

Multilevel Lumbar Fusion and Sacral Fusion Affect Joint Space Narrowing of the Hip: A Retrospective Study

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Abstract

Background: This study aimed to elucidate the effect of lumbosacral fusion on joint space narrowing of the hip.

Methods: We retrospectively studied 511 hips of 261 patients who had undergone lumbar fusion. Whole-spine X-ray was performed for all the patients before surgery and at final follow-up. Center edge angle, joint space of the hip, sagittal vertical axis, thoracic kyphosis, lumbar lordosis, pelvic incidence, pelvic tilt, and sacral slope were measured. The number of lumbar fusion levels, inclusion of sacral fusion, follow-up duration, and wear of the hip joint (mm/year) were also recorded. Multi regression analysis was performed to identify the risk factors for joint space narrowing.

Results: Female sex ($P=0.04$), number of fixed lumbar levels ($P=0.002$), sacral fusions ($P=0.039$), and follow-up period ($P<0.001$) were independent risk factors for joint space narrowing of the hip. The patients who underwent four or more levels of lumbar fusion experienced more rapid wearing of the hip joint space than that experienced by patients with less than three levels of lumbar fusion ($P=0.044$).

Conclusion: Surgeons should pay attention to joint space narrowing of the hip after performing multiple lumbar fusions or sacral fusion in women.

Background

Osteoarthritis (OA) of the hip is not a life-threatening disease, but it greatly affects quality of life (QOL) and mental health. The number of total hip arthroplasty (THA) surgeries performed worldwide is estimated to increase 174% from 2005 to 2030 [1], and the prevention of hip OA is increasing in importance. Hip OA is caused by multiple factors such as age, sex, and body weight [2,3], but the correlation between spinal sagittal alignment and the hip joint gained attention after Offierski and MacNab [4] reported on hip-spine syndrome. Spinal sagittal alignment affects not only the spinal and hip muscles [5,6] but also physical ability [7], QOL [8-13], and activities of daily living that can lead to locomotive syndrome [14]. Thus, correction of sagittal alignment may improve the function of the hip.

Patients with hip OA frequently present with spinal sagittal malalignment [15]. Compared to the incidence of lumbar spondylolisthesis of 5% in a cadaver study [16] and 8.9% in the elderly population [17], the incidence of lumbar spondylolisthesis among patients with hip OA was 22% [18]. This suggests a strong association between hip OA and spinal deformity, with some patients undergoing both hip and spinal surgeries. Esposito et al. postulated that decreased spinal motion causes excessive mechanical loading of the hip [19], and inappropriate mechanical loading of the joint has been shown to be a risk factor for the progression of hip OA [20]. Tateuchi et al. also reported that sagittal alignment and mobility of the lumbar spine affect the progression of secondary hip OA [21]. Overloading of the hip may be improved by correcting spinal deformity, but spinal fusion decreases spinal mobility and may increase loading of the hip joint. Spinal fusion that includes the pelvis restricts spinopelvic mobility and can induce dislocation

after THA by causing impingement of the femoral head on the acetabular rim [22,23]. These past reports suggest the influence of spinal fusion on the progression of hip OA.

Although spinal fusion is widely performed, the impact of spinal fusion on joint space narrowing of the hip is still unclear. The aim of this study was to elucidate the influence of lumbar fusion levels and sacral fusion on joint space narrowing of the hip. We hypothesized that the number of lumbar fusion levels and sacral fusion accelerates joint space narrowing of the hip.

Methods

Patient enrollment

This study retrospectively examined 511 hip joints of 265 patients (190 hips of 95 men and 321 hips of 170 women) who had undergone primary lumbar fusion between May 2010 and May 2020. All procedures were approved by the Institutional Review Board of Tokai University Hospital (21R-043). Inclusion criteria were as follows: (1) patients aged over 50 years who had undergone a lumbar fusion surgery; (2) patients who had their whole-spine standing X-ray evaluated before and after surgeries; and (3) patients with a follow-up period of over 1 year. Exclusion criteria were as follows: (1) patients who had undergone a previous hip surgery; (2) patients with connective tissue disease; (3) patients who had no hip joint space during patient recruitment; (4) patients without whole-spine standing X-ray; and (5) patients with no follow-up data. Baseline parameters of the patients included in this study are shown in Table 1.

