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Clinical Studies

Predictors of segmental lumbar lordosis following midline posterior (transforaminal) lumbar interbody fusion: Does interbody device type matter?

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ABSTRACT

Background: Controversy exists regarding the ability of posterior (transforaminal) lumbar interbody fusion (PLIF/TLIF) to achieve lordosis. We hypothesized that an interbody device (IBD) designed for positioning in the anterior disc space produces greater lordosis than IBDs designed for straight-in positioning. The purpose of this study is to determine if using either an anterior-position or straight-in position IBD design were associated with successful achievement of postoperative lordosis.
Methods: A consecutive series of patients undergoing a undergoing a single-level, posterior open midline (transforaminal) lumbar interbody fusion procedure for degenerative spine conditions during a time period when the two types of interbody devices were being used at surgeon discretion were identified from a multi-surgeon academic training center. Patient demographics and radiographic measures including surgical level lordosis (SLL), anterior disc height, middle disc height, posterior disc height, IBD height, and IBD insertion depth were measured on preop, immediate postop, and one-year postop standing radiographs using PACS. Group comparison and regression analysis were performed using SPSS.
Results: Sixty-one patients were included (n=37 anterior, n=34 straight-in). Mean age was 59.8±8.7 years, 32 (52%) were female. There was no difference between IBD type (anterior vs. straight-in) for mean Pre-op SLL (19±7° vs. 20±6°, p=0.7), Post-op SLL (21±5° vs 21±6°, p=0.5), or Change in SLL (2±4° vs. 1±5°, p=0.2). Regression analysis showed that Pre-op SLL was the only variable associated with Change in SLL (Beta = negative 0.48, p=0.000). While the mean Change in SLL could be considered clinically insignificant, there was wide variability: from a loss of 9° to a gain of 13°. Gain of lordosis >5° only occurred when Pre-op SLL was <21°, and loss of lordosis >5° only occurred when Pre-op SLL was >21°.
Conclusions: While group averages showed an insignificant change in segmental lordosis following a posterior (transforaminal) interbody fusion regardless of interbody device type, pre-operative lordosis was correlated with a clinically significant change in segmental lordosis. Preoperative hypolordotic discs were more likely to gain significant lordosis, while preoperative hyperlordotic discs were more likely to lose significant lordosis. Surgeon awareness of this tendency can help guide surgical planning and technique.

Introduction

Loss of lumbar lordosis is a frequent concern when treating degenerative spine pathology. Both the natural history of the degenerative spine, as well as iatrogenic loss of lordosis from suboptimal surgical techniques, can lead to sagittal malalignment conditions such as "flatback" deformity and accelerate adjacent level degeneration. [1-8] Contemporary goals of spine fusion techniques include the maintenance or restoration of anatomic segmental lordosis [1–8].

Controversy exists regarding the ability of posterior (transforaminal) lumbar interbody fusion procedures to achieve improvement or desired segmental lordosis. [1-7] Additional controversy exists regarding the importance of surgical technique variables [1–7].

The purpose of the current study was to analyze a consecutive multi-surgeon series of posterior (transforaminal) interbody fusion procedures using either an anterior position or straight-in position interbody device (IBD) design to determine if this variable was associated with successful achievement of postoperative lordosis.

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We hypothesized that posterior interbody devices designed for positioning in the anterior aspect of the disc space would result in greater lordosis than interbody devices designed for straight-in positioning. Secondarily, we hypothesized that the preoperative variables of disc height and lordosis may impact postoperative lordosis.

Methods

The study was designed as a retrospective comparative observational cohort. A multi-surgeon (four attending surgeons with additional fellow involvement), consecutive series from at large academic training center was used to improve the generalizability of the findings.

All patients underwent a primary single-level, open midline posterior (transforaminal) interbody fusion at L3/L4 or L4/L5 with IBD design type determined by individual surgeon discretion during a time period when both interbody device types were commonly used (2013-2017). We intentionally excluded L5/S1 cases due to the preference of some of the participating surgeons to perform an anterior interbody fusion at the L5/S1 level.

