JB&JS OPEN ACCESS

Proposal of a New Type of Innominate Osteotomy without the Use of Bone Graft in Children

A Preliminary Study

Mitsuaki Morita, MD, PhD, Makoto Kamegaya, MD, PhD, Daisuke Takahashi, MD, PhD, Hiroshi Kamada, MD, PhD, Yuta Tsukagoshi, MD, PhD, and Yohei Tomaru, MD

Investigation performed at the Chiba Child and Adult Orthopaedic Clinic (Chiba Pediatric Orthopaedic Group), Chiba, Japan

Background: Good long-term outcomes have been reported for the Salter innominate osteotomy (SIO), which is widely used to correct developmental dysplasia of the hip (DDH) in children. In this study, we describe the procedure and early outcomes of a new pelvic osteotomy termed "angulated innominate osteotomy" (AIO).

Methods: Twenty-one patients (22 hips) underwent AIO. We evaluated age at the time of surgery, operative time, blood loss, and time to bone union. Several radiographic parameters were assessed preoperatively, immediately postoperatively, and at the time of the latest examination. Measurements were compared with those of 20 previous patients who underwent SIO. The AIO is made to form an isosceles triangle. This enables 2 points of contact between the proximal and distal bone fragments, eliminating the need for a bone graft.

Results: Mean age at the time of surgery was 5.9 years, and the mean duration of follow-up was 30.8 months. The mean operative time was 103 minutes, mean blood loss was 33 mL, and mean time to bone union was 9.8 weeks. Immediately postoperatively, the mean "distance d" (lateral displacement of the distal fragment), mean ratio of the obturator heights (ROH), and mean lateral rotation angle (LRA) were 7.2 mm, 70.4%, and 19.3°, respectively. At the latest examination, the mean acetabular index (AI), center-edge angle (CEA), and acetabular head index (AHI) were 16.4°, 23.7°, and 85.5%, respectively, each of which were significantly improved compared with the preoperative values. Moreover, the mean postoperative iliac length difference (ILD) between the operative and contralateral sides was only 0.1 mm. Those treated with AIO had a significantly shorter operative time and time to bone union, and less blood loss, than those treated with SIO. The mean distance d, ROH, and LRA did not differ significantly from SIO results, while the mean ILD was significantly less.

Conclusions: AIO is a less-invasive procedure that does not require a bone graft, and the short-term outcomes were favorable. Sufficient coverage of the acetabulum with displacement of the distal bone fragment to an extent similar to SIO can be achieved; we consider AIO a worthy surgical procedure that has the potential to provide good long-term outcomes similar to those seen with SIO.

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

The Salter innominate osteotomy (SIO) is widely used in children to correct the residual subluxation and acetabular dysplasia seen after the initial treatment of developmental dysplasia of the hip (DDH)[1,2]. Good long-term outcomes have been reported[2-5]. We similarly obtained good outcomes using SIO in preschool children[6].

In 2014, we first proposed the angulated innominate osteotomy (AIO), which is less invasive than the SIO and as effective but does not require the use of bone grafts. In addition, this procedure prevents pelvic deformity and elongation of the ilium on the operative side after the procedure. The entire operative process is reproducible to perform. In this article, we report

Disclosure: The authors indicated that no external funding was received for any aspect of this work. The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSOA/A113).

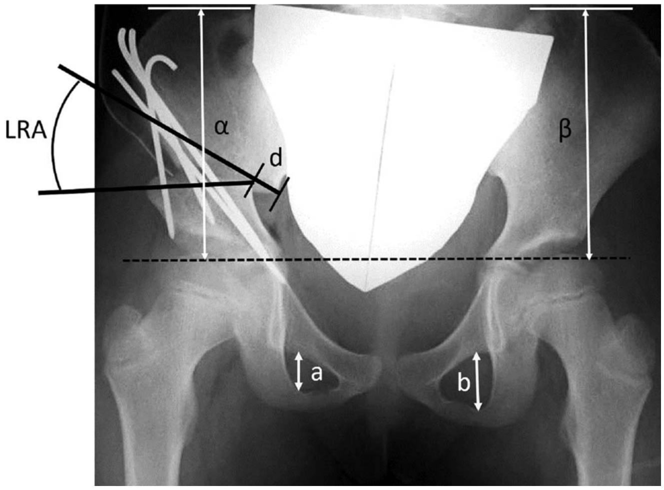

Fig. 1
Anteroposterior view on radiographs immediately after the angulated innominate osteotomy (AIO) procedure. Lateral displacement of the distal fragment was measured as the "distance d" (in millimeters), the distance between the distal inner edge of the proximal bone fragment and the proximal inner edge of the distal bone fragment. The change in the height of the obturator foramen was measured as the ratio of the obturator heights (ROH): the maximum height of the obturator foramen on the operative side (a) relative to that on the contralateral side (b), calculated as a percentage: a/b × 100. The extent of lateral rotation of the distal fragment was measured as the lateral rotation angle (LRA), the angle between the inclination of the distal fragment (the base of the isosceles triangle) and of the proximal fragment (the posterior side of the isosceles triangle). The iliac length difference (ILD) was measured as the difference (in millimeters) between the operative side (α) and the contralateral side (β) with respect to the maximum length of a perpendicular line drawn from the superior margin of the iliac crest to the Hilgenreiner line (horizontal dashed line); this was noted as positive when the operative side was longer.

