



## Postural and Chronological Change in Pelvic Tilt Five Years After Total Hip Arthroplasty in Patients With Developmental Dysplasia of the Hip: A Three-Dimensional Analysis



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### ABSTRACT

The pelvis generally tilts to the posterior with movement from the supine to standing position, and with time after total hip arthroplasty (THA). This study aimed to investigate changes in pelvic tilt from the preoperative supine position to the standing position at 5 years after THA (pelvic change, PC). We measured pelvic tilt using a 2D–3D matching technique in 77 unilaterally affected patients who underwent primary THA. PC in 8% of all patients was  $\leq -20^\circ$ , and the greatest PC was  $-25^\circ$ . In these patients, posterior pelvic tilt continued up to 5 years after THA. These patients were older, and their lumbo-lordotic angle was small. For such cases, cup orientation should be planned to account for continuous posterior change in pelvic tilt after THA.

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Total hip arthroplasty (THA) is a widely used procedure to treat osteoarthritis of the hip; however, malposition of the implant causes postoperative complications such as polyethylene wear, implant failure, and dislocation. Kummer et al [1] reported that the adequate range of cup inclination was  $35^\circ$  to  $45^\circ$ , and that of cup anteversion was  $0^\circ$  to  $10^\circ$ . Lewinnek et al [2] recommended cup inclination of  $30^\circ$  to  $50^\circ$  and cup anteversion of  $5^\circ$  to  $25^\circ$ . Widmer and Zurfluh [3] reported that the sum of cup anteversion and 0.7 times the stem antetorsion should equal  $37.3^\circ$  to achieve a maximal and stable postoperative range of motion (ROM) of the hip.

When planning THA, it is common to use radiographs of the pelvis in the supine position. Additionally, in three-dimensional planning using preoperative computed tomography (CT) images of the pelvis, several authors recommend using the pelvic plane in the supine position as the reference pelvic plane in most cases [4,5]. However, when a precise cup orientation is obtained at the time of THA, the functional cup inclination and anteversion will change if the pelvis tilts after THA [6–10].

**Abbreviations:** AP, anteroposterior; APP, anterior pelvic plane; ASIS, anterior superior iliac spines; CT, computed tomography; FPP, functional pelvic plane; LEP, lower end plate; LLA, lumbo-lordotic angle; PC, pelvic change;  $PT_{\text{stand}}$ , pelvic tilt in the standing position;  $PT_{\text{supine}}$ , pelvic tilt in the supine position; ROM, range of motion; SB, sagittal balance; THA, total hip arthroplasty; TKA, thoraco-kyphotic angle; UEP, upper end plate.

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Lembeck et al [11] reported that cup anteversion changes by  $0.7^\circ$  per  $1^\circ$  change in pelvic tilt, and Babisch et al [12] reported that cup inclination changes by about  $0.3^\circ$  and cup anteversion by about  $0.8^\circ$  per  $1^\circ$  change in pelvic tilt.

We sometimes treat cases in which the pelvis tilts greatly to the posterior from the supine to the standing position and with time after THA. In such cases, the cup anteversion increases greatly, and the cup orientation deviates from the adequate range for cup orientation in the postoperative situation. Therefore, when planning THA for such cases, it might be reasonable to set the reference pelvic plane more posteriorly than that in the preoperative supine position and to reduce cup anteversion by several degrees in order to account for the posterior change in pelvic tilt that will occur after THA. Several authors reported that pelvic tilt changes with patients' posture and over time after THA [13–16]. In general, the pelvis tilts to the posterior with movement from the supine position to the standing position, as well as with time after THA. In terms of postural change, Nishihara et al [4] reported that the pelvis tilts posteriorly from the supine to standing position in most cases. In terms of chronological change, Taki et al [17] reported that the pelvis tilts posteriorly after THA. Therefore, it is likely that the change in pelvic tilt from the preoperative supine position to the postoperative standing position would reflect the greatest change to the posterior for patients who underwent THA.

During preoperative planning for THA, it might be helpful to estimate the postoperative change in pelvic tilt after THA, especially for patients who are likely to demonstrate significant posterior change in pelvic tilt from the preoperative supine position to the postoperative

standing position. However, there are few reports concerning the relationship between patients' preoperative condition and the postural or chronological change in pelvic tilt up to 5 years after THA for patients with a unilateral functional disorder of the hip. We hypothesized that the change in pelvic tilt after THA was affected by preoperative factors such as the condition of the contralateral hip or spinal alignment.

Therefore, our objective was to determine which patients were likely to demonstrate a significant posterior change in pelvic tilt based on a combination of postural and chronological changes after THA. We investigated postural and chronological change in pelvic tilt up to 5 years after THA, using a 2D–3D matching technique with a three-dimensional CT model. Additionally, we evaluated the change in pelvic tilt from the preoperative supine position to the standing position at 5 years after THA (pelvic change, PC) as the maximum posterior change in pelvic tilt based on a combination of postural and chronological changes after THA and examined the preoperative factors that affect PC.

