Original article

Changes in spinopelvic indices after hip arthroplasty and its influence on acetabular component orientation

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ABSTRACT

Objective: To evaluate spinopelvic changes after hip arthroplasty in standing and ready-to-rise positions. **Methods:** We compared pelvic tilt, sacral slope, cobb's angle, and hip flexion on pre and postoperative spinopelvic radiographs.

Results: Standing: All postoperative indices were similar to preoperative ones except sacral slope (mean difference: 1.6° , $p = 0.046$).

Ready-to-rise: All postoperative indices were similar to preoperative ones except pelvic tilt which was significantly greater postoperatively (mean difference: 5.1° , $p = 0.017$). Fifteen patients showed $>10^\circ$ increase in pelvic tilt postoperatively.

Conclusion: Changes in pelvic tilt in ready-to-rise position can predispose to posterior edge loading, edge wear, and dislocation; especially with inadequate cup anteversion.

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1. Introduction

Acetabular component orientation after hip arthroplasty can influence dislocation rates,¹ impingement,² wear,³ and range of motion (ROM).⁴ Changes in pelvic tilt can alter acetabular orientation.^{5,6} Hence it is important to understand the changes in pelvic tilt after hip arthroplasty in order to ensure that desirable acetabular orientation is maintained postoperatively. Scientific literature in this area is limited and often contrasting.^{7–10} Moreover, previous studies have focused mainly on changes in standing, supine, and sitting (back-rested) pelvic tilt after total hip arthroplasty (THA).^{7,8,10,11} There is no report on changes in pelvic tilt in ready-to-rise position after hip arthroplasty. This is a routinely performed activity of daily living and involves loading of the posterior edge of the liner due to a posteriorly directed force vector. Thus, the aim of our study was to compare spinopelvic changes before and after hip arthroplasty in standing and ready-to-rise position. We hypothesized that the spinopelvic indices would not demonstrate a significant change after surgery.

2. Materials and methods

Informed consent was obtained from all patients included in the study. Forty-four patients undergoing unilateral hip arthroplasty (34 THAs, 10 hip resurfacings) for primary osteoarthritis (OA) from a consecutive series were included in the study. Patients with bilateral hip disease, previous ipsilateral hip surgery, or contralateral hip arthroplasty were excluded. In addition, patients with incomplete set of radiographs or radiographs of unsatisfactory quality were also excluded. Of the 34 THAs, 31 were operated using direct anterior approach (DAA) and three using posterior approach. The senior author preferred DAA for THA unless body habitus or complexity of the case precluded its use. The three patients that underwent posterior approach were obese and had a 'fat apron' around the abdomen that precluded the use of DAA. All hip resurfacings were performed using posterior approach. The mode of fixation was uncemented in 23 THAs and hybrid in 11 THAs. The bearings were ceramic-on-ceramic in 23 THAs and ceramic-on-polyethylene in 11 THAs. All patients undergoing resurfacing received ADEPT® (MatOrtho, Surrey, UK) implants.

Lateral spinopelvic radiographs including at least second lumbar vertebra and upper third of femur were obtained in standing and ready-to-rise positions preoperatively and 6 months postoperatively. All radiographs were obtained in a standardized manner with a film to focus distance of 180 cm and the x-ray film in contact with the side of the body. The patients were positioned to obtain a true lateral view such that the two anterior superior

Abbreviations: ROM, range of motion; THA, total hip arthroplasty; OA, osteoarthritis; DAA, direct anterior approach; ASIS, anterior superior iliac spine; SD, standard deviation; APP, anterior pelvic plane; FPP, functional pelvic plane.

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Fig. 1. Figures showing standing (a) and ready- to- rise (b) positions in which radio graphs were obtained.

iliac spines (ASIS) were superimposed on each other. Anatomical landmarks were palpated in order to aid the same. For radiographs in ready-to-rise position, patients were made to sit on a height-adjustable chair without arm rests. The height was adjusted such that the legs were perpendicular to the floor. The patients were then instructed to lean forward and simulate a ready-to-rise position with their hands around the ankles. Patient position while obtaining the radiographs is shown in Fig. 1a and b. Radiographs were evaluated by one of the authors for pelvic tilt, sacral slope, Cobb's angle, and hip flexion. Pelvic tilt, Cobb's angle, and hip flexion were determined as described previously.¹² Anterior pelvic tilt was denoted as positive and posterior tilt as negative. Pelvic excursion was calculated as the difference between pelvic tilts in standing and ready- to- rise positions. Sacral slope was measured as an angle between the endplate of S1 vertebra and the horizontal. All measurements were performed on IntelViewer™ application for Windows (Intelrad®, Melbourne, Australia).

