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Sitting With or Without Wedge-Shaped Cushion After Lumbar Spinal Fusion

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Abstract

Introduction: Transition from standing to sitting significantly decreases lumbar lordosis (LL). Fusion of lumbar segments eliminates motion and therefore, adjacent mobile segments are recruited during transition from standing to sitting to compensate. Prescription of a wedge-shaped seat cushion to retain LL while seated is a common practice. However, its effect has not been evaluated before and after posterior lumbar spinal fusion (PSF).

Methods: Patients undergoing PSF at a single academic institution between May 2022 and August 2023 were included in the study. Radiographic spinopelvic parameters were measured in the standing, relaxed sitting, and sitting on a wedge-shaped cushion positions before and after surgery.

Results: Twenty patients were included for analysis (female to male, 11:9). Mean age was 67 ± 10 years. Mean body mass index was 26.3 ± 3.3 kg/m2. Median LL significantly decreased before the surgery from the standing 43° (33.5-49.5°) to the sitting positions with and without a cushion (24° (13-32°) vs 25° (8.5-34.5°); p<.001). After surgery LL also significantly decreased from the standing 38° (32- 47°) to the sitting positions with and without a cushion (26° (16.5-36°) vs 26° (19-38°); p<.001). But there was no significant difference in LL between the sitting positions without and with a cushion before and after the surgery 1° (-2-4°) and -2 (-4-2°), respectively.

Conclusions: Sitting significantly decreases lumbar lordosis and increases pelvic tilt, but use of a wedge-shaped seat cushion does not alter lumbar lordosis compared with regular sitting before or after fusion surgery.

Keywords: Sitting; Standing; Sagittal Alignment; Wedge Seat Cushion; Instrumented Spinal Fusion; Spinopelvic Parameters; lumbar lordosis

Introduction

In a survey of almost 28,000 individuals, the mean daily sitting time was 5 hours and 18.5% of participants reported daily sitting times exceeding 7.5 hours [1]. Compared with standing, in the seated position, lumbar lordosis (LL) and thoracic kyphosis (TK) decrease and the pelvis rotates posteriorly [2,3].

Current surgical strategies for sagittal realignment in patients with degenerative spinal diseases largely reference the radiographic alignment of the entire spine when imaged in the standing position [4]. Spinal instrumentation alters the ability of the spine to adapt its form while sitting,

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which can cause additional stress on implants or adjacent segments [5]. Such stress may play a significant role in complications such as implant loosening, cage subsidence, junctional kyphosis, and junctional failure [4,6–8]. Sitting on a chair or the floor increases the posterior tilt of the pelvis and decreases LL [9]. Cho et al. in their study of 30 healthy male volunteers studied the effect of five different sitting positions on lumbar lordosis. They observed that the lumbar lordosis (LL) was significantly reduced in all sitting positions compared to standing (mean LL 47°). The reduction in lumbar lordosis compared to standing was least observed on a chair with lumbar support (36°). An increasing lumbar flexion was observed when sitting on a 90°-angled chair (18°), sitting on a stool (1°) and sitting cross-legged on the floor (-7°) [10]. Moon et al. in their study of sixteen healthy volunteers demonstrated that the change in LL from standing (37°) to sitting is the least when a kneel sitting position (32°) is chosen as compared to sitting on a chair (18°) [11]. Sitting on a chair is the most common position in daily life and work. Use of a simple wedge-shaped seat cushion when sitting on a regular chair may assist in tilting the pelvis anteriorly, which aligns the spine in a position similar to its position when standing [12] [13].

To the best of our knowledge, the effect of a wedge-shaped cushion in the seated position after spinal fusion to decrease lumbar spine flexion has never been formally examined, even though it is routinely prescribed by spine surgeons. This study aimed to evaluate the effect of this ergonomic aid in lumbar spinal fusion patients by assessing and comparing spinopelvic alignment parameters in the standing and seated positions with and without a wedge-shaped cushion, both before and after surgery.

Material and Methods

Patients undergoing lumbar posterior spinal fusion (PSF) between May 2022 and August 2023 were prospectively identified. We excluded patients with incomplete pre- or postoperative radiological evaluations and those with a history of previous spinal fusion surgery. All patients were treated in a university hospital setting by a fellowship-trained spinal surgeon. Inpatient and outpatient medical records were reviewed to record demographic, clinical, and surgical data. The study was approved by the Cantonal Ethic Committee Zurich, Switzerland BASEC-Nr. 2022-00193. All patients provided written informed consent.

