The Severity of Cervical Disc Degeneration Does Not Impact 2-year Postoperative Outcomes in Patients With Cervical Spondylotic Myelopathy Who Underwent Laminoplasty

Habibi, Hasibullah / Suzuki, Akinobu / Tamai, Koji / Ohyama, Shoichiro / Hori, Yusuke / Yabu, Akito / Terai, Hidetomi / Hoshino, Masatoshi / Toyoda, Hiromitsu / Takahashi, Shinji / Ahmadi, Sayed Abdullah / Nakamura, Hiroaki

Citation	SPINE. 45(18); E1142-E1149
Issue Date	2020-09-15
Type	Journal Article
Textversion	Author
Relation	This is the Final Peer-Reviewed Manuscript. This is a non-final version of an article published in final form in SPINE: Volume 45, Issue 18, p.E1142-E1149. https://doi.org/10.1097/BRS.0000000000003528
DOI	10.1097/BRS.0000000000003528

Self-Archiving by Author(s)
Placed on: Osaka City University Repository

Habibi, H., Suzuki, A., Tamai, K., Ohyama, S., Hori, Y., Yabu, A., Terai, H., Hoshino, M., Toyoda, H., Takahashi, S., Ahmadi, S. A., & Nakamura, H. (2020). The Severity of Cervical Disc Degeneration Does Not Impact 2-year Postoperative Outcomes in Patients With Cervical Spondylotic Myelopathy Who Underwent Laminoplasty. *Spine*, 45(18), E1142–E1149. <https://doi.org/10.1097/brs.0000000000003528>

The severity of cervical disc degeneration does not impact two-year postoperative outcomes in patients with cervical spondylotic myelopathy who underwent laminoplasty

Hasibullah Habibi MD, Akinobu Suzuki MD, Koji Tamai MD, Shoichiro Ohyama MD, Yusuke Hori MD, Akito Yabu MD, Hidetomi Terai MD, Masatoshi Hoshino MD, Hiromitsu Toyoda MD, Shinji Takahashi MD, Sayed Abdullah Ahmadi MD, Hiroaki Nakamura MD

Department of Orthopaedic Surgery, Osaka City University Graduate School of Medicine

*Corresponding author:

Koji Tamai M.D.

Dept. of Orthopedic surgery, Osaka City University Graduate School of Medicine, Osaka, Japan

1-5-7, Asahimachi, Abenoku, Osaka city, Osaka, 545-8585, Japan

E-mail: koji.tamai@msic.med.osaka-cu.ac.jp

TEL +81-6-6645-3851 FAX +81-6-6645-6260

The submitted manuscript does not contain any information about medical drugs.

No funds were received in support of this work.

No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

The study protocol was approved by the Institutional Review Board of Osaka City University

Abstract

Study design:

Retrospective cohort study.

Objective:

To evaluate the impact of cervical disc degeneration (CDD) severity on 2-year postoperative outcomes following laminoplasty.

Summary of background data:

The impact of CDD on postoperative outcomes of cervical laminoplasty has not been well established.

Methods:

A total of 144 patients who underwent open-door laminoplasty for cervical spondylotic myelopathy (CSM) were enrolled. Six cervical discs were independently analyzed for degeneration severity using a previously reported grading system (grade 0: none, grade 3: severest). The relationship between the segmental range of motion (ROM) and the severity of CDD was evaluated. Subsequently, after dividing overall patients into mild and severe CDD groups by the average of CDD scores, the mixed-effect model was applied to assess 2-year postoperative outcomes, including physician-assessed myelopathy scores, patient-reported outcomes, and preoperative radiographic parameters. Finally, as additional analysis, the severe CDD group was further divided into two groups: group 1 included patients with a grade 3 CDD change in their most stenotic level and group 2 included the others. The 2-year postoperative myelopathy score was compared between groups 1 and 2.

Results:

The cervical segments with grade 3 CDD showed significantly smaller ROM compared with those with grade 0, 1, or 2 CDD ($p<0.01$). There were no significant differences in postoperative improvements in myelopathy, pain, patient-reported physical and mental status, and radiographic parameters, except for quality of life (QOL) scores between CDD groups. A significant ($p=0.02$) postoperative improvement in QOL scores was noted in the severe CDD group. In an additional analysis, myelopathy score at 2 years postoperatively was significantly higher in group 1 than group 2 ($p=0.041$).