our early results, including a comparison of the operative procedures and preoperative and postoperative radiographic results.

Materials and Methods

This study received institutional review board approval.

Included were 21 patients and 22 hips (20 girls and 1 boy; 4 right hips and 18 left hips) treated in our hospital or affiliated facilities from August 2014 to December 2017. Eighteen patients had unilateral DDH (18 hips), 1 patient had bilateral DDH with bilateral procedures (2 hips), and 2 patients had bilateral DDH with a unilateral procedure (2 hips). The initial reduction methods used for DDH were as follows: Pavlik harness (6 hips), abduction brace (2 hips), gradual traction reduction (4 hips), closed reduction (4 hips), and open reduction after unsuccessful nonoperative treatment (4 hips). The remaining 2 hips (2 patients) had acetabular dysplasia without dislocation.

We investigated the time from reduction until the osteotomy procedure, age at the time of surgery, operative time, perioperative blood loss, time to bone union (time until removal of internal fixation), and duration of follow-up for these patients. Radiographic evaluation was performed using anteroposterior radiographs of the hips preoperatively, immediately postoperatively, and at the latest examination. Care was always taken to keep the patient's pelvis level for coronal and transverse-plane images and hips in neutral throughout the radiographic process. The measurement parameters evaluated included the acetabular index (AI), acetabular head index (AHI), and center-edge angle (CEA), which were assessed preoperatively and at the latest examination. Immediately postoperatively, lateral displacement of the distal fragment was measured on an anteroposterior hip radiograph as the "distance d," the distance (in millimeters) between the distal inner edge of the proximal bone fragment and the proximal inner edge of the distal bone fragment, as illustrated in Figure 1; change in the height of the obturator foramen was measured as the ratio of the obturator heights (ROH): the maximum height of the obturator foramen on the operative side relative to that of the contralateral side, reported as a percentage, representing the degree of rotation

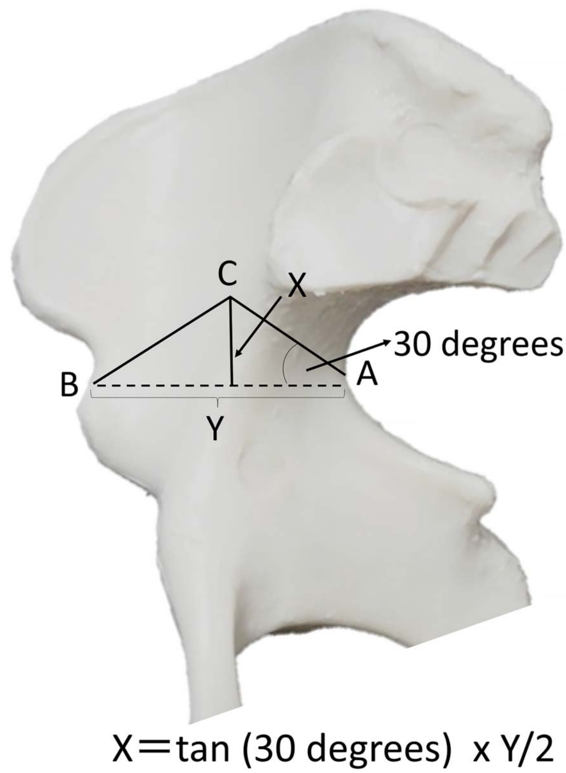

Fig. 2.
The inner iliac wall. Distance Y = the distance from the greater sciatic notch (A) to a point superior to the anterior inferior iliac spine (B). Distance X = the perpendicular distance from the midpoint of Y to the vertex of the isosceles triangle (C), calculated by the following formula: X = tan(30°) × Y/2 = 0.3Y. With a 30° AIO, the osteotomy is made with a T-saw heading upward toward C (X cm above the midpoint of Y), and then heading downward from C toward B to complete the osteotomy.