Radiographic Analysis

Spinopelvic parameters were evaluated on full-length lateral radiographs obtained using the EOS imaging system (EOS Imaging, Paris, France) before and after surgery in three positions: standing, sitting, and sitting on a commercially available wedge-shaped seat cushion (38 cm × 38 cm × 8/1cm (10° slope), polyurethane foam; Schaumstoff Haerti AG, Winterthur, Switzerland). Postoperative radiographs were taken in the hospital during the admission for surgery.

Lateral radiographs of the spine and pelvis were obtained in the fist-on-clavicle position while standing and with the patient's hands on the clavicles while sitting according to the study performed by Wang et al. (Figure 1) [14].

Figure 1 a-c: Standardized positions of the study participant during the radiological examination. a) Standing. b) Relaxed sitting on a stool. c) Relaxed sitting on a wedge- shaped cushion.

For the sitting position radiographs, patients were placed on a stool without back rest (45cm seat height) with their hips and knees flexed to approximately 90° and were instructed to sit relaxed, without leaning forward or backward. The reproducibility of position was reinforced through standardized verbal instructions.

The following sagittal parameters were measured: LL (between L1 and S1), pelvic incidence, PT, sacral slope (SS), and TK. On the postoperative radiographs, fusion segment lordosis, upper residual lumbar lordosis (URL), and lower residual lumbar lordosis (LRL) were additionally evaluated. Spinal sagittal curves in the natural, relaxed sitting position were classified as C- or S-shaped before surgery as described by Hey et al. [4]. A patient with a C-shaped curve would not have an inflection point, but rather a single apical vertebra/disc. Patients were also grouped according to incorporation of the sacrum in the fusion into lumbosacral fusion and floating fusion groups.

Sample size calculation and statistical analysis

Based on the variability we observed, a total of 17 subjects would be sufficient to show a minimal clinically important difference of 5° in change in lumbar lordosis when using a wedge-shaped cushion (postoperatively) at a type I error rate of 5% with a power of 90%. The resulting effect size was calculated with 0.8969.

Due to non-normality of the data, non-parametric tests were utilized. Spinopelvic parameters in the standing position were compared to those in the sitting position, both with and

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without a wedge-shaped cushion, using Wilcoxon signed-rank tests. Similarly, the impact of the wedge-shaped cushion was evaluated by comparing the spinopelvic parameters between sitting without the cushion and sitting with it. These comparisons were further extended to data stratified by sacral involvement in the fusion and by the type of spinal sagittal curves to assess differential effects. The analysis was conducted with SPSS (Version 28.0. Armonk, NY: IBM Corp) and MATLAB (The MathWorks Inc. (2022b), Natick, Massachusetts). P-values below 0.05 were considered statistically significant.

Results

Twenty patients were included for analysis, 11 women and nine men. Mean age was 66.7 ± 10.13 years. Mean body mass index was 26.27 ± 3.32 kg/m2. Ten patients underwent floating single-level fusion, one at L2/3, one at L3/4, and eight at L4/5. Among the ten patients in the lumbosacral fusion group, four underwent L5/S1 fusion, three underwent L4-S1 fusion, two underwent L3-S2/iliac fusion, and one underwent L4-S2/iliac fusion.

Spinopelvic parameters

Spinopelvic parameters before and after surgery in each position examined are shown in Table 1.

Before surgery, PT significantly differed between the standing 22° (14.5- 26.5°), sitting without a cushion 36° (27-42.5°), and sitting on a cushion 40° (34-44°) positions (p<.001). Corresponding preoperative SS values (28.5° (26-31.5°), 14.5° (7-27°), and, and 10.5° (7.5-16°), respectively; p<.001)) and LL values (43°(33.5-49.5°), 25° (8.5-34.5°) , and 24° (13- 32°), respectively; p<.001) also significantly differed. PT was higher with sitting on a cushion than sitting without one, but the difference was not significant (p=.055); conversely, SS was significantly lower (p=.049). Before surgery, TK was significantly higher in the standing position than sitting without a cushion (44° (33-48°) vs. 38° (30.5-44.5°))(p=.010).

