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Review Article

# The Impact of Spino-Pelvic Alignment on Total Hip Arthroplasty Outcomes: A Critical Analysis of Current Evidence

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ABSTRACT

*Background:* In this review, we (1) evaluated the effect of adult spine deformity (ASD) and its surgical correction on patients who had a total hip arthroplasty (THA); (2) evaluated the outcomes of THA in patients who have had previous spinal fusion; and (3) we presented an algorithm on how to surgically address patients who simultaneously require THA and ASD correction.
*Methods:* A comprehensive literature search was conducted. Our final analysis included 14 studies. Overall, there were 3 studies that reported on the impact of ASD on THA outcomes, 6 studies reported on the effect of ASD correction on THA outcomes, and 5 studies reported on the effect of spinal fusion on THA outcomes.
*Results:* Patients with concurrent ASD and THA are at increased risk of THA dislocations and revisions with studies reporting a compiled 2.9% dislocation rate in 1167 patients. Patients who underwent ASD correction demonstrated a post-operative reduction of acetabular anteversion (mean reduction range 4.96°-11.2°, $P < .001$) and tilt (mean −7° ± 10°, $P < .001$). In THA patients with concurrent lumbosacral fusion, dislocation rates ranged between 3% at 1 year and 7.5% at 2 years compared to 0.4%-2.1% dislocation rates in matching cohorts ($P < .001$).
*Conclusion:* Spine balance can alter THA outcomes, but the exact mechanism is yet to be elucidated. We aimed at bridging the gap between hip and spine surgeons with an up-to-date analysis of the best available evidence and presented an algorithm for approaching patients who may simultaneously need ASD correction and THA.



In total hip arthroplasty (THA), accurate acetabular cup placement is essential for impingement free and stable range-of-motion. For decades, hip surgeons have relied on traditional safe acetabular zones [1] to reduce prosthetic instability. However, recent evidence from multiple studies has challenged this concept [2–4]. Abdel et al [5] reported that close to 60% of 206 dislocated THAs had a cup placed within the so-called safe zone. Moreover, acetabular orientation is a dynamic parameter that can be impacted by forces acting on the pelvis by changes in pelvic tilt, obliquity, and rotation [6–11]. These forces may originate from above the hip joint (eg, change in spinal alignment), at the hip (eg, muscle weakness or advanced hip degeneration), or below the hip (eg, limb-length discrepancy). These parameters can be altered to change the acetabular socket orientation secondary to pelvic motion. Furthermore, even with navigation systems [12–15], the estimation of the so-called “safe zone” remains largely dependent on static measurements that do not address the pelvis dynamic changes.

Changes in the spinal balance can alter pelvic rotation through changes in pelvic tilt and obliquity [16]. Pelvic tilt may have different definitions between hip and spine surgeons [6,17,18] (see Fig. 1A). In hip reconstruction, pelvic tilt is usually defined as the angle between the global coronal axis of the body and the anterior pelvic plane, while for spine surgeons, it is an angle formed by a line dropped from the midpoint of the sacral endplate to the center of the bicoxo-femoral axis and a vertical line extending this axis in the standing position. When the pelvic tilt is neutral, using anterior referencing points in THA is representative of the patient's functional anatomy. However, any condition that alter the pelvic

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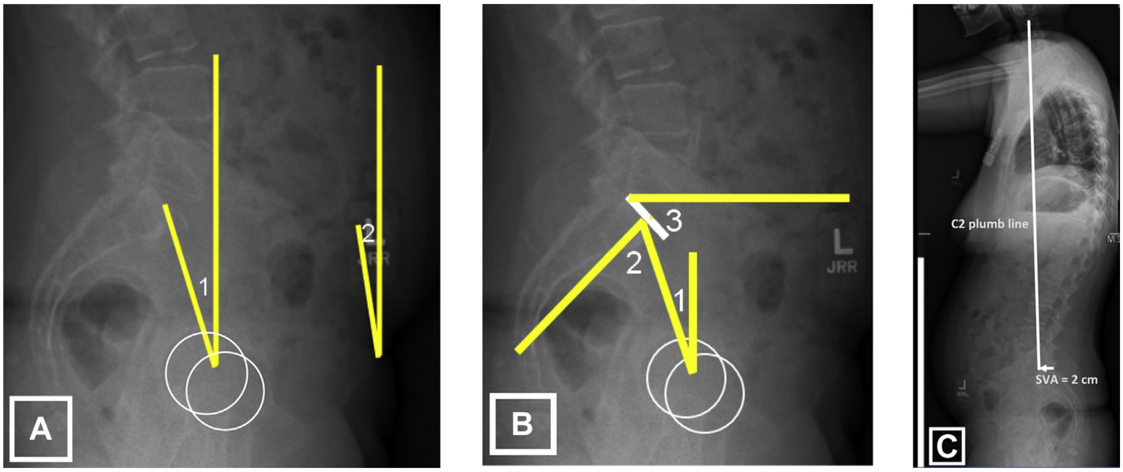