Diagnoses included spondylolisthesis, foraminal stenosis, and central/lateral recess stenosis requiring facetectomy for adequate decompression. The standard surgical technique included an open midline exposure sufficient to place cortical bone trajectory screws and a laminectomy/facetectomy sufficient to perform a posterior interbody fusion. Patient positioning in a lordotic (abdomen free) position and compression during rod insertion were standard.

Patient demographics and radiographic measures included surgical level lordosis (SLL), anterior disc height, middle disc height, posterior disc height, IBD height, and IBD insertion depth.

Pre-operative and immediate post-operative standing radiographs were measured using standard picture archiving and communication software with image magnification and contrast adjustments made to optimize visualization of the endplates. SLL was measured using standard Cobb angle measurements were made using the superior endplate of the cranial (upper) level and the inferior endplate of the caudal (lower) level. Interbody insertion depth percent was calculated as a distance measured from the most posterior point of the disc space to the most posterior point on the IBD divided by the anterior-posterior distance of the disc space (similar to percent slip for spondylolisthesis grading).

For each radiographic variable, three independent measurements were performed and a mean was calculated. Mean values were used for all analyses.

Statistical analyses including group comparison and regression analysis were performed by a trained statistician using SPSS software.

Results

Sixty-one patients were included in the study. Thirty-seven patients had an interbody device designed for placement in the anterior disc space (“banana” or “crescent” shaped), while thirty-four patients had an IBD designed for straight-in placement (“bullet” shaped). Mean patient age was 59.8±8.7 years. Thirty-two patients (52%) were female. Fifty-four patients (89%) had surgery at the L4/L5 level and seven patients (11%) had surgery at the L3/L4 level.

Comparative group statistics are presented in Table 1. There was no significant difference for mean preoperative surgical level lordosis between IBD type (anterior versus straight-in) (19±7 degrees versus 20±6 degrees, p=0.7). There was no significant difference for mean postoperative surgical level lordosis between IBD type (anterior versus straight-in) (21±5 degrees versus 21±6 degrees, P=0.5). There was no significant difference in mean change in surgical level lordosis between IBD type (anterior versus straight-in) (2±4 degrees versus 1±5 degrees, p=0.2). Although measured IBD height was less for the anterior group (13 mm versus 15 mm, p=0.01), IBD height to preoperative disc height ratio showed no significant difference between groups (2.2 versus 2.5, p=0.2).

Table 1
Comparative group statistics.

N	Anterior 37 Mean (SD)	Straight-in 34 Mean (SD)	p-value
Segmental Lordosis			
Pre-Operative, °	19.06 (6.58)	19.62 (6.27)	0.714
Post-Operative, °	21.49 (5.21)	20.69 (5.78)	0.544
Change (Post minus Pre), °	2.45 (3.67)	1.07 (4.76)	0.182
Pre-Operative			
Anterior Disc Height, mm	10.49 (3.23)	10.95 (3.60)	0.571
Posterior Disc Height, mm	5.41 (1.77)	5.77 (2.74)	0.522
Middle Disc Height, mm	6.91 (2.20)	6.79 (2.42)	0.819
Interbody Device			
Insertion depth, %	0.47 (0.11)	0.18 (0.10)	0.000
Height, mm	13.34 (2.80)	15.12 (2.77)	0.010
IBD: Disc Height Ratio	2.20 (1.13)	2.56 (1.24)	0.206

Table 2
Regression analysis of variables associated with change in segmental lordosis.

	Standardized Beta Coefficient	p-value
Device Type	-0.054	0.778
Depth of IBD insertion	0.183	0.323
Postop-Preop Disc Height	0.202	0.121
IBD Height	-0.129	0.388
IBD Height Ratio	0.105	0.482
Preop Lordosis	-0.478	0.000
Preop Anterior Disc Height	-0.013	0.926
Preop Posterior Disc Height	0.187	0.108

As expected from the difference in IBD design and technique, IBD insertion depth was significantly different between groups with the posterior portion of the IBD inserted further into the disc in the anterior group (47% vs. 18%, p=0.000).

