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The Conceptualization and Derivation of the Cervical Lordosis Distribution Index

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STRUCTURED ABSTRACT

SUMMARY OF BACKGROUND DATA: *Yilgor* et al developed the lumbar Lordosis Distribution Index to individualize the pelvic mismatch to each patient's pelvic incidence. The cervical lordosis distribution in relation to its apex has not been characterized.

OBJECTIVE: Tailor correction of cervical deformity by incorporating the cervical apex into a distribution index(CLDI) to maximize clinical outcomes while lowering rates of junctional failure.

STUDY DESIGN/SETTING: Retrospective cohort

METHODS: CD patients with complete 2Y data were included. Optimal outcome is defined by no DJF, and meeting *Virk* et al Good Clinical Outcome Criteria:[Meeting 2 of 3: 1)an NDI<20 or meeting MCID, 2)mJOA>=14, 3)an NRS-Neck<=5 or improved by 2 or more points]. C2-T2 lordosis was divided into cranial (C2 to apex) and caudal (apex to T2) arches postoperatively. A cervical lordosis distribution index(CLDI) was developed by dividing the cranial lordotic arch(C2 to apex) by the total segment(C2-T2) and multiplying by 100. Cross-tabulations developed categories for CLDI producing the highest chi-square values for achieving Optimal Outcome at two years and outcomes were assessed by multivariable analysis controlling for significant confounders.

RESULTS: 84 CD patients were included. Cervical apex distribution postoperatively was: 1% C3,42% C4,30% C5,27% C6. Mean cervical LDI was 117±138. Mean cranial lordosis was 23.2±12.5°. Using cross-tabulations, a CLDI between 70 and 90 was defined as 'Aligned'. Chi-square test revealed significant differences among CLDI categories for DJK, DJF, Good Clinical Outcome, and Optimal Outcome(all p<.05). Patients aligned in CLDI were less likely to develop DJK(OR: 0.1,[0.01-0.88]), more like to achieve GCO (OR: 3.9,[1.2-13.2]) and Optimal Outcome (OR: 7.9,[2.1-29.3] at two years. Patients aligned in CLDI developed DJF at a rate of 0%.

CONCLUSION: The cervical lordosis distribution index, classified through the cranial segment, takes each unique cervical apex into account and tailors correction to the patient in order to better achieve good clinical outcomes and minimize catastrophic complications following cervical deformity surgery.

Keywords: Cervical deformity, spine, cervical lordosis distribution, complex realignment, DJK, DJF

Level of Evidence: III

KEY POINTS

- The lumbar Lordosis Distribution Index has been used to individualize the pelvic mismatch to each patient's pelvic incidence.
- It is unknown whether cervical lordosis distribution in relation to its apex has any association with outcomes, either clinically or radiographically.
- Our study highlights the use of the cervical lordosis distribution index, which is classified through the cranial segment and takes each unique cervical apex into account.
- The generated parameter and classification can aid spine surgeons in the assessment of deformity relative to their native alignment and tailor correction to the patient in order to better achieve good clinical outcomes.

INTRODUCTION

Adult cervical deformity is a heterogeneous condition leading to neurological deficits, axial and upper extremity pain, and a significantly decreased quality of life.[1-5] While the symptoms may be more easily observed, the etiology of the presentation is much more difficult to discern. Realignment systems have been developed to properly categorize the severity of deformity across numerous cervical parameters.[6,7] Yet, use and validation of these realignment strategies have led to inconsistent results in terms of clinical improvement and minimizing complications, especially compared to those utilized in adult spinal deformity (ASD) surgery.[6-9]

While studying and aligning lumbopelvic mismatch and global parameters has contributed to clinical improvement from ASD surgery, research has started to examine the proportionality and distribution of deformity within the spine.[25,27] These studies found the normal lordosis for each patient is more dependent on their pelvic incidence value, and the concentration of lordosis within the lower segment (L4-S1) relative to overall lordosis also are pivotal in preventing development of mechanical complications in ASD surgery. The importance to these findings can be summarized by not viewing a parameter out of context, but more so, assessing each in light of each other. Similar approaches have sought to categorize cervical deformity relative to a patient's age and global alignment.[26] Patients malaligned in this cervical deformity score were at a more significant risk for both distal junctional kyphosis (DJK) and mechanical failure following surgical correction.