Table 1. Demographic data

| Demographics | All patients (n=261) |
|--|----------------------|
| Age (years, mean \pm SD) | 71.1 \pm 7.9 |
| Sex (male:female) | 95 : 170 |
| Body mass index (mean \pm SD) | 23.4 \pm 3.8 |
| Follow-up duration (years, mean \pm SD) | 2.9 \pm 1.7 |
| Sacral fusion (frequency/total number of hips) | 168/511 |
| Number of lumbar fusion levels (mean \pm SD) | 4.2 \pm 4.3 |
| Joint space narrowing (mm/year, mean \pm SD) | 0.12 \pm 0.2 |

SD, standard deviation

Surgical indication for spine fusion

Spine fusion was performed for patients with foraminal stenosis, segmental instability, or global sagittal malalignment. Short fusion (one to two fixations) was performed to decompress foraminal stenosis or correct segmental instability. Long fusion was performed to correct global sagittal malalignment.

Radiographic evaluation

Radiographic evaluations were performed both preoperatively and more than 1 year after surgery. Sagittal alignment was assessed using whole-spine X-rays in which patients stood relaxed at a shoulder-width stance looking straight ahead, with elbows bent and knuckles placed in the bilateral supraclavicular fossae [24]. The following parameters were evaluated as spinal parameters: sagittal vertical axis (SVA), thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS) (Figure 1) [25,26]. The number of lumbar fusion levels and the presence or absence of sacral fusion were also recorded. The following hip parameters were measured: the center-edge (CE) angle [27] and minimum joint width (MJW) of the hip (Figure 2). The joint width was measured in 0.1-mm increments and the narrowest space between the acetabulum and femoral head was recorded as the MJW. Postoperative joint space was measured at the same point as that of the preoperative measurement. The MJW was standardized by dividing the decreased width by the follow-up years (mm/year). Considering that Conrozier reported the hip joint space narrowing to be 0.43 mm/year before THA [28], we defined hip OA progression as hip joint space narrowing of ≥ 0.4 mm/year and divided the patients into non-progression and OA-progression groups.

All measurements were performed using a picture archiving and communication system (Techmatrix Corporation, Tokyo, Japan). All radiological assessments were performed by a single orthopedic surgeon, and two other orthopedic surgeons evaluated 80 randomly selected radiographs. Intraclass reliability of the radiographic evaluation parameters was as follows: SVA, 0.96; TK, 0.8; LL, 0.82; PI, 0.85; PT, 0.94; SS, 0.87; CE angle, 0.63; and MJW, 0.73.

Statistical analysis

A power analysis was performed using G-Power software (ver. 3.1.9.2, Germany) to calculate the minimum sample size necessary to perform linear multiple regression (effect size = 0.15, alpha = 0.05, power = 0.95, number of predictors = 13), which indicated a required sample size of 189 samples.

Multiple regression analyses were performed to identify the independent predictors of hip joint space narrowing. Independent variables that were included in the multiple regression analysis are as follows: age, sex, body mass index, CE angle, postoperative SVA, postoperative TK, postoperative LL, postoperative PI, postoperative PT, postoperative SS, the number of lumbar fusion levels, sacral fusion, and follow-up duration. Wilcoxon signed-rank test was performed to compare preoperative SVA, TK, LL, PI, PT, and SS with their postoperative values. The Mann–Whitney U test was performed to compare the parameters of the non-progression and OA-progression groups along with the parameters of patients who had undergone four or more levels of lumbar fusion against those who had undergone up to three levels

of fusion. A P value <0.05 was considered statistically significant. Analyses were performed using the SPSS software (version 26, IBM Corp., Armonk, NY, USA).

