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Original Article

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Clinical Impact and Correlations of Odontoid Parameters Following Multilevel Posterior Cervical Fusion Surgery

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Objective: C2 slope (C2S), a cervical parameter mathematically approximated as T1 slope minus cervical lordosis (T1S–CL), predicts functional improvement in cervical deformity patients. Nonetheless, C2S is a positional parameter based only on the horizontal axis. The current study aims to introduce novel odontoid parameters and establish their relationships with patient-reported health-related quality of life (HRQoL).
Methods: Lateral plain radiographs of 32 adults who underwent multilevel posterior cervical fusion were analyzed. The odontoid parameters included odontoid incidence (OI), C2S, odontoid tilt (OT), and gravity line-C2 distance (GL-C2), while the cervical parameters were the Cobb angle at C0–1, C1–2, C0–2, C2–7, C2–7 sagittal vertical axis (cSVA), T1 slope, and T1S–CL. The range of motion (ROM) of the occipito-atlantoaxial complex was measured in flexion and extension plain radiographs. Scores on the Neck Disability Index (NDI) and visual analogue scale (VAS) for axial neck (VASn) and arm pain were measured.
Results: Compared to asymptomatic subjects, patients had larger C2S, cSVA, and T1S–CL, and smaller OT. Preoperatively, OI was significantly correlated with the ROM of C1–2 ($r = 0.37$, $p < 0.05$) and C0–2 ($r = 0.46$, $p < 0.01$). OT and C2S had significant correlations with the C0–1, C1–2, and C0–2 angles, GL-C2, and T1S–CL. Postoperative NDI scores were significantly correlated with OI ($r = -0.40$, $p < 0.05$) and OT ($\rho = -0.37$, $p < 0.05$). VASn was significantly correlated with GL-C2 ($r = -0.35$, $p < 0.05$).
Conclusion: The odontoid parameters were significantly correlated with established cervical parameters and HRQoL measures. OI is a constant parameter representing the individual's compensatory reservoir at the upper cervical spine.

Keywords: C2 slope, T1 slope minus cervical lordosis, Odontoid, Health-related quality of life, Posterior cervical fusion, Sagittal alignment

INTRODUCTION

Over the last few decades, the concept of sagittal spinal alignment in the thoracolumbar spine has been extensively studied. The idea of optimal alignment of the thoracolumbar spine is well-established, and pelvic parameters are the foundation of sagittal alignment of the spine.[1] A mismatch greater than 9° between pelvic incidence (PI) and lumbar lordosis (LL) is a significant predictor of disability.[2,3] Accordingly, numerous attempts have been made using various parameters to define optimal cervical alignment.[4] Analogous to the aforementioned PI-LL, a greater mismatch in T1 slope (T1S) minus cervical lordosis (CL; T1S–CL) is associated with a greater degree of cervical malalignment and worse health-related quality of life (HRQoL) outcomes.[5-9]

To simplify the assessment of cervical malalignment, a novel parameter—C2 slope (C2S), which is mathematically approximated as T1S–CL—has been proposed.[10] Functional improvement in patients with cervical deformity and the likelihood of achieving optimal outcomes can be predicted with C2S.[11] Nonetheless, unlike the pelvic parameters, C2S is limited in that it is a positional parameter based only on the horizontal axis. The optimal range of C2S may vary among individuals, as the thoracolumbar positional parameters differ between individuals depending on PI.[12] A supplementary parameter based on the vertical axis with a constant value would be essential for a profound assessment of cervical alignment. A recent study proposed a novel concept of odontoid parameters, analogous to the pelvic parameters, as an adjunct to C2S.[13] However, the clinical and prognostic postoperative correlations of these parameters have not been demonstrated.

The current study aims to introduce novel odontoid parameters and investigate their relationship with patient-reported HRQoL outcomes following multilevel posterior cervical fusion. We also sought to explore the relationship between the head position and cervical alignment.