**Fig. 1.** (A) This shows the measurement of PT by 2 methods. Spine surgeons usually measure angle (1) which is formed by a line dropping from the midpoint of the sacral endplate to the center of the bicoxo-femoral axis and a vertical line extending to the bicoxo-femoral axis. Hip surgeons usually use angle (2) which is the angle between the global coronal axis of the body and the anterior pelvic plane. (B) This illustrates important spino-pelvic parameters which are: (1) PT; (2) PI, which is the angle subtended by a line drawn perpendicular to the center of the sacral endplate and a line connecting the center of sacral endplate and the bicoxo-femoral axis; and (3) SS, which is the angle subtended by a line drawn parallel to the endplate of the sacrum and a horizontal reference line from the posterior superior corner of the sacrum. A mathematical relationship exists between these 3 parameters so that PI = PT + SS. (C) This illustrates neutral sagittal balance and normal sagittal plane diameter in a 36-inch spine radiograph. Normally, the SVA distance should be 2 cm or less from the posterior-superior corner of S1 to a vertical plumb line dropped from C7 or C2. PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis.

tilt, whether it was pre-existing at the time of THA implantation or following surgery, may consequently translate into functional malposition of the acetabular cup [4,10,11,19–23]. Studies have demonstrated an increase in acetabular anteversion (AA) of 0.7° for every 1° increase in posterior pelvic tilt [9,20,24]. Similarly, pelvic obliquity secondary to a structural spinal curve and fixed deformity may hinder the stability of a concurrent THA [21]. Although it is feasible to account for the pelvic obliquity caused by intrinsic hip degenerative changes or leg-length discrepancies during THA surgery, the clinical scenario is often much more challenging with planned THA in a patient with a limb-length discrepancy and a concurrent coronal fixed spine deformity, with very few studies investigating these patients [17,25,26]. Conversely, sagittal plane deformity of the spine has a more evident role and may be an important factor impacting the acetabular orientation [17,27], and subjecting these patients to instability, accelerated wear, and hardware failure [28–30].

In patients with adult spine deformity, sagittal plane deformity is often described as positive sagittal balance and is most commonly measured by the sagittal vertical axis distance (see Fig. 2A, B) [17]. Pelvic incidence (PI) is a fixed morphological parameter specific for every individual that does not change with body position and reflects a fixed sagittal plane relationship between the sacrum and the pelvis (see Fig. 1B, C) [17]. In a spine with neutral sagittal balance, the lumbar lordosis (LL) must mathematically "match" the PI, with PI−LL = ±10° (see Fig. 2A, B) [17]. In the most simplistic terms, the substantial morbidity encountered in adult spine deformity (whether it is degenerative spine disease or failed fusions) originates from positive sagittal balance that is caused by loss of LL and its mismatch with PI [10,27,31]. These patients will try to compensate for their inability to stand up straight by a cascade of mechanical changes in the pelvis and the hips, namely increased pelvic tilt and hip extension (see Fig. 2C, D) [27]. Increased pelvic tilt is another marker of worse morbidity in these patients [17]. In fact, a reduction in pelvic tilt is one of the goals of deformity correction and has shown to correlate with positive clinical outcomes [10,17,32–35]. Consequently, through the effect on pelvic tilt, both spine deformity and corrective surgical osteotomy procedures can result in changes in acetabular orientation, possibly altering the outcomes of an existing or planned THA.

In recent years, the impact of adult spine deformity and spinal corrective surgical procedures on THA outcomes have attracted more interest. Due to the paucity of available evidence, we conducted this review to (1) evaluate the effect of adult spine deformity and its surgical correction on patients who have had a THA; (2) evaluate the outcomes of THA in patients who have had a previous spinal fusion; and (3) present an algorithm on how to surgically address patients who simultaneously require THA and adult spine deformity correction based on the best available evidence.

## Methods

A comprehensive literature review was conducted by searching the following databases: PubMed, EMBASE, EBSCO Host, and SCOPUS. Studies published between January 2000 and July 2017 were reviewed. The following key words were used in combination with Boolean operators AND or OR for the literature search: "Total hip arthroplasty," "Spinal," "Spine," "deformity," "spino-pelvic," "parameters," "pelvic tilt," "obliquity," "acetabular anteversion," "hip," "instability," "dislocation," and "pedicle subtraction osteotomy". Inclusion criteria for studies to be in this review were studies reporting clinical or radiological THA outcomes in patients with (1) concurrent adult spine deformity; or (2) those that had corrective surgery for the deformity; or (3) patients with prior spinal fusion. Studies were excluded if they were (1) not in the English language, or (2) broadly reporting on degenerative spine conditions without specific description of spine deformity—related parameters; or (3) reporting on back pain in THA patients. Additionally, we excluded case reports and duplicate studies among searched databases.

The initial database search yielded 137 reports that were screened for relevant studies. This yielded 43 reports whose abstracts were thoroughly reviewed for eligibility according to the inclusion and exclusion criteria, which in turn yielded 12 studies. The manuscripts were further reviewed for final eligibility. The reference lists were also reviewed for any other relevant studies, which yielded an additional 2 reports. Therefore, our final analysis included 14 studies. The study selection process is summarized in Figure 3. Overall, there were 3 studies that reported on the impact of adult spine deformity on THA outcomes, 6 that reported on the