Conclusions:

The severity of CDD did not negatively impact 2-year postoperative laminoplasty outcomes. The postulated reason is that the decreased segmental instability in the level with severe CDD may affect surgical outcomes positively.

Keywords: cervical spine, disc degeneration, laminoplasty, myelopathy, outcome, pain, quality of life, SF-36, range of motion, visual analog scale

Level of evidence: Level 3, Treatment Benefits

Key points:

- The impact of cervical disc degeneration (CDD) on postoperative outcomes of cervical laminoplasty has not been well established.
- Current results revealed that the severity of CDD did not negatively impact 2-year postoperative laminoplasty outcomes.
- Decreased segmental instability in the region with severe CDD may affect surgical outcomes positively.

Mini abstract

The impact of CDD on postoperative outcomes of cervical laminoplasty has not been well established. A total of 144 patients who underwent open-door laminoplasty for cervical spondylotic myelopathy were enrolled. The severity of CDD did not negatively impact 2-year postoperative laminoplasty outcomes.

Introduction

Cervical spondylotic myelopathy (CSM) is a degenerative spine condition involving cervical spinal cord compression. This condition is caused by excess pressure and deformation of the spinal cord in response to factors such as anterior disc herniation, spondylotic spurs, posterior longitudinal ligament ossification, and spinal stenosis ^{1,2}.

When surgical intervention is warranted, one of the standard approaches is cervical laminoplasty, which results in good clinical outcomes and effective pain relief ³⁻⁷. Compared with other CSM surgical treatments such as anterior cervical discectomy and fusion and posterior laminectomy and fusion, this approach is superior in preserving cervical motion ⁸.

Cervical disc integrity is a key factor that supports load distribution and proper head motion ⁹. Throughout the normal aging process, it is common for degeneration to occur between cervical discs, which is a key factor contributing to chronic neck pain ¹⁰, disability, and deterioration of daily activities ¹¹. Moreover, research has demonstrated a significant correlation between the quality of life (QOL) and cervical disc degeneration (CDD) ^{12,13}, which is further supported by recent studies showing several psychological comorbidities such as anxiety and depression in patients with CDD ¹⁴.

Currently, the impact of CDD on the postoperative outcomes of cervical laminoplasty is not well established. We hypothesized that CDD could have a negative effect on surgical outcomes of laminoplasty for CSM patients because laminoplasty preserves cervical motion. To explore this connection and determine whether CDD negatively impacts postoperative cervical mobility, this study evaluated the severity of preoperative disc degeneration and its impact on postoperative clinical scores and radiologic parameters. The results of this study can serve as a guide for improved preoperative surgical planning for CSM patients.

Methods

The current study is a retrospective analysis of prospectively collected data from patients who underwent laminoplasty for treating CSM. All study participants provided informed consent, and the study protocol was approved by the Institutional Review Board of our institution (No. 3170). No funds were received in support of this work.

Patient population

A total of 144 consecutive patients who underwent open-door laminoplasty from C3 to C6 for CSM from 2010 to 2015 at the authors' affiliated university hospital were included in the current study. Both pre- and 2-year postoperative data were collected.

Surgery protocol

Patients were diagnosed with multilevel stenosis-associated myelopathy and underwent open-door laminoplasty^{4,15,16}. The surgery involved the placement of hydroxyapatite spacers at every opened lamina section¹⁷. Postoperatively, patients were instructed to wear a soft neck collar for one week. A day after surgery, patients were encouraged to sit up, stand, and walk around as much as possible. Patients were also encouraged to start neck mobility stretches seven days after surgery, which was consistent with guidelines provided by the rehabilitation department of our university.