Statistical analysis: Numerical data was subjected to descriptive analysis and expressed as mean $\pm$ standard deviation (SD), and range. Categorical data was expressed as frequency and percentage. Continuous data between groups was compared using student's *t*-test. Categorical data between groups was compared

using Fisher's exact or chi- squared test. A 'p' value < 0.05 was considered to be statistically significant. Correlation was analysed using Pearson's correlation coefficient. Power analysis ($\alpha = 0.5$, $\beta = 0.80$) showed that for detecting at least 1° change in cup anteversion, the minimum number of subjects must be 39. For every 1° change in pelvic tilt, cup anteversion changes by 0.7° .⁶ Therefore, a change in pelvic tilt of 1.4° would result in change of cup anteversion by 1° . Murphy et al⁷ showed a mean ($\pm$ SD) difference in standing pelvic tilt before and after THA of $0.5^\circ \pm 3^\circ$. These values were used to perform power analysis. Data was analysed using Statistical Package for Social Science SPSS v 17.0 (Chicago, IL).

3. Results

The mean age of the patients at surgery was 65.8 years (Range: 38–94 years). There were 19 males and 25 females. Comparison of spinopelvic indices in standing and ready- to- rise positions before and after surgery is shown in Table 1.

Standing position: In standing position, all indices after surgery were similar to the respective preoperative ones ($p \geq 0.343$) except sacral slope that showed a 'just significant' difference (mean

Table 1

Comparison of spinopelvic indices in standing and ready- to- rise positions before and after surgery.

	Standing position			Ready- to- rise position		
	Pre- op (Mean $\pm$ SD)	Post- op (Mean $\pm$ SD)	p value	Pre- op (Mean $\pm$ SD)	Post- op (Mean $\pm$ SD)	p value
Pelvic tilt	-3.7 ± 7.4	-3.7 ± 7.3	0.981	6.1 ± 13.1	11.2 ± 12.1	0.017
Sacral slope	37.5 ± 7.7	35.9 ± 8.2	0.046	44.4 ± 16.6	48.6 ± 12.5	0.093
Cobb's angle	41.7 ± 12.5	41.6 ± 11.3	0.951	16.7 ± 11.9	15.9 ± 10.4	0.552
Hip flexion	7.2 ± 3.8	6.6 ± 3.3	0.343	83.1 ± 8.1	86 ± 7.8	0.099

SD: standard deviation; All indices are in degrees ($^\circ$)

Fig. 2. Box and whisker charts comparing pre and postoperative pelvic tilts in standing and ready-to-rise positions.

difference: 1.6° , $p=0.046$). Three patients showed a change in pelvic tilt of $>10^\circ$ after surgery.

Ready-to-rise position: There was a significant increase in mean pelvic tilt after surgery as compared to before (mean difference: $5.1^\circ \pm 13.5^\circ$, $p=0.017$). None of the other indices were significantly different after surgery as compared to their respective preoperative ones ($p \geq 0.093$). Twenty-one patients showed a change of $>10^\circ$ in pelvic tilt after surgery. Fifteen of these patients showed an increase of $>10^\circ$, with a mean increase of 19.3° in pelvic tilt.

Fig. 2 shows a box and whisker chart comparing pre & postoperative pelvic tilt in standing and ready-to-rise positions.

Pelvic excursion after surgery ($14.9^\circ \pm 12.4^\circ$) was significantly greater than the preoperative one ($9.8^\circ \pm 13.9^\circ$) with a mean increase of $5.1^\circ \pm 14.2^\circ$ ($p=0.021$). Pelvic mobility was graded on the basis of pelvic excursion. Table 2 shows distribution of patients according to their pelvic mobility. Significantly greater number of patients had $>10^\circ$ change in pelvic tilt after surgery in ready-to-rise position as compared to standing (21/44 vs. 3/44, $p < 0.0001$). Preoperative pelvic tilt was a stronger predictor of postoperative tilt in standing position ($r=0.68$, $p < 0.001$) as compared to ready-to-rise position ($r=0.43$, $p=0.004$).

4. Discussion

The anatomic or anterior pelvic plane (APP) is defined by the two ASIS and symphysis pubis. In comparison, the functional pelvic plane (FPP) takes into consideration the individual pelvic tilt and is recommended as a reference for acetabular component orientation.^{5,7,11} Authors have recommended that the acetabular component orientation be adjusted according to the patient's pelvic tilt at the time of cup insertion.^{5,6,13,14} Modern navigation systems are able to accommodate for the individual pelvic tilt in order to obtain a desired acetabular orientation in the FPP. However, this would not be very useful if pelvic tilt changes significantly after hip arthroplasty.

Changes in pelvic tilt following hip arthroplasty have been previously reported.^{7–11,14} In standing position, Murphy et al.⁷ and

Blondel et al.⁸ reported no significant difference in pelvic tilt before and after surgery. DiGioia et al. reported a difference of 1.1° in mean standing pelvic tilt before and after surgery.¹⁰ These are similar to the findings in our study. In contrast, Parratte et al. reported significant dynamic changes in pelvic tilt one year after THA using gait analysis.⁹ However, the data obtained during gait analysis in their study was based on superficially placed skin markers which may not accurately represent the anatomical bony landmarks.