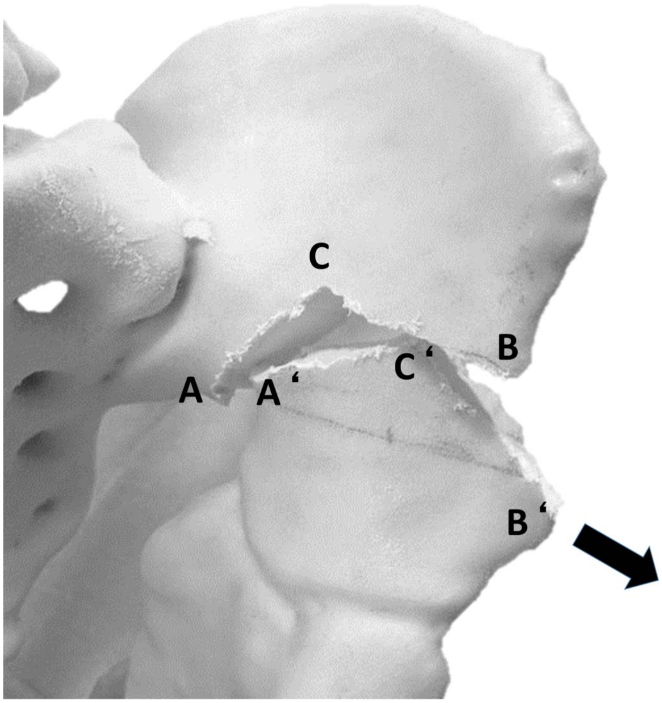

Fig. 3.
The appearance of distal fragment displacement with a plaster model. After osteotomy, the distal bone fragment is pulled out anterolaterally (arrow). Point A of the distal bone fragment is moved to Point A‘, Point B is moved to Point B‘, and Point C is moved to Point C‘. Points A‘ and C‘ create 2 contact points between the bone fragments. The outer wall of the proximal bone fragment is in contact with the inner wall of the distal bone fragment around Point C‘.

of the postoperative distal fragment anterolaterally (rotation around the axis of the pubic symphysis and the greater sciatic notch shown in biomechanical theory by Rab[7]) (Fig. 1); and the abduction angle of inclination of the distal fragment relative to the proximal bone fragment was measured as the lateral rotation angle (LRA) (Fig. 1), according to the methods described by Kitoh et al.[8]. The iliac length difference (ILD), also assessed immediately postoperatively, was measured as the difference (in millimeters) between the operative side and the contralateral side with respect to the maximum length of a perpendicular line drawn from the superior margin of the iliac crest to the Hilgenreiner line, and this was noted as positive when the operative side was longer (Fig. 1).

An additional 20 patients (18 girls and 2 boys, 15 left and 5 right hips) who had previously undergone unilateral SIO using a bone graft were evaluated with respect to time from reduction until surgery, age at surgery, operative time, perioperative blood loss, time to bone union, and duration of follow-up. As with the AIO group, the following radiographic measures were assessed immediately postoperatively: distanced, ROH, LRA, and ILD. In addition, the radiographic parameters of the AI, CEA, and AHI were measured preoperatively and at 2 to 3 years postoperatively, which was similar to the follow-up duration for AIO. We compared the results with those of patients who underwent AIO.

Our osteotomy group was selected without bias and were the consecutive 22 patients without any concomitant procedure. The 20 patients in the SIO group were randomly selected from among past patients who had undergone SIO and whose age at surgery was within the same range as that of our osteotomy group.

With the exception of patients with a late diagnosis of DDH, and on the basis of surgical indications for pelvic osteotomy, the subjects were patients with residual acetabular dysplasia by 4 to 6 years of age with no tendency toward improvement in the observation period. General criteria for radiographic measurements were an AI of ≥30°, CEA of ≤10°, and AHI of ≤70%. AIO was performed simultaneously with open reduction for patients ≥2 years of age with a late diagnosis of DDH. AIO may be combined with femoral varus osteotomy (FVO) when concentricity of the femoral head and acetabular coverage cannot be sufficiently achieved with AIO alone in cases of femoral head deformity or thickening of the bottom of the acetabulum.

Surgical Procedure

A 5 to 6-cm bikini skin incision is made. Without vertically dividing the iliac crest apophysis, the gluteus medius and minimus muscles on the outer wall and the iliacus muscle on the inner wall are dissected from the iliac crest and separated as far as the greater sciatic notch extraperiosteally. Using an extraperiosteal technique prevents damage to the subperiosteal bridging veins, thereby reducing blood loss. Initially, a Gigli saw was used for the iliac osteotomy; however, we recently began using a threadwire saw (Diamond T-saw; MANI). A T-saw is less likely to damage the surrounding soft tissue during the osteotomy and is extremely smooth to operate. In SIO, the bone is cut in a straight line from the sciatic notch to a point immediately superior to the anterior inferior iliac spine; however, in AIO, the line is raised approximately 30° proximal to the Salter osteotomy line, with the center of the osteotomy line as the vertex, and then an angulated osteotomy is made to a point immediately superior to the anterior

