CLINICAL ARTICLE

Change of Pelvic Sagittal Tilt after Total Hip Arthroplasty in Patients with Bilateral Crowe Type IV Developmental Dysplasia of the Hip

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Objective: To explore and analyze the change of pelvic sagittal tilt (PST) after total hip arthroplasty (THA) in patients with bilateral Crowe type IV developmental dysplasia of the hip (DDH).

Methods: The study retrospectively evaluated 43 patients with bilateral Crowe type IV DDH undergoing THA from January 2008 to June 2019 who were followed up for 12 months postoperatively. Four parameters, including the ratio between the height and width of the obturator foramina(H/W ratio), the vertical distance between the upper edge of the symphysis and the middle of the sacrococcygeal joint (SSc distance), the vertical distance between the upper edge of the symphysis and the line connecting bilateral hip centers (SC distance) and the vertical distance between the upper edge of the symphysis and the line connecting the bilateral lower ends of the sacroiliac joints (SSi distance), which could indirectly reflect the change of PST, were observed and measured by radiographs. The change of each parameter before operation, immediately after operation, and in 3, 6 and 12 months postoperatively was compared and analyzed.

Results: Compared with the value before operation, the H/W ratio immediately after operation and in 3, 6 and 12 months postoperatively were 0.61 ± 0.12 ($t = 0.893$, $P = 0.377$), 0.61 ± 0.11 ($t = 1.622$, $P = 0.112$), 0.67 ± 0.10 ($t = 5.995$, $P < 0.001$) and 0.76 ± 0.12 ($t = -9.313$, $P < 0.001$), respectively, and the SSc, SC and SSi distance in 6 months postoperatively were 30.12 ± 7.06 mm ($t = 3.506$, $P = 0.002$), 42.8 ± 7.7 mm ($t = 5.843$, $P < 0.001$), 129.3 ± 12.6 mm ($t = 5.888$, $P < 0.001$), respectively, and in 12 months postoperatively were 27.24 ± 7.68 mm ($t = 6.510$, $P < 0.001$), 36.1 ± 9.1 mm ($t = 9.230$, $P < 0.001$), 118.9 ± 14.9 mm ($t = 8.940$, $P < 0.001$), respectively. The radiographs obtained in 6 and 12 months postoperatively demonstrated a significantly increased H/W ratio and decreased SSc, SC and SSi distance. At the last follow-up, the clinical evaluations significantly improved in all patients and there were no revisions.

Conclusion: The significant change of pelvic sagittal posterior tilt in patients with bilateral Crowe type IV DDH might be a significant phenomenon after THA, which could occur in 6 months postoperatively.

Key words: Crowe type IV; Developmental dysplasia of the hip; Pelvic landmark; Sagittal tilt; Total hip arthroplasty

Introduction

Bilateral Crowe type IV developmental dysplasia of the hip (DDH), associated with the most severe morphological abnormalities of the femur and acetabulum and the highest degree of hip dislocation, is a recognized cause of progressive hip osteoarthritis (OA).[1–9] The skeletal deformity of Crowe type IV DDH occurs not only in the hip joint but in the pelvis and the spine, which is reflected in pathological compensatory sagittal pelvic anterior tilt and lumbar lordosis owing to the inadequate support for bilateral anatomic

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alacetabulum without femoral heads. Total hip arthroplasty (THA) could eliminate deformities of the hip and establish a new spine-pelvic sagittal balance, which is the most effective solution to this condition.[10–13]

Change of pelvic sagittal tilt (PST) before and after THA caused by DDH reveals that operations have effects on the pelvic sagittal plane and the anteversion angle of the acetabulum.[14–20] Though Blondel *et al.*[19] reported no significant change in pelvic morphology after THA for unilateral OA with a 3-year follow-up, and Maratt *et al.*[21] studied 138 patients with unilateral OA before and 6 weeks after THA and found that the change of pelvic tilt in all patients had no significant differences. Also, Tamura *et al.*[15] reported a 10-year follow-up of patients with OA undergoing THA and found that the PST in the supine position showed no significant changes. However, Suzuki *et al.*[22] studied the PST of patients with unilateral DDH, demonstrating a significant posterior change in 5 years after THA.