After surgery, PT was significantly higher with sitting without a cushion 31° (26-38°) than standing 24° (20.5-30°) p=.008) and significantly higher with sitting on a cushion 34° (28.5-38.5°)(35° ± 9°) than standing (p<0.001). PT was significantly higher with sitting on a cushion than

Table 1: Spinopelvic parameters before and after posterior lumbar spinal fusion

	Preop				Postop			
	Standing	**Sitting without cushion**	**Sitting on cushion**	**Difference with cushion**	**Standing**	**Sitting without cushion**	**Sitting on cushion**	**Difference with cushion**
PI	48.5 (44, 57.5)	-	-	-	-	-	-	-
PT	22 (14.5, 26.5)	36 (27, 42.5) ,	40 (34, 44),	2.5 (0, 6),	24 (20.5, 30)	31 (26, 38),	34 (28.5, 38.5),	4.5 (0, 6),
		p < 0.001	**p < 0.001**	p = 0.055		**p = 0.008**	**p < 0.001**	**p = 0.007**
SS	28.5 (26, 31.5)	14.5 (7, 27),	10.5 (7.5, 16),	-2 (-8, 0),	25 (21.5, 30.5)	17 (12, 24.5),	17.5 (10.5, 22.5),	-3.5 (-6, 2),
		p < 0.001	**p < 0.001**	**p = 0.049**		**p = 0.003**	**p < 0.001**	**p = 0.029**
LL	43 (33.5, 49.5)	25 (8.5, 34.5),	24 (13, 32),	1 (-2, 4),	38 (32, 47)	26 (19, 38),	26 (16.5, 36),	-2 (-4, 2),
		p < 0.001	**p < 0.001**	p = 0.779		**p < 0.001**	**p < 0.001**	p = 0.123
TK	44 (33, 48)	38 (30.5, 44.5),	39 (32.5, 46),	1.5 (-2, 4),	41 (27.2, 46.8)	39 (29.5, 44),	40 (31.2, 44),	1 (-3, 4),
		p = 0.010	p = 0.070	p = 0.111		p = 0.192	p = 0.585	p = 0.669
URL	-	-	-	-	13 (8, 19)	2.5 (-5, 10),	2 (-5.5, 11),	0 (-2, 2),
						p < 0.001	**p < 0.001**	p = 0.658
LRL	-	-	-	-	1.5 (0, 9)	0 (0, 6),	0 (0, 3.5),	0 (-1, 0),
						p = 0.062	**p = 0.035**	p = 0.742

Median (Inter-quartile range) spinopelvic parameters before and after posterior lumbar spinal fusion in standing and sitting position without and with wedge-shaped cushion. P-values refer to the comparisons of standing position vs. sitting without and with cushion and to the difference in spinopelvic parameters that using the wedge-shaped cushion induced. Statistically significant differences are marked in bold. preop, preoperative; postop, postoperative; PI, pelvic index; PT, pelvic tilt; SS, sacral slope; LL, lumbar lordosis; TK, thoracic kyphosis; URL, upper residual lordosis; LRL, lower residual lordosis

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sitting without one 4.5° (0-6°); (p=.007). Postoperative SS significantly differed between the standing 25° (21.5-30.5°), sitting without a cushion 17° (12-24.5°), and sitting on a cushion 17.5° (10.5-22.5°) positions (p<.029). Corresponding postoperative LL values (38° (32-47°), 26° (19-38°), and 26° (16.5-36°), respectively; p<.001) and URL values (13° (8-19°), 2.5° (-5- 10°), and 2° (-5.5- 11°), respectively; p<.001) also significantly differed. Postoperative TK values did not significantly differ between the three positions. The difference in URL and LRL between standing and sitting with and without a cushion was not significant. LL did not significantly differ between sitting with and without a cushion either before or after surgery.

PT, LL, TK, URL and LRL values in the floating and lumbosacral fusion groups after surgery in each position examined are shown in Figure 2.

A significant increase in PT was observed in the lumbosacral fusion group when a cushion was used in comparison to sitting without one (32.5° (27-49°) vs 30.5° (26-40°; p=.037). A significant decrease in LL was observed in the floating fusion group when a cushion was used in comparison to sitting without one (27.5° (22-34°) vs 30 (26-36°); p=.016). Sagittal spinal curve was classified as C-shaped in six patients (Fig. 3) and S-shaped in 14 (Fig. 4).

PT, LL, TK, URL and LRL values in the C- and S-shaped curve groups are shown in Figure 5.

Postoperative the PT significantly increased in the C-shaped curve group when a cushion was used in comparison to sitting without one (33.5° (33-39°) vs 28.5° (26-36°); p=.031).

