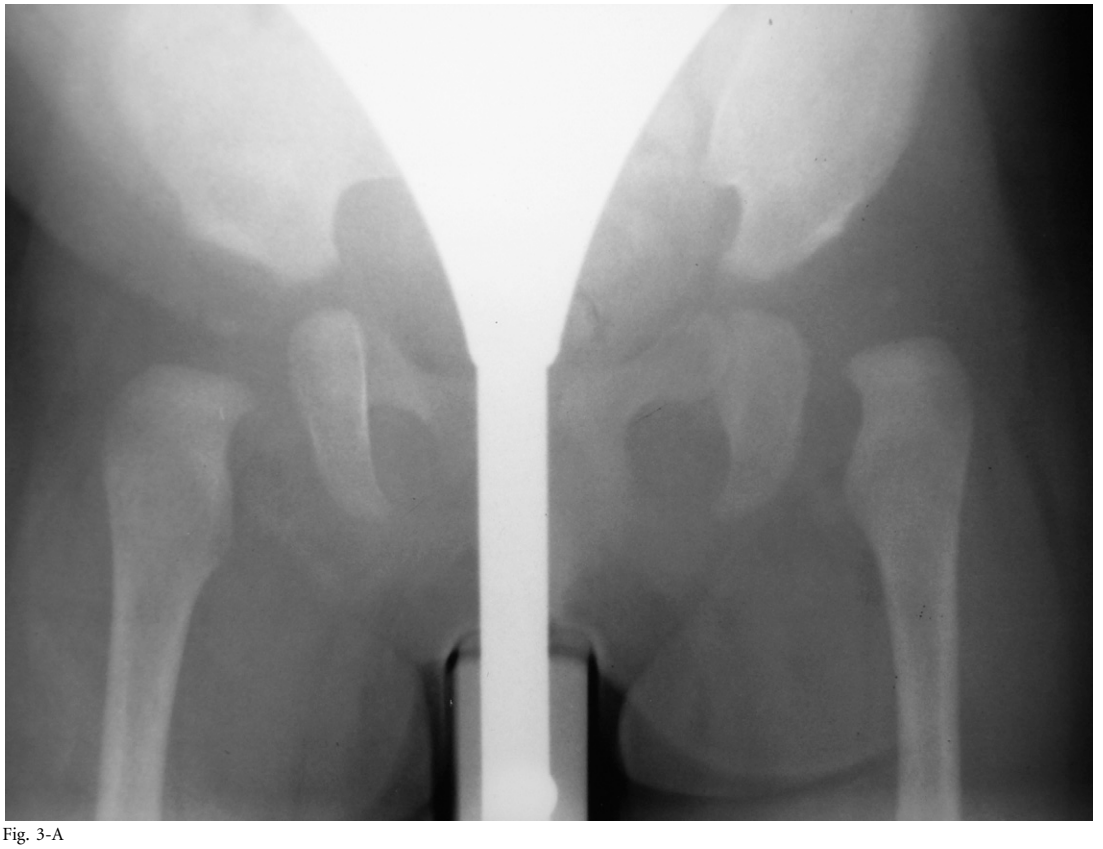

Fig. 3-A

Figs. 3-A, 3-B, and 3-C Anteroposterior pelvic radiographs showing both hips in a girl with an initial diagnosis of unilateral (left) hip dysplasia. **Fig. 3-A** At the age of four months, the right hip had a normal appearance.

group; with the numbers studied, this difference was not significant. Three patients in the primary acetabular dysplasia group had a center-edge angle of >15°.

Developmental Change of the Center-Edge Angle

The developmental changes in the center-edge angle after the age of three years in both groups are demonstrated in Figure 1. A significant difference in the center-edge angle between the two groups was noted at each evaluating period ($p < 0.05$) after the age of six years. In the normal group, a significant increase in the center-edge angle was observed between the ages of three and six years, between the ages of six and nine years, and between the ages of nine and twelve years, whereas in the primary acetabular dysplasia group, no significant increase in the center-edge angle was seen after the age of nine years. However, twenty-two patients in the normal group had poor acetabular coverage and three patients in the primary acetabular dysplasia group had good acetabular coverage at the age of nine years. The percentage of patients with an abnormal center-edge angle (<20°) in both groups at each time period is shown in Table II. The most remarkable difference between patients in the primary acetabular dysplasia group and those in the normal group was poor hip development after the age of nine years in the primary acetabular dysplasia group. In the normal group, the center-edge angle increased after the age of nine years, but in the primary acetabular dysplasia group, there was no further improvement in the center-edge angle. There was no patient with a center-edge angle of <15° at the age of twelve years in the normal group.