MATERIALS AND METHODS

1. Materials

After obtaining Institutional Review Board approval from Seoul National University Hospital (IRB approval No. B-2208-773-104) a retrospective analysis of clinical and radiographic outcomes was performed for patients who received a single-stage multilevel (3 or more) posterior cervical fusion. The patients were treated for cervical spondylotic myelopathy and/or radiculopathy, ossification of the posterior longitudinal ligament, degenerative disc disorders, and deformities at a single academic center by 5 attending spine surgeons. Standing lateral radiographs of the cervical spine were obtained with patients in a comfortable neutral position. The patients were instructed to look straight ahead, with the upper extremities positioned naturally at the side of the body. The inclusion criteria were patients with more than 1 year of follow-up, an upper instrumented vertebra below C2 to investigate changes in the axial cervical spine, and an acceptable range of the chin-brow vertical angle over -1.5° while maintaining a horizontal gaze in the neutral position in order to minimize the positional deviation in the cervical curvature.[14] Patients with trauma, tumor, or infection of the spine, pseudarthrosis, a misplaced screw, junctional pathologies, or adjacent level disc herniation were excluded in order to verify the impact of the alignment on HRQoL. From 2007 to 2019, 81 patients were treated with multilevel single-stage posterior cervical fusion. After exclusion, a total of 32 patients (male:female, 22:10; age at surgery was 58.72 years) were enrolled in this study. The upper instrumented vertebra was from C2 to C4 and the lowest instrumented vertebra was from C7 to T3. Patient demographics were recorded, including age, sex, body mass index, preoperative diagnosis, and the number of fused levels.

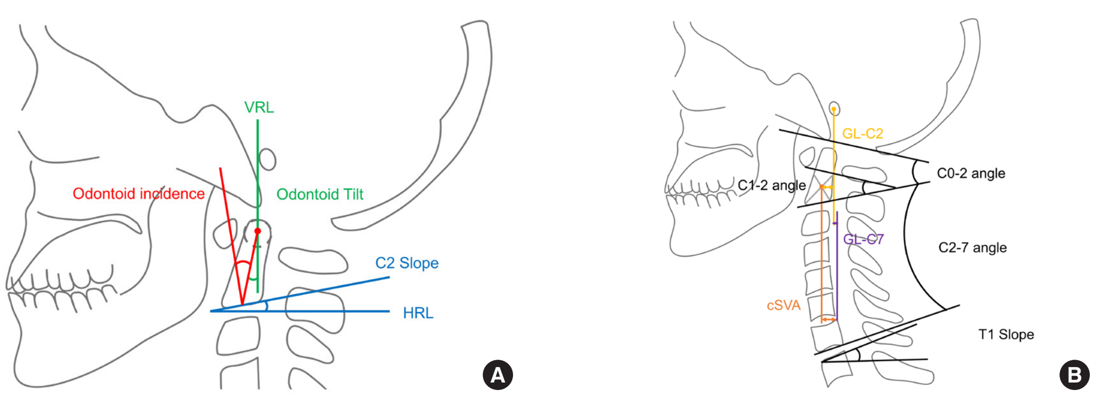

Fig. 1. (A) Schematic drawing of the odontoid parameters. Odontoid incidence: the angle between the line perpendicular to the C2 endplate at its midpoint and the line connecting this point to the center of the odontoid process (the center of a circle with an anterior/posterior border and the apex of the dens as a tangent). Odontoid tilt: the angle created by a line running from the C2 endplate midpoint to the center of the odontoid process and the vertical axis (VRL) C2 slope: the angle between the C2 endplate and a horizontal line (HRL). (B) Schematic drawing of cervical parameters. The gravity line (GL) to C2 distance (GL-C2) was defined as the distance between the GL, defined as the plumb line from the center of the acoustic meatus, and the centroid of C2. The cervical sagittal vertical axis (cSVA) was defined as the distance between a plumb line from the centroid of C2 and the posterosuperior aspect of C7.

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2. Analysis of Radiographic Images

1) Odontoid parameters

Odontoid incidence (OI) was defined as the angle between the line perpendicular to the C2 endplate (C2EP) at its midpoint and the line connecting this point to the center of the odontoid process (the center of a circle with an anterior/posterior border and the apex of the dens as a tangent). Odontoid tilt (OT) was defined as the angle created by a line running from the C2EP midpoint to the center of the odontoid process and the vertical axis. Negative values indicated that the center of the odontoid process was placed anterior to the C2EP midpoint. C2S was defined as the angle between the C2EP and a horizontal line. A geometric construction using complementary angles showed that OI is the algebraic sum of OT and C2S (Fig. 1A). The distance from the gravity line (GL), defined as the plumb line from the center of the acoustic meatus, to the centroid of C2 (GL-C2) and the posterosuperior aspect of C7 (GL-C7) were measured (Fig. 1B).