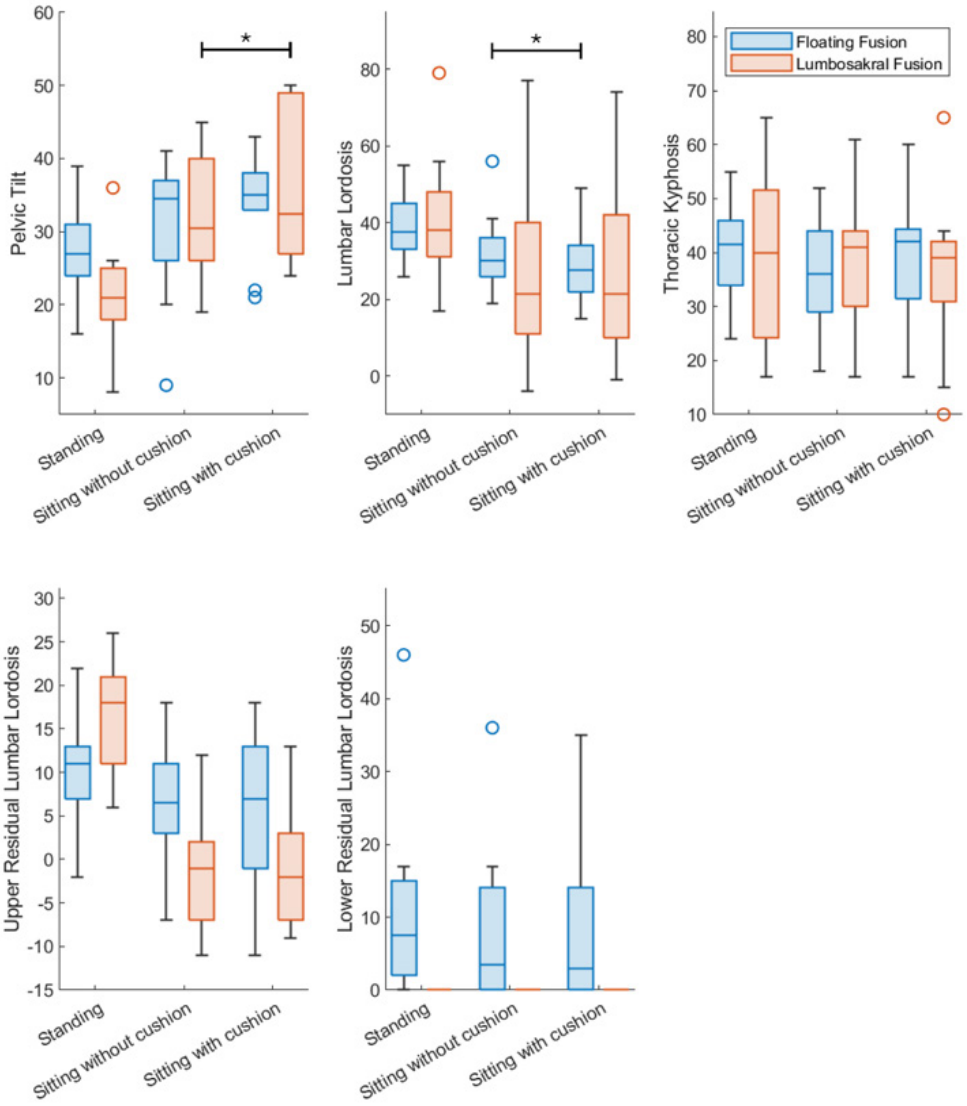

Figure 2: Postop Spinopelvic parameters stratified by fusion sacral involvement. Asterisk: Significant ($p < 0.05$) difference of spinopelvic parameter with or without wedge-shaped cushion. Box: Inter-quartile range; Whiskers: Range; Circles: Outliers