Clinical evaluation

Clinical evaluations were performed preoperatively and 2 years postoperatively. The Cervical Japanese Orthopedic Association (cJOA) score, which is a physician-assessed score used to evaluate the severity of cervical myelopathy, was determined¹⁸. In addition to the physician-based metric, three types of patient-based questionnaires, the 36-Item Short-Form Health Survey (SF-36), Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ), and visual analog scale (VAS)¹⁹⁻²¹ were included. Information in the SF-36 questionnaire is divided into two parts: the physical component

summary (PCS) and the mental component summary (MCS). JOACMEQ is divided into five components: cervical spine function, upper extremity function, lower extremity function, bladder and bowel function, and QOL. This questionnaire is scored from 0 to 100 (0 = worst, 100 = best) and is calculated based on the patient-reported responses to the 24 questions. The VAS scores measured patient-reported neck pain, shoulder stiffness, arm pain, and arm numbness using a horizontal line in which one side indicated “no symptoms” and the other indicated “worst symptoms imaginable;” the patients indicated the place on the line that most accurately described their symptoms.

Radiographic evaluation

Both pre- and postoperative cervical spine X-ray images taken in the neutral sitting position were analyzed using Synapse software (Fujifilm, Japan). The radiographic parameters for cervical spine assessment included: cervical sagittal vertical axis (cSVA), defined as the horizontal distance between the center of C2 and the posterior superior corner of the C7 vertebral body ²²; C7 slope, defined as the angle between a horizontal line and the C7 upper-end plate ²³; C2–C7 lordotic angle, defined as the angle between the tangent lines of the lower endplates of C2 and lower endplates of C7 vertebral bodies ^{16,24,25}; cervical mismatch, the number of the patients whose “C7 slope minus C2–7 lordotic angle” was more than 15 degrees ²⁶; segmental range of motion (ROM), defined as the difference in lordotic angles of each segment between the maximum flexion and extension positions; and C2–C7 ROM, defined as the difference in C2–7 lordotic angles between the maximum flexion and extension positions ²⁵. In addition, the severity of the canal stenosis was evaluated using a previously reported classification ²⁷ with preoperative magnetic resonance imaging (MRI). The levels that showed grade 2 or 3 stenoses were defined as the stenosis level, and the number of the stenosis level of each patient was counted.

CDD grading

To evaluate the severity of disc degeneration, six discs from C2–C3 to C7–T1 were assessed using T2-weighted MRI on the midline of the sagittal slice. Disc degeneration severity was categorized into four

grades, as previously reported^{28,29}. In brief, grade 0 criteria included normal presentation, homogeneous, and high disc intensity; grade 1 criteria included mild degeneration, non-homogeneous, low or intermediate disc intensity, and no apparent disc bulging; grade 2 criteria included moderate degeneration, apparent disc bulging, very low disc intensity, and unclear nucleus border; grade 3 criteria included severe degeneration and a disc height decrease >25% (Figure 1). Two observers (H.H. and K.T.) independently evaluated all preoperative MR images; any differences in the evaluation were settled by consensus of the two observers. The kappa coefficient with one observer after a three-month interval was 0.883 ($p < 0.001$) and that between two observers was 0.801 ($p < 0.001$).

Study design and statistical analysis

The severity of disc degeneration was first evaluated using the Chi-square test and residual analysis. The residual analysis result was described as significant when all variables had $|r| > 1.96$, according to the Haberman method³⁰. In addition, the average segmental ROM was compared between each CDD grade using Bonferroni adjustment after one-way analysis of variance.

Subsequently, the average of six individual disc values from C2–3 to C7–T1 was calculated for each patient. These average values were used to define the CDD severity for each patient, who were then separated into the mild or severe CDD group. The cutoff value between the two groups was defined as the average value of the overall CDD score. After CDD group allocation, univariate comparisons were performed between CDD groups using the Mann–Whitney U-test. Finally, a mixed-effects model was used to identify significant differences between preoperative and 2-year postoperative outcomes between the mild and severe CDD groups for all clinical metrics and radiological parameters.

To evaluate the impact of CDD severity on improving myelopathy as secondary analysis, patients of the severe CDD group were further divided into two groups according to the following criteria: group 1 included patients with grade 3 CDD at the most stenotic level and group 2 included patients with grade 0, 1, or 2 CDD at the most stenotic level. Preoperative and 2-year postoperative cJOA scores were compared between groups 1 and 2 using the Mann–Whitney U-test. For all analyses, all p -values $< .05$ were considered

statistically significant. The analyses were conducted using SPSS software version 23.0 (SPSS, Chicago, IL).