For bilateral Crowe type IV DDH, which is one of the most complicated hip diseases, most studies just focused on the analysis of the pelvic pathological morphology without operations. Tani *et al.*[23] studied 25 patients with unilateral DDH who were not classified by Crowe classification after periacetabular osteotomy for a 2-year follow-up on PST, showing PST decreased from an average of 8.3° before the operation to 6.2° in supine position. Huang *et al.*[24] reported that the pelvis of patients with unilateral Crowe type IV DDH possessed the characteristics of asymmetry deformity and average 8° anteversion in PST, and the change of PST after operation needs to be studied further. Limited studies have focused on the pelvic sagittal change of patients with bilateral Crowe type IV DDH after THA.

Therefore, this study aimed to: (i) observe and measure the parameters representing PST on plain anteroposterior (AP) radiographs in patients with bilateral Crowe type IV DDH; (ii) evaluate the variation of PST after THA; and (iii) analyze the influence of the change in PST.

Patients and Methods

Inclusion and Exclusion Criteria

The inclusion criteria were: (i) adult patients with bilateral Crowe type IV DDH; (ii) patients who underwent primary THA receiving modular cementless prosthesis (S-ROM, DePuy, Warsaw, IN, USA) from a single surgeon in our institution between January 2008 and June 2019; (iii) results evaluated by four parameters indirectly reflecting the change of PST, Harris hip score (HHS), visual analogue scale (VAS), Trendelenburg sign and limp; and (iv) a retrospective study. The exclusion criteria were patients with histories of neuromuscular diseases or operations for spine.

Patients

This study involved a retrospective analysis of 48 patients with bilateral Crowe type IV DDH undergoing primary THA from January 2008 to June 2019, which was approved by the Institutional Review Board of our hospital (S2020-138-01). All patients were informed of the study that required AP radiographs of the pelvis before operation, immediately after operation, and in 3, 6, and 12 months postoperatively. Written informed consent was obtained. After excluding one patient with prior hip operation and four patients with incomplete radiographs, a total of 43 patients who were classified to Crowe type IVA according to the Crowe and Zhou classifications were investigated[2,13,25] and named as Group A and Group B was defined in the Radiographic measurement(Table 1).

Surgical Process

Anesthesia and Position

All procedures were performed by one senior surgeon (Y. G. Zhou) in lateral decubitus position under general anesthesia, as previously described.[2–4,13]

Approach and Exposure

All operations were performed using a posterolateral approach. Briefly, the fascia and gluteus maximus were split, and the short external rotators were divided. Subsequently, the hip joint was dislocated, and the true acetabulum was exposed.

Resection

The femoral head was resected based on the preoperative templating. The malformed and undeveloped acetabulum were reamed posteriorly and inferiorly.

TABLE 1 Demographics of patients

Demographics	Group A	Group B	*t*-value[a]	*P*-value
Number of patients	43	28		
Female/male	38/5	26/2	0.384	0.536
Age (years)*	38.4 ± 12.1	39.6 ± 11.9	−0.415	0.679
Height (cm)*	153.9 ± 6.9	153.1 ± 7.4	0.455	0.650
BMI (kg/m^2)*	22.8 ± 3.8	23.0 ± 4.1	−0.225	0.823

Abbreviation: BMI, body mass index.; Group A includes all 43 patients; Group B includes the patients whose SSc distance (one of four radiographic parameters) is visible for measurement out of all patients (28/43), because the interference of bowel gas in radiographs exists in residual patients (15/43).; [a] The *t*-value in gender ratio is expressed by chi-squared value.; * The values are expressed as the mean and standard deviation.

Fixation of Prosthesis

A cementless acetabular cup of ceramic-on-ceramic bearing (Pinnacle, DePuy, Warsaw, IN, USA) was implanted at the anatomic position. Two or three screws were used to fix the cup to augment the primary stability. Contracted soft tissue were released to achieve the proper tension. Shortening subtrochanteric osteotomy was performed if the reduction was difficult. The length of osteotomy was equaled to the distance between the center of true acetabular and the center of femoral head minus approximately 15 mm. A triangular or cone sleeve that was selected to match the femoral canal best was chosen according to the intramedullary morphology of proximal femur, in which the point of osteotomy was fixed using cerclage wiring. Prostheses with a modular titanium alloy femoral stem with a titanium sintered proximal sleeve were used in all hips.

