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Original Research

Is It Necessary to Obtain Lateral Pelvic Radiographs in Flexed Seated Position for Preoperative Total Hip Arthroplasty Planning?

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A B S T R A C T

Background: Many of the current total hip arthroplasty (THA) planning tools only consider sagittal pelvic tilt in the standing and relaxed sitting positions. Considering that the risk of postoperative dislocation is higher when bending forward or in sit-to-stand move, sagittal pelvic tilt in the flexed seated position may be more relevant for preoperative planning. We hypothesized that there was a significant difference in sagittal pelvic tilt between the relaxed sitting and flexed seated positions as measured by the sacral slope in preoperative and postoperative full-body radiographs.
Methods: This was a multicenter retrospective analysis of the preoperative and postoperative simultaneous biplanar full-body radiographs of 93 primary THA patients in standing, relaxed sitting, and flexed seated positions. The sagittal pelvic tilt was measured using the sacral slope relative to the horizontal line.
Results: The mean difference between the preoperative sacral slope in the relaxed sitting position and the flexed seated position was 11.3° (−13° to 43°) ($P < .0001$). This difference was >10° in 52 patients (56%) and >20° in 18 patients (19.4%). The mean difference between the postoperative sacral slope in a relaxed sitting position and the sacral slope in a flexed seated position was 11.3° ($P < .0001$). This difference was >10° in 51 patients (54.9%) and >30° in 14 patients (15.1%) postoperatively.
Conclusions: There was a significant difference in sagittal pelvic tilt between the relaxed and flexed seated positions. A flexed seated view provides valuable information that might be more relevant for preoperative THA planning in order to prevent postoperative THA instability.

Introduction

In recent decades, researchers have understood the importance of 3-dimensional analysis of pelvic and hip motions for the preoperative planning of total hip arthroplasty (THA) [1–7]. This is conducted through the acquisition of preoperative lateral radiographs of the lumbosacral junction or simultaneous biplanar anteroposterior and lateral radiographs (EOS, EOS imaging SA, Paris, France) in functional positions such as standing and relaxed sitting positions. Due to the limitations in access to low-radiation simultaneous biplanar imaging (EOS) as well as the cost of the additional radiographs, most surgeons and preoperative planning software rely on a single acquisition of 1 standing radiograph and 1 relaxed sitting radiograph [8–11]. However, posterior THA dislocation is more prevalent with the hip in flexion, similar to when the patient is bending forward or in a flexed seated position (also called a deep-seated or sit-to-stand position) [12–15].

Radiographic imaging of the lumbosacral junction was performed to assess the more extreme pelvic tilt in the flexed seated position [10,16,17]. In this position, the patients are asked to bend forward while seated and simulate the motion to get up from the seated position. Depending on the severity of the hip pathology or flexibility of the lumbar spine and lumbosacral junction, the sagittal, axial, and coronal pelvic tilt change compared with the relaxed seated position (Figs. 1a-d and 2a-d). Patients with more