Results

The mean age of the 144 patients was 65.6 ± 13.8 years; the study included 88 women and 56 men. On preoperative MRI, 18 patients showed single level stenosis, 78 showed double level stenosis, 33 showed triple level stenosis, and 3 showed quadruple level stenosis.

Disc degeneration analysis

Eight-hundred sixty-four individual cervical discs from 144 participating patients were analyzed. Grade 2 degeneration (40.3%) was most common, followed by grade 1 (30.5%). The incidence of high-grade degeneration was more common in the middle levels, such as C4–5, C5–6, and C6–7, whereas the incidence of the mild-grade degeneration was more common in the upper and lower cervical levels, such as C2–3, C3–4, and C7–T1 ($p < 0.05$, Table 1). The segments with grade 3 CDD change had a significantly smaller ROM than those with grade 0, 1, and 2 CDD change (Figure 2).

Comparison of preoperative clinical scores

A cutoff value of 2.0 was applied, which was the average of all patients' CDD scores. Patients were classified into either the mild CDD group ($n=69$, mean score 1.6 ± 0.3) or the severe CDD group ($n=75$, mean score 2.2 ± 0.3). Univariate analysis of preoperative metrics indicated that patients classified in the severe CDD group were significantly older ($p=0.023$), had greater shoulder stiffness ($p=0.027$), and lower QOL ($p=0.02$) than patients classified in the mild CDD group (Table 2). No significant ($p > 0.05$) differences were observed between CDD groups regarding neck pain, arm pain, arm numbness, PCS and MCS SF-36 score, and JOACMEQ.

Comparison of preoperative radiographic parameters

Comparison of preoperative radiographic parameters indicated that there was no significant difference between CDD groups among measured radiographic parameters and number of patients with a cervical mismatch (Table 2).

Comparison of postoperative changes

Mixed-model testing revealed that the only statistically significant ($p<0.05$) difference between CDD groups pre- and postoperatively was in patient-reported QOL scores. There was no significant difference between the mild and severe CDD groups in the cJOA score; VAS of neck pain, shoulder stiffness, arm pain, arm numbness; MCS and PCS SF-36 scores; and JOACMEQ score of cervical function, upper extremity function, lower extremity function, and bladder and bowel function (Figure 3 and 4). Specifically, this analysis showed that patients in the severe CDD group were more likely to exhibit postoperative improvements in QOL scores than those in the mild CDD group ($p=0.02$). Moreover, no changes were observed in included radiographic parameters such as cSVA, C7 slope, C2–7 angle, and ROM (Figure 5).

The effect of CDD severity at the most stenotic level on the surgical outcome

To evaluate the impact of CDD severity at the most stenotic level, the severe CDD group was further divided into two groups. Among the 74 patients in the severe CDD group, 20 patients with grade 3 CDD change at their most stenotic level were included in group 1. The other 54 patients with grade 0, 1, or 2 CDD change at their most stenotic level were included in group 2. Although there were no significant differences in the preoperative cJOA score (Group 1: 9.6 ± 3.1 , Group 2: 9.3 ± 3.5 , $p=0.762$), the cJOA score at 2 years postoperatively was significantly higher in group 1 than group 2 (group 1: 13.3 ± 1.9 , group 2: 11.9 ± 3.4 , $p=0.041$).

Discussion

This study showed that in addition to age, preoperative metrics such as patient-reported shoulder stiffness and QOL were significant factors related to CDD severity. However, CDD severity did not significantly negatively impact 2-year postoperative outcome metrics, such as cJOA score, VAS score, JOACMEQ score, SF-36 score, and radiographic parameters.