Multivariate regression analysis showed that preoperative surgical level lordosis was the only variable associated with change in surgical level lordosis (Beta = negative 0.48, p=0.000) (Table 2).

While the mean change (1 or 2 degrees) in surgical level lordosis could be considered clinically insignificant, there was wide variability: from a loss of 9 degrees of lordosis to a gain of 13 degrees of lordosis (Figure 1).

Post-hoc analysis of the cases where the changes in lordosis are more likely to be clinically significant showed that gain of lordosis >5 degrees only occurred when preoperative surgical level lordosis was <21 degrees (Figures 2-4), and loss of lordosis >5 degrees only occurred when preoperative surgical level lordosis was >21 degrees (Figures 5-6). Other technical factors that resulted in a significant loss of lordosis included an over-sized and posteriorly positioned IBD in three cases (one example is seen Figure 5).

Discussion

While prior studies on posterior interbody fusion techniques and lordosis have improved our understanding of the variables involved, the somewhat inconsistent and inconclusive findings lead to the purpose of the current study.

In 2014, Lindley et al compared minimally invasive transforaminal interbody fusion with a straight-in “bullet” interbody device (n=16) versus an anteriorly placed “steerable” interbody device (n=19). Both groups had approximately 5 degrees of mean preoperative (disc space) lordosis. The authors reported no significant change in (disc space) lordosis in the straight-in group, while the anteriorly placed group showed a mean of 13 degrees of postoperative (disc space) lordosis. Correlations between preoperative lordosis and postoperative lordosis were not reported. The apparent difference in preoperative lordosis in the Lindley et al study (5 degrees) and the current study (20 degrees) can be partially explained by different measurement techniques: Lindley et al measured

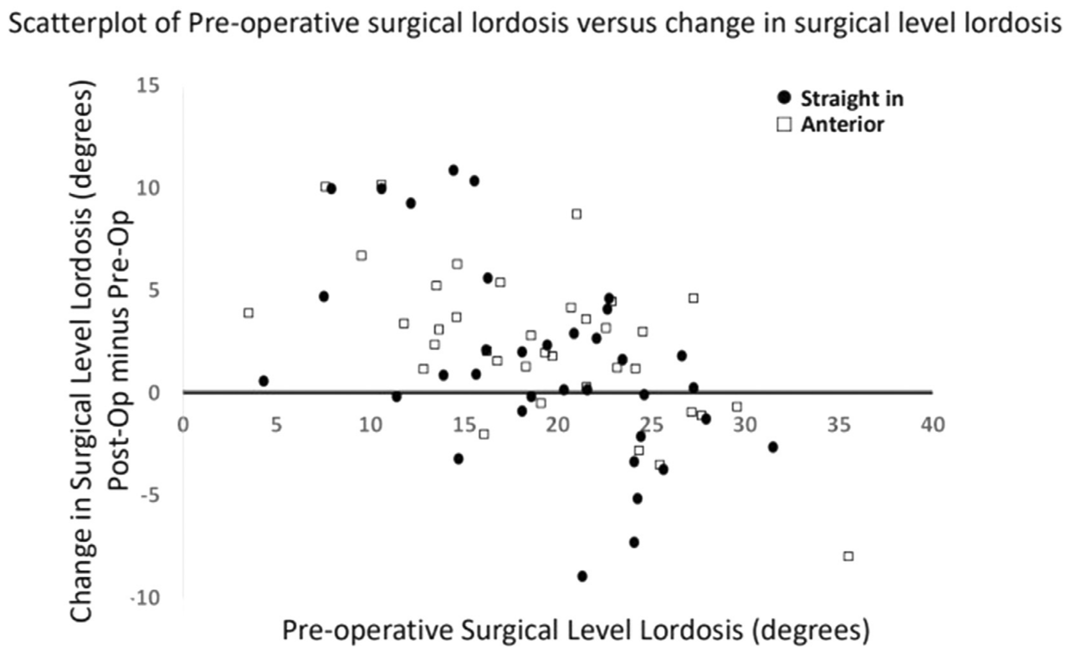

Figure 1. Scatterplot of Preoperative Lordosis versus Change in Surgical Level Lordosis (Post-operative minus pre-operative) showing wide variability in the change in surgical lordosis. The type of interbody device (Anterior versus Straight in) has no impact on the change in surgical level lordosis.