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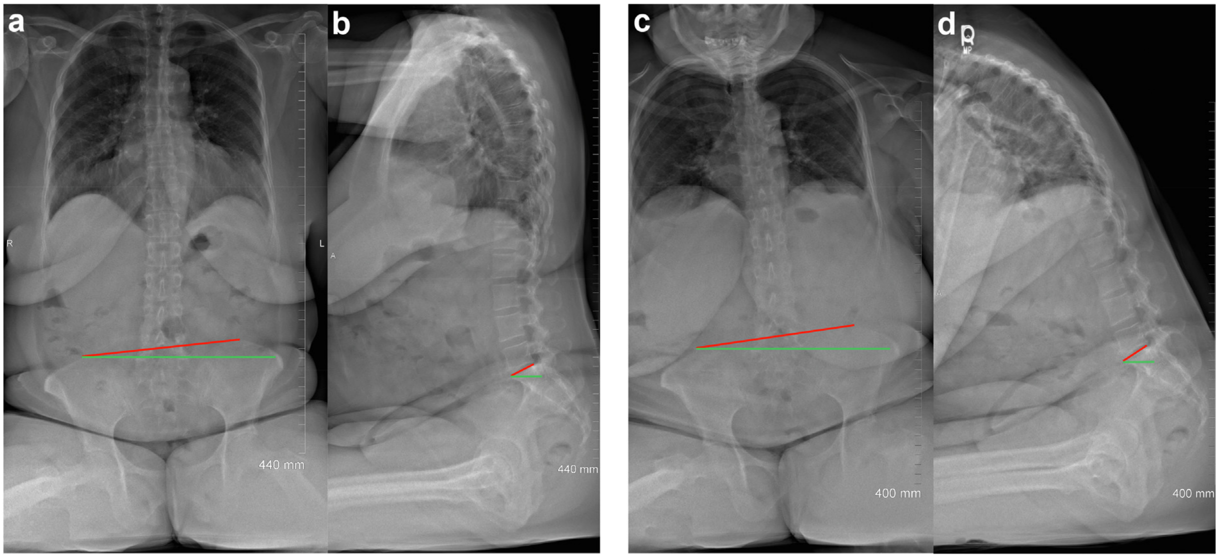

Figure 1. This figure shows the preoperative EOS imaging in relaxed seated (a and c) and flexed seated (b and d) of a patient who underwent primary THA. Coronal (lateral) pelvic tilt was shown in Figure 1a and c (relative to the horizontal line). Sacral slope was shown in Figure 1b and d (relative to the horizontal line). There was increase in pelvis flexion (anterior tilt) and coronal tilt (lateral tilt) of the pelvis in flexed seated position. Green line represents the horizontal line.

severe hip pathology may have less hip flexion due to pain or periarticular contractures, and as a result, they may try to flex their spine forward more in order to move their center of gravity forward to be able to stand up from a seated position. Patients with more severe spine stiffness may rely more on their anterior pelvic tilt and hip flexion to move their center of gravity forward to get up from the sitting position.

This study aimed to investigate the preoperative and postoperative simultaneous biplanar anteroposterior, and lateral pelvic imaging of primary THA patients and compare the pelvic tilt in standing, relaxed sitting, and flexed seated positions. We designed this study to answer the following question: does sagittal pelvic tilt, as measured by the sacral slope, differ significantly among the standing, relaxed sitting, and flexed seated positions preoperatively and postoperatively? We hypothesized that there is a significant difference in sagittal pelvic tilt among the standing, relaxed sitting, and flexed seated positions as measured by the sacral slope, which may validate that flexed seated position radiographs are a valuable view for preoperative planning. We also hypothesized that patients would have different pelvic tilts in relaxed and flexed seated positions postoperatively due to the improvement in hip pain and hip range of motion after THA.

Material and methods

In this multicenter study, we conducted a retrospective analysis of preoperative and postoperative full-body standing, relaxed sitting, and deep-seated simultaneous biplanar imaging (EOS) of patients who underwent primary THA.