Developmental Change in the Sharp Angle

The developmental changes in the Sharp angle in both groups are demonstrated in Figure 2. No significant difference between the normal group and the primary acetabular dysplasia group was found at the ages of six or nine years. After that, the tendency in the changes in the Sharp angle was almost the same as those noted above for the center-edge angle. There was a significant ($p < 0.05$) difference between the two groups at each time period after the age of twelve years. In the normal group, a significant decrease in the Sharp angle was noted at each interval from the ages of six to twelve years. In the primary acetabular dysplasia group, no significant change in the Sharp angle was seen throughout this observation period.

Secondary Ossification Center

A secondary ossification center at the acetabular rim was recognized in eighty-two patients (93.2%); in all cases, the secondary ossification center appeared before the age of twelve years. In six patients, all in the primary acetabular dysplasia group, no secondary ossification center was seen.

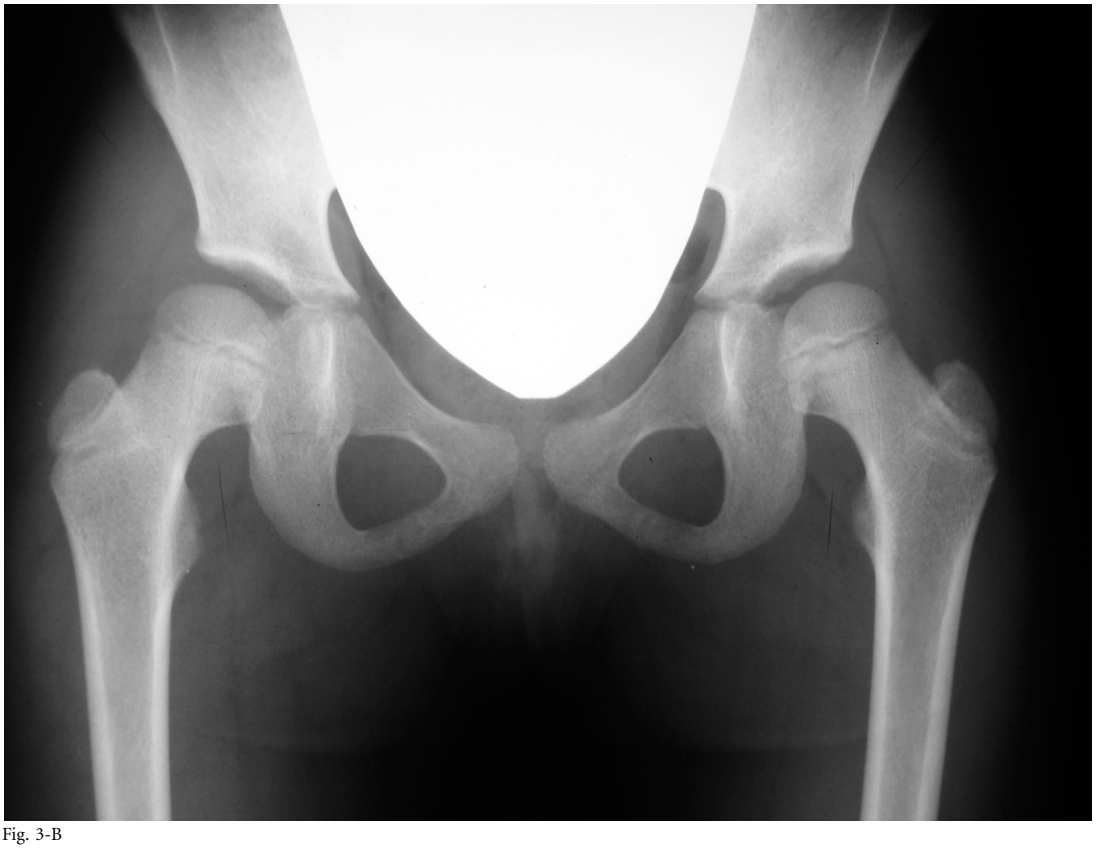

Fig. 3-B

Anteroposterior pelvic radiograph made at the age of three years. The acetabular index of the right (unaffected) hip was 27°, and the center-edge angle was 6°.