Regarding the location of CDD, C4–5, C5–6, and C6–7 exhibited increased degeneration compared with upper cervical discs, which is consistent with findings of a previously reported study³¹. Compared with other studies that utilize a five-grade cervical spine severity assessment system^{31,32}, this study utilized a system that was specifically designed for assessing the degeneration of cervical discs. We believe that the utilization of this CDD-specific classification improves upon previous CDD assessment methods because it allows for the assessment of the severity of other factors and compares them with clinical outcomes for patients exhibiting multiple changes, such as those with both disc and facet joint impairments^{33,34}. However, it is important to note that a potential weakness of this method is that patients with abnormal measurements could be falsely classified into the wrong severity group, although the reproducibility of the classification was sufficiently reliable (kappa coefficient interobserver and between observers were 0.893 and 0.801, respectively).

The analysis of preoperative metrics revealed that there was a significant relationship between age, which is consistent with a previous study showing that multilevel disc degeneration is more common in the active and aging population³⁵. Regarding the relationship between preoperative QOL and CDD severity, the current results showed that the QOL component of the JOACMEQ showed significant differences between groups; whereas the SF-36 did not show differences. This could reflect differences in the nature of the scoring; JOACMEQ is designated to evaluate only patients with cervical disease; meanwhile, SF-36 can be used for many kinds of disease. Therefore, JOACMEQ may provide more accurate information than SF-36 for patients in the current study. A previous study showed a decreased QOL in patients with CDD, which

is consistent with the findings from the present study¹². In general, decreased QOL in patients with severe CDD is related to discogenic and/or cervical spinal cord compression-related pain, radiculopathy, and myelopathy symptoms. Our results showing that patients with severe CDD are more likely to exhibit a significant improvement in QOL scores may indicate that the lower preoperative QOL score in patients with severe CDD could be caused by radiculopathy and/or myelopathy rather than by discogenic pain. However, this explanation must be validated in future studies of nerve root blocks or disc blocks to evaluate the relationship between severity of CDD and patient QOL.

In contrast to our hypothesis, the improvements in cJOA score, VAS score, and SF-36 score showed no significant differences between the patients with mild and severe CDD. One potential explanation for these results could be linked to the stability at the level of cervical stenosis. Our results demonstrated that the segmental ROM of cervical segments with grade 3 (i.e. severest) CDD was significantly smaller than in those with grade 0, 1, or 2 CDD. Namely, the cervical segments with severe CDD were more stabilized compared to those with moderate, mild, or no CDD. Furthermore, we showed that patients with grade 3 CDD at their most stenotic level experienced significantly better cJOA score improvements compared with patients with grade 0, 1, or 2 CDD at their most stenotic level. These two results suggest that severe CDD at the most stenotic segments may aid improvement from myelopathy owing to increased stability. This hypothesis may be similar to the mild “fusion effect”, in which fusion surgery accelerates neurological improvements more than surgery without fusion^{36,37}. The current results can encourage surgeons to include laminoplasty into their surgical choices, even when the patients have severe CDD changes at the surgical level.

While the findings of the current study increase what is currently known about the association between CDD severity and postoperative outcomes following laminoplasty, it is important to note its limitations. First, because this study is retrospective, a selection bias is hard to rule out; in particular, we evaluated only patients who underwent C3–C6 laminoplasty and who completed the postoperative survey up to 2 years

after surgery. Second, while the current study approach of assessing patients 2 years following the laminoplasty procedure yielded useful insight into recovery outcomes, more extensive studies that extend the follow-up to at least 10 years after surgery would provide adequate information to specify the impact of CDD severity on laminoplasty outcomes. Finally, owing to the relatively small number of subjects in our secondary analysis, several scores with wide standard deviation, including SF-36, JOACMEQ and VAS, were not evaluated. However, to the best of our knowledge, this is the first study to evaluate the impact of CDD severity on 2-year postoperative outcomes following laminoplasty and advocate the postulated reason for our results. We believe this study will provide useful information for surgeons who are considering better criteria for the treatment for patients with CSM.

In conclusion, CDD severity was not associated with a decreased surgical outcome in patients with CSM who underwent laminoplasty 2 years postoperatively. We suggest that the increased stability in the level with severe CDD may positively affect surgical outcomes. These results demonstrate that CDD severity should not dissuade surgical intervention, i.e., laminoplasty, in patients with CSM.