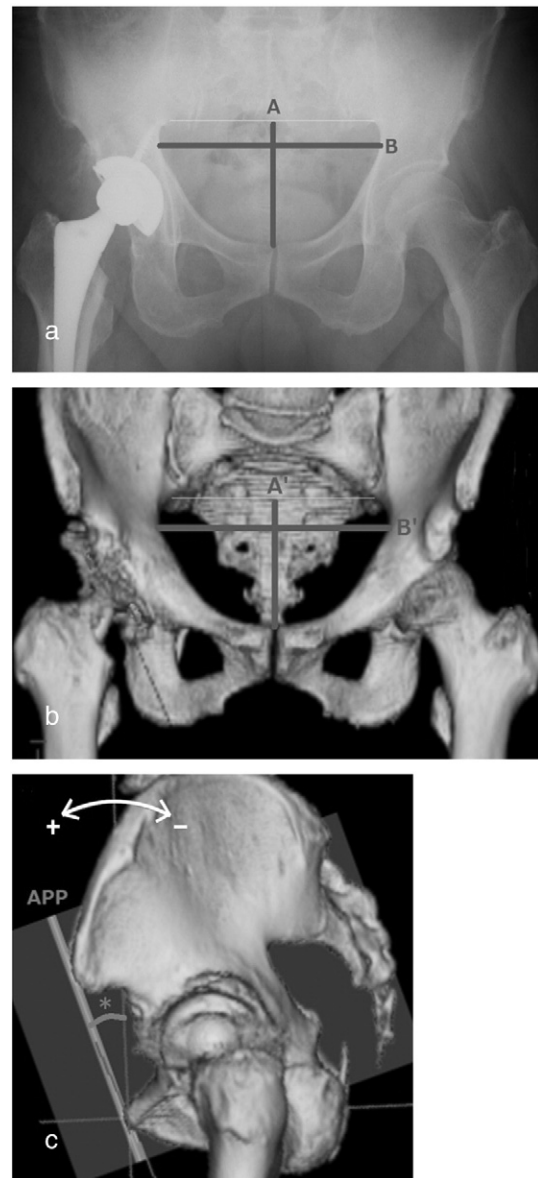
## Materials and Methods

This study was approved by the authors' institutional review board, and informed consent was obtained from all patients.

We assessed 77 hips of 77 patients who were unilaterally affected by secondary osteoarthritis due to developmental dysplasia of the hip and who underwent primary THA at our institution. The group consisted of 64 women and 13 men, with a mean age of 64.4 years (range: 44–82 years). To evaluate the severity of the developmental dysplasia of the hip, we used the Crowe classification [18]. We also examined clinical outcomes using the Harris hip score (HHS) [13]. The HHS consists of four components: pain (0–44), function (0–47), absence of deformity (0–4), and ROM (0–5), with higher scores representing a better functional status. All surgeries were performed with the patient in the lateral position on the operating table, using a modified mini-incision direct lateral approach [19]. A CT-based navigation system was used for all cases in the current study (Stealth Station TREON Plus, Medtronic Inc., Louisville, KY), along with metal-backed acetabular cups and cementless femoral stems. Leg length was equalized under guidance of the navigation system. Sixty-one patients underwent THA with Trilogy® cups and VerSys® Fiber Metal MidCoat stems (Zimmer Inc., Warsaw, IN), 8 patients with TriAD® cups and Secure-Fit® stems (Stryker Inc., Mahwah, NJ), 6 patients with REFLECTION® cups and SL-PLUS® stems (Smith & Nephew Inc., Memphis, TN), and 2 patients with TriAD® cups and Accolade® TMZF stems (Stryker Inc., Mahwah, NJ). The implanted head size was 26 mm in 68 patients and 28 mm in 9 patients.

Antero-posterior (AP) radiographs of the pelvis were taken in the supine and standing positions preoperatively and once annually after THA. The target for the central X-ray beam was over the superior margin of the pubic symphysis. AP radiographs of the pelvis were also taken so that the line between the anterior superior iliac spines (ASIS) was perpendicular to the central beam. CT images of the pelvis were obtained at 1 week after THA for all cases.

In order to match AP radiographs of the pelvis with the three-dimensional CT model, we measured two parameters on AP radiographs in the supine and standing positions, consistent with the report of Nishihara et al [4] (Fig. 1): one (A) was the distance between the line connecting the inferior margins of the bilateral sacroiliac joints and the superior margin of the pubic symphysis, and the other (B) was the maximum horizontal diameter of the pelvic foramen. Distance A was then divided by Diameter B to give the A/B ratio. The three-dimensional CT model was rotated around the horizontal axis until its A/B ratio matched that of the AP radiograph. The pelvic tilt was defined as the angle between the anterior pelvic plane (APP) in this position and the standard plane. The standard planes were the horizontal plane in the supine position and the vertical plane in the standing position. The APP was defined as the plane of the bilateral ASIS and the superior margin of the pubic symphysis. A positive pelvic tilt angle indicates anterior



**Fig. 1.** Measurement of pelvic tilt using a 2D–3D matching technique. (A) AP radiograph of the pelvis: Distance A is the distance between the inferior margins of the sacroiliac joints and the superior margin of the pubic symphysis. Diameter B is the maximum horizontal diameter of the pelvic foramen. Distance A was then divided by Diameter B to give the A/B ratio. (B) The three-dimensional CT model is rotated around the horizontal axis, until its A'/B' ratio is matched with that of the AP radiograph. In this manner, the supine and standing positions are able to appear on the CT model. (C) Pelvic tilt: the angle between the anterior pelvic plane (APP) and the standard plane (\*). The standard plane was the horizontal plane in the supine position, and the vertical plane in the standing position.

tilt, and a negative pelvic tilt angle indicates posterior tilt. When the distance A could not be recognized because change in pelvic tilt was severely posterior, the maximum vertical and horizontal diameters of the right obturator foramen were used to measure pelvic tilt.

We examined postural and chronological change in pelvic tilt from the preoperative supine position to the standing position at 5 years after THA (pelvic change, PC) as the maximum posterior change in pelvic tilt based on a combination of postural and chronological changes after THA. PC was the value that was calculated by subtracting the pelvic tilt in the preoperative supine position from the pelvic tilt in the standing position at 5 years after THA. Therefore, a negative value of PC indicates posterior change in pelvic tilt from the preoperative supine position to the standing position at 5 years after THA. The patients

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