TABLE I Comparison of Preoperative and Latest Postoperative Radiographic Measurements in the AIO Group*

	Angulated Innominate Osteotomy (AIO)		
	Preop.	Latest Postop.	P Value†
AI *(°)*	30.0 ± 4.9 (21 to 41)	16.4 ± 4.9 (6 to 24)	<0.001
CEA *(°)*	6.2 ± 4.7 (−9 to 14)	23.7 ± 5.1 (15 to 39)	<0.001
AHI *(%)*	62.1 ± 7.5 (45 to 71)	85.5 ± 5.0 (73 to 94)	<0.001

*The values are given as the mean and standard deviation, with the range in parentheses. AI = acetabular index, CEA = center-edge angle, and AHI = acetabular head index. †All variables were evaluated using paired t tests.

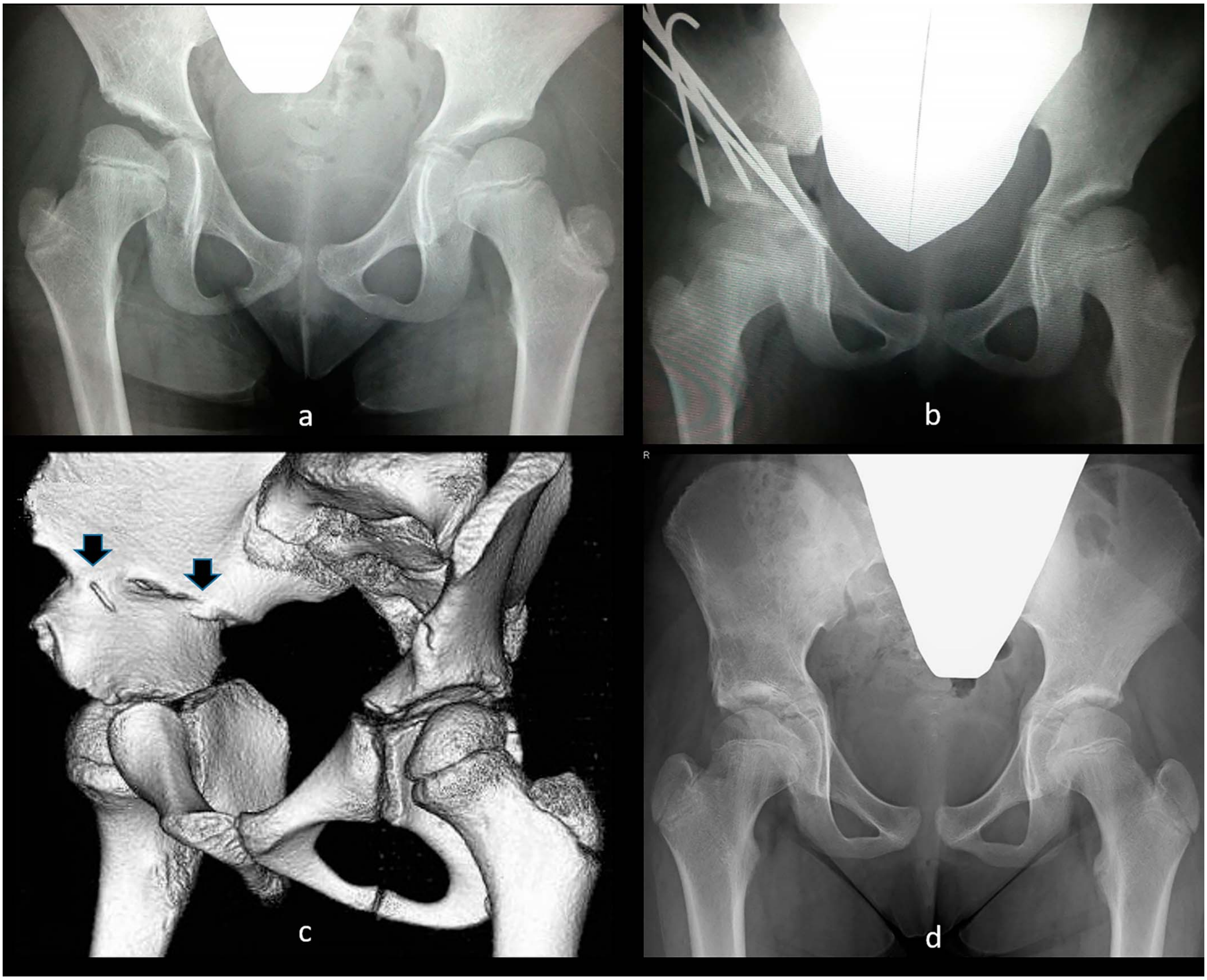

Fig. 4

Figs. 4-A through 4-D Female patient with right developmental dysplasia of the hip who was 6.5 years of age at the time of angulated innominate osteotomy (AIO). **Fig. 4-A** Preoperative anteroposterior radiograph. AIO was performed for right acetabular dysplasia, with an acetabular index (AI) of 32°, center-edge angle (CEA) of 3°, and acetabular head index (AHI) of 63%. **Fig. 4-B** Immediate postoperative radiograph. "Distance d" was 11 mm, the ratio of the obturator heights (ROH) was 65%, the lateral rotation angle (LRA) was 22°, and the iliac length difference (ILD) was −2 mm. **Fig. 4-C** Three-dimensional computed tomography (CT) image from 8 weeks postoperatively. Two points of bone union are visible on the proximal and distal bone fragments (arrows). **Fig. 4-D** Postoperative radiograph made at 53 months. Marked improvement in acetabular dysplasia was noted, with an AI of 6°, CEA of 39°, and AHI of 92%.

inferior iliac spine to form an isosceles triangle (Fig. 2). This osteotomy angle was set on the basis of results obtained through biomechanical analysis of the Salter method in a study by Rab, which produced correction with a bend of approximately 30°[7]. In reality, when performing the osteotomy, it is vital to first identify the vertex. The vertex is on a perpendicular line proximal to the midpoint of the distance from the sciatic notch to a point immediately superior to the anterior inferior iliac spine (original Salter osteotomy line) and is placed at the distance obtained with the formula shown in Figure 2. After osteotomy, the distal bone fragment is rotated distally as done with an SIO and fixed with 3 to 4 wires (one 3-mm-diameter threaded Kirschner wire and two to three 2-mm-diameter Kirschner wires). During this process, the distal bone fragment is maneuvered anterolaterally to ensure that the outer wall of the proximal bone fragment is in contact with the inner wall of the distal bone fragment. This manipulation creates 2 points of contact between the proximal and distal bone fragments, thereby enabling stable fixation and good bone-healing without the use of a bone

TABLE II Comparison of AIO and SIO*

	AIO (N = 22)	SIO (N = 20)	P Value†
Operative time *(min)*	103	126	0.008
Blood loss *(mL)*	33	73	<0.001
Time to bone union *(wk)*	9.8	11.8	0.03