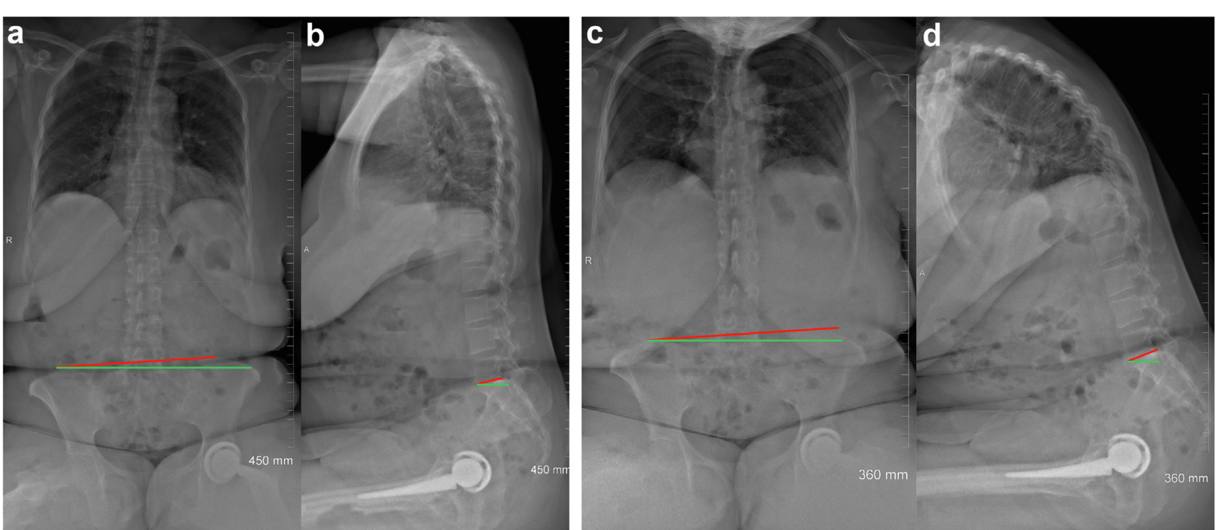

Figure 2. This figure shows the postoperative EOS imaging in relaxed seated (a and c) and flexed seated (b and d) in the same patient. The pelvis was in less flexion (less anterior tilt) in both relaxed seated and flexed seated views. There was less coronal tilt as well. Green line represents the horizontal line.

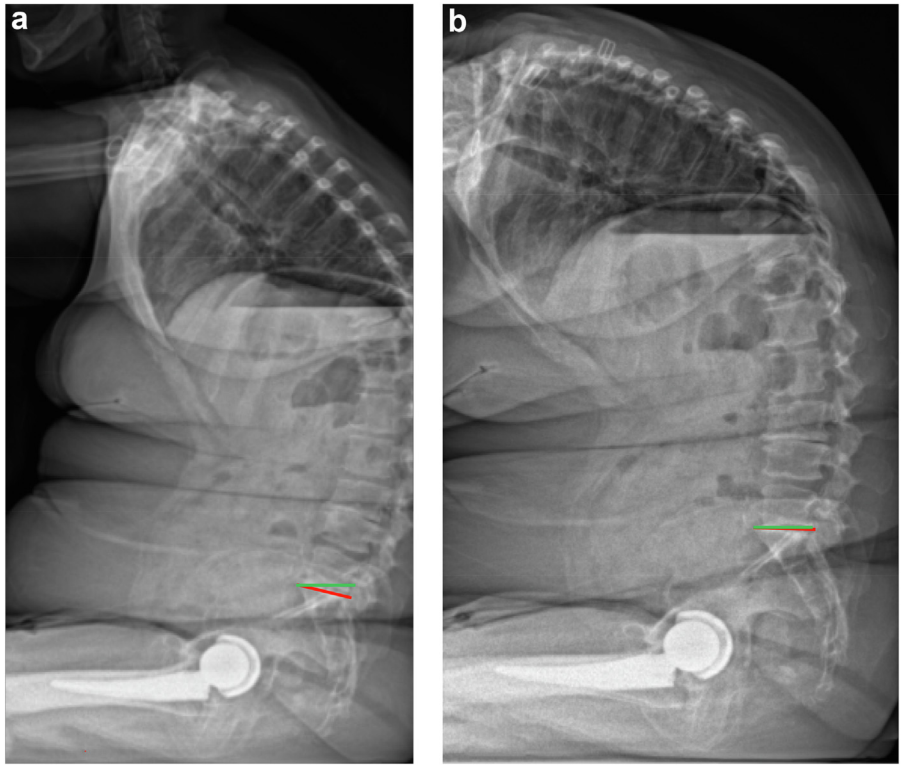

Figure 3. This figure shows the postoperative EOS imaging in relaxed sitting and flexed seated positions in a patient. Sacral slope was −14° in relaxed sitting position (a), which changed to −1° in flexed seated position (b). Patient uses the thoracolumbar junction as well for bending forward. Green line represents the horizontal line.