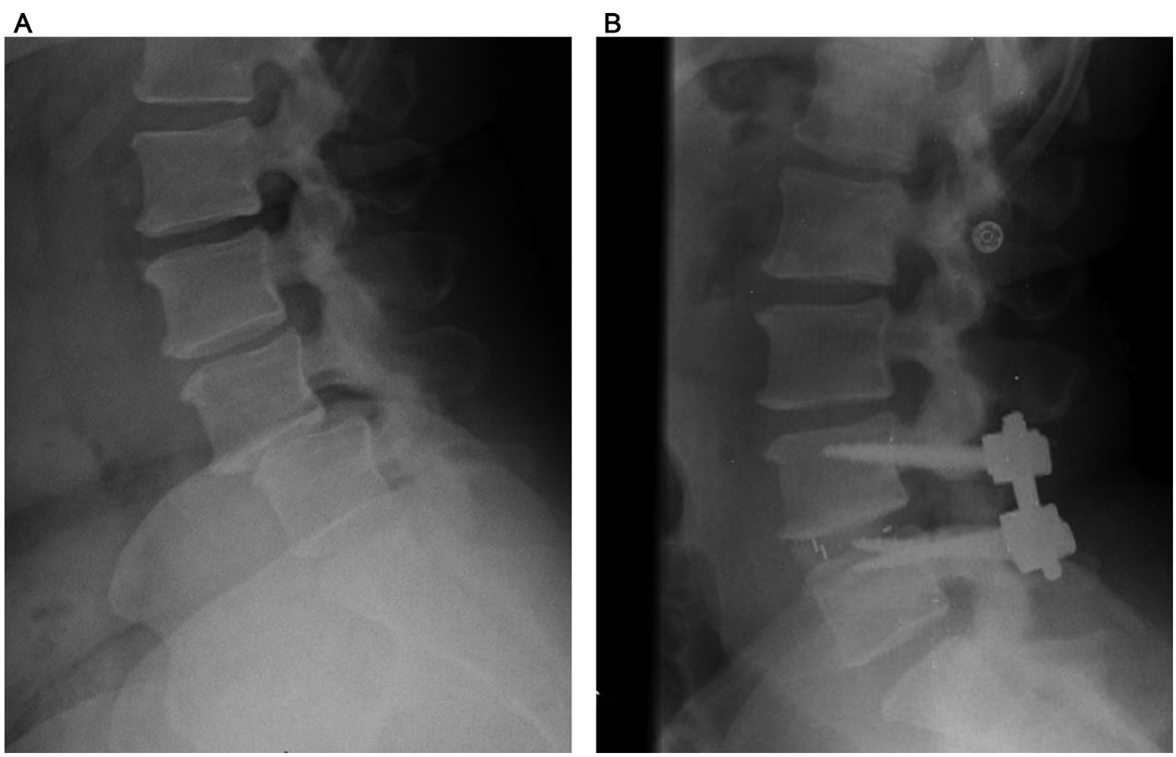

Figure 2. **(A)** Patient with a "falling forward" degenerative spondylolisthesis and loss of normal lordosis (preoperative hypolordosis of 7.3°). **(B)** Post-operatively lordosis improved 13° to 20.3° with Straight-In IBD type.

the inferior endplate of the cranial (upper) level and the superior endplate of the caudal (lower) level (i.e. measured lordosis within the disc space). In the current study, the authors chose a more traditional Cobb method using the superior endplate of the cranial (upper) level and the inferior endplate of the caudal (lower) level. While the method used in the current study may allow for more accurate visualization of the endplate due to the lack of the interbody device interference, it does add any lordosis inherent in the vertebral body itself, which is relatively common, especially at L5 (Figs. 2-6). Perhaps more importantly, the current study included several patients with segmental hyperlordosis, which may not have been included in the Lindley et al study.