References

1. Matsunaga S, Komiya S, Toyama Y. Risk factors for development of myelopathy in patients with cervical spondylotic cord compression. *Eur Spine J* 2015;24 Suppl 2:142-9.
2. Nouri A, Tetreault L, Singh A, et al. Degenerative Cervical Myelopathy: Epidemiology, Genetics, and Pathogenesis. *Spine (Phila Pa 1976)* 2015;40:E675-93.
3. Hirabayashi K, Miyakawa J, Satomi K, et al. Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. *Spine (Phila Pa 1976)* 1981;6:354-64.
4. Hirabayashi K, Toyama Y, Chiba K. Expansive laminoplasty for myelopathy in ossification of the longitudinal ligament. *Clin Orthop Relat Res* 1999;35-48.
5. Satomi K, Nishu Y, Kohno T, et al. Long-term follow-up studies of open-door expansive laminoplasty for cervical stenotic myelopathy. *Spine (Phila Pa 1976)* 1994;19:507-10.
6. Seichi A, Takeshita K, Ohishi I, et al. Long-term results of double-door laminoplasty for cervical stenotic myelopathy. *Spine (Phila Pa 1976)* 2001;26:479-87.
7. Wang MY, Green BA. Laminoplasty for the treatment of failed anterior cervical spine surgery. *Neurosurg Focus* 2003;15:E7.
8. Yang K, Guo S, Xu J, et al. Cervical Range of Motion after Anterior Corpectomy and Fusion versus Laminoplasty for Multilevel Cervical Spondylotic Myelopathy: A Three-Dimensional Comparison Based on the Coda Motion System. *World Neurosurg* 2019;132:e274-e82.
9. Friedenberg ZB, Edeiken J, Spencer HN, et al. Degenerative changes in the cervical spine. *J Bone Joint Surg Am* 1959;41-A:61-70 passim.
10. Peng B, DePalma MJ. Cervical disc degeneration and neck pain. *J Pain Res* 2018;11:2853-7.
11. Kelly MP, Mitchell MD, Hacker RJ, et al. Single-level degenerative cervical disc disease and driving disability: results from a prospective, randomized trial. *Global Spine J* 2013;3:237-42.
12. Ament JD, Yang Z, Chen Y, et al. A Novel Quality-of-Life Utility Index in Patients With Multilevel Cervical Degenerative Disc Disease: Comparison of Anterior Cervical Discectomy and Fusion With Total Disc Replacement. *Spine (Phila Pa 1976)* 2015;40:1072-8.
13. Fehlings MG, Tetreault LA, Kurpad S, et al. Change in Functional Impairment, Disability, and Quality of Life Following Operative Treatment for Degenerative Cervical Myelopathy: A Systematic Review and Meta-Analysis. *Global Spine J* 2017;7:53S-69S.
14. Stoffman MR, Roberts MS, King JT, Jr. Cervical spondylotic myelopathy, depression, and anxiety: a cohort analysis of 89 patients. *Neurosurgery* 2005;57:307-13; discussion -13.
15. Ogawa Y, Chiba K, Matsumoto M, et al. Long-term results after expansive open-door laminoplasty for the segmental-type of ossification of the posterior longitudinal ligament of the cervical spine: a comparison with nonsegmental-type lesions. *J Neurosurg Spine* 2005;3:198-204.
16. Hirabayashi K, Watanabe K, Wakano K, et al. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. *Spine (Phila Pa 1976)* 1983;8:693-9.
17. Tamai K, Suzuki A, Terai H, et al. Laminar closure after expansive open-door laminoplasty: fixation methods and cervical alignments impact on the laminar closure and surgical outcomes. *Spine J* 2016;16:1062-9.
18. Yonenobu K, Abumi K, Nagata K, et al. Interobserver and intraobserver reliability of the Japanese orthopaedic association scoring system for evaluation of cervical compression myelopathy. *Spine (Phila Pa 1976)* 2001;26:1890-4; discussion 5.
19. Fukuhara S, Bito S, Green J, et al. Translation, adaptation, and validation of the SF-36 Health Survey for use in Japan. *J Clin Epidemiol* 1998;51:1037-44.
20. Fukui M, Chiba K, Kawakami M, et al. JOA Back Pain Evaluation Questionnaire (JOABPEQ)/JOA Cervical Myelopathy Evaluation Questionnaire (JOACMEQ). The report on the development of revised versions. April 16, 2007. The Subcommittee of the Clinical Outcome Committee of the Japanese Orthopaedic Association on Low Back Pain and Cervical Myelopathy Evaluation. *J Orthop Sci* 2009;14:348-65.
21. Bijur PE, Silver W, Gallagher EJ. Reliability of the visual analog scale for measurement of acute pain. *Acad Emerg Med* 2001;8:1153-7.