The goal of cervical deformity surgery is to provide clinical improvement and restore quality of life to patients debilitated by this condition. In addition to prevent troubling complications after cervical deformity surgery, the present study seeks to identify the proper distribution of lordosis located within the cranial segments relative to the apex of lordosis within the cervical spine and if there is any relation to outcomes. The present study will look at effective delineations in this measurement in regards to both patient-reported outcomes and complications, most notably distal junctional kyphosis and junctional failure.

MATERIALS AND METHODS

Study Inclusion Criteria

As previously published, the current database comprises 13 distinct centers across the United States, contributing consecutively enrolled, consented patient data with Institutional Review Board approval to a prospectively enrolled Adult Cervical Deformity (ACD) database that the present study utilized via retrospective analysis, utilizing previously published radiographic parameter criteria for inclusion.[11,12] Patients that were included in the present study also had baseline and up to two-year data.

Data Collection

We abstracted demographic (age, body mass index [BMI], biological sex, Charlson Comorbidity Index [CCI], *Passias* et al modified Cervical Deformity Frailty Index [mCD-FI]), surgical (levels fused, operative time, length of stay, surgical approach, performance of decompressions and osteotomies, ISSG CD invasiveness score), and clinical (complications, reoperations) data.[13-15]

Complication assessments were made based on review of imaging, patient reports, and clinical follow-up. Clinical outcomes including neck disability (as assessed by the Neck Disability Index, NDI), EuroQOL 5-Dimension Questionnaire (EQ-5D) Visual Analog Scale (VAS), pain Numerical Rating Scale for both neck [NRS-neck] and back [NRS-back], and myelopathy score (as assessed by the modified Japanese Orthopaedic Assocation, mJOA) were collected at baseline and follow-up intervals by the individual centers and were accessed via a multi-center registry.

Radiographic Assessment

Baseline and up to two-year postoperative radiographs were measured using validated software programming (SpineView; ENSAM Laboratory of Biomechanics, Paris, France) at a single academic center.[16-18] Cervical sagittal alignment and balance was evaluated using C2-7 Cobb angle for cervical lordosis (CL: angle between the lower endplates of C2 and C7), cervical sagittal vertical axis (cSVA: C2 plumbline offset from the postero-superior corner of C7), the mismatch between T1 slope and CL (TS-CL), and the apex of cervical lordosis. Individual vertebral superior endplate slopes (C2 slope, C3 slope, etc.) were measured and assessed. Global sagittal alignment was assessed via the C7-S1 sagittal vertical axis (SVA), the mismatch between pelvic incidence and lumbar lordosis (PI-LL), and pelvic tilt (PT).

Assessment of Distal Junctional Kyphosis and Failure

Distal junctional kyphosis, per previous literature, was defined radiographically as DJK angle (kyphosis between the superior endplate of the lowest instrumented vertebra [LIV] and the inferior endplate of the second distal vertebra [LIV-2]) $<-13°$, and a pre- to postoperative change in DJK angle <-13°.[19] Severe DJK, also known as distal junctional failure (DJF), was defined as DJK angle <-20° and postoperative change of <-20° from the presumed baseline LIV-2, or DJK leading to reoperation.[20]

Definition of Clinical Outcomes

The minimally clinically important difference (MCID) for the mJOA was set at 1.8 based on published values.[21] The MCID for Neck Disability Index was set as 15; this is double the published MCID value because our NDI score was collected on a 0-100 scale as opposed to 0-50).[22] The NRS Neck MCID was set as 2.5 per previously published values.[32] *Virk* et al. defined 'Good Clinical Outcome' criteria as meeting two or more of the following: 1) an NDI score less than 20 or meeting MCID in NDI by two years, 2) mild myelopathy (mJOA score equal to or greater than 14 by two years), 3) an NRS-Neck score less than or equal to 5 or improved by 2 or more points from baseline by two years.[23] Optimal outcome was defined as meeting Good Clinical Outcome, and not developing DJF by two years (**Table 1**).