Results

Multiple regression analysis revealed that the female sex (P=0.04), the number of fusion levels (P=0.002), sacral fusion (P=0.039), and the follow-up period (P<0.0001) were independent risk factors for joint space narrowing (Table 2). Regarding the spinal parameters, postoperative TK (33.8±15.6°), LL (33.4±16.6°), and sacral slope (26±11.3°) had significantly increased compared with the preoperative measurements (TK: 29.3±15.7°, LL: 26.8±16.9°, and SS: 23.8±10.9°). In contrast, postoperative SVA (73.8±55.7 mm) and PT (23.3±9.9°) had significantly decreased compared with the preoperative measurements (SVA: 89.2±64.2 mm and PT: 26.1±10.2°; Table 3). The number of lumbar fusion levels in the OA-progression group was significantly higher than that in the non-progression group (P=0.009; Table 4). In contrast, no statistically significant difference was observed in the CE angle or sagittal alignment between the two groups (Table 4). The hip joint space of patients who underwent four or more levels of lumbar fusion wore more rapidly (0.15±0.26 mm/year) than that of those who underwent less than three levels of lumbar fusion (0.1±0.17 mm/year; P=0.044).

Table 2. Results of multiple regression analyses

| Variable | Standard error | Standardized beta coefficient | T value | P value |
|-------------------------|----------------|-------------------------------|---------|----------|
| Age | 0.001 | -0.055 | -1.247 | 0.213 |
| Sex: female | 0.02 | 0.098 | 2.056 | 0.04* |
| Body mass index | 0.002 | -0.001 | -0.019 | 0.984 |
| Center edge angle | 0.001 | -0.002 | -0.054 | 0.957 |
| Sagittal vertical axis | 0 | 0.03 | 0.523 | 0.601 |
| Thoracic kyphosis angle | 0.001 | -0.055 | -0.883 | 0.378 |
| Lumbar lordosis | 0.001 | -0.037 | -0.348 | 0.728 |
| Pelvic incidence | 0.003 | 0.069 | 0.365 | 0.715 |
| Pelvic tilt | 0.003 | -0.125 | -0.813 | 0.416 |
| Sacral slope | 0.003 | -0.074 | -0.42 | 0.675 |
| Number of fusion levels | 0.004 | 0.229 | 3.047 | 0.002* |
| Sacral fusion | 0.03 | -0.146 | -2.074 | 0.039* |
| Follow-up years | 0.005 | -0.298 | -6.51 | <0.0001* |

*: statistically significant predictors

Table 3. Comparison between preoperative and postoperative radiographic parameters

| Radiographic parameters; n=511 | Preoperative (mean ± SD) | Postoperative (mean ± SD) | P value |
|-----------------------------------|-----------------------------|------------------------------|----------|
| Sagittal vertical axis (mm) | 89.2±64.2 | 73.8±55.7 | <0.0001* |
| Thoracic kyphosis angle (°) | 29.3±15.7 | 33.8±15.6 | <0.0001* |
| Lumbar lordosis angle (°) | 26.8±16.9 | 33.4±16.6 | <0.0001* |
| Pelvic incidence (°) | 51.3±12.4 | 51.2±12.7 | 0.479 |
| Pelvic tilt (°) | 26.1±10.2 | 23.3±9.9 | <0.0001* |
| Sacral slope (°) | 23.8±10.9 | 26.0±11.3 | <0.0001* |

*: statistically significant difference; SD, standard deviation

Table 4. Comparison between hip OA-progression group and non-progression group

| Radiographic parameters | All patients (n=511) | Non-progression (n=471) | OA progression (n=40) | P value |
|---|-------------------------|----------------------------|--------------------------|------------|
| | | (<0.4 mm/year) | (≥0.4 mm/year) | |
| Center edge angle (°) | 27.5±7.8 | 27.6±7.8 | 26.4±8.0 | 0.259 |
| Postoperation | | | | |
| Sagittal vertical axis (°) | 73.8±55.7 | 74.2±54.4 | 68.9±69.1 | 0.076 |
| Thoracic kyphosis angle (°) | 33.8±15.6 | 33.7±15.7 | 35.3±15.1 | 0.532 |
| Lumbar lordosis angle (°) | 33.4±16.6 | 33.1±16.3 | 37.6±19.5 | 0.124 |
| Pelvic tilt (°) | 23.3±9.9 | 23.4±10.0 | 22.9±10.3 | 0.454 |
| Pelvic incidence (°) | 51.2±12.7 | 51.0±12.6 | 52.6±13.4 | 0.454 |
| Sacral slope (°) | 26.0±11.3 | 25.9±11.2 | 27.6±12.8 | 0.383 |
| Fusion levels | 4.2±4.3 | 4.0±4.3 | 5.6±4.5 | 0.009* |
| Sacral fusion (frequency/number of patients) | 168/511 | 151/471 | 17/40 | 0.177 |