22. Tang JA, Scheer JK, Smith JS, et al. The impact of standing regional cervical sagittal alignment on outcomes in posterior cervical fusion surgery. *Neurosurgery* 2012;71:662-9; discussion 9.
23. Tamai K, Buser Z, Paholpak P, et al. Can C7 Slope Substitute the T1 slope?: An Analysis Using Cervical Radiographs and Kinematic MRIs. *Spine (Phila Pa 1976)* 2018;43:520-5.
24. Scheer JK, Tang JA, Smith JS, et al. Cervical spine alignment, sagittal deformity, and clinical implications: a review. *J Neurosurg Spine* 2013;19:141-59.
25. Van Mameren H, Drukker J, Sanches H, et al. Cervical spine motion in the sagittal plane (I) range of motion of actually performed movements, an X-ray cinematographic study. *Eur J Morphol* 1990;28:47-68.
26. Ames CP, Smith JS, Eastlack R, et al. Reliability assessment of a novel cervical spine deformity classification system. *J Neurosurg Spine* 2015;23:673-83.
27. Kang Y, Lee JW, Koh YH, et al. New MRI grading system for the cervical canal stenosis. *AJR Am J Roentgenol* 2011;197:W134-40.
28. Suzuki A, Daubs MD, Hayashi T, et al. Patterns of Cervical Disc Degeneration: Analysis of Magnetic Resonance Imaging of Over 1000 Symptomatic Subjects. *Global Spine J* 2018;8:254-9.
29. Suzuki A, Daubs MD, Hayashi T, et al. Magnetic Resonance Classification System of Cervical Intervertebral Disk Degeneration: Its Validity and Meaning. *Clin Spine Surg* 2017;30:E547-E53.
30. Haberman SJ. The Analysis of Residuals in Cross-Classified Tables. *Biometrics* 1973;29:205-20.
31. Miyazaki M, Hong SW, Yoon SH, et al. Kinematic analysis of the relationship between the grade of disc degeneration and motion unit of the cervical spine. *Spine (Phila Pa 1976)* 2008;33:187-93.
32. Kolstad F, Myhr G, Kvistad KA, et al. Degeneration and height of cervical discs classified from MRI compared with precise height measurements from radiographs. *Eur J Radiol* 2005;55:415-20.
33. Tamai K, Suzuki A, Yabu A, et al. Preoperative severity of facet joint degeneration does not impact the 2-year clinical outcomes and cervical imbalance following laminoplasty. *Spine J* 2019;19:246-52.
34. Pang H, Bow C, Cheung JPY, et al. The UTE Disc Sign on MRI: A Novel Imaging Biomarker Associated With Degenerative Spine Changes, Low Back Pain, and Disability. *Spine (Phila Pa 1976)* 2018;43:503-11.
35. Lundine KM, Davis G, Rogers M, et al. Prevalence of adjacent segment disc degeneration in patients undergoing anterior cervical discectomy and fusion based on pre-operative MRI findings. *J Clin Neurosci* 2014;21:82-5.
36. Ataka H, Tanno T, Yamazaki M. Posterior instrumented fusion without neural decompression for incomplete neurological deficits following vertebral collapse in the osteoporotic thoracolumbar spine. *Eur Spine J* 2009;18:69-76.
37. Ghogawala Z, Dziura J, Butler WE, et al. Laminectomy plus Fusion versus Laminectomy Alone for Lumbar Spondylolisthesis. *N Engl J Med* 2016;374:1424-34.