Cervical Lordosis Distribution Parameters

The inflection point between cervical lordosis and thoracic kyphosis has been described more distal to the cervicothoracic junction, located primarily at T2.[25] C2-T2 lordosis was divided into a cranial (C2 to apex) and caudal (apex to T2) arch on postoperative radiographs. A cervical lordosis distribution index was developed by dividing the lordosis in cranial arch by the total C2-T2 lordosis and multiplying by 100 (**Figure 1**).

Statistical Analysis

The means of basic baseline demographic, clinical and radiographic factors were determined for the cohort. Spearman's rank-order correlation and linear regression analysis assessed the impact of postoperative CLDI at three months on follow-up HRQLs or development of complications (DJK, DJF, and reoperation) by two years. Optimal cutoff points for the CLDI were identified using both theoretical and clinical justification and statistical analyses.[24] The cutoff points were chosen where the cross-tabulation of parameter subgroups versus achieving Optimal Outcome criteria by two years reached maximal chi-square values.[25] Cross-tabulations of categories were compared to Ames-ISSG categories for cSVA (<40 mm, 40-80 mm, >80 mm).[6] Thresholds were assessed using multivariable logistic regression analysis, accounting for age, diagnosis of osteoporosis, baseline C2-C7, location of cervical apex, invasiveness score, and the use of an osteotomy, on the likelihood of achieving Good Clinical Outcome, Optimal Outcome, and developing DJK or DJF for patients aligned in CLDI, as well as those corrected to low deformity in Ames-ISSG cSVA. In all testing, significance was established a-priori for odds ratios and 95% confidence intervals (CI) exclusive of 1.0 and $p<0.05$. All statistical analyses were conducted using SPSS, version 25.0 (Armonk, NY).

RESULTS

Cohort Overview

We included 84 ACD patients in the present study. The mean age of the cohort was 61.4 ± 10.8 years, 65% were female, mean BMI of 29.2 ± 7.8 kg/m^2, and mean CCI of 1.0 ± 1.2. Examination of surgical details revealed a mean levels fused of 9.2 ± 3.7, average estimated blood loss (EBL) of 878 ± 915 mL, and mean operative time of 368 ± 197 minutes. By surgical approach, 14.3% of the cohort underwent an anterior-only approach, 59.5% a posterior-only, and

26.2% underwent combined anterior-posterior approach. The mean length of stay was 6.9 ± 5.8 days. Cohort demographics, surgical details, and baseline HRQLs are displayed in **Table 2.**

Radiographic Assessment

Table 3 conveys the pre- and postoperative radiographic measurements of the cohort. Postoperatively, the mean cranial lordosis was 23.4 ± 12.5° (min: -12.4, max: 50.9) and the mean caudal lordosis was 2.0 ± 12.4° (min: -36.1, max: 35.3). When dividing cranial lordosis by the total C2-T2 Lordosis and multiplying by 100, the mean Cervical LDI (CLDI) was 118.7 ± 139.7 (min: -505.3, max: 721.1).

Cohort Outcomes

Regarding clinical outcomes, 48 (57.1%) of patients met Good Clinical Outcome. Regarding complications, 18 (21.3%) developed DJK, 9 (10.7%) developed DJF, and 13 (15.7%) underwent reoperation. In total, this equated to 36 (42.9%) patients meeting Optimal Outcome by two years.

Derivation of Cervical Lordosis Distribution Index Categories

The cutoff thresholds for postoperative CLDI were chosen where the cross-tabulation of parameter subgroups versus achieving Optimal Outcome criteria by two years reached maximal chi-square values. The following subcategories of the CLDI were identified: <70, hypolordotic; 70-90 aligned; 90-150, moderately hyperlordotic; >150, severely hyperlordotic. Preoperative characteristics, surgical details, and outcomes for patients above and below each threshold are displayed in **Tables 4 and 5** and **Figure 1**. **Table 6** highlights the postoperative parameters of those aligned in CLDI. Of note, patients aligned in CLDI met Good Clinical Outcome at a rate of 81.0%, developed DJK at a rate of 5.6%, DJF at a rate of 0.0%, and achieved Optimal Outcome by two years at a rate of 73.7%. Those Severely Hyperlordotic developed DJK and DJF at rates of 43.8% and 23.5%, respectively. Those Hypolordotic in CLDI achieved the lowest rates of meeting Good Clinical Outcome and Optimal Outcome at 40.7% and 26.9%, respectively. Comparatively, Ames-ISSG cSVA categories were significant across DJK, DJF, and meeting Optimal Outcome (all p<.05), but not significant across Good Clinical Outcome (p>.5).