In 2016, Uribe et al published a review of preservation or restoration of lordosis using minimally invasive lumbar interbody fusion techniques. Among other findings, they reported that lower preoperative lordosis predicted a greater increase in postoperative lordosis using a simple linear regression analysis. This finding is consistent with the re-

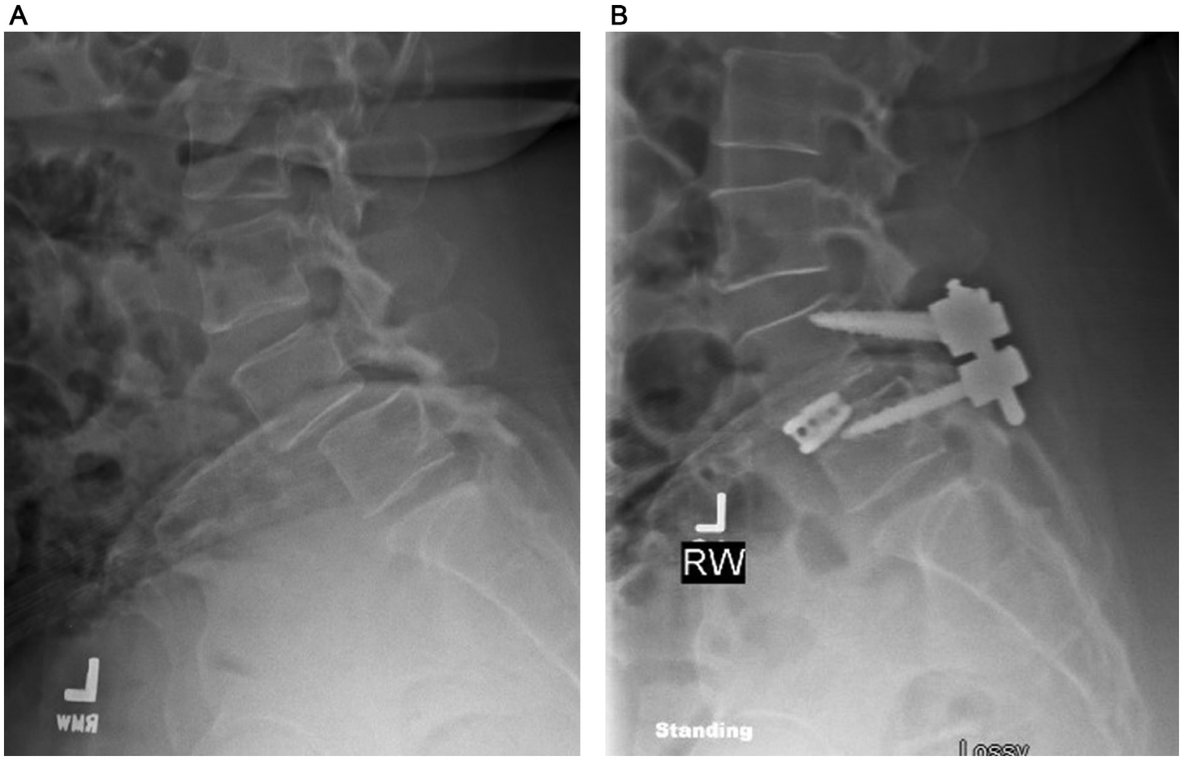

Figure 3. **(A)** Patient with a "falling forward" degenerative spondylolisthesis and loss of normal lordosis (preoperative hypolordosis of 7.8°). **(B)** Post-operatively lordosis improved by 10° to 18° with Anterior IBD type.