*: statistically significant difference

Discussion

In this study, we evaluated how lumbosacral fusion surgery affects joint space narrowing of the hip and found that female sex, the number of lumbar fusion levels, and sacral fusion were independent risk factors for joint space narrowing of the hip. In particular, the hip joint space of patients who underwent four or more levels of lumbar fusion wore more rapidly than that of those who underwent up to three levels of lumbar fusion surgery.

The relationship between spinal alignment and hip OA progression has been receiving increasing attention recently, with various articles reporting a correlation between spinal parameters and hip OA. As LL decreases in the degenerating lumbar spine, the pelvis tilts more posteriorly and the acetabular roof coverage of the hip decreases. A decrease in the acetabular roof coverage correlates with an increase in the hip joint load and leads to the progression of hip OA. Tateuchi et al. reported that larger anterior inclination and decreased mobility of the spine were predictors of radiographic progression of hip OA, because the internal hip extension caused by the forward tilting of the trunk consequently increases the mechanical load on the hip [21]. Damm et al. also reported that tilting the trunk doubles the load on the hip joints [29], but this study included only patients in the pre-, early, and advanced stages of OA and excluded people with normal hip joints. Although we agree that sagittal alignment could affect the progression of hip OA, our study indicated that sagittal alignment was not an independent risk factor for the progression of hip OA. This discrepancy may arise because our study included participants with normal hip joints along with those in the pre- and early hip OA stages; the difference in the hip OA progression likely affected the results.

Compared to that in healthy individuals, the mobility of the thoracolumbar spine is decreased in patients with hip OA [30]. Lumbar fusion surgery directly affects the mobility of the thoracolumbar spine and lumbar-pelvic structure. Spinal mobility worsens as the number of spinal fusion levels increases, which may lead to progression of hip OA. Lum et al. reported that female sex and a longer fusion increase the risk of hip OA progression requiring THA [31]. They reported that the relative risk of undergoing THA after fusion of >7 spinal levels was 1.03 among men compared to 2.19 among women. Kawai et al. also reported that longer spinal fusion was associated with the progression of hip joint narrowing [32]. Their findings are similar to ours. However, our study assessed not only joint space narrowing but also pre- and postoperative spinal alignment simultaneously and revealed that a long fusion had a greater influence on joint space narrowing of the hip than spinal parameters. The reason is that our results showed that most spinal parameters (SVA, TK, LL, and PT) improved through surgery (Table 3), which would theoretically decrease the load on the hips. On the other hand, no statistically significant difference was observed in the postoperative sagittal alignments between the OA-progression and non-progression groups (Table 4). It is reported that 16.5% and 36.1% of patients with posterior lumbar arthrodesis had adjacent segmental degeneration at five and ten years, respectively [33]. The lumbar spine and hip joints are adjacent segments especially when the fusion construct extends down to the sacrum and ilium, so the number of lumbar fusion levels and inclusion of sacral fusion significantly affect joint space narrowing of the hip. Our study revealed that although spinal alignment is improved by spinal fusion, it greatly affects joint space narrowing of the hip. Furthermore, women are more susceptible to joint space narrowing of the hip

after long spinal fusion surgery. Therefore, spine surgeons should pay attention to joint space narrowing of the hip after performing long fusion surgery in women, especially when performing sacral fusions.