Table1 Analysis of preoperative Cervical Disc Degeneration

	Grade0	Grade1	Grade2	Grade3	P-value
Total	26 (3.01)	263 (30.5)	347 (40.3)	225 (26.1)	
C2-3	5 (19.2)	129 (49.0)*	10 (2.9)*	1 (0.4)*	<0.001
C3-4	6 (23.1)	27 (10.3)*	78 (22.5)*	32 (14.2)	
C4-5	1 (3.8)	17 (6.5)*	82 (23.6)*	42 (18.7)	
C5-6	1 (3.8)	4 (1.5) *	58 (16.7)	80 (35.6) *	
C6-7	2 (7.7)	13 (4.9) *	72 (20.7) *	56 (24.9) *	
C7-T1	11 (42.3) *	73 (27.8) *	47 (13.5)	14 (6.2) *	

“*” indicates the $P < 0.05$ in residual analysis

Table 2 Patients Demographics of Cervical Disc Degeneration groups

	Mild CDD group	Severe CDD group	p-value
Number	69	75	
Age (years old)	63.5 ± 13.7	68.4 ± 11.4	0.02 [#]
Gender (Female/Male)	44/25	44/31	0.53 [†]
Preoperative clinical score			
cJOA score (points)	10.5 ± 3.0	9.4 ± 3.3	0.05 [#]
VAS (mm)			
Neck pain	18.4 ± 26.3	21.1 ± 24.8	0.63 [#]
Shoulder stiffness	22.8 ± 26.7	36.4 ± 28.2	0.03 [#]
Arm pain	35.0 ± 36.4	34.6 ± 35.0	0.96 [#]
Arm numbness	50.9 ± 33.1	55.2 ± 32.8	0.55 [#]
SF-36			
PCS	26.3 ± 12.4	23.2 ± 15.0	0.26 [#]
MCS	41.8 ± 12.9	38.4 ± 14.5	0.22 [#]
JOACMEQ			
Cervical spine function	66.1 ± 26.8	63.1 ± 32.5	0.64 [#]
Upper extremity function	70.7 ± 24.2	61.7 ± 32.1	0.14 [#]
Lower extremity function	52.7 ± 32.1	43.1 ± 35.2	0.19 [#]
Bladder function	80.2 ± 15.9	76.6 ± 23.0	0.39 [#]
Quality of life	46.5 ± 18.7	36.0 ± 21.1	0.02 [#]
Preoperative radiographic parameters			
C2–C7 SVA (mm)	26.4 ± 15.0	29.5 ± 16.9	0.27 [#]
C7 slope (degree)	30.3 ± 16.0	30.4 ± 14.0	0.96 [#]
C2–C7 ROM (degree)	31.5 ± 15.4	30.7 ± 18.8	0.79 [#]
C2–C7 lordotic angle (degree)	7.4 ± 17.3	12.3 ± 15.0	0.08 [#]
Cervical mismatch (patients)	30	32	1.00 [†]

Mann-Whitney U test, [†] Chi-squared test

CDD: cervical disc degeneration, cJOA score: cervical Japanese Orthopaedic Association score, VAS: visual analog scale, SF-36; 36-Item Short-Form Health Survey, PCS: physical component summary, MCS: mental component summary, JOACMEQ; Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire, SVA: sagittal vertical axis, ROM: range of motion

Figure legends

Figure 1: Representative images of each degeneration grade.

grade 0 criteria included normal presentation, homogeneous, and high disc intensity; grade 1 criteria included mild degeneration, non-homogeneous, low or intermediate disc intensity, and no apparent disc bulging; grade 2 criteria included moderate degeneration, apparent disc bulging, very low disc intensity, and unclear nucleus border; grade 3 criteria included severe degeneration, and a disc height decrease $>25\%$

Figure 2: Relationship between cervical disc degeneration and range of motion. Bonferroni adjustment after one-way analysis of variance

Figure 3: Changes from pre-op to 2-year post-op between group and clinical outcomes such as cJOA, VAS score, and SF-36 of MCS and PCS. Mixed-effect model

Figure 4: Changes from pre-op to 2-year post-op between group and clinical outcome such as JOACMEQ. Mixed-effect model

Figure 5: Changes from pre-op to 2-year post-op between group and radiographic parameters. Mixed-effect model