The Effect of an Adjustable Hinged Operating Table on Lumbar Lordosis during Lumbar Surgery

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**Study Design:** Prospective observational study

**Objectives:** Quantify the amount of lumbar lordosis achieved on a hinged operative table in neutral, flexion, and extension.

**Summary of Background Data:** Hinged operative tables may allow surgeons to adjust lumbar spine positioning intraoperatively. The amount of lumbar lordosis in neutral, flexion, and extension positions has not been quantified prospectively using a hinged table.

**Methods:** Thirty patients undergoing elective lumbar surgery were enrolled. Standing x-rays taken in neutral, maximal flexion, and maximal extension were obtained. Following prone positioning on a hinged operative table, x-rays in neutral, maximal flexion, and maximal extension were taken. Total lumbar lordosis was calculated for all 6 images by two physicians. Disc degeneration was graded using Pfirrmann grades.

**Results:** Lumbar lordosis on the operative table was $56.5^\circ \pm 2.1^\circ$, $43.6^\circ \pm 2.2^\circ$, $63.2^\circ \pm 2.0^\circ$ compared to $46.9^\circ \pm 3.1^\circ$, $33.2^\circ \pm 2.8^\circ$, $52.3^\circ \pm 3.3^\circ$ on the standing films in neutral, flexion, and extension respectively. Average flexion ($12.9^\circ \pm 1.1^\circ$) and extension ($6.7^\circ \pm 1.2^\circ$) were significantly different from neutral on the table ($p < .001$). Lumbar lordosis was significantly higher on the operative table ($p< .001$). Total range of motion was $19.6^\circ \pm 1.9^\circ$ on the table and $19.1^\circ \pm 2.0^\circ$ with standing ($p = 0.42$). Average Pfirrmann disc grade was $2.77 \pm 0.10$ which did not correlate with range of motion ($p = 0.40$).

**Conclusions:** In this cohort, the hinged operative table allowed for a physiologic arc of motion of nearly 20° from flexion to extension. A considerable amount of lumbar sagittal motion can be obtained on hinged operative tables without decreasing overall lumbar lordosis below physiologic levels.

**Key Words:** hinged operative table, lumbar lordosis

**Level of Evidence:** 3
Introduction

Several studies have examined the changes in lumbar lordosis produced by different operative tables and positions.[1-4] Previous work has shown that positioning on an Andrews spinal frame, Hastings frame, and C.H.O.P. frame result in a significant reduction in lumbar lordosis.[1, 2] In contrast, positioning utilizing chest rolls or a Jackson table has been shown to increase lumbar lordosis.[2] While differing operative tables and positioning techniques have varying effects on lumbar lordosis, the importance of maintaining physiologic lumbar lordosis cannot be overemphasized.[5-7] Inadequate restoration of lordosis during spinal fusion can lead to adjacent segment degeneration, mechanical back pain, and sagittal malalignment.[5] Lumbar hypolordosis and sagittal imbalance have a significant negative impact on patient outcomes and quality of life. [8-12]

While most traditional operative tables do not offer positioning flexibility intraoperatively, hinged operative tables allow surgeons to modify the position of the lumbar spine during the operation.[13] Intraoperative lumbar lordosis can be adjusted to facilitate decompression and fusion done in relative flexion and extension respectively. Although hinged operative tables provide theoretical flexibility intraoperatively, this has never been quantified prospectively. We hypothesize that the hinged table can produce ranges of motion similar to that obtained in standing flexion-extension. The specific aim of this study is to measure changes in lumbar lordosis achieved on a hinged operative table in comparison to range of motion achieved in the standing position.
Methods

After obtaining IRB approval, from May 2013 to November 2014, a total of 29 patients scheduled to undergo lumbar discectomy were consented and enrolled in the study. Patients undergoing non-lumbar, non-elective, and spinal fusion procedures were excluded from the study. Standard radiographs were obtained preoperatively including standing lateral lumbar neutral, maximal flexion, and maximal extension views. Radiographs were obtained in the same radiology suite and according to institutional protocol patients holding the arms in the clavicular position with elbows flexed and fists resting on ipsilateral clavicles. All patients were positioned prone with Gardner-Wells tongs on the OSI Axis Jackson table (Mizuho, OSI®) following the induction of general anesthesia. Lateral lumbar radiographs or fluoroscopic images were obtained in neutral, maximal flexion, and maximal extension utilizing the table settings. (Figure 1A-C)

Radiographs were measured using QREADS software functions (Clinical Image Viewer, Version 5.4.0.1). Measurements were made by two reviewers unrelated to surgery to assess inter-rater and intra-rater reliability. Total lumbar lordosis was calculated for all 3 pre-operative and 3 intraoperative images using the Cobb method. [14] The measurements were made using the superior endplates of L1 and S1 as bony landmarks. The degeneration of the lumbar intervertebral discs was graded using Pfirrmann MRI disc grading scores.[15] Images were assessed by both reviewers separately twice in random order to determine rater reliability.