Multivariate Results of Being Aligned in Cervical Lordosis Distribution

Multivariable logistic regression analysis, controlling for age, osteoporosis, baseline C2-C7 SVA, location of cervical lordosis apex, invasiveness score, and the use of an osteotomy, assessed the likelihood of outcomes if aligned in CLDI, seen in **Table 7**. Patients were significantly less likely to develop DJK if aligned in CLDI (OR: 0.1, 95% CI: [0.01-0.88]; p=.038), and more likely to meet Optimal Outcome by two years (OR: 7.9, [2.1-29.3]; p=.002). Comparatively, correction to low deformity in cSVA per Ames-ISSG classification led to lower likelihood of DJK (OR: 0.04, [0.01-0.28]; p=.001), but no significance was found for DJF (OR: 0.3, [0.1-2.2]; p=.246), Good Clinical Outcome (OR: 1.2, [0.4-3.7]; p=.740), or Optimal Outcome (OR: 3.5, [0.9-13.3]; p=.076) by two years.

DISCUSSION

Assessing radiographic parameters in the context of a patient's alignment to individualize their realignment goals has paid dividends both in the realm of adult spinal deformity (ASD) and adult cervical deformity (ACD) surgery.[26-28] Therefore, we sought to classify the distribution of lordosis within the cranial segment, deemed C2 to the lordosis apex, relative to the entirety of lordosis in the C2 to T2 segment. In doing so, we found patients with a distribution between 70-90% concentrated within the cranial segment more often met superior clinical outcomes while avoiding the troublesome complications of DJK and DJF. Similarly, patients malaligned in this measure, either hypolordotic or severely hyperlordotic, experienced high rates of complications with diminished clinical improvement.

Previous cervical deformity classifications have identified thresholds delineating clinical improvement.[6-8] However, follow-up studies and reviews have found less correlation with these parameters.[29] More recent studies have found better association with clinical improvement and radiographic complications among cervical parameters, but are only exploratory in nature and suggest investigation into more individualized target goals.[30] *Lafage* et al expanded upon these parameters by incorporating T1 slope, TS-CL, and a global deformity parameter, SVA, into a cervical deformity score to mitigate mechanical complications following ACD surgery.[27] Featuring age-adjusted targets, this score highly correlated with development of mechanical complications, while also reducing the incidence of DJK. Likewise, aligning the distribution of cervical lordosis within our study showed significant benefit in minimizing radiographic complications, with rates of DJK and DJF as low as 5.6% and 0.0%, respectively. Additionally, this index was associated with superior clinical outcomes when aligned, meeting the *Virk* et al Good Clinical Outcome criteria at two years at a rate of 81.0%.

In addition, malalignment within cervical lordosis distribution was also associated with poor outcomes. *Smith* et al, when examining the best versus the worst outcomes of a cervical deformity cohort, found patients with less increase in cervical lordosis were more likely to achieve a 'worst' outcome.[9] While cervical lordosis and cervical apex of lordosis in our study had no direct correlation with either complications or clinical outcomes, the value of each in context to one another demonstrated significant associations. Realignment has shown limited clinical benefit in targeting single parameters, whereas individualizing realignment to the characteristics of a patient's deformity, by way of pelvic incidence or cervical lordosis apex, or to tailor correction to their medical profile, incorporating age, frailty, and bone mineral density, may be the missing links separating ACD surgery from achieving favorable outcomes more often. This could be better summarized by the findings compared to cSVA. When examining unadjusted categorical trends, cSVA had significance across DJK, DJF, and Optimal Outcome rates. However, when assessing those corrected to low deformity and controlling for baseline deformity and patient-specific factors, there was only significance found between cSVA and DJK, but not DJF, Good Clinical Outcome, or Optimal Outcome by two years. Therefore, the findings of our study may be just an introductory piece to more accurately categorizing and treating this heterogeneous condition.