Postoperative Reconstruction

All patients received antithrombotic prophylaxis with aspirin and assistance by two crutches to load two legs for 6 weeks postoperatively.

Radiographic Measurement

Standardized AP radiographs of the pelvis were obtained in supine positions before operation, immediately after operation, and in 3, 6, and 12 months postoperatively in all selected patients. The central X-ray beam was focused over the superior margin of the pubic symphysis, and the line between the anterior superior iliac spines was perpendicular to the central beam. Each patient was placed in a comfortable and the same posture when radiographs were obtained.

Different parameters were analyzed associated with pelvic tilt on AP pelvic radiographs. We followed the methods of Tannast *et al.*[26] and Kanazawa *et al.*[20] to measure four parameters indirectly estimating pelvic tilt based on plain AP radiographs in supine positions.

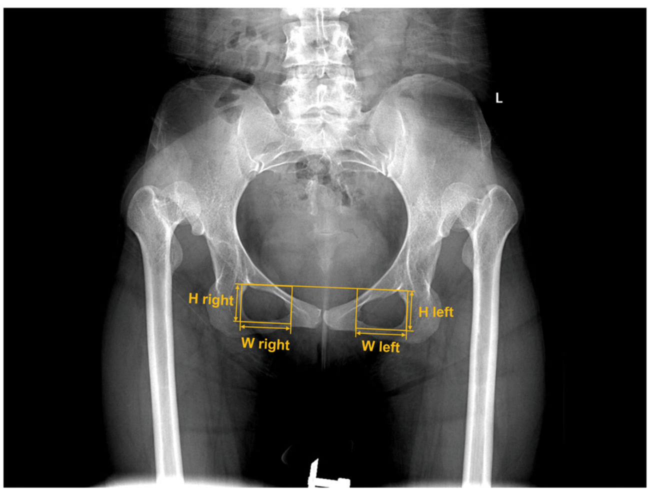

Fig. 1 The ratio between the height and width of the obturator foramina (H/W ratio): H-right was the height of the right obturator foramina, which is the maximum lengths vertical to the both inter-teardrop lines; W-right was the width of the right obturator foramina, which is the maximum length vertical to the H-right; H-left was the height of the left obturator foramina, which is the maximum lengths vertical to the both inter-teardrop lines; W-left was the width of the left obturator foramina, which is the maximum length vertical to the H-left

H/W Ratio

H/W ratio is the ratio between the height and width of the obturator foramina (the mean value of H right /W right and H left /W left). The widths of the obturator foramina were defined as the maximum lengths (W right and W left) parallel to both inter-teardrop lines, and the heights (H right and H left) were defined as the maximum lengths vertical to the line defining the widths of the obturator foramina (Fig. 1).

SSc Distance

SSc distance is the vertical distance between the upper edge of the symphysis and the middle of the sacrococcygeal joint (Fig. 2). The SSc distance was measured in 28 out of 43 selected patients, since the sacrococcygeal joint was invisible in a small proportion of patients (15/43) because of bowel gas. The 28 patients who showed no significant demographic differences from Group A were named as Group B (Table 1).

SC Distance

SC distance is the vertical distance between the upper edge of the symphysis and the line connecting bilateral hip centers (Fig. 3).

SSi Distance

SSi distance is the vertical distance between the upper edge of the symphysis and the line connecting the bilateral lower ends of the sacroiliac joints (Fig. 4).