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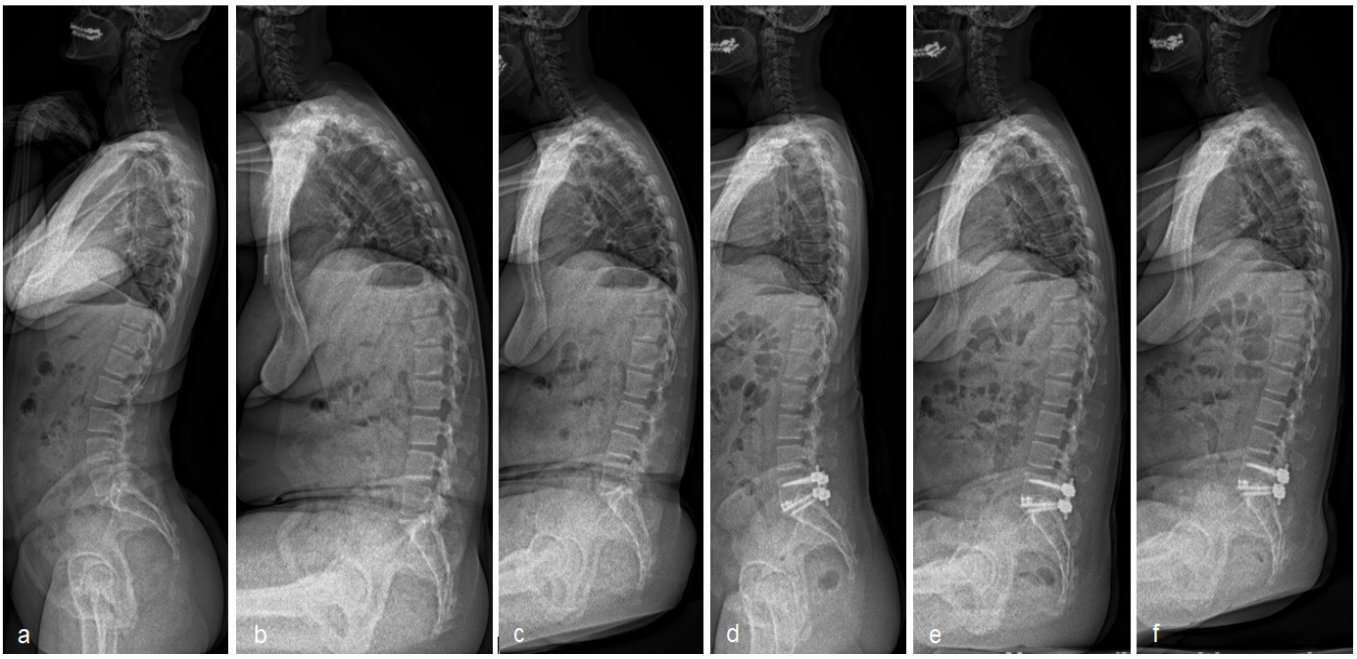

Figure 3: Pre- and postoperative lateral full spine x-rays of a 44 year old female patient that underwent posterior spinal fusion L5/S1 with TLIF L5/S1 after two microsurgical decompression surgeries at this level. Pre-/ postoperative x-rays in three postures: standing (a/d), relaxed sitting (b/e), sitting on a wedged seat cushion (c/f). This patient was classified as a C-shaped sagittal spine profile in the preoperative natural, relaxed sitting posture.