This study has several limitations. First, this study was retrospective, and four hips of four patients underwent THA after spine fusion. However, the number of patients who underwent THA after spine fusion was too small, and we could not perform a clinical assessment of the hip. Thus, we cannot determine whether spine fusion affects conversion to THA. We plan to perform clinical assessment of the hip before and after spine fusion to elucidate how much spine fusion affects conversion to THA. Second, we set the minimum follow-up duration at 12 months from baseline X-ray measurements similar to a previous report [21], and we observed a gradual narrowing of the hip joint space as time progressed. Our mean follow-up duration of 2.9 ± 1.7 years is relatively shorter than that in other reports [21,34], so a higher rate of hip OA may be revealed with longer observation periods. However, only a few reports have investigated the effect of lumbar and sacral fusions on joint space narrowing of the hip, and we believe that this study adds important information to the literature. Third, this study did not include a control group. However, multiple regression analysis is more appropriate than comparative analysis to elucidate multiple unknown factors. Fourth, the definition of hip OA progression is not unified across studies. Some authors defined the progression of hip OA as an increase in the Kelgren-Laurence grade of more than one [35-37], but we found Kelgren-Laurence grading to be highly variable. Yearly joint space narrowing has also been used to assess progression of hip OA [28,38]. Although the measurement of joint space may also be variable, we found the intraclass reliability from three separate examiners measuring joint space to be highly reliable.

Conclusion

Female sex, the number of lumbar fusion levels, and sacral fusion were risk factors for joint space narrowing of the hip. Careful follow-up is needed for female patients with joint space narrowing of the hip after surgeons perform lumbosacral fusion. In particular, four or more lumbar fusion levels affect joint space narrowing of the hip to a higher degree compared to three lumbar fusion levels.

List Of Abbreviations

OA – osteoarthritis

QOL – quality of life

THA – total hip arthroplasty

SVK – sagittal vertical axis

TK – thoracic kyphosis

LL – lumbar lordosis

PI – pelvic incidence

PT – pelvic tilt

SS – sacral slope

CE – centre edge

MJW – minimum joint width

Declarations

Ethics approval and consent to participate

All procedures were performed in accordance with the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Tokai University Hospital (21R-043). Informed consent was waived owing to the retrospective nature of this study, which used extracted data from medical records.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

TU conceptualized and designed this study; TU, KY, and HO acquired and analyzed the data; TU drafted the article; HK and MW critically revised the important intellectual content of the manuscript. All authors read and approved the final manuscript.

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Figures

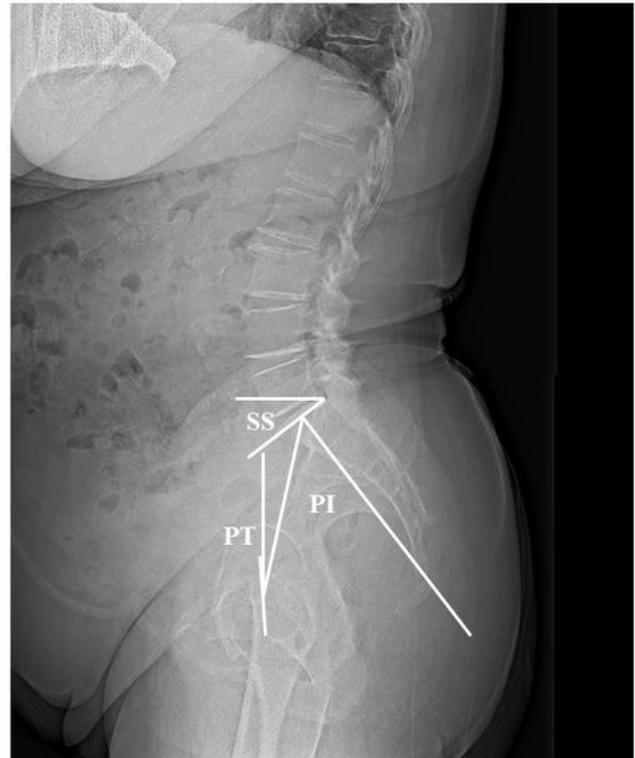


Figure 1

Figure 1

Measurements of spinal parameters

(a) Sagittal vertical axis (SVA) is the distance from the vertical line drawn from the seventh cervical vertebra to the edge of the sacral plate. Thoracic kyphosis (TK) angle is the angle between the lines drawn along the inferior endplate of the twelfth thoracic vertebra and the superior endplate of the fourth thoracic vertebra. Lumbar lordosis (LL) angle is the angle between the lines drawn along the superior endplate of the first lumbar vertebra and the superior endplate of the first sacral vertebra. (b) Pelvic incidence (PI) angle is the angle between the line of the upper endplate of the first sacral vertebra and the femoral head axis. Pelvic tilt (PT) is the angle between the vertical line and the line joining the middle of the upper endplate of the first sacral vertebra. Sacral slope (SS) is the angle between the horizontal line and the upper endplate of the first sacral vertebra.