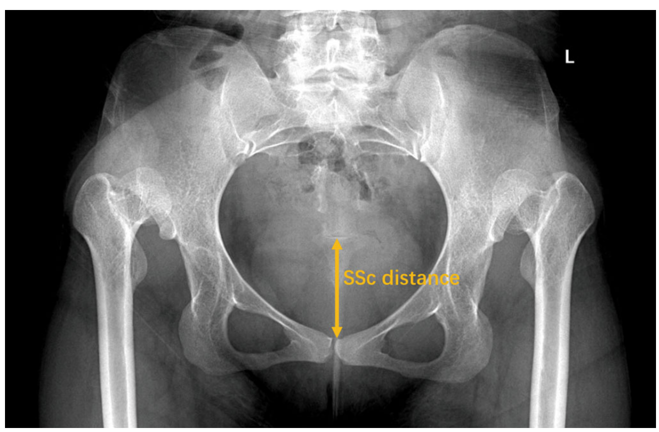

Fig. 2 The vertical distance between the upper edge of the symphysis and the middle of the sacrococcygeal joint (SSc distance)

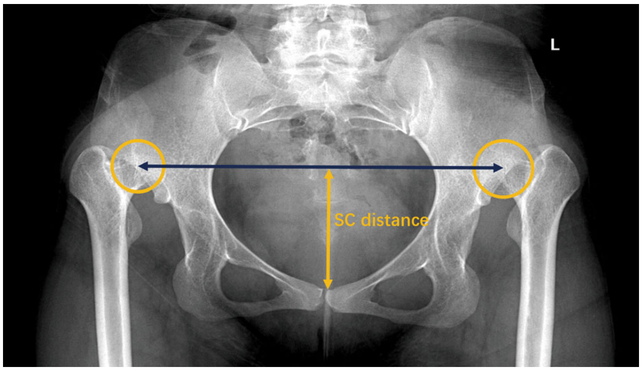

Fig. 3 The vertical distance between the upper edge of the symphysis and the line connecting bilateral hip centers (SC distance)

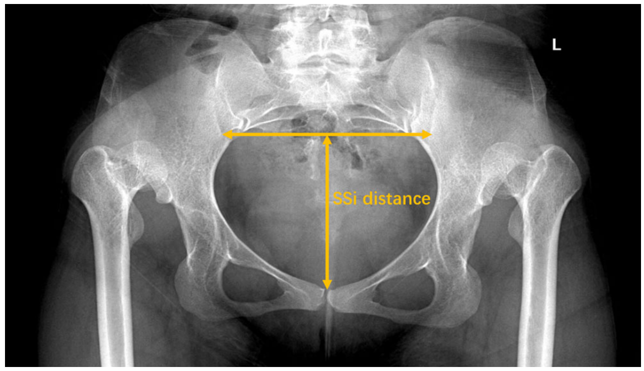

Fig. 4 The vertical distance between the upper edge of the symphysis and the line connecting the bilateral lower ends of the sacroiliac joints (SSi distance)

All the radiographs were viewed and measured by two independent observers on the AP pelvic radiographs using a picture archiving and communication system version 4.0 (UniWeb Viewer, EBM technologies, Medcare, Qingdao, China) to assess inter-observer reliability. After 4 weeks, these measurements were repeated to assess intra-observer reliability.

Clinical Outcome Assessment

Harris Hip Score (HHS)
The patients were evaluated in terms of HHS, which was used to evaluate postoperative hip function before operation and at the last follow-up. The HHS score system mainly includes four aspects as pain, function, absence of deformity, and range of motion. The score has scales up to 100 as follows: excellent (90–100), good (80–89), fair (70–79), or poor (<70).[27]

Visual Analogue Scale (VAS)
VAS was used to measure the extent of intangible quantities, such as pain, quality of life, and anxiety. The pelvic anterior tilt was common in patients with bilateral Crowe type IV DDH because of hip dislocations, followed by low back pain. VAS was used to assess pain intensity, in which a score of 10 indicates "worst pain imaginable," and a score of 0 indicates "no pain."

Trendelenburg Sign and Limp
Trendelenburg sign was used to assess the strength of gluteus medius. Any visual evidence of unbalanced movement of lateral pelvis during gait was considered as limp.[4,10]

Statistical Analysis
Continuous variables such as demographics, radiographic measurements, and clinical scores were described as the mean and standard deviation. The normal distribution of the values was checked using Shapiro–Wilk normality test for all results. Differences in mean values among each period were analyzed using paired Student's *t*-test. Categorical variables were assessed by chi-squared test. The significance level was set at $P < 0.05$. All analyses were performed using SPSS Version 26.0 software (IBM, Armonk, NY, USA).