In addition to the results found in our study, we recognize several limitations. First, utilizing a retrospective database of patients undergoing operation is subject to the risk of selection, expertise and indication bias. Our study examined 84 patients, which may not fully encompass the variability within the underlying diagnoses, surgical approaches taken, and surgeon expertise present in other medical centers and may present confounders that play role in the radiographic and clinical outcomes, as well as development of complications. Additionally, our deformity cohort included patients with both cervicothoracic deformity and multi-segment focal cervical deformity, which may limit the recommendations of this study to all deformity patients encountered in practice. Third, this exploratory approach is retrospective in nature and should not dictate surgical candidacy or planning until further validated with larger, more generalizable populations. Lastly, human error is subject to occur in both data collection and statistical analysis. Further prospective studies with long-term follow-up should aim to validate the results of the correlations and thresholds reported in the setting of cervical deformity corrective surgery, along with development of other associations with meaningful outcome variables.

CONCLUSIONS

Past classifications of cervical realignment have derived fixed parameters that produce inconsistent clinical results. This exploratory approach has demonstrated the cervical lordosis distribution index, classified through the cranial segment, takes each unique cervical apex into account and tailors correction to the patient in order to better achieve favorable clinical outcomes and minimize catastrophic complications following cervical deformity surgery.

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Figure 1. Representation of C2-T2 Lordosis

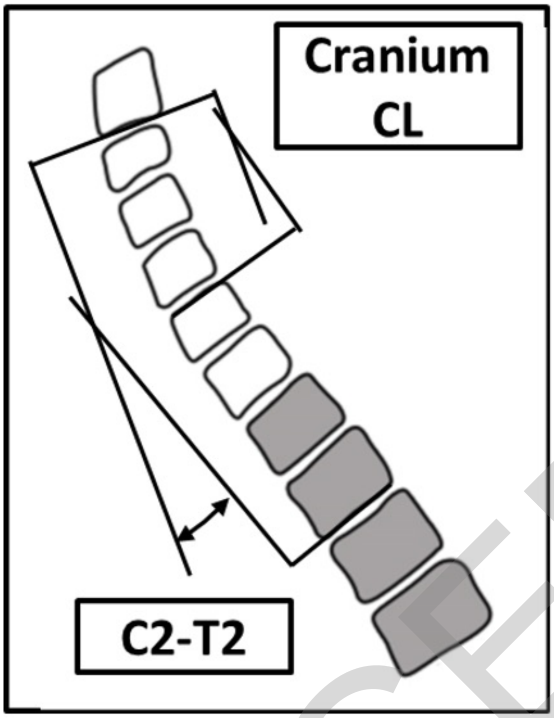

Table 1. Definitions of Two-Year Outcomes

Clinical Outcome	**Two-Year Definition**
MCID in mJOA	Improvement ≥ 1.8
MCID in NDI	Improvement ≥ 15
MCID in NRS Neck	Improvement ≥ 2.5
Good Clinical Outcome	Meeting any 2 of the 3: 1) an NDI score less than 20 or meeting MCID in NDI 2) mild myelopathy (mJOA score equal to or greater than 14) 3) an NRS-Neck score less than or equal to 5 or improved by 2 or more points from baseline
Optimal Outcome	Meeting all 4: 1) Meeting Good Clinical Outcome 2) No occurrence of DJF 3) No occurrence of mechanical complication 4) No reoperation

Abbreviations: MCID – Minimal Clinically Important Difference; NDI – Neck Disability Index; NRS – Numeric Rating Scale; mJOA – modified Japanese Orthopaedic Association; DJK – Distal Junctional Kyphosis; DJF – Distal Junctional Failure