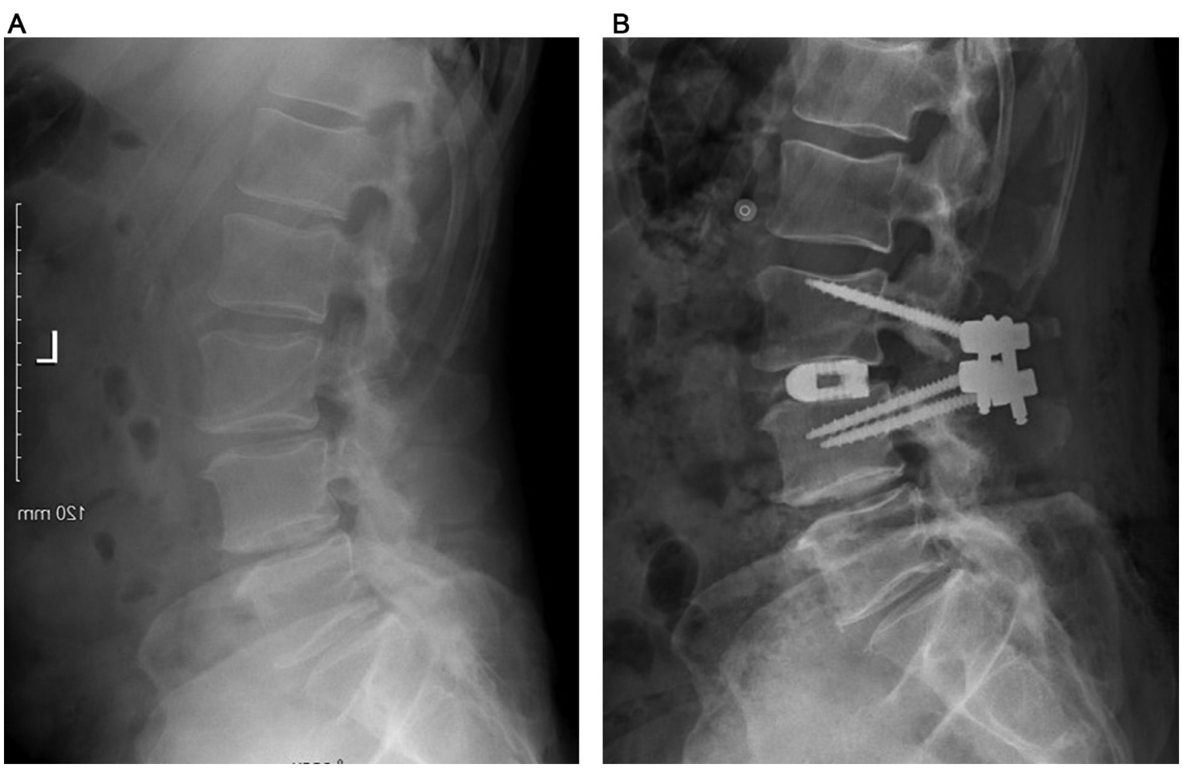

Figure 4. **(A)** Patient with a mild degenerative scoliosis and symptomatic foraminal stenosis on the concavity at L3/L4 (preoperative lordosis of 12°). **(B)** Post-operatively lordosis improved by 10° to 22° with Straight-In IBD type.