Results

General Results and Follow-Up
The demographic characteristics of Groups A and B are shown in Table 1. In Group A, the mean operative time was 4.5 ± 0.7 h, and the mean intraoperative blood loss was 980 ± 403 ml. In Group B, the mean operative time was 4.3 ± 0.7 h, and the mean intraoperative blood loss was 880 ± 341 ml. No significant difference was observed in operative time ($t = 0.741$, $P = 0.461$) and intraoperative blood loss ($t = 1.082$, $P = 0.283$) between the two groups. Follow-up was conducted in 3, 6, and 12 months postoperatively. The follow-up time in all patients was 1 year.

Radiographic Results
In comparison with preoperative radiographs, radiographs obtained in 6 and 12 months postoperatively demonstrated a significant increase in mean H/W ratio and significant decrease in mean SSc, SC, and SSi distance (Fig. 5).

H/W Ratio
The mean H/W ratio of all patients (Group A) before operation, immediately after operation, and in 3, 6, and 12 months postoperatively were 0.60 ± 0.11, 0.61 ± 0.12, 0.61 ± 0.11, 0.67 ± 0.10, and 0.76 ± 0.12, respectively. There were no significant differences in H/W ratio immediately after operation ($t = 0.893$, $P = 0.377$) and 3 months postoperatively ($t = 1.622$, $P = 0.112$) compared to the preoperative value. However, the increased H/W ratio in 6 and 12 months postoperatively both significantly differed ($t = 5.995$, $P < 0.001$; $t = 9.313$, $P < 0.001$) in all patients.