Study population

We obtained institutional review board approval from all institutions. We included 93 consecutive patients (aged 19-89 years) who underwent primary THA at our institution between 2015 and 2020. We included patients who underwent primary THA (posterior approach) and had high-quality preoperative and postoperative imaging. All postoperative imaging was performed between 6-12 weeks after the primary THA. None of the patients underwent additional spine or lower extremity surgery between the preoperative and postoperative imaging. The mean patient age was 61.6 years (20-89 years). None of the patients experienced a postoperative hip dislocation. We excluded any patients who had missing preoperative or postoperative EOS imaging, any patients who underwent revision THA or had previous lower extremity surgery that could affect their posture in standing or sitting (long bone fractures, amputations, etc.), THA for femoral neck fractures or any patient who underwent additional spine or lower extremity surgery between the preoperative and postoperative EOS imaging. None of the patients had severe contralateral hip pathology that prevented them from standing or sitting during the EOS imaging.

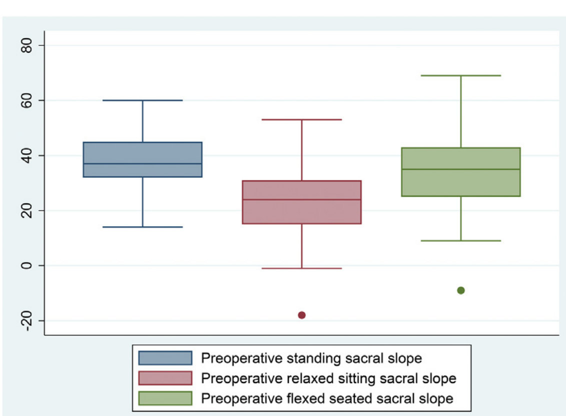

Figure 4. Difference between preoperative sacral slope in standing, relaxed sitting and flexed seated positions. Positive number means more anterior pelvic tilt (pelvic flexion) for flexed seated position and negative number means less anterior pelvic tilt (and occasionally retroversion) for flexed seated position.

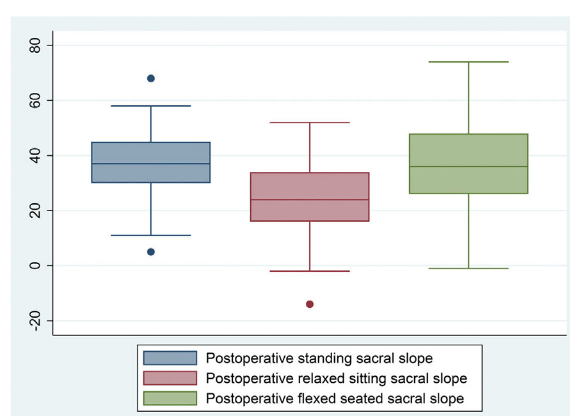

Figure 5. Difference between postoperative sacral slope in standing, relaxed sitting and flexed seated positions. Positive number means more anterior pelvic tilt (pelvic flexion) for flexed seated position and negative number means less anterior pelvic tilt (and occasionally retroversion) for flexed seated position.

Radiographic imaging technique

Each patient stood comfortably in the imaging machine, and their position was specifically checked to avoid superimposition of anatomical structures on the lateral view. For the relaxed sitting position, patients sat in a relaxed position on a radiolucent chair with adjustable height, with the knees bent to 90° and feet flat on the floor. After imaging of the relaxed position was completed, the patients were asked to bend forward and simulate the getting out of chair motion while keeping their feet on the floor.

Study variables

Sacral slope was defined as the angle between the superior plate of S1 and the horizontal line. The change in sacral slope from standing to relaxed sitting was calculated as "standing sacral slope − relaxed sitting sacral slope". The change in sacral slope from the standing to flexed seated position was calculated as "standing sacral slope − flexed seated sacral slope". Patients were grouped based on changes in sacral slope to normal (≥10° of change in sacral slope from standing to relaxed sitting) vs stiff (<10° of change in sacral slope from standing to sitting) according to a published classification [8]. An increase in sacral slope and positive numbers represented anterior pelvic tilt (pelvic flexion). A decrease in the sacral slope and negative numbers show posterior pelvic tilt (pelvic extension).