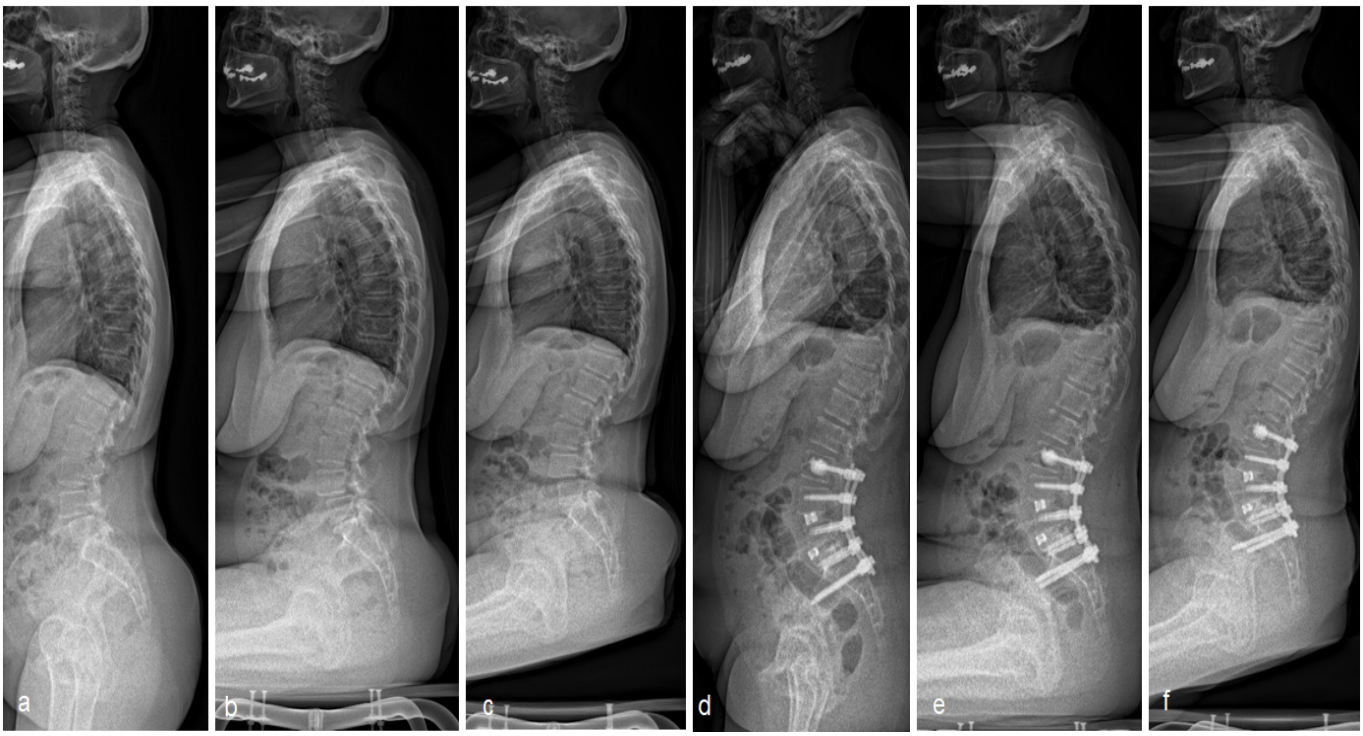

Figure 4: Pre- and postoperative lateral full spine x-rays of a 67 year old female patient that underwent posterior spinal fusion L3-S2 iliac with TLIF L4/5 and L5/S1 and decompression L3/4. Pre-/ postoperative x-rays in three postures: standing (a/d), relaxed sitting (b/e), sitting on a wedged seat cushion (c/f). This patient was classified as a S-shaped sagittal spine profile in the preoperative natural, relaxed sitting posture.

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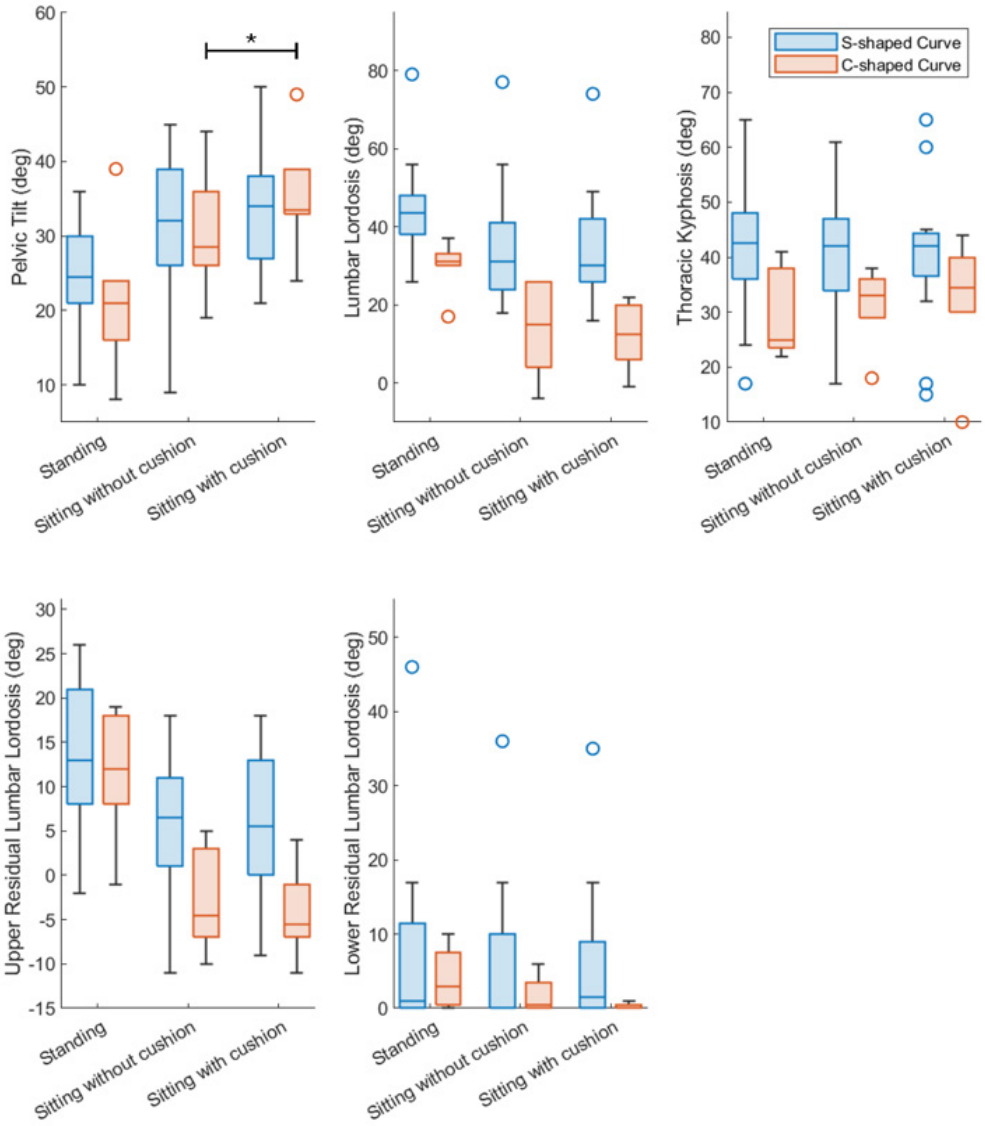