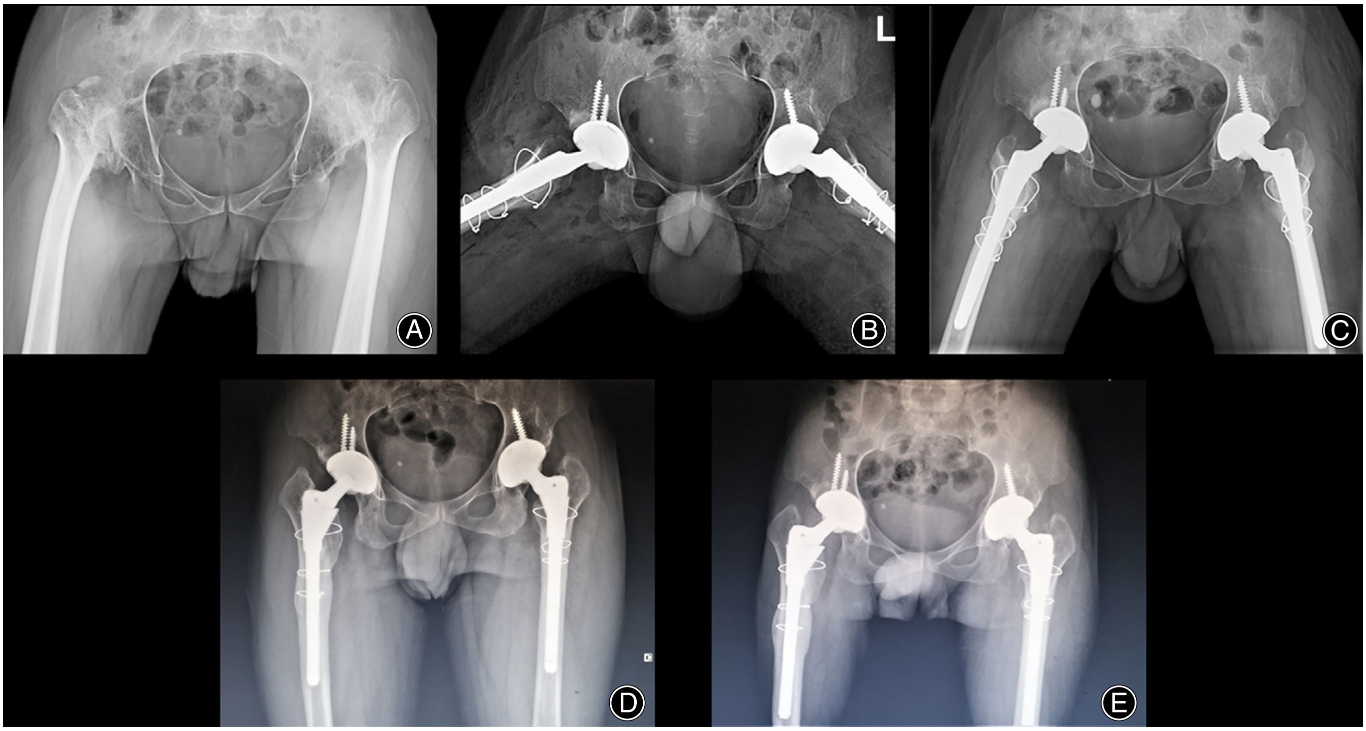

Fig. 5 Compared with preoperative radiographs which demonstrated the pelvis was in sagittal anterior tilt (A), and radiographs taken immediately after THA (B) and in 3 months postoperatively (C) demonstrated the insignificant change of pelvic sagittal tilt. The radiographs taken in six (D) and 12 months (E) postoperatively demonstrated significant increase in H/W ratio and significant decrease in SSc, SC, and SSi distance, which showed the distinct change in pelvic sagittal posterior tilt

SSc Distance

The mean SSc distance of patients in Group B before operation, immediately after operation, and in 3, 6, and 12 months postoperatively were 31.90 ± 6.64, 31.70 ± 6.61, 31.79 ± 6.15, 30.12 ± 7.06, and 27.24 ± 7.68 mm, respectively. In comparison with the preoperative value, no significant change was observed in SSc distance immediately after operation (t = 1.476, P = 0.152) and in 3 months postoperatively (t = 0.359, P = 0.723). However, the value measured in 6 months (t = 3.506, P = 0.002) and 12 months (t = 6.510, P < 0.001) postoperatively significantly decreased.

SC Distance and SSi Distance

The mean SC distances of all patients (Group A) before operation, immediately after operation, and in 3, 6, and 12 months postoperatively were 47.6 ± 8.3 mm, 47.0 ± 8.8 mm (t = 0.781, P = 0.439), 47.1 ± 8.2 mm (t = 1.389, P = 0.172), 42.8 ± 7.7 mm (t = 5.843, P < 0.001), and 36.1 ± 9.1 mm (t = 9.230, P < 0.001); while the mean SSi distances were 137.2 ± 13.6 mm, 136.5 ± 14.4 mm (t = 0.574, P = 0.569), 136.9 ± 13.5 mm (t = 0.508, P = 0.614), 129.3 ± 12.6 mm (t = 5.888, P < 0.001), 118.9 ± 14.9 mm (t = 8.940, P < 0.001), respectively. Both parameters were significantly decreased in 6 and 12 months postoperatively (P < 0.001) compared with the preoperative value. Reliability analysis demonstrated that the ICC of both inter-observer and intra-observer agreements were larger than 0.81.

Clinical Outcome Assessment

HHS and VAS

In both Groups A and B, the HHS at the last follow-up significantly increased, and the VAS significantly decreased. In Group A, the mean HHS improved from 49.45 ± 13.58 points to 93.94 ± 3.06 points (t = 29.332, P < 0.001), and the mean VAS decreased from 5.88 ± 1.12 points to 0.65 ± 0.62 points (t = 27.737, P < 0.001). In Group B, the mean HHS improved from 48.77 ± 13.69 points to 92.98 ± 2.94 points (t = 23.058, P < 0.001), and the mean VAS decreased from 5.87 ± 1.24 points to 0.75 ± 0.63 points (t = 19.834, P < 0.001). No significant differences were observed in HHS and VAS between the two groups (Table 2).