Statistical analysis

Normal distribution of the values was checked using the Shapiro-Wilk normality test for each series of measurements. For data analysis, a paired t-test with a significance level of 5% was used as patients are their own control group which makes the results more robust, and requires a smaller sample size. Statistical analysis was performed using Stata 14.1 (StataCorp LP, College Station, Texas, USA).

Power analysis

A post hoc power analysis was conducted using G*Power v. 3.1.9 to determine the power of the study considering the current sample size. Using an alpha of 0.05 and an effect size of 0.89, calculated using Stata software, our total sample size of 93 provided a study power of 0.97.

Results

The mean preoperative standing sacral slope was 37.6° (min: 14°, max: 60°, range: 46). The mean postoperative standing sacral slope was 36.4° (min: 5°, max: 68°, range: 63) ($P = .06$). This shows extension (posterior tilt) of the pelvis in the standing position and a wider range at 6-12 weeks after surgery. The mean preoperative relaxed sitting sacral slope was 23.5° (min: −18°, max: 53°, range: 71). The mean postoperative relaxed sitting sacral slope was 25° (min: −14°, max: 52°, range: 66) ($P = .06$). This also shows more pelvic extension in a relaxed sitting position after surgery. The mean preoperative flexed seated sacral slope was 34.7° (min: −9°, max: 69°, range: 60). The mean postoperative flexed seated sacral slope was 36.3° (min: −1°, max: 74°, range: 75) ($P = .3$). This showed no significant difference in sacral slope between the preoperative and postoperative flexed seated positions, however, the range increased slightly. Sacral slope could be negative in relaxed and flexed seated positions in some patients depedning on their anatomy and hip-spine relation (Fig. 3).

The difference between the preoperative standing sacral slope and the preoperative flexed seated sacral slope was trending toward significance ($P = .07$) but this needed a larger sample size to test (Fig. 4). The postoperative sacral slope in standing and flexed seated positions was not significantly different ($P = .94$) (Fig. 5). There was significant difference between the preoperative relaxed seated and flexed seated sacral slopes in paired t-test (mean: 11.3°, range: −13° to 43°) ($P < .0001$). This difference was >10° in 52 patients (56%) and >20° in 18 patients (19.4%). There was significant difference between the preoperative relaxed seated and flexed seated sacral slope in paired t-test (mean: 11.3°, range: −13° to 37°) ($P < .0001$). This difference was >10° in 51 patients (54.9%) and >30° in 14 patients (15.1%) postoperatively.

We classified the patients into normal and stiff spines based on changes in the sacral slope. When we considered the preoperative sacral slope change from standing to relaxed sitting position, 36 patients (38.7%) were in the stiff spine group. This changed postoperatively, with 44 patients (47.3%) in the stiff spine group. Among our patients, 28 changed group (30.1%) postoperatively. Among these 28 patients, 10 (35.7%) changed their group from stiff spine to normal spine, and 18 (64.3%) changed their group from normal spine to stiff spine. As there is no classification based on the change in sacral slope from standing to flexed seated position, and our sample size was not large enough, we could not draw any conclusion.

Discussion

Static radiographic imaging in standing, relaxed sitting, flexed seated position, and 1-leg standing positions are currently utilized for the assessment of sagittal pelvic tilt in patients who undergo THA. Most preoperative planning is performed using only 1 standing and 1 relaxed sitting radiograph. In this study, we showed a significant difference between the relaxed sitting and flexed seated positions both preoperatively and postoperatively. We also found no difference in sacral slope between standing and flexed seated positions. We also found significant postoperative changes in pelvic tilt for each of these positions.