Statistical Method
Mean and standard deviation were calculated to describe total lumbar lordosis, maximal flexion and maximal extension for all 6 images. A two tailed t-test was performed to compare measurements made on the preoperative radiographs and those made on the Axis Jackson table. Intra-class correlation (ICC) coefficients were calculated for all measurements made by the two reviewers. Using accepted standards, ICC coefficients values less than 0.40 were considered poor, 0.40-0.59 fair, 0.60-0.74 good, and greater than 0.74 excellent. All statistical analyses were performed with JMP software (Version 9.0.1, JMP for Windows).

**Results**

Of the 29 patients enrolled in the study, 11 were female and 18 were male with a mean age of 42.5 years (21-65).

*Standing flexion extension motion*

Total lumbar lordosis in the preoperative standing neutral position ranged from 15.5° to 79.9° with a mean of 46.9° ± 3.1°. In the standing maximal flexion position lumbar lordosis ranged from 3.6° to 59° with a mean of 33.2° ± 2.8°. In the standing maximal extension position lumbar lordosis ranged from 7.7° to 86.7° with a mean of 52.3° ± 3.3° range of motion. (Table 1)

*Intraoperative alignment*

On the Axis Jackson table, lumbar lordosis in the neutral position ranged from 37.5 to 79 with a mean of 56.5° ± 2.1°. Lumbar lordosis on the table in the maximal flexion position ranged from 21.4° to 61.4° with mean of 43.6° ± 2.2°. In the maximal extension position on the table, lumbar lordosis ranged from 41.2° to 86.4° with a mean 63.2° ± 2.0°.(Table 1)

*Comparison of standing and intraoperative motion*
Lumbar lordosis was significantly higher in intraoperative neutral (8.8°), flexion (10.6°), and extension (9.7°) compared to standing preoperative radiographs (p < .001). Average flexion (12.9° ± 1.1°) and extension (6.7° ± 1.2°) were significantly different from neutral on the table (p < .001). Total range of motion (maximal extension to maximal flexion) was 19.6° ± 1.9° on the table and 19.1° ± 2.0° on standing films without significant difference (p = 0.42). (Figure 2)

Influence of disc degeneration

The mean Pfirrmann grade for all lumbar discs was 2.86 ± 0.10. The mean Pfirrmann grades at each level were 2.75 ± 0.16 (L1-2), 2.68 ± 0.15 (L2-3), 2.54 ± 0.11 (L3-4), 2.93 ± 0.14 (L4-5), 3.39 ± 0.12 (L5-S1). The L5-S1 discs did have significantly higher Pfirrmann grades (p = .003). In this cohort there was no significant correlation between the mean Pfirrmann lumbar disc grades and lumbar spine flexibility as measured by total lumbar range of motion.

Reliability of measurements

ICC coefficients for standing neutral (0.85), flexion (0.86), and extension (0.84) lordosis measurements were all excellent. Excellent ICC coefficients were also found for lordosis measurements in neutral (0.78), flexion (0.89), and extension (0.80) made on the table.

Discussion

Maintenance of physiologic lordosis during lumbar spine fusion surgery has been shown to optimize patient outcomes. Segmental kyphosis in the lumbar spine can lead to adjacent segment disc degeneration and loss of sagittal balance.[16-18] Similarly, hyperlordosis of the lumbar spine can lead to compensatory malalignment and low back pain.[19, 20] While restoring physiologic lordosis is always the goal following lumbar spinal surgery especially in lumbar...
spinal fusion, achieving this goal can often be difficult and the ideal intraoperative position is not fully understood.\cite{2, 13, 21-23} Restoration of physiologic lordosis requires a careful attention to spinopelvic parameters preoperatively and assessment of lordosis following intraoperative positioning. \cite{24, 25} In particular, surgeons need to examine lumbar lordosis, pelvic incidence, and sacral slope. Critical evaluation of how positioning affects the relationship of lumbar lordosis to pelvic incidence is key to achieving appropriate sagittal balance following lumbar fusion.

Previous investigations have shown that the use of chest rolls or other adjuncts during prone positioning can help restore physiologic lordosis. \cite{1} However, such positioning is difficult in obese patients and can lead to visceral compression and greater epidural bleeding from venous engorgement.\cite{13} In addition, more lordotic positioning can make spinal decompression more difficult as it increases overlap between vertebral segments. As a result many surgeons favor Wilson frames and standard Jackson tables for positioning. The hinged operative table offers the theoretical advantage of allowing for maximal flexion during spinal decompression and extension during spinal fusion to optimize patient positioning using the table controls. However, no prospective studies have evaluated range of motion and lordosis that can be achieved using a hinged operative table.