Often studies have reported pelvic changes in isolation without information on changes in the spinal indices or hip flexion after THA. Pelvic tilt can be influenced by spinal factors or hip flexion. We found no significant change in Cobb's angle or hip flexion before and after surgery in standing position ($p \geq 0.343$). Although, change in sacral slope before and after surgery was 'just significant' ($p=0.046$), the mean difference of 1.6° may not be significant clinically. These changes most likely explain why there was no significant difference in pelvic tilt before and after hip arthroplasty in our study. In terms of change in standing pelvic tilt after surgery, Blondel et al.⁸ reported that none of their 50 patients had a variation of $>10^\circ$, whereas Ishida et al.¹⁵ reported a change of $>10^\circ$ in nearly 17% (25/149) patients. The proportion of patients with $>10^\circ$ change in standing pelvic tilt after surgery in our study was about 7% (3/44), an intermediate number compared to these authors.

There is no literature reporting changes in spinopelvic indices in ready-to-rise position after hip arthroplasty. We found a significant increase in mean pelvic tilt after surgery (mean difference: $5.1^\circ \pm 13.5^\circ$, $p=0.017$). Ready-to-rise position simulation involved maximum possible forward leaning. We believe that hip arthroplasty relieved hip stiffness and improved hip excursion which increased mean pelvic tilt postoperatively. This was accompanied by a corresponding increase in sacral slope of about 4° and hip flexion of about 3° postoperatively. The significant increase in pelvic tilt is likely to predispose the hip to posterior edge loading. This may increase posterior edge wear and the risk of posterior dislocation. These changes are likely to be pronounced in cases with insufficient cup anteversion. In an analysis of 54

Table 2

Distribution of patients according to pelvic mobility before and after surgery.

Change in tilt between standing and ready-to-rise (Pelvic excursion)	Pre-operative (No. of hips)	Post-operative (No. of hips)
-35° to -20.1°	2	0
-20° to 0°	9	4
0° to 20°	25	30
20.1° to 35°	6	8
$>35.1^\circ$	2	2

retrieved alumina-on-alumina ceramic bearings, Esposito et al. reported that posterior edge loading was found in nearly 60% (32/54) of the retrievals.¹⁵ These findings can be explained by the fact that there is a significant increase in forward pelvic tilt after hip arthroplasty in ready-to-rise position as seen in our study. Forward pelvic tilt is associated with functional acetabular retroversion; 0.7° change in version for every 1° change in pelvic tilt.⁶ Progressive reduction in functional anteversion with increasing forward pelvic tilt would be associated with a progressively increasing load on the posterior acetabular edge. This in turn causes posterior edge wear and may increase the risk of dislocation. Twenty one patients had >10° change in pelvic tilt in ready-to-rise position after surgery in our study. Fifteen of these patients showed an increase of >10°, with a mean increase of 19.3° in pelvic tilt. This means a mean loss of functional anteversion of about 14°. In other words, one third of the patients in our study will have a loss of functional acetabular version of nearly 14° in ready-to-rise position. This further underscores the importance of ensuring adequate acetabular anteversion in order to reduce the risk of posterior edge loading.

Nishihara et al.¹¹ and Murphy et al.⁷ reported a significant positive correlation of 0.77 and 0.87 respectively between pre and postoperative standing pelvic tilt. We found a significant positive correlation of 0.68 ($p < 0.001$) between pre and postoperative standing tilt in our study. In comparison, the correlation between pre and postoperative pelvic tilt in ready-to-rise position was 0.43 ($p = 0.004$). This weak correlation can be explained by the fact that the mean postoperative tilt was significantly greater than the respective preoperative one in ready-to-rise position.

Our study has a few drawbacks. Our population may appear heterogeneous as we have included patients undergoing THA or hip resurfacing in our study. However, the indication of surgery was the same in all the patients, i.e. primary OA. We do not feel that the pattern of changes in spinopelvic indices would be different in patients undergoing THA or resurfacing as these two procedures are principally similar. We did not determine intra and inter-observer reliability of our radiographic measurements. However, previous studies have shown that anatomical landmark based measurements on lateral pelvic radiographs are accurate and reliable.^{8,16} There could be errors introduced due to rotation of the pelvis or limb length discrepancy in the lateral spinopelvic radiographs. However, every effort was made to avoid these by palpating the anatomical landmarks and positioning the patient correctly at the time of obtaining the radiographs.

5. Conclusion

Standing pelvic tilt showed no significant change after hip arthroplasty in our study. However, pelvic tilt in ready-to-rise position increased significantly after hip arthroplasty. This may predispose to posterior edge loading, edge wear, and dislocation; especially in cases with inadequate acetabular component anteversion.

Conflict of interest

The authors have none to declare.

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Author contributions

Siddharth Mahesh Shah- study design, data collection & analysis, drafting of manuscript.

Selin Munir- data analysis, drafting of manuscript.

William Lindsay Walter- study design, manuscript editing.

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