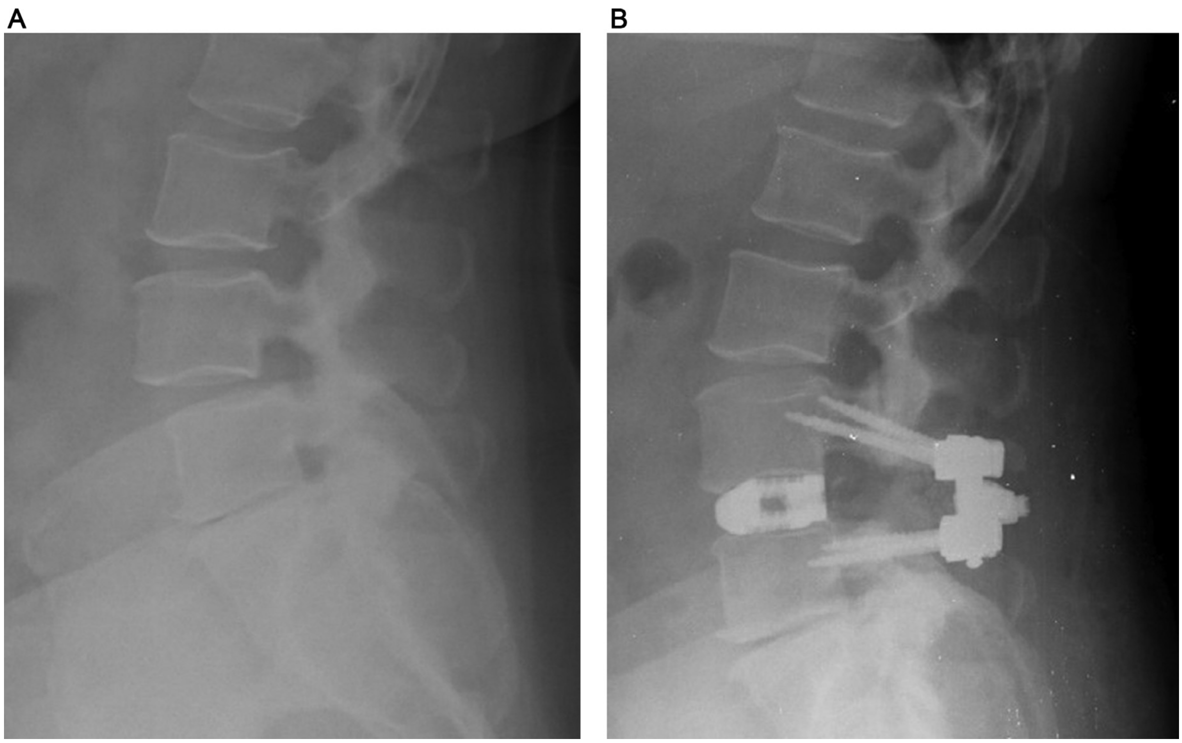

Figure 5. **(A)** Patient with a "falling backwards" degenerative spondylolisthesis and preoperative lordosis > 21 degrees (hyperlordosis of 21°). **(B)** Post-operatively lordosis worsened by 9° to 12° with Straight-In IBD type. Technical factors such as an over-sized and posteriorly positioned implant appear to have contributed to the loss.