2) Cervical spine parameters

The Cobb angle at C0–1, C1–2, C0–2, C2–7, T1S, C2–7 sagittal vertical axis (cSVA), and T1S minus CL (TIS–CL) were measured. For the C0–2 angle, an angle between the C2EP and the McRae line was measured. C0–1 angle was an angle between the McRae line and the line linking the inferior anterior and posterior arch of the atlas; C1–2 angle was defined as an angle between the line linking the inferior anterior and posterior arch of the atlas and the C2EP. T1S was defined as an angle between the T1 upper endplate and the horizontal plane. cSVA was defined as the distance between a plumb line from the centroid of C2 and the posterosuperior aspect of C7 (Fig. 1B). The range of motion (ROM) of occipito-atlanto-axial complex (C0–1, C1–2, C0–2) was calculated by subtracting the extension angle from the flexion angle.

3. Analysis of Patient-Reported Outcomes

Two commonly used self-assessment metrics for HRQoL were employed to measure disability after spine surgery: the Neck Disability Index (NDI) and visual analog pain scale (VAS) for the axial neck (VASn) and arm (VASa) pain.

4. Statistical Analysis

A picture archiving and communication system (p view, Infinitt, Seoul, Korea) was used for measurements. The test for normality was done using the Shapiro-Wilk test. The correlations between the parameters and HRQoL scores were analyzed using Pearson correlation coefficients or Spearman rank-order correlation coefficients for nonparametric variables. Univariable linear regression analysis was performed to determine the possible threshold of radiographic parameters. The statistical analysis was conducted using SPSS software (version 25.0), and a p-value < 0.05 was considered to indicate statistical significance.

RESULTS

1. Demographics and Baseline Cervical Alignment

In total, 32 patients (male, 22; female, 10) met the inclusion criteria for the study, with a mean age of 58.7 ± 14.3 years. The

Table 1. Baseline demographic, radiographic, and surgical parameters (n = 32)

Variable	Value
Demographic	
Age (yr)	58.72 ± 14.34
Male sex	22 (68.8)
Heigh (cm)	163.10 ± 7.41
Weight (kg)	64.75 ± 12.23
Body mass index (kg/m^2)	24.33 ± 4.23
Fused level	3.94 ± 1.08
Baseline HRQoL metrics	
VAS neck	4.63 ± 2.96
VAS arm	5.87 ± 3.18
Neck Disability Index	21.44 ± 10.58
Mean radiographic parameters	
Odontoid incidence	18.22 ± 3.56
Odontoid tilt	-0.39 ± 12.41
C2 slope	18.61 ± 12.29
C0–2 angle	-28.72 ± 9.76
Extension, C0–1	-9.70 ± 6.08
Extension, C1–2	-33.67 ± 4.96
Extension, C0–2	-43.37 ± 8.12
Range of motion, C0–1	14.79 ± 5.42
Range of motion, C1–2	8.36 ± 3.62
Range of motion, C0–2	22.89 ± 6.58
C2–7 angle	-1.42 ± 20.83
Gravity line-C2	-1.58 ± 9.11
Gravity line-C7	23.66 ± 15.74
C2–7 sagittal vertical axis	25.25 ± 11.56
T1 slope	23.51 ± 9.23
T1 slope minus cervical lordosis	22.09 ± 15.61

Values are presented as mean ± standard deviation or number (%).
HRQoL, health-related quality of life; VAS, visual analogue scale.

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preoperative diagnosis for multilevel fusion included cervical spondylotic myelopathy and/or radiculopathy (n = 9), ossification of the posterior longitudinal ligament (n = 18), ossified ligamentum flavum (n = 1), and cervical deformity (n = 4). The average number of levels fused was 3.94 ± 1.08 (range, 3–6). The number of levels fused did not show a statistically significant correlation with either the radiographic parameters or HRQoL scores. Patient demographics and baseline radiographic parameters can be found in Table 1. Table 2 summarizes the cervical measurements compared with normative data from asymptomatic subjects.[13] Symptomatic patients had larger C2S, cSVA, and T1S–CL and smaller OT values than asymptomatic subjects.