*The values are given as the mean. AIO = angulated innominate osteotomy, and SIO = Salter innominate osteotomy. †All variables were evaluated using non-paired t tests.

graft (Fig. 3). Postoperatively, the child wears a spica cast for 6 weeks, after which fully loaded walking is permitted. The wires are removed when bone union is confirmed on a radiograph.

Statistical Methods

Paired t tests were used to compare the preoperative and latest postoperative AI, CEA, and AHI values in the AIO group, and the preoperative and 2 to 3-year postoperative values for these same measures in the SIO group. Non-paired t tests were used to evaluate the time from reduction until surgery, age at the time of surgery, operative time, blood loss, and time until bone union as well as the radiographic measures of the distance d, ROH, LRA, and ILD immediately postoperatively between the AIO and SIO groups. In addition, postoperative AI, CEA, and AHI values were compared between the groups.

Two staff surgeons (M.K. and M.M.) who have >20 years of experience measured all radiographic parameters separately to evaluate interobserver error. The staff surgeons remeasured the values in the same series of patients to evaluate intraobserver error. Intraclass correlation coefficients (ICCs) were used to assess intra- and interobserver reliability.

A p value of <0.05 was considered significant. All statistical analyses were performed using JMP software (version 13; SAS Institute).

Results

In the AIO group (n = 22), the mean time from reduction to surgery (excluding the 2 hips with acetabular dysplasia without dislocation) was 5.0 years (range, 2.5 to 7.3 years), the mean age at surgery was 5.9 years (range, 4.3 to 8.2 years), the mean duration of follow-up was 30.8 months (range, 10 to 57 months), and the mean age at the latest examination was 8.1 years (range, 5.7 to 11.2 years). The mean operative time was 103 minutes (range, 65 to 130 minutes), mean blood loss was 33 mL (range, 5 to 110 mL), and mean time to bone union was 9.8 weeks (range, 6 to 25 weeks). The mean preoperative radiographic measurements (and standard deviation) were as follows: AI, 30.0° ± 4.9° (range, 21° to 41°); CEA, 6.2° ± 4.7° (range, −9° to 14°); and AHI, 62.1% ± 7.5% (range, 45% to 71%). The mean immediate postoperative measurements were as follows: distance d, 7.2 ± 2.1 mm (range, 4 to 11 mm); ROH (n = 20), 70.4% ± 9.2% (range, 50% to 87%); LRA, 19.3° ± 5.6° (range, 9° to 29°); and ILD (n = 20), 0.1 ± 2.7 mm (range, −4 to 5 mm). At the time of the latest examination, the mean values were as follows: AI, 16.4° ± 4.9° (range, 6° to 24°); CEA, 23.7° ± 5.1° (range, 15° to 39°); and AHI, 85.5% ± 5.0% (range, 73% to 94%), each of which were significantly improved compared with the preoperative values (p < 0.001) (Table I). At the time of this writing, no postoperative complication, such as deformity of the femoral head, leg-length discrepancy, and scoliosis, had been found (Fig. 4).