Figure 5: Spinopelvic parameters stratified by type of spinal shape. Asterisk: Significant ($p < 0.05$) difference of spinopelvic parameter with or without wedge-shaped cushion. Box: Inter-quartile range; Whiskers: Range; Circles: Outliers

Postoperative the PT significantly increased in the C-shaped curve group when a cushion was used in comparison to sitting without one (33.5° (33-39°) vs 28.5° (26-36°); p=.031).

Discussion

The spine adapts to the sitting posture by modifying PT and LL [15]. In healthy individuals a 25° decrease in LL was reported comparing the sitting to the standing positions. PT increases by 50% (retroversion) in the seated position [2]. The lumbar spine is the primary site of sagittal adaptation because of the anatomical morphology of its facet joints [16]. Sielatycki et al. [17] demonstrated that lumbar kyphosis is greater with sitting than with standing flexion on radiographs performed in adult patients, which shows the considerable lumbar spinopelvic adaptations that occur with sitting; these authors suggest the use of seated lateral radiographs when performing dynamic assessment of the lumbar spine.

Spinopelvic adaptation when moving from a standing to a sitting position is altered in patients with a lumbar fusion as the segment above the fusion must compensate for the decrease in LL when moving from a standing to a sitting posture. Repetitive posture changes may concentrate mechanical stresses at the junction between the fused segment and adjacent ones, which may cause development of adjacent segment degeneration with proximal junctional kyphosis or proximal junctional failure [5,18]. Junctional kyphosis is common after spinal fusion surgeries—reported incidence rates range from 17% to 62% [7,19].

Many spine surgeons prescribe a wedge-shaped seat cushion after spinal fusion surgery, with the rationale that

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it alleviates postural changes in spinopelvic parameters and therefore reduces mechanical stress at junctional sites, mainly due to reduction of the assumed kyphosing effect of sitting. To the best of our knowledge, however, the effect of this ergonomic aid has never been formally investigated by standardized radiographic measurements before and after fusion surgery.

In this study of 20 lumbar PSF patients, PT was higher with sitting on the cushion than without, both before (40° (34-44°) vs. 36° (27-42.5°); p=.055) and after surgery (34°(28.5-38.5°) vs. 31° (26-38°) ; p=.007). Sitting radiographs were obtained with the patients on a stool in a relaxed sitting posture without a backrest to observe maximum flexion of the spine. Low back support does not appear to be necessary for maintaining a balanced and natural sitting posture with greater degrees of seat pan tilt (tilt of the sitting surface) [20]. In addition, the majority of laborers work with their back unsupported for most of the work day, although it depends on the task being performed [20]. This is probably also true for elderly patients sitting for prolonged periods.

In a study of 30 asymptomatic volunteers, Bae et al. [9] demonstrated a significant loss of LL between standing (50° ± 9°), sitting on a chair (30° ± 16°), and sitting cross- legged on the floor (14° ± 14°). Segmental contribution to the loss of lordosis when sitting on a chair and on the floor was greatest at L5/S1. This implies a large degree of mobility at the L5/S1 level, which may explain why the incidence of nonunion is high at this level after fusion surgery [9,21].