Preoperatively, the odontoid parameters showed statistically significant correlations with established cervical parameters (Table 3). Both OT and C2S were found to have strong correlations with T1S–CL (r = -0.84 and 0.92, respectively, $p < 0.01$). C2S was strongly correlated with the C0–1 (r = -0.61, $p < 0.01$), C1–2 (r = -0.50, $p < 0.01$), C0–2 (r = -0.68, $p < 0.01$), and C2–7 Cobb angles (r = 0.55, $p < 0.01$), GL-C2 (r = 0.71, $p < 0.01$), and GL-C7 (r = 0.51, $p < 0.01$). OT also showed similar correlations with the C0–1 (r = 0.58, $p < 0.01$), C1–2 (r = 0.36, $p < 0.01$), C0–2 (r = 0.60, $p < 0.01$), and C2–7 Cobb angles (r = -0.52, $p < 0.01$), GL-C2 (r = -0.71, $p < 0.01$), and GL-C7 (r = -0.52, p < 0,01). Dynamic alignment was assessed with ROM, which was calculated by subtracting extension alignment measures from flexion alignment measures. The C1–2 ROM was 8.36° ± 3.62°, and the C0-2 ROM was 22.89° ± 6.58°. OI showed significant correlations with the ROM of C1–2 (r = 0.37, $p < 0.05$) and C0–2 (r = 0.46, $p < 0.01$), as well as the C1–2 extension angle (r = -0.40, $p < 0.05$). OT and C2S showed statistically significant correlations with the C0–1, C1–2, and C0–2 angles, GL-C2, and T1S–CL (Table 3).

Table 2. Comparison of cervical measurements to normative Data

Variable	Asymptomatic	Preoperative	p-value
Odontoid incidence	17.7 ± 3.7	18.22 ± 3.56	0.570
Odontoid tilt	6.7 ± 5.3	-0.39 ± 12.41	0.005*
C2 slope	10.9 ± 6.2	18.61 ± 12.29	0.001*
C0–2 angle	-25.6 ± 8.8	-28.72 ± 9.76	0.305
C2–7 angle	-10.4 ± 7.3	-1.41 ± 20.83	0.144
T1 slope	23.1 ± 6.3	23.51 ± 9.23	0.686
C2–7 sagittal vertical axis	17.80 ± 6.78	25.25 ± 11.56	0.000*
T1 slope minus cervical lordosis	12.7 ± 6.5	22.09 ± 15.61	0.003*

Values are presented as mean ± standard deviation.
*Statistically significant differences ($p < 0.05$).

Table 3. Correlation of odontoid parameters with established parameters of the cervical spine at baseline

Variable	OI	OT	C2S
OI	NA	0.30†	0.02†
OT	0.30†	NA	-0.93**,†
C2S	0.02†	-0.93**,†	NA
C0–1	-0.07	0.58**,†	-0.61**,†
C1–2	-0.40*	0.36*,†	-0.50**,†
C0–2	-0.27†	0.60**,†	-0.68**,†
GL-C2	-0.13	-0.71**,†	0.71**,†
GL-C7	-0.33	-0.52**	0.51**
ROM, C1–2	0.37*	0.01†	0.09†
ROM, C0–2	0.46**	-0.02†	0.18†
C2–7	0.09†	-0.52**,†	0.55**,†
cSVA	-0.31†	-0.3†	0.29†
T1S	0.03	0.04†	0.01†
T1S–CL	0.09†	-0.84**,†	0.92**,†

OI, odontoid incidence; OT, odontoid tilt; C2S, C2 slope; GL-C2, gravity line-C2 distance; GL-C7, gravity line-C7 distance; ROM, range of motion; cSVA, C2-7 sagittal vertical axis; CL, cervical lordosis; T1S–CL, T1 slope minus cervical lordosis.
*$p < 0.05$. **$p < 0.01$. †Spearman ρ.

2. Associations Between Odontoid Parameters and Postoperative Outcomes

The postoperative NDI scores ranged from 0 to 39, with an

Table 4. Postoperative correlations of odontoid parameters and health-related quality of life

Variable	VAS neck	VAS arm	NDI
OI	-0.27	-0.10	-0.40*
p-value	0.14	0.57	0.02
OT	-0.13†	-0.26†	-0.37*,†
p-value	0.50	0.14	0.03
C2S	0.08	0.25	0.31
p-value	0.65	0.18	0.08
GL-C2	0.35*	0.24	0.32
p-value	0.04	0.18	0.08
GL-C7	0.17	0.17	0.27
p-value	0.34	0.19	0.28

VAS, visual analogue scale; NDI, Neck Disability Index; OI, odontoid incidence; OT, odontoid tilt; C2S, C2 slope; GL-C2, Gravity line-C2 distance; GL-C7, gravity line-C7 distance.
*$p < 0.05$, statistically significant differences. †Spearman ρ.