Illustrative Case

A four-month-old girl had developmental dislocation of the left hip (Fig. 3-A). Clinical examination revealed a positive Ortolani sign in the left hip only. Radiographic examination revealed dislocation of the left hip but no sign of dislocation or subluxation of the right hip. The left hip was reduced and treated with a Pavlik harness for three months. At the age of three years, the acetabular index of the unaffected hip was 27° and the center-edge angle was 6° (Fig. 3-B). Between the ages of three and six years, no increase in the center-edge angle was observed in either hip. A Salter innominate osteotomy was performed on the affected hip at the age of six years and one month. In the unaffected hip, there was a slight increase in the center-edge angle and a decrease in the Sharp angle between the ages of six and nine years; however, there was no further improvement of the acetabulum with age. At the age of eighteen years, the center-edge angle was 14° and the Sharp angle was 50°. The patient was classified as having Severin type-III dysplasia of the previously apparently unaffected right hip[9]. Acetabular coverage was better in the affected hip, in which a pelvic osteotomy had been performed (Fig. 3-C).

Discussion

Several authors have commented on the frequency of bilateral acetabular dysplasia in patients with unilateral developmental dysplasia of the hip. Song et al.[10] stated that 43% of patients who were diagnosed with unilateral developmental dysplasia of the hip were eventually diagnosed with bilateral hip dysplasia, suggesting that occult contralateral hip dysplasia in adolescents who have been previously managed for unilateral developmental dysplasia of the hip is common. They therefore recommended continued evaluation of the contralateral hip until skeletal maturity. Jacobsen et al.[11] reported that 34% of patients with unilateral dislocation of the hip had development of contralateral acetabular dysplasia, confirming that patients with unilateral developmental dysplasia are at risk for the development of a contralateral dysplastic malformation. The present study, in which 13.6% of the patients with unilateral developmental dysplasia of the hip had development of primary acetabular dysplasia, seems to suggest a lower frequency than both of those reports. However, our findings suggest that the contralateral hip in a patient with unilateral developmental dysplasia of the hip may have poor acetabular development. It is thus likely that primary acetabular dysplasia exists in some children who have no history of developmental dysplasia of the hip as infants. Therefore, the true incidence of primary acetabular dysplasia in the normal population remains unknown.

Some authors have noted the relationship between acetabular growth and proximal femoral anatomy[12-14]. A large

Fig. 3-C

Anteroposterior pelvic radiograph made at the age of eighteen years. A Salter osteotomy of the left hip had been performed at the age of six years. Acetabular dysplasia is noted in the previously apparently unaffected right hip.

neck-shaft angle and anteversion of the femur may result in poor acetabular coverage. In the present study, no patient had an obvious femoral deformity on the anteroposterior hip radiograph. To confirm the relationship between proximal femoral anatomy and primary acetabular dysplasia, a prospective study involving the use of computed tomography is required.

An investigation of the influence of the method of treatment of developmental dysplasia of the hip on future acetabular growth would be of interest. In the present study, there was no clear difference in the primary acetabular dysplasia group among the various treatments for developmental dysplasia of the hip, but the number of subjects may have been too small to allow us to detect a difference. Osteonecrosis of the femoral head is considered to be a major risk factor for acetabular growth, but there were no patients in the present study with femoral growth disturbance of the contralateral hip.

Does primary acetabular dysplasia present at birth, during infancy, or at an older age? Bolton-Maggs and Crabtree[15] reported on developmental growth in the contralateral hip in patients with a unilateral congenitally dislocated hip. In that study, the authors stated that the center-edge angle was the best prognostic sign; however, they also noted that a single measurement was unreliable for predicting hip development because of the wide range of normal. In the present study, acetabular coverage at the age of three years revealed no difference between the primary acetabular dysplasia group and the normal group. Patients with a poor acetabular index (>30°) at the age of three years may or may not develop poor acetabular coverage. In contrast, two patients with a center-edge angle of 17° at the age of three years joined the primary acetabular dysplasia group at skeletal maturity, which suggests we cannot predict the future growth of the acetabulum at this early age. After the age of six years, a significant difference in the center-edge angle was found between the normal group and the primary acetabular dysplasia group. Thus, it seems reasonable to propose that primary acetabular dysplasia presents after the age of six years. However, some patients in the primary acetabular dysplasia group had good radiographic acetabular coverage at the age of six years, so even at this age a complete prediction of future acetabular growth seems difficult. The critical point was the center-edge angle at the age of twelve years. Patients with a center-edge angle of <15° at the age of twelve years did not develop a normal acetabulum. Fredensborg[16] reported that, in children under the age of twelve years, a minimum center-edge angle value of 15° might be a reasonable threshold for normality and an angle of between 15° and 20° should be considered uncertain. Our findings seem to support the theory that prediction of the presence of primary acetabular dysplasia is possible after the age of twelve years. We found that the center-edge angle is a more reliable indicator for