In the SIO group (n = 20), the mean follow-up duration (79.2 months) was necessarily longer, but the mean time from reduction until operation (4.4 years) and the mean age at the time of surgery (5.2 years) did not differ significantly from the AIO group. The mean operative time was 126 minutes, and the mean blood loss was 73 mL, indicating that cases treated with AIO alone had a significantly shorter operative duration (p = 0.008) and less blood loss (p < 0.001). The mean time to bone union was 11.8 weeks with SIO, which was significantly longer than the time to union for AIO (p = 0.03) (Table II). The mean immediate postoperative distance d was 6.8 ± 2.2 mm (range, 4 to 13 mm), ROH was 75.8% ± 12.4% (range, 49% to 96%), and LRA was 20.6° ± 3.9° (range, 16° to 28°), all of which did not differ significantly from the values for AIO, while the mean ILD was 5.8 ± 2.7 mm (range, −1 to 9 mm), indicating a significantly longer postoperative iliac length than that noted for AIO (p < 0.001) (Table III). The preoperative AI, CEA, and AHI were 31.0° ± 0.7° (range, 30° to 32°), 4.5° ± 3.0° (range, 1° to 9°), and 56.0% ± 2.1% (range, 53% to 59%), respectively. The corresponding postoperative measurements (2 to 3 years postoperatively) were 15.8° ± 3.0° (range, 12° to 20°), 26.3° ± 5.5° (range, 21° to 35°), and 86.3% ± 2.8% (range, 83% to 89%), respectively. Each measure was significantly improved compared with the preoperative values (p < 0.001). In addition, there was no significant difference between these measurements 2 to 3 years postoperatively in the SIO group and at the latest examination in the AIO group (Table IV).

With respect to the reliability of assessments between M.K. and M.M., analysis yielded an interobserver correlation coefficient of 0.95 (95% confidence interval [CI], 0.91 to 0.97). Intraobserver correlation coefficients for the 2 observers were

TABLE III Comparison of Immediate Postoperative Radiographic Measurements by Procedure*

	AIO (N = 22)†	SIO (N = 20)	P Value‡
Distance d *(mm)*	7.2 ± 2.1 (4 to 11)	6.8 ± 2.2 (4 to 13)	NS
ROH *(%)*	70.4 ± 9.2 (50 to 87)	75.8 ± 12.4 (49 to 96)	NS
LRA *(°)*	19.3 ± 5.6 (9 to 29)	20.6 ± 3.9 (16 to 28)	NS
ILD *(mm)*	0.1 ± 2.7 (−4 to 5)	5.8 ± 2.7 (−1 to 9)	<0.001

*The values are given as the mean and standard deviation, with the range in parentheses. AIO = angulated innominate osteotomy, SIO = Salter innominate osteotomy, NS = not significant, ROH = ratio of the obturator heights, LRA = lateral rotation angle, and ILD = iliac length difference. †N = 20 for the ROH and ILD measurements. ‡All variables were evaluated using non-paired t tests.

TABLE IV Comparison of Postoperative Radiographic Parameters by Procedure*

	AIO (N = 22) Latest Postop.	SIO (N = 20) 2 to 3 Yr Postop.	P Value†
AI *(°)*	16.4 ± 4.9 (6 to 24)	15.8 ± 3.0 (12 to 20)	NS
CEA *(°)*	23.7 ± 5.1 (15 to 39)	26.3 ± 5.5 (21 to 35)	NS
AHI *(%)*	85.5 ± 5.0 (73 to 94)	86.3 ± 2.8 (83 to 89)	NS

*The values are given as the mean and standard deviation, with the range in parentheses. AIO = angulated innominate osteotomy, SIO = Salter innominate osteotomy, AI = acetabular index, NS = not significant, CEA = center-edge angle, and AHI = acetabular head index. †All variables were evaluated using non-paired t tests.

0.98 (95% CI, 0.97 to 0.99) ($p < 0.0001$) and 0.96 (95% CI, 0.93 to 0.98) ($p < 0.0001$). These results indicate excellent intra- and interobserver reliability.