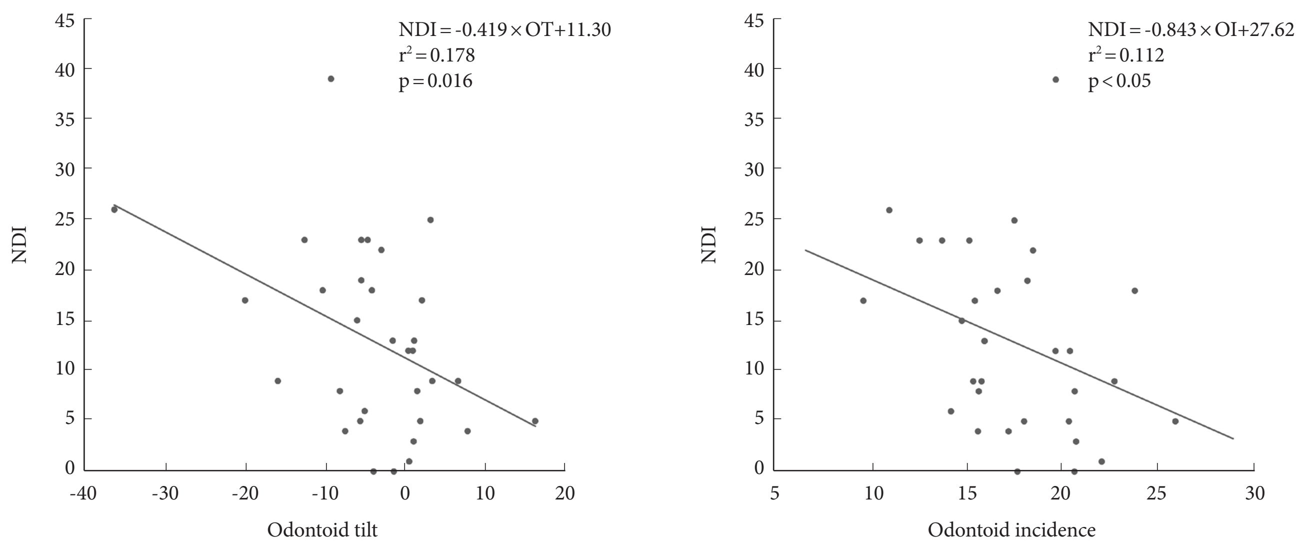

Fig. 2. Linear regression analysis of the odontoid parameters and Neck Disability Index (NDI). Positive correlations between odontoid incidence (OI), odontoid tilt (OT), and Neck Disability Index (NDI) scores are noted.

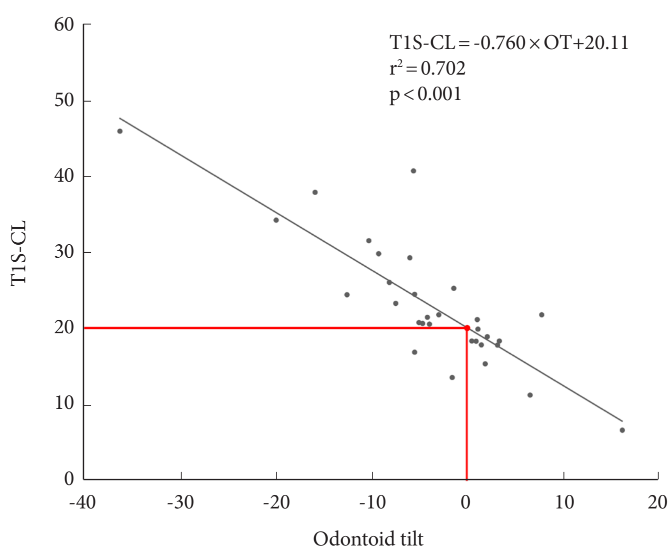

Fig. 3. Negative correlation between odontoid tilt (OT) and T1 slope minus cervical lordosis (T1S–CL). The linear regression model indicates that a T1S–CL value of 20° corresponded to an OT value of 0°.

average of 12.84 ± 9.12. The VASn scores ranged from 0 to 8, with a mean of 3.06 ± 2.51, and the VASa scores ranged from 0 to 10, with a mean of 3.53 ± 3.04. The correlations between odontoid parameters and HRQoL measures were analyzed (Table 4). The NDI scores were correlated with OI ($r = -0.40$, $p < 0.05$) and OT ($\rho = -0.37$, $p < 0.05$) after surgery (Fig. 2). VASn showed a significant correlation with GL-C2 ($r = -0.35$, $p < 0.05$). Using linear regression, OT was also found to be a key factor for predicting NDI: NDI = -0.42 × OT + 11.3 ($r^2 = 0.1776$, $p < 0.01$). The OT was matched to cervical malalignment, as determined by T1S–CL, in the entire cohort. An OT of 0° matched a T1-CL of 20° ($r^2 = -0.760$, $p < 0.001$) (Fig. 3).