Noro et al. [20] demonstrated in a study looking at zabutons (commercial cushion used for the zazen postures in Zen floor sitting during prolonged sitting mediations to promote postural stability) with and without pelvic support that there was a marked decrease of pelvic retroversion (9.5°) with the addition of a pelvic support. In contrast to our study population, the 44 healthy subjects were instructed to assume a sitting posture with their pelvis rotated forward. They also noted considerable variability in PT between individuals that appeared to be related to differences in physical size.

We found no significant difference in LL between sitting with and without a wedge-shaped cushion, which is in accordance with the findings of De Carvalho et al. [22]. They examined office chair features such as seat pan tilt, scapular relief, and lumbar support and concluded that the features were limited in their ability to reduce the degree of spinal and pelvic retroversion when sitting. Chair features only influenced posture locally at the point of contact. Forward tilt of the seat pan was the only feature that demonstrated a significant effect on anterior rotation of the pelvis compared with regular sitting; however, it had no significant effect on LL (22° ± 14° vs, 18° ± 13°).

Zhou et al. [23] reported that in patients with a lumbosacral fusion, the difference in LL between standing and sitting significantly decreased and the difference in URL significantly increased; in patients with a floating fusion, pre- and postoperative LL and URL values did not differ significantly. Since fused segments are rendered immobile in a fixed curve, the change in LL required to adapt to changes in posture occurs in the mobile, non-fused segments.

In our patients the addition of a wedge-shaped cushion did not cause changes in URL compared with regular sitting in the floating and lumbosacral fusion groups.

Change in pelvic retroversion from standing to sitting was restricted after lumbar fusion in our patients, which has also been previously reported [23]. Fusion of the lumbosacral junction forces the spine and pelvis to move as a whole. As a result, PT can affect the movement of the spine more directly [23].

Patients with a high PI are capable of compensating by inducing a large posterior tilt and reducing the SS; conversely, those with a low PI are not [24].

Cecchinato et al. [25] demonstrated that patients who underwent long thoracolumbar fusion extended to the pelvis were unable to retrovert the pelvis; to adapt, they developed kyphosis above the fusion segment. These patients showed an increase in proximal junctional angle while sitting. The study concluded that excluding the pelvis from the fusion seems to have a protective effect on the proximal junctional angle while sitting.

In a study of patients undergoing posterior lumbar fusion, fusing across the lumbosacral junction significantly increased the change in URL between the standing and sitting positions [6].

In general, patients who have undergone a long spinal fusion are instructed to sit in an elevated seat with the knees lower than the hips. This posture reduces hip flexion, which reduces pelvic retroversion [25].

Most of our patients (14 of 20) had an S-shaped sagittal curve in the natural, relaxed sitting position. Although the natural, relaxed sitting posture transforms the sagittal profile of the spine into a C-shape with a single apex located within the thoracolumbar junction in healthy adults [26], some retain a typical S-shaped profile with preservation of LL and TK when sitting; however, the degree of LL and TK in these individuals is decreased and increased, respectively. An S-shaped spine is indicative of relative stiffness and associated with degenerative spondylolisthesis and degenerative scoliosis [4]. In our patients, many of whom were older with degenerative spine disease, PI significantly differed between the C- and S-shaped curve groups (42° (34-49°) and 54° (47-59°) , respectively). However, URL did not significantly change between sitting with and without a cushion in either group.

This study has several limitations. First, the radiographs were obtained at discrete points in time in a controlled setting and do not reflect any variations in sitting posture over time. Pan et al. demonstrated that the reproducibility of sitting radiographs is worse than of standing. During sitting, the base of support is formed by the buttocks and the feet, during standing only by the feet. Therefore, larger upper body motions are possible in sitting without loosing balance [27]. However, the patients were instructed to seat in a standardized manner.

Second, the sample size was small. However, this is one of the few studies that is able to report full radiological data of the standing and sitting spine before and after fusion surgery, gathered in a prospective manner. Third, patients were not specifically instructed to rotate the pelvis forward on the nonslip wedged seat cushion and the stool was not specifically adapted to patient height. This aspect of the study design was chosen by purpose to reflect normal behavior of the patients.

In conclusion we demonstrated in this prospective cohort study that the routine prescription of a wedged seat cushion for patients undergoing PSF does not alter the lumbar lordosis closer to the standing posture compared to regular sitting pre- or postoperatively. The authors therefore recommend against the routine use of a wedged seat cushion in the postoperative care of lumbosacral fusion patients.

Conflict of interest: None

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