acetabular dysplasia than the Sharp angle is, as shown in the difference between the two groups presented earlier. However, in the normal group, only 60.5% of the patients had a normal center-edge angle at the age of six years, whereas in the primary acetabular dysplasia group, 91.7% of the patients had an abnormal center-edge angle at the age of six years. At younger ages, the center-edge angle had a high sensitivity but not a high specificity for acetabular dysplasia; however, after the age of nine years, both the sensitivity and the specificity of the center-edge angle increased.

In contrast to the considerable acetabular growth that occurred in the normal group after the age of nine years, acetabular growth in the primary acetabular dysplasia group was extremely poor. Ponseti[17], in his anatomical, histological, and roentgenographic study, reported that the depth of the acetabulum increases during development as a result of interstitial growth in the acetabular cartilage, appositional growth at the periphery of this cartilage, and periosteal new-bone formation at the acetabular margin. Noritake et al.[2] noted that the impairment of acetabular growth between the ages of eight and twelve years may be attributable to impaired secondary ossification in the acetabular rim. The present study showed that, in the normal group, the acetabulum developed from a secondary ossification center that appeared at the acetabular rim before the age of twelve years, whereas in the primary acetabular dysplasia group, a secondary ossification center was not observed in six of the twelve patients. The appearance of a secondary ossification center at the acetabular rim in the normal group was associated with an increase in the center-edge angle and a decrease in the Sharp angle between the ages of nine and twelve years. It is thus possible to conclude that absent or poor formation of a secondary ossification center may be a major cause of primary acetabular dysplasia.

Our data were obtained from the contralateral hip in patients with unilateral developmental dysplasia of the hip; therefore, we cannot be certain that these results reveal the true natural history of primary acetabular dysplasia. Currently, the Severin classification system[9] is used to evaluate the results of procedures used for the treatment of developmental dysplasia of the hip, such as open reduction, closed reduction, use of a Pavlik harness, and several types of hip osteotomies. According to this classification system, patients with a center-edge angle of <15° between the ages of six and fourteen years and of <20° after the age of fourteen years are classified as having Severin type-III dysplasia, which constitutes the poor results group. However, considering the poor acetabular growth of patients with primary acetabular dysplasia, even if the treatment of developmental dysplasia of the hip is performed perfectly, the ultimate result may not be good acetabular coverage in all patients. Because acetabular coverage cannot be expected to increase by more than the developmental potential of each patient, it is important to consider the presence of primary acetabular dysplasia when evaluating the results of treatment of developmental dysplasia of the hip.

How should we treat primary acetabular dysplasia? Although acetabular dysplasia can lead to osteoarthritis, it is also possible that some patients with primary acetabular dysplasia may develop osteoarthritis as early as adolescence. This would seem to indicate the need for early acetabular osteotomy surgery. However, the present study showed that the center-edge angle and the Sharp angle are unreliable predictors of primary acetabular dysplasia before the age of twelve years. Thus, pelvic osteotomy probably should be delayed at least until the age of twelve years to avoid excessive surgery. Some authors have reported a relationship between acetabular dysplasia and the progression of osteoarthritis. Murphy et al.[18] reported that no patient with a center-edge angle of <16° had a well-functioning hip at the age of sixty-five years. Cooperman et al.[19] reviewed various hip parameters (including the center-edge angle, the Sharp angle, the percentage of femoral head coverage by the acetabulum, the acetabular depth, and the inclination of the lateral lip of the acetabulum), but none of those indicators proved to be a reliable prognostic aid for predicting the rate at which osteoarthritis developed in any one patient. This supports the notion that the choice of treatment for young patients with no symptoms and moderate or severe acetabular dysplasia is difficult. A long-term prospective randomized study will be needed to provide objective criteria to assist in this difficult surgical decision-making process.