Table 2. Baseline Cohort Details

Baseline Demographics	
Age	61.4 ± 10.8 years
Sex	65% F
BMI	29.2 ± 7.8 kg/m^2
CCI	1.0 ± 1.2
Frailty	0.34 ± 0.19
Osteoporosis	17%
Surgical Details	
EBL	878 ± 915 mL
Operative Time	368 ± 197 min
Number of Levels Fused	9.2 ± 3.7 levels
Osteotomy	56%
Decompression	52%
Invasiveness	60.5 ± 26.1
Surgical Approach	Anterior: 14.3%, Posterior: 59.5%, Combined: 26.2%
Length of Stay	6.9 ± 5.8 days
Baseline HRQLs	
EQ-5D VAS	58.5 ± 22.5
EQ-5D	0.739 ± 0.064
NDI	48.0 ± 17.7

NRS Back	5.2 ± 2.9
NRS Neck	6.8 ± 2.4
mJOA Score	13.6 ± 2.8

Abbreviations: BMI – Body Mass Index; CCI – Charlson Comorbidity Index; EBL – Estimated Blood Loss; EQ-5D – EuroQOL 5 Dimensions; VAS – Visual Analog Scale; NDI – Neck Disability Index; NRS – Numerical Rating Scale; mJOA – modified Japanese Orthopaedic Society

Table 3. Cohort Baseline Radiographic Measurements

Radiographic Parameters	Baseline	Postoperative	p-value
TS-CL	40.7 ± 19.3°	28.1 ± 14.1°	<.001
C2-C7 Lordosis	–6.2 ± 23.3°	8.7 ± 16.4°	<.001
C2-slope	40.5 ± 20.2°	26.4 ± 13.9°	<.001
T1-slope	34.5 ± 18.1°	36.9 ± 16.4°	.176
cSVA	42.3 ± 19.2 mm	34.1 ± 15.7 mm	<.001
C2-T3	-18.4 ± 24.1°	0.6 ± 14.9°	<.001
Cervical Apex	34.2% C4, 50.7% C5, 15.1% C6	1.2% C3, 36.9% C4, 36.9% C5, 25.0% C6	.572
McGregor Slope	5.2 ± 14.2°	-2.4 ± 7.9°	<.001
T4-T12	-40.3 ± 16.1°	-43.1 ± 16.1°	.028
PI	53.2 ± 12.2°	53.3 ± 12.3°	.927
PI-LL	1.8 ± 18.4°	5.0 ± 18.7°	.005
PT	20.4 ± 11.8°	21.5 ± 12.2°	.153
SVA	-1.2 ± 69.9 mm	23.1 ± 65.8 mm	<.001
T1PA	13.9 ± 12.3°	16.8 ± 13.2°	<.001
GAP Score	3.8 ± 3.0	5.8 ± 3.4	<.001

Abbreviations: TS-CL – T1 minus Cervical Lordosis; cSVA – cervical SVA; PI – Pelvic Incidence; PI-LL – Pelvic Incidence minus Lumbar Lordosis; PT – Pelvic Tilt; SVA – Sagittal Vertical Axis; T1PA – T1 Pelvic Angle; GAP – Global Alignment and Proportion

Table 4. Characteristics of CLDI Categories

CLDI Categories	Hypolordotic (<70; n=27)	Aligned (70-90; n=21)	Moderately Hyperlordotic (90-150; n=19)	Severely Hyperlordotic (>150; n=17)	p-value
Age	65.9 ± 9.3	59.0 ± 11.6	58.2 ± 9.5	61.1 ± 11.7	**.495**
Sex (% F)	74%	67%	61%	53%	**.092**
BMI	26.9 ± 6.1	28.0 ± 7.9	31.6 ± 10.8	31.5 ± 5.8	**.111**
CCI	0.9 ± 1.0	0.9 ± 1.6	0.7 ± 0.8	1.7 ± 1.1	**.248**
Frailty	0.34 ± 0.20	0.30 ± 0.17	0.33 ± 0.21	0.39 ± 0.18	**.677**
Osteoporosis	26%	14%	6%	18%	**.002**
Surgical Details					
EBL	775 ± 738	961 ± 1083	1017 ± 1042	782 ± 845	**.761**
Operative Time	385 ± 197	357 ± 240	373 ± 204	350 ± 136	**.715**
Number of Levels Fused	8.8 ± 3.4	9.1 ± 3.4	9.9 ± 6.0	8.7 ± 4.2	**.052**
Osteotomy	92.6%	81.0%	94.7%	70.6%	**<.001**
Three-Column Osteotomy	22.2%	28.6%	21.1%	29.4%	**.532**
Invasiveness	59.0 ± 28.8	70.0 ± 23.0	61.1 ± 24.5	50.5 ± 25.0	**.824**
Posterior-Only Approach	48.2%	57.1%	57.9%	82.4%	**<.001**
Length of Stay	6.8 ± 6.8	8.1 ± 7.1	7.2 ± 4.0	5.4 ± 3.5	**.763**