Discussion

There was marked improvement postoperatively in the radiographic measures of AI, CEA, and AHI in the group treated with AIO. Operative time was shorter and less blood loss occurred when compared with use of SIO, and thus, this method is less invasive than SIO. Furthermore, there was a shorter time to bone union and less elongation of the ilium postoperatively.

Several favorable mid to long-term outcomes have been reported regarding SIO for DDH[3-5]. Based on the current study, the biomechanical movement of the distal bone fragment immediately after surgery using AIO was almost identical to that of SIO; thus, good long-term clinical and radiographic outcomes can be anticipated using AIO as well.

In SIO, it is important to pull out the distal fragment anterolaterally and to fix the fragment after osteotomy[1,2]. Kitoh et al. measured the lateral displacement distance of the distal bone fragment (distance d) and the ROH as indices of the extent of anterolateral displacement of the distal bone fragment in patients treated with SIO and found mean values of 4 mm and 73%, respectively; they reported that these values were strongly correlated with postoperative CEA[8]. Kaneko et al. conducted a similar investigation, finding that cases with poor outcomes following SIO had a significantly smaller distance d; in contrast, all of the cases with good outcomes had a distance d of ≥3.5 mm, thus concluding that sufficient lateral displacement of the distal bone fragment was a factor related to good long-term outcomes[9]. We also measured the distance d and ROH in our cases; the mean values were 7.2 mm and 70.4%, respectively, similar to those obtained with SIO. Therefore, a similar level of anterolateral movement of the distal bone fragment can be attained with AIO.

We previously reported a modification using a hydroxyapatite block instead of a bone graft[10], but the fixing pins could not be inserted into the block, which created some problems with postoperative fixation strength. It was also reported that pelvic length increases because the bone-graft fragment is sandwiched in the osteotomy section when using bone grafts or a hydroxyapatite block[11-13]; Wang et al. reported that postoperative pelvic length in SIO was longer on the operative side than on the contralateral side, which generated pelvic tilt[11]. On this point, we found no difference between the left and right iliac lengths with AIO; thus, the spine should not be affected by pelvic tilt using this method. There are also reports that a distal bone fragment associated with longer iliac length placed increased compression force on the femoral head, which may cause postoperative deformation of the femoral head[13,14], but the AIO method would have a minimal effect regarding this point as well.

In SIO, the iliac apophysis on the affected side is split vertically and the bone graft is harvested from the same site[1], which can cause growth disturbance and deformation of the pelvis postoperatively. Rossillon et al. reported cases in which vertical division of the apophysis and bone-graft harvesting with SIO caused growth disturbance of the ilium on the operative side[15]. AIO has the advantage of avoiding postoperative pelvic deformation and maintaining symmetry in the balance between the trunk and the pelvis.

A number of modifications to the SIO have been reported to date. Kalamchi reported on a modification that added a triangular osteotomy to the proximal bone fragment to prevent postoperative medial and posterior migration of the distal bone fragment and prevent leg lengthening, but the osteotomy method is complex because it needs 2 divergent osteotomies, starting at the same point in the sciatic notch to remove a triangular bone wedge from the proximal fragment, and still requires a bone graft[12]. Eren et al. changed the direction of the pelvic osteotomy and reported a modification that does not require internal fixation, but this method still requires the bone graft[16]. Sanchez Mesa and Yamhure reported on a percutaneous curved pelvic osteotomy technique that does not require bone grafts, but the specific osteotomy methods were not presented, making the method difficult to reproduce[17].

The limitations of the current study include its lack of long-term follow-up and the small number of cases; therefore, additional study will be needed to confirm the results. However, the short-term results, including some radiographic parameters immediately postoperatively, encourage us to continue to perform this procedure. We hope to accumulate patient data for further study.

We conclude that the AIO is less invasive than the SIO, and it does not require bone grafts; good short-term outcomes were noted in the current study. The procedure enabled displacement of the distal bone fragment to an extent similar to SIO and ensured sufficient coverage of the acetabulum. Therefore, in terms of surgical effect, we consider the AIO a worthy surgical procedure that has the potential to provide good long-term outcomes similar to those seen with the SIO. ■

Mitsuaki Morita, MD, PhD[1]
Makoto Kamegaya, MD, PhD[1]

Daisuke Takahashi, MD, PhD[2]
Hiroshi Kamada, MD, PhD[3]
Yuta Tsukagoshi, MD, PhD[3]
Yohei Tomaru, MD[3]

[1]Chiba Child and Adult Orthopaedic Clinic (Chiba Pediatric Orthopaedic Group), Chiba, Japan

[2]Department of Orthopedic Surgery, Graduate School of Medicine, Hokkaido University, Hokkaido, Japan

[3]Department of Orthopaedic Surgery, University of Tsukuba, Ibaraki, Japan

Email address for M. Morita: moritamituaki@gmail.com

ORCID iD for M. Morita: 0000-0002-9638-5472
ORCID iD for M. Kamegaya: 0000-0003-0394-849X
ORCID iD for D. Takahashi: 0000-0003-4740-3643
ORCID iD for H. Kamada: 0000-0003-4976-6683
ORCID iD for Y. Tsukagoshi: 0000-0003-4080-2828
ORCID iD for Y. Tomaru: 0000-0002-5693-3366

References

1. Salter RB. Innominate osteotomy in the treatment of congenital dislocation and subluxation of the hip. J Bone Joint Surg Br. 1961 Aug;43-B(3):518-39.