DISCUSSION

T1S–CL is a global assessment of sagittal alignment, detecting mismatches between the cervical and remaining thoracolumbar spine.[15] T1S–CL depicts the harmony of a patient's cervical alignment with the thoracic alignment that T1S describes. T1S is a vital factor influencing overall cervical sagittal alignment, and an increase in T1S is significantly correlated with more significant sagittal malalignment of the dens.[16] C2S is mathematically approximated as T1S–CL.[10] Accordingly, C2S has been suggested as a key to understanding cervical deformity relative to the thoracic alignment, combined with its clear visibility on radiographs compared to the C7-slope or T1S and its correlation with T1S–CL.[10,11,17] If a patient has insufficient CL in a given T1S, anterior tilting of the dens occurs, leading to an increase in the C2S and inversely a decrease in OT (Fig. 4).[10] The extent of the T1S–CL mismatch can be represented by the sagittal malalignment of the dens, which can be meticulously described with odontoid parameters, as OI is an anatomical feature unique to each individual, regardless of its position, and C2S and OT are inversely related.[13]

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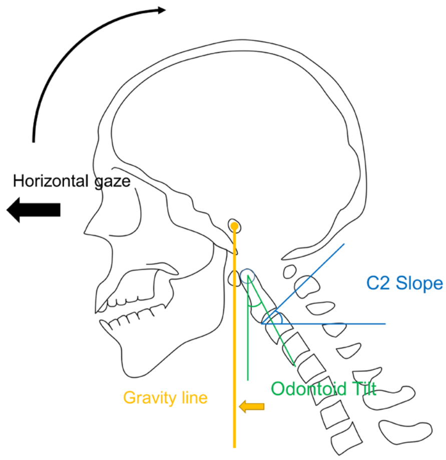

Fig. 4. An increase in C2 slope indicates the possibility of failure to achieve horizontal gaze. An increase in C2 slope leads to forward-shifting of the head or forward-shifting of the gravity line (yellow line). The patient extends the upper cervical spine to maintain a horizontal gaze. Patients with large odontoid incidence have larger neck extension reservoirs and can compensate with neck extension.

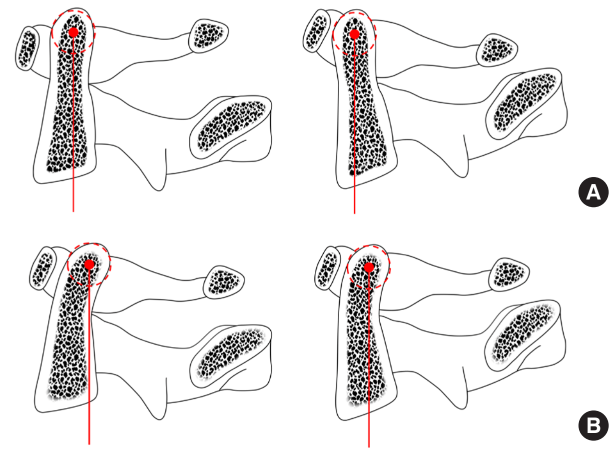

Fig. 5. Schematic drawings illustrating the different spatial orientations of the dens with identical C2 slope and different odontoid incidence values. (A) A dens with a straight curvature is conducive to a small odontoid incidence, prone to anterior tilting of the center of the dens. (B) A dens with a greater posterior inclination is able to maintain the center of the dens more posteriorly.