Table 5. Two-Year Outcomes of CLDI Categories

CLDI Categories	Hypolordotic (<70; n=27)	Aligned (70-90; n=21)	Moderately Hyperlordotic (90-150; n=19)	Severely Hyperlordotic (>150; n=17)	X^2, p-value
Change in mJOA	0.3 ± 3.0	1.5 ± 2.1	0.1 ± 2.4	-1.4 ± 5.6	**p=.048**
Change in NDI	-11.0 ± 16.5	-12.1 ± 16.5	-11.4 ± 13.7	-13.3 ± 19.0	**p=.559**
Change in NRS Neck	-3.2 ± 3.3	-2.8 ± 2.4	-2.2 ± 3.2	-3.1 ± 2.3	**p=.178**
Virk's Good Clinical Outcome	40.7%	81.0%	52.6%	58.8%	**8.005; p=.046**
DJK	23.1%	5.6%	13.3%	43.8%	**8.080; p=.044**
DJF	11.1%	0.0%	0.0%	23.5%	**9.048; p=.029**
Optimal Outcome	26.9%	73.7%	38.9%	35.2%	**10.600; p=.013**

Abbreviations: CLDI – Cervical Lordosis Distribution Index; mJOA – modified Japanese Orthopaedic Association; NDI – Neck Disability Index; NRS – Numerical Rating Scale; DJK – Distal Junctional Kyphosis; DJF – Distal Junctional Failure

Table 6. Radiographic Outcomes of CLDI Categories

CLDI Categories	Hypolordotic (<70)	Aligned (70-90)	Moderately Hyperlordotic (90-150)	Severely Hyperlordotic (>150)	p-value
Cranial Lordosis	16.0°	27.7°	30.3°	22.3°	**<.001**
C2-C7 Lordosis	12.6°	12.5°	9.5°	-3.6°	**.004**
C2-T2 Lordosis	29.1°	33.7°	25.9°	9.0°	**<.001**
cSVA	29.4 mm	29.7 mm	38.5 mm	42.7 mm	**.011**
C2 Slope	24.4°	19.8°	27.5°	37.4°	**.001**
T1 Slope	40.0°	33.8°	37.9°	34.3°	.536
McGregor's Slope	-2.1°	-4.9°	-3.5°	0.6°	.209
T4-T12	-48.9°	-37.7°	-40.2°	-43.1°	.087

Abbreviations: CLDI – Cervical Lordosis Distribution Index; TS-CL – T1 minus Cervical Lordosis; cSVA – cervical SVA; PI – Pelvic Incidence; PI-LL – Pelvic Incidence minus Lumbar Lordosis; PT – Pelvic Tilt; SVA – Sagittal Vertical Axis; T1PA – T1 Pelvic Angle; GAP – Global Alignment and Proportion

Table 7. Multivariate Results of Aligned in CLDI and Likelihood of Two-Year Outcomes

Two-Year Outcomes	**Likelihood of Development if Aligned in CLDI Odds Ratio, [95% Confidence Interval]**	**p-value**
Virk's Good Clinical Outcome	OR: 3.9, [1.2-13.2]	**p=.027**
DJK	OR: 0.1, [0.01-0.88]	**p=.038**
DJF	*	**p=.029**
Optimal Outcome	OR: 7.9, [2.1-29.3]	**p=.002**

***Unable to run regression because all Aligned patients avoided incidence of DJF**

Abbreviations: CLDI – Cervical Lordosis Distribution Index; DJK – Distal Junctional Kyphosis; DJF – Distal Junctional Failure