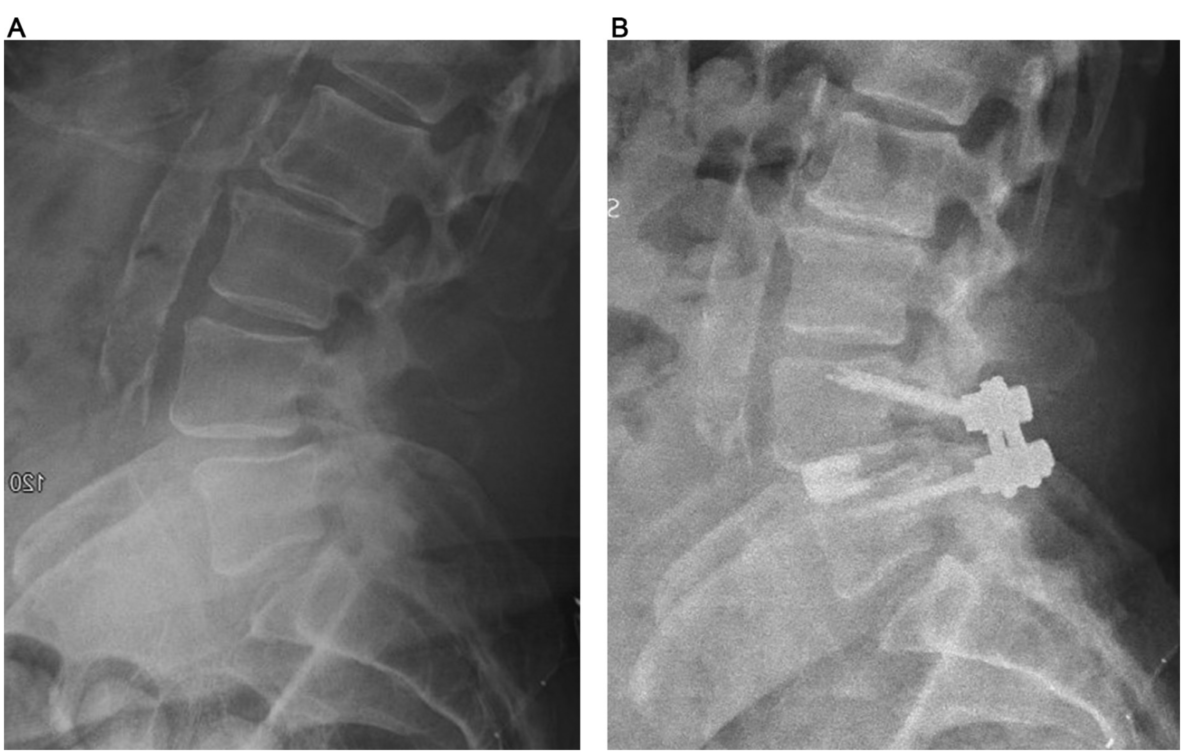

Figure 6. **(A)** Patient with "falling backwards" degenerative spondylolisthesis and preoperative lordosis > 21 degrees (hyperlordosis of 36°). **(B)** Post-operatively lordosis worsened by 8° to 28° with Anterior IBD type.

sults of the current study. Posterior interbody device type was not reported, although the potential importance of such was mentioned in the discussion.

In 2018, Robertson et al published a cadaver study evaluating the contribution of surgical techniques and cage variables in lordosis re-creation in transforaminal and posterior interbody fusion. Using eight cadaveric motion segments, they showed that the major contributors to lordosis re-creation were the addition of posterior column osteotomy and paired shorter cages (straight-in design). Although posterior column osteotomies were not included in the current study, future studies are warranted.

In 2019, Carlson et al published a systematic review of restoration of lumbar lordosis following transforaminal lumbar interbody fusion. Sixteen studies met the inclusion criteria and the results were variable. Weighted-mean preoperative segmental lordosis (SL) was 12.7 ± 4.3 degrees. Weighted-mean postoperative SL was 15.0 ± 4.5 degrees with a post-pre difference of 2.1 ± 1.7 degrees. The authors reported a need for future studies to fully elucidate the capabilities of TLIF to restore lordosis.

The strength of the current study design includes a multi-surgeon series with various use of interbody device types among surgeons. While differences in surgical techniques such as amount of posterior column resection (osteotomy) and posterior instrumentation compression may vary among surgeons and individual patients, the consensus on a surgical goal of restoring or maintaining lordosis should lead to equal surgeon effort to obtain lordosis in all cases (and in both groups). It is important to note that, while the current study did not show a significant difference based on interbody device type, the traditional reliance on group averages may not be the best way to analyze (and learn from) the data. The outlier cases (rare occurrences) may have more educational value: There was a trend for the straight-in position (three cases in straight-in position group versus one case in the anterior position group) to lead to a clinically significant loss of lordosis (more than 5 degree loss). However, this only occurred in patients with significant preoperative segmental lordosis (>21 degrees). Gain of clinically significant lordosis (more than 5 degree gain) appeared to be equally possible with either interbody device design (five cases in straight-in position group versus seven cases in the anterior position group) when the pre-operative lordosis was less than 21 degrees. Preoperative lordosis was clearly the most important factor to predict a clinically significant change in lordosis in the current study.

With an improved understanding of the various factors involved (especially preoperative lordosis), clinicians and researchers alike can continue to work to improve our ability to maintain and/or restore segmental lordosis when treating degenerative spine pathology.

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Declarations of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2022.100145.

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