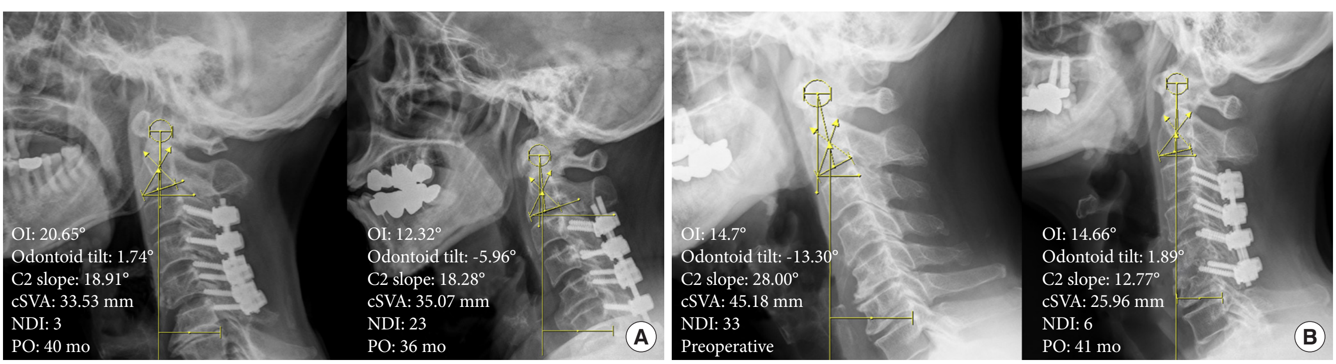

Fig. 6. Comparison of effects of odontoid tilt on the Neck Disability Index (NDI). (A) Even with an identical C2 slope, a smaller odontoid incidence is related to a smaller odontoid tilt and poorer health-related quality of life outcome score. (B) Postoperative improvement of odontoid parameters. The anterior inclination of the dens is related to cervical malalignment. OI, odontoid incidence; cSVA, cervical sagittal vertical axis; PO, postoperative.

Recent studies have reported multiple cutoff values for the optimal T1S–CL. In one study, a cutoff value of 20° for the T1S–CL predicted moderate clinical disability according to the NDI score following multilevel cervical fusion,[18,19] and another demonstrated that moderate NDI could be predicted if the C2S exceeds 17°.[10] The average reported OI is approximately 17°, and if we subtract the C2S presented above from the OI, we obtain an OT of 0°. An OT of approximately 0° also corresponds to a T1S–CL mismatch of 20°, as shown through the current study's linear regression model (Fig. 3). It can be assumed that anterior tilting of the dens axis (a line running from the C2EP midpoint to the center of the odontoid process) beyond the vertical line illustrates the dissonance of a patient's cervical alignment. Understanding the spatial orientation of the dens is essential. However, each individual has a unique morphology of the dens.[13] PI reflects the relative position of the pelvis. Subsequently, patients with low PI have a low sacral slope and a low reservoir of pelvic retroversion or PT.[20] Likewise, the morphology of the dens differs among individuals, and the clinical impact of the C2S may differ.[13] At a given C2S, patients with a larger OI have a smaller clinical impact than patients with a smaller OI (Fig. 5). As a result, at a given C2S, a patient with a larger OI can maintain a larger OT than a patient with a smaller OI (Fig. 6A). A patient with a smaller OI is unable to maintain a positive value of OT as C2S increases, which results in a poorer NDI outcome. The correlation of exacerbating NDI with decreasing OT ($r = -0.37$, $p < 0.05$) was well demonstrated in the current study. When cervical malalignment is corrected, anterior inclination of the dens resolves, which is associated with an improved NDI score (Fig. 6B).

In cervical malalignment, subsequent forward-shifting of the head results in chronic neck pain and leads to a downward gaze. Subsequently, the upper cervical spine extends to maintain a horizontal gaze (Fig. 4).[21-23] Through reciprocal changes, the thoracolumbar spine can compensate for malalignment, but it leads to further pain and disability.[24-27] Similar results were obtained in the current study. The forward-shifting of the head correlates with anterior-shifting of the GL (GL-C2, $r = -0.71$, $p < 0.01$ and GL-C7, $r = -0.52$, $p < 0.01$), and the correlation between VASn score and GL-C2 ($r = 0.35$, $p < 0.05$) indicates increasing neck pain as the head shifts forward. A decrease in OT indicates the shifting of the GL away from the center of the body, resulting in imbalance and disability. OT was found to be correlated with the NDI score ($r = -0.37$, $p < 0.05$) in the current study. Regarding the cone of economy, the cervical spine shows a larger stable zone, indicating a larger compensatory reservoir. In the setting of malalignment, the cervical spine may easily adapt to remain in balance. Thus, other factors may contribute to the overall disability of the cervical spine, which resulted in small correlation coefficients regarding HRQoL measures. Nevertheless, from a statistical perspective, OT showed a more significant correlation—in terms of correlation coefficient value (-0.37 vs. 0.19)—than the previous study related to the tilt angle of C2.[15] It can be assumed that the amount of tilt of C2 is related to HRQoL measured and it differs between each individual.