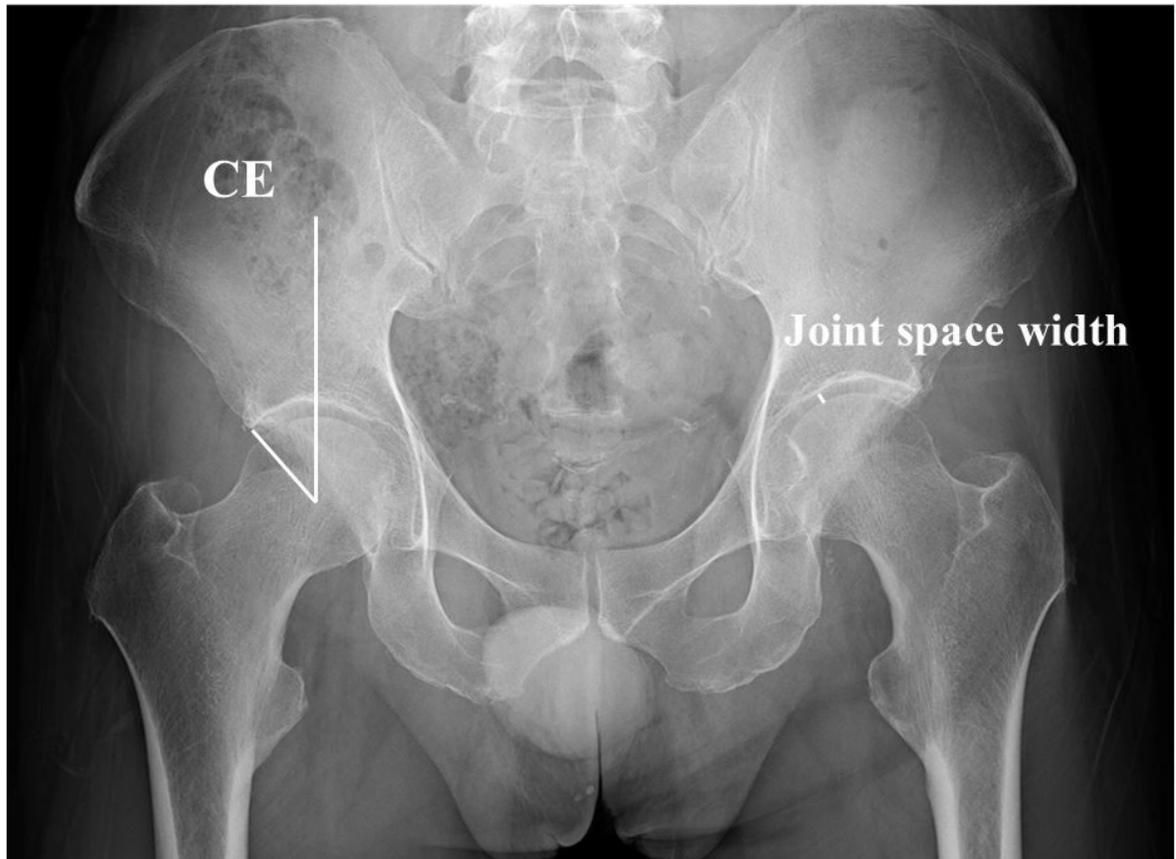


Figure 2

Figure 2

Measurements of the hip parameters

The center-edge angle (CE) is the angle between the vertical line and the line joining the center of the femoral head and the lateral margin of the acetabulum. Joint space width is the measurement from the narrowest space from the lateral margin of the acetabulum to the fovea of the femoral head.