2. Salter RB, Dubos JP. The first fifteen year's personal experience with innominate osteotomy in the treatment of congenital dislocation and subluxation of the hip. Clin Orthop Relat Res. 1974 Jan-Feb;(98):72-103.

3. Böhm P, Brzuske A. Salter innominate osteotomy for the treatment of developmental dysplasia of the hip in children: results of seventy-three consecutive osteotomies after twenty-six to thirty-five years of follow-up. J Bone Joint Surg Am. 2002 Feb;84(2):178-86.

4. Thomas SR, Wedge JH, Salter RB. Outcome at forty-five years after open reduction and innominate osteotomy for late-presenting developmental dislocation of the hip. J Bone Joint Surg Am. 2007 Nov;89(11):2341-50.

5. Morin C, Bisogno J, Kulkarni S, Morel G. Treatment of late-presenting developmental dislocation of the hip by progressive orthopaedic reduction and innominate osteotomy. Our results with more than 30 years of follow up. J Child Orthop. 2011 Aug;5(4):251-60. Epub 2011 Jun 2.

6. Saisu T, Kamegaya M, Nakamura J, Someya M, Koizumi W, Ochiai N, Miura Y, Mannouji T, Moriya H. Long-term results after Salter innominate osteotomy for the treatment of development dysplasia of the hip. J Jpn Ped Orthop Ass. 2006;15(2): 214-9. Japanese.

7. Rab GT. Biomechanical aspects of Salter osteotomy. Clin Orthop Relat Res. 1978 May;(132):82-7.

8. Kitoh H, Kaneko H, Ishiguro N. Radiographic analysis of movements of the acetabulum and the femoral head after Salter innominate osteotomy. J Pediatr Orthop. 2009 Dec;29(8):879-84.

9. Kaneko H, Kitoh H, Mishima K, Matsushita M, Kadono I, Ishiguro N, Hattori T. Factors associated with an unfavourable outcome after Salter innominate osteotomy in patients with unilateral developmental dysplasia of the hip: does occult dysplasia of the contralateral hip affect the outcome? Bone Joint J. 2014 Oct;96-B(10):1419-23.

10. Kamegaya M, Shinohara Y, Shinada Y, Moriya H, Koizumi W, Tsuchiya K. The use of a hydroxyapatite block for innominate osteotomy. J Bone Joint Surg Br. 1994 Jan;76(1):123-6.

11. Wang CW, Wang TM, Wu KW, Huang SC, Kuo KN. The comparative, long-term effect of the Salter osteotomy and Pemberton acetabuloplasty on pelvic height, scoliosis and functional outcome. Bone Joint J. 2016 Aug;98-B(8): 1145-50.

12. Kalamchi A. Modified Salter osteotomy. J Bone Joint Surg Am. 1982 Feb;64(2): 183-7.

13. Synder M, Forlin E, Xin S, Bowen JR. Results of the Kalamchi modification of salter osteotomy in the treatment of developmental dysplasia of the hip. J Pediatr Orthop. 1992 Jul-Aug;12(4):449-53.

14. Barrett WP, Staheli LT, Chew DE. The effectiveness of the Salter innominate osteotomy in the treatment of congenital dislocation of the hip. J Bone Joint Surg Am. 1986 Jan;68(1):79-87.

15. Rossillon R, Desmette D, Rombouts JJ. Growth disturbance of the ilium after splitting the iliac apophysis and iliac crest bone harvesting in children: a retrospective study at the end of growth following unilateral Salter innominate osteotomy in 21 children. Acta Orthop Belg. 1999 Sep;65(3):295-301.

16. Eren A, Pekmezci M, Demirkiran G, Cakar M, Guven M, Yazici M. Modified Salter osteotomy for the treatment of developmental dysplasia of the hip: description of a new technique that eliminated the use of pins for internal fixation. J Bone Joint Surg Br. 2007 Oct;89(10):1375-8.

17. Sanchez Mesa PA, Yamhure FH. Percutaneous innominate pelvic osteotomy without the use of bone graft for femoral head coverage in children 2-8 years of age. J Pediatr Orthop B. 2010 May;19(3):256-63.