The patient's compensation to maintain a horizontal gaze may be represented by C2S.[11] Incremental inclination is represented by C2S, which reflects the need for more extension of the upper cervical spine. Thus, the capacity to extend the upper cervical spine is related to a patient's ability to maintain the horizontal gaze during cervical malalignment. Recently, the reserve of extension (ROE) of C0–2 has been reported to be associated with improved clinical outcomes. The correction of cervical alignment is proportional to the relaxation of cervical hyperextension, which increases the upper cervical ROE.[22] In the current study, we found that a larger OI leads to a larger C1–2 extension angle, C1–2 ROM, and C0–2 ROM, as shown in a previous biomechanical study.[28] The potential to extend the upper cervical spine relates to the anatomical characteristics of the dens. A dens demonstrating greater posterior inclination, or a larger OI, leads to an increased ROM of C1 relative to C2. A patient with a larger OI can be assumed to have a larger compensatory reservoir or ROE. As a result, a patient with a larger OI can maintain a positive OT, which is significantly correlated with an improved NDI score ($r = -0.40$, $p < 0.05$) (Fig. 2).

In this study, we sought to elucidate the relationships of the odontoid parameters with clinical outcomes and radiographic cervical alignment in patients following multilevel posterior cervical fusion. This study bridges the gap between the conventional cervical parameters and explains the clinical improvement observed after cervical realignment surgery. C2S presents a simplified understanding of cervical alignment and is suggested as a unified key to understanding cervical alignment relative to the thoracic spine.[11] OT, like PT, denotes the spatial orientation of the dens, which may vary according to the balance of the cranium and horizontal gaze. OI, like PI, is related to the compensatory reservoir of cervical extension. A profound analysis of the cervical alignment and the patient's compensatory status is possible using the odontoid parameters. The utilization of the odontoid parameters has some advantages. OI is an independent and individually specific parameter not affected by external factors.[13] Furthermore, C2S is able to distill the concept of cervical and thoracic harmony into a single measurement, enabling a simplified analysis.[10] Complementing C2S with other odontoid parameters may provide a more profound and individualized understanding of cervical alignment in both the horizontal and vertical axes. Lastly, the dens is more visible on plain radiographs than on either C7 or T1; thus, observing the alignment of the dens enhances the reliability of the analysis.[13,29]

This study has certain limitations. First, it is a retrospective study with a small number of patients who had not been randomized. As a result, a detailed analysis was not possible, and we could not provide a valid cutoff value regarding NDI and OT. However, the study demonstrated significant correlations between the odontoid parameters and T1S–CL, allowing a simplified multiaxial assessment of cervical alignment harmony using the dens. In addition, the study was done with a heterogeneous cohort of patients. The majority of the patients in the present study underwent surgery not for cervical deformity, but for degenerative cervical disorders. Nonetheless, solid fusion was demonstrated to determine the true cause of disability, and we excluded patients with a misplaced screw, pseudarthrosis, facet arthrosis, or adjacent level disc herniation. After excluding other common causes of pain, we were able to assume that poor

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HRQoL was due to malalignment. The results from the current study revealed that odontoid parameters are valuable in assessing the relationship between cervical alignment and HRQoL. In the future, larger series of homogeneous populations undergoing cervical deformity corrective surgery can validate the results of our study.

Our study examined the novel odontoid parameters as an adjunct to the widely used C2S. Our findings demonstrate that similar to pelvic parameters, the severity of cervical malalignment differs due to the anatomical characteristics of each individual. The spatial orientation of the dens can be different between patients with identical C2S, since the angulation of the dens may vary. As OI represents the patient's compensatory reservoir, it is possible to assess the compensatory status of a patient and meticulously plan the optimal cervical alignment correction.

CONCLUSION

OI is the algebraic sum of OT and C2S. The odontoid parameters were significantly correlated with established cervical parameters and HRQoL measures following multilevel posterior cervical fusion. While C2S has shown utility in describing cervical deformities simply and effectively, it is limited in that it is a positional parameter, and its normal range may vary in each individual. In contrast, OI is a constant parameter and can represent the individual's compensatory reservoir at the upper cervical spine, like PI. Odontoid parameters can provide an effective tool for surgeons in assessing cervical malalignment. Based on the results of this study, in a given C2S, postoperative HRQoL scores showed better results in patients with larger OI. A larger OI resulted in larger cervical ROM, allowing more upper cervical spine extension, indicating a larger ROE. Therefore, it is essential to consider not only C2S, but all odontoid parameters, as an adjunct to C2S to assess the cervical alignment thoroughly.

NOTES

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