Trendelenburg Sign and Limp

Clinically, the negative Trendelenburg sign was presented in 94.2% (81/86) of hips, which was significantly better than the preoperative condition. Furthermore, only one patient occurred limp, which may be associated with the lack of exercise after THA.

TABLE 2 Functional evaluation

	HHS				VAS			
Groups	preoperatively	last follow-up	*t*-value	*P*-value	preoperatively	last follow-up	*t*-value	*P*-value
Group A*	49.45 ± 13.58	93.34 ± 3.06	29.332	<0.001	5.88 ± 1.12	0.65 ± 0.62	27.737	<0.001
Group B*	48.77 ± 13.69	92.98 ± 2.94	23.058	<0.001	5.87 ± 1.24	0.75 ± 0.63	19.834	<0.001
t-value	0.291	0.694			0.019	−0.650		
p-value	0.771	0.489			0.985	0.518		

Abbreviations: HHS, Harris hip score; VAS, visual analogue scale.; Group A includes all 43 patients; Group B includes the patients whose SSc distance (one of four radiographic parameters) is visible for measurement out of all patients (28/43), because the interference of bowel gas in radiographs exists in residual patients (15/43).; * The values are expressed as the mean and standard deviation.

Complications

Dislocations occurred in two hips. One was in the right hip in 1 month postoperatively, the other was in the left hip in 3 months postoperatively. Both underwent open reduction immediately. Periprosthetic fracture of right femur occurred in one hip in 4 days after operation because of osteoporosis. Open reduction and enhanced internal fixation were performed immediately to stabilize the femoral prosthesis, and the fracture healed in 6 months. No other complications and revisions were observed. All patients achieved inspiring outcomes at the last follow-up.

Discussion

Previous studies evaluating the PST on patients with DDH have mainly focused on the pathological morphology without operation.[7–9,22–25] And the overall change of PST after THA in bilateral Crowe type IV DDH has not been analyzed.

Time of Change in PST

The pelvic anterior tilt and compensation of total sagittal alignment of spine is common in bilateral Crowe type IV DDH owing to the high dislocation of the hip.[7,9,26,28] Radiographically, in our study there were different changes in H/W ratio and SSc, SC, and SSi distance from preoperative period to 12 months postoperatively. While the significant increase in H/W ratio and decrease in the other three parameters just were shown in 6 and 12 months postoperatively, which indicated that early pelvic sagittal posterior tilt could occur in 6 months after THA. And this result reflected that the time of soft-tissue reconstruction in the pelvis and hips might last up to 6 months or even longer.

Compared to our results, Ren *et al.*[9] revealed that patients with Crowe type IV DDH exhibited abnormal spinal-pelvic alignment characterized by pelvic anterior tilt, but there were no results about the change of PST after THA, which were just limited to the morphological descriptions without any solutions for this hip disease. Taki *et al.*[14] suggested that pelvic sagittal plane significantly tilted posteriorly over 2 to 4 years postoperatively in 86 patients who consisted of 69 patients with DDH, which was similar to our findings. While the change and reconstruction in PST for bilateral Crowe type IV DDH could occur earlier because of more severe preoperative deformity, like the PST in our study could change significantly in 6 months postoperatively. To our knowledge, this study is the first to examine the change of PST after THA in patients with bilateral Crowe type IV DDH.

Degree of Hip Deformity Affects PST

Suzuki *et al.*[22] reported patients with unilateral DDH after THA showed a posterior change in pelvic tilt until 5 years postoperatively, which was different from what we demonstrated. However, the pelvis existing bilateral hip OA and a higher hip dislocation would occur more severe anterior tilt because of soft-tissue contracture than those with unilateral OA and slight dislocation, and patients with larger anterior tilt preoperatively could occur more obvious changes of PST after the operations.[16,18,29] Therefore, the posterior change of PST after THA in our study could happen earlier and more distinctly compared to the results reported by Suzuki *et al.*, because bilateral Crowe type IV DDH may be one of the most severe conditions characterized by severe high dislocation, pelvic deformity and lumbar hyper-lordosis.[6,7,9,24,30]

For the patients with simple hip OA, Shareghi *et al.*[17] suggested that pelvic posterior tilt occurred a little up to 7 years postoperatively, and Kanto *et al.*[31] and Blondel *et al.*[19] reported no significant changes happened in PST in the first year after THA. This might be explained by the differences in demography and diagnoses of hip diseases. Blondel *et al.* excluded the patients with spinal deformity and bilateral arthritis, and the OA without DDH showed less deformities of hip and pelvis, resulting in insignificant change or no change in PST compared to the cases in our study.