In this cohort of patients undergoing lumbar discectomy and decompression, the hinged operative table allowed for a lumbar lordosis that was about 10° greater in all positions compared to standing radiographs. In addition, lumbar lordosis achieved on the hinged table in the neutral position (56.5° ± 2.1°) is consistent with previous studies examining normal lordosis in healthy individuals. \cite{26-28} The arc of motion of nearly 20° obtained on the hinged table from flexion to extension was not significantly different from the range of motion obtained in the standing position.
positions. This suggests that a considerable amount of lumbar sagittal motion can be obtained on hinged operative tables without decreasing overall lumbar lordosis below physiologic levels. This may allow for easier decompression and placement of interbody grafts in a maximal flexion position, and then adjustment into extension to maximize lumbar lordosis.[13] In addition osteotomies can be reduced theoretically under controlled condition.

While previous studies have shown that disc degeneration and lumbar spondylosis can affect range of motion, measurements of lumbar flexibility were unaffected by disc degeneration scores in this study.[29-31] The overall Pfirrmann grades for our cohort were moderate (2.86 ± 0.10) with no grade 5 discs identified. A significant correlation between disc degeneration and lumbar range of motion may have been observed if older patients (average age 42.5 years) or patients with more advanced disc degeneration had been enrolled.

This study demonstrates the potential lordosis that can be achieved on a hinged operative table. However, the impact intraoperative positioning and lordosis achieved intraoperatively on long term outcomes are unclear. In a retrospective analysis of lordosis following short-segment posterior lumbar interbody fusion, Lee et al demonstrated no difference with different intraoperative positioning and operative tables.[22] In addition, other studies have shown that loss of lordosis during operative positioning does necessarily lead to hypolordosis postoperatively.[32] However, it is important to note that segmental loss of lordosis at the operative levels in short segment fusions may lead to compensatory hyperlordosis at adjacent levels and possibly accelerated degeneration.[33]

There are some limitations to this study. When obtaining standing flexion/extension radiographs there is always some variability in patient effort and positioning despite protocols.
Given this, standing radiographs may underestimate the true lumbar range of motion. Furthermore, intraoperative positioning of the legs and the anesthetic relaxation can play a major role in range of motion and may introduce some variability to the measurements. Our cohort of patients were on average were fairly young with less spondylosis than would be expected for an older group of patients. It is possibly that with patients with more advanced spondylosis and disc degeneration less motion would be achieved on the flexible table. Furthermore, while no adverse events related to table positioning were observed in our study, it still needs to be determined whether for longer cases the flexible nature of the table causes any issues with skin breakdown, brachial plexopathy, or graft dislodgement in the case of interbody fusions. It is important to note that over 1000 cases have been performed at our institution utilizing a hinged table without any adverse events related to the table itself. In the case of decompression only procedures we have found that the table allows for minimal bony resection. However, we recommend adjusting the table to a physiologic alignment to check the adequacy of decompression prior to completion of the case.

In conclusion, in this cohort of patients undergoing lumbar discectomy and decompression, the hinged operative table allowed for a physiologic arc of motion of nearly 20° from flexion to extension. While, a considerable amount of lumbar sagittal motion can be obtained on hinged operative tables, future studies are needed to determine if this is maintained with more advanced degenerative conditions and whether this has a significant impact on long term outcomes.
References

16. Kumar, M.N., A. Baklanov, and D. Chopin, Correlation between sagittal plane changes and adjacent segment degeneration following lumbar spine fusion. European spine journal : official publication of the European Spine Society, the European Spinal


Figure 1 a-c: Hinged operative table in neutral (a), flexion (b), and extension (c) respectively.
Figure 2: Total lumbar lordosis measured on standing radiographs versus intraoperative images on the hinged operative table.
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<tr>
<th></th>
<th>Standing</th>
<th>Table</th>
<th>P value</th>
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<tbody>
<tr>
<td><strong>Total Lumbar Lordosis</strong></td>
<td></td>
<td></td>
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<tr>
<td>Flexion</td>
<td>33.2° ± 2.8°</td>
<td>43.6° ± 2.2°</td>
<td>p &lt; .001</td>
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<td>Neutral</td>
<td>46.9° ± 3.1°</td>
<td>56.5° ± 2.1°</td>
<td>p &lt; .001</td>
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<tr>
<td>Extension</td>
<td>52.3° ± 3.3°</td>
<td>63.2° ± 2.0°</td>
<td>p &lt; .001</td>
</tr>
<tr>
<td><strong>Total Range of Motion</strong></td>
<td>19.6° ± 1.9°</td>
<td>19.1° ± 2.0°</td>
<td>p = 0.42</td>
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*Table 1:* Total lumbar lordosis and total range of motion standing versus on the operative table.