Hip instability and dislocation are a major cause of THA failure [13–15,18,19]. Most THA dislocations are posterior and occur during activities requiring hip flexion, such as bending forward or flexed seated positions while getting up from a chair. Investigators have shown the importance of hip-spine relations and how differences in pelvic tilt in different positions can affect the risk of THA impingement [1,3,6,16,20–22]. Computer simulations and preoperative planning software have been developed to optimize the orientation of acetabular implants by considering sagittal pelvic tilt [23–29]. Many of these software programs concentrate on pelvic tilt in standing and relaxed sitting positions, but sagittal pelvic tilt in flexed seated positions is not always considered. Behery et al. investigated sagittal pelvic tilt in flexed seated and 1-leg stand positions among 43 patients who underwent THA [16]. They found significant differences between the relaxed and flexed seated positions in terms of sagittal pelvic tilt, which supported their hypotheses. Pierrepont et al. also investigated sagittal pelvic tilt in 1517 patients [30]. They reported that the mean change in sagittal pelvic tilt in standing and flexed seated positions was approximately 1.8° (−51.8° to 39.5°). In our study, we not only showed a difference in preoperative sagittal pelvic tilt but also a significant difference in the postoperative sagittal pelvic tilt between these 2 positions. Although the mean difference was only 1.8° in Pierrepont's study, 2° in Behery's study, and 11.3° in our study, the range of change in sagittal pelvic tilt was high. This difference was >10° in 52 patients (56%) and >20° in 18 patients (19.4%). Behery et al. reported a difference of >10° in 73.1% of patients [16]. If we consider the change in sacral slope as a measurement of spine stiffness as proposed in this published classification [8] the patient categorization will change, requiring different preoperative planning for a fair amount of the patients. Many patients and surgeons limit the forward flexion during the first 6-12 weeks to lower the risk of dislocation. It is quite possible that patients bend forward more after the first 6-12 weeks, which will increase the difference between the flexed and relaxed sitting pelvic tilt as well. This, of course, has to be investigated in future studies. This extreme difference in sagittal pelvic tilt requires close attention to optimize acetabular implant orientation and avoid impingement that can lead to THA dislocation. Patients with more anterior pelvic tilt while getting up from a sitting position (mimicked by flexed seated view) would require more cup anteversion and a potentially higher cup inclination angle to prevent prosthetic impingement compared to those who do not have significant anterior pelvic tilt while getting up from sitting position. We also found no significant differences between the standing and flexed seated sacral slopes. This means that surgeons can potentially use the amount of pelvic tilt in standing for the flexed seated position if they do not have the flexed seated view; however, a larger study is required to investigate this finding further and determine whether this finding is valid for all patients.

Our study has several limitations. This was a retrospective analysis of imaging studies. None of the patients experienced a postoperative dislocation. Consequently, a correlation of the findings with the occurrence of dislocation was not possible. We only measured sagittal pelvic tilt, while coronal and axial pelvic tilt was not measured. Previous studies using computer simulations have shown that coronal and axial pelvic tilt could also affect the risk of prosthetic impingement [31,32]. The effect of the contralateral hip pain and pathology on the posture in standing and sitting positions, especially in the flexed seated position, needs further investigation with a large sample size.

Conclusions

There was a significant difference in sagittal pelvic tilt between relaxed sitting and flexed seated positions both preoperatively (mean: 11.3°, −13° to 43°) and postoperatively (mean: 11.3°, −13° to 37°). However, the difference between the standing and flexed seated view was not significant. A flexed seated view provides valuable information that might be more relevant for preoperative THA planning to prevent postoperative impingement that may lead to THA instability. If radiograph in flexed seated is not available, surgeons might use the sagittal pelvic tilt in standing position to test for impingement in flexed seated position instead; however, this requires more investigation in studies with larger sample size.

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Conflicts of interest

One of the authors (AEP) is funded by the National Institute of Arthritis, Musculoskeletal and Skin Diseases (USA)(NIAMS) K08 Grant to investigate THA dislocation and the hip-spine relationship. One or more of the authors (RS) certify receipt of personal payments or benefits, during the study period, in an amount of less than 10,000 USD from Intelijoint and 10,000 USD to 100,000 USD from Smith and Nephew. The other authors certify that there are no funding or commercial associations (consultancies, stock ownership, equity interest, patent or licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article related to the author or any immediate family members.

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