The elimination of the contracture in hips, relief of pain in hips and the lower back, and recovery of muscle strength could be achieved in 1 year postoperatively according to the satisfactory HHS, VAS and the good results in Trendelenburg sign and limp in this study.

The Influence of PST and Radiographic Position

Babisch *et al.*[32] reported that when using preoperative radiographs to inform the placement of the acetabular component, surgeons should note the dynamic change of PST and effect on postoperative acetabular alignment, which could decrease the occurrence of adverse outcomes, such as the dislocations in our study.[17,22,33,34]

Routinely, the observation of the pelvis is determined by radiographs in the supine position in perioperative period,[17] and the measurement of PST from a single supine film is valid and reliable for evaluating the pelvic position.[17,26,33–35] In addition, AP pelvic radiographs remain the standard of care imaging modality for pre and postoperative assessment during THA owing to easy accessibility, cost effectiveness, low radiation exposure, and widespread availability,[18,26,33,36] and the use of AP radiographs to assess changes in pelvis has been validated,[34,37] which proved that the position and radiographic methods we used in this study was appropriate. And radiographic overlap could occur in a lateral position between right and left hips, making the diagnostic evaluation complicated and less efficient.[18,35,38]

Comparison of Parameters for Evaluating PST

In this study, we followed the method of Tannast *et al.*[26] to evaluate the change in PST by the measurements of pelvic landmarks and the obturator foramina. Tannast *et al.* compared six methods on plain AP radiographs and revealed that the H/W ratio of the obturator foramina was one of the parameters having a significantly strong correlation with PST in both males and females.[20,26] Matsuyama *et al.*[7] proposed that the deformity of DDH, especially in Crowe type IV DDH, included not only the pelvic anatomical shape and lumbar lordosis but also the abnormal positional relationship of the pelvis in various planes, which determined parameters related to the inner diameter of the pelvis could not be used to assess PST accurately. Therefore, the use of H/W ratio of the obturator foramina and the SSc distance in our study were less affected by the deformity resulting from DDH and could achieve more convincing results. In addition, it would be more intuitive and effective to identify the change of PST by observing and measuring the obturator foramina with H/W ratio. Tannast *et al.*[26] and Uemura *et al.*[35] showed that only the SSc distance had a moderately strong positive correlation with PST, which could be found for all patients based on a large group. While the inability to reliably identify the required landmarks on radiographs using the SSc distance presented the obstacle because of the bowel gas or other abdominal artifacts, thus limiting the broad application. It was unable to identify the coccyx in 35% (15/43) of our cases, nevertheless, there were no statistical differences in demographics between Groups A and B, so our results in Group B were also generally representative.

Limitations

This study has several limitations. First, we did not set more subgroups because of the small sample size. However, bilateral Crowe type IV DDH is a rare condition, and a study with a larger sample size is hard to perform. Second, this study is retrospective in nature. However, our patients were identified from a consecutive series with DDH, which may reduce the possibility of selection bias. Third, our study was performed in East Asia. Our results might not be generalizable to patients with a higher body mass index in western countries. Finally, although radiological inclusion criteria could ensure standardization in the AP radiographs, we did not investigate small variations of radiological beam angle or the position of patients, which may have slight effect.

Conclusion

In comparison with preoperative radiographs, the patients with bilateral Crowe type IV DDH have exhibited a change of posterior PST in AP radiographs after THA to restore the normal pelvic anatomical position, and the change is dynamic and fluctuating. The significant change of PST could occur in 6 months postoperatively. Furthermore, identifications of these patients before the THA could be beneficial to obtain the optimum position and alignment of implants, decreasing the risk of complications and increasing the survival rate.

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