In summary, we have documented the existence of primary acetabular dysplasia in adolescence in 13.6% of patients who previously presented with unilateral developmental dysplasia of the hip. Many patients with primary acetabular dysplasia showed a normal radiographic appearance at the age of three years. Therefore, a normal radiographic appearance of the hip at this age does not rule out the possibility of acetabular dysplasia at skeletal maturity. Acetabular growth showed slower development in the primary acetabular dysplasia group as compared with the normal group, particularly between the ages of three and six years and between the ages of nine and twelve years. The critical time point between the normal group and the primary acetabular dysplasia group was the age of twelve years. After this age, a complete prediction of acetabular growth was possible. Therefore, when evaluating the long-term results of treatment of developmental dysplasia of the hip, one should keep in mind the possibility of primary acetabular dysplasia in the contralateral hip. ■

D. Kobayashi, MD
S. Satsuma, MD
Department of Orthopaedic Surgery,
Kobe Children's Hospital,
1-1-1 Takakuradai, Suma-ku, Kobe, Hyogo 654-0081 Japan.
E-mail address for D. Kobayashi: kobayashi_kch@hp.pref.hyogo.jp

R. Kuroda, MD
M. Kurosaka, MD
Department of Orthopaedic Surgery,
Kobe University Hospital,
7-5-2 Kusunoki-cho, Chuo-ku, Kobe,
Hyogo 650-0017 Japan

References

1. Weintroub S, Green I, Terdiman R, Weissman SL. Growth and development of congenitally dislocated hips reduced in early infancy. J Bone Joint Surg Am. 1979; 61:125-30.

2. Noritake K, Yoshihashi Y, Hattori T, Miura T. Acetabular development after closed reduction of congenital dislocation of the hip. J Bone Joint Surg Br. 1993; 75:737-43.

3. Malvitz TA, Weinstein SL. Closed reduction for congenital dysplasia of the hip. Functional and radiographic results after an average of thirty years. J Bone Joint Surg Am. 1994;76:1777-92.

4. Tasnavites A, Murray DW, Benson MK. Improvement in acetabular index after reduction of hips with developmental dysplasia. J Bone Joint Surg Br. 1993;75: 755-9.

5. Harris NH, Lloyd-Roberts GC, Gallien R. Acetabular development in congenital dislocation of the hip. With special reference to the indications for acetabuloplasty and pelvic or femoral realignment osteotomy. J Bone Joint Surg Br. 1975;57: 46-52.

6. Cherney DL, Westin GW. Acetabular development in the infant's dislocated hips. Clin Orthop Relat Res. 1989;242:98-103.

7. Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint. With special reference to the complication of osteoarthritis. Acta Chir Scand. 1939;83 Suppl 58:5-135.

8. Sharp IK. Acetabular dysplasia: the acetabular angle. J Bone Joint Surg Br. 1961;43:268-72.

9. Severin E. Contribution to the knowledge of congenital dislocation of the hip joint. Late results of closed reduction and arthrographic studies of recent cases. Acta Chir Scand. 1941;84 Suppl 63:1-142.

10. Song FS, McCarthy JJ, MacEwan GD, Fuchs KE, Dulka SE. The incidence of occult dysplasia of the contralateral hip in children with unilateral hip dysplasia. J Pediatr Orthop. 2008;28:173-6.

11. Jacobsen S, Rømer L, Søballe K. The other hip in unilateral hip dysplasia. Clin Orthop Relat Res. 2006;446:239-46.

12. Clohisy JC, Nunley RM, Carlisle JC, Schoenecker PL. Incidence and characteristics of femoral deformities in the dysplastic hip. Clin Orthop Relat Res. 2009; 467:128-34.

13. Steppacher SD, Tannast M, Werlen S, Siebenrock KA. Femoral morphology differs between deficient and excessive acetabular coverage. Clin Orthop Relat Res. 2008;466:782-90.

14. Kim HW, Morcuende JA, Dolan LA, Weinstein SL. Acetabular development in developmental dysplasia of the hip complicated by lateral growth disturbance of the capital femoral epiphysis. J Bone Joint Surg Am. 2000;82:1692-700.

15. Bolton-Maggs BG, Crabtree SD. The opposite hip in congenital dislocation of the hip. J Bone Joint Surg Br. 1983;65:279-84.

16. Fredensborg N. The CE angle of normal hips. Acta Orthop Scand. 1976;47: 403-5.

17. Ponseti IV. Growth and development of the acetabulum in the normal child. Anatomical, histological, and roentgenographic studies. J Bone Joint Surg Am. 1978;60:575-85.

18. Murphy SB, Ganz R, Müller ME. The prognosis in untreated dysplasia of the hip. A study of radiographic factors that predict the outcome. J Bone Joint Surg Am. 1995;77:985-9.

19. Cooperman DR, Wallensten R, Stulberg SD. Acetabular dysplasia in the adult. Clin Orthop Relat Res. 1983;175:79-85.