Clinical Outcomes Comparison of C2 Dome-like Expansive Laminoplasty Versus C2 Open-door Laminoplasty for Multilevel Cervical Ossification of the Posterior Longitudinal Ligament Involving C2

Xin Zhou
Shanghai Changzheng Hospital
Bo Xia
Jining No 1 People's Hospital
Fei Chen
Shanghai Changzheng Hospital
Jun Yang
changzheng hospital
Xiang Guo
changzheng hospital
Zhao Han
changzheng hospital
Xuhua Lu
Shanghai Changzheng Hospital
Qunfeng Guo
Shanghai Changzheng Hospital
bin ni (94438728@qq.com)
Second Military Medical University second Hospital: Changzheng Hospital

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Abstract

Background: Cervical laminoplasty is a well-established surgical treatment for patients with cervical myelopathy due to OPLL. However, for cases with OPLL involving C2 segment, some surgeon preferred C2EL technique, but destruction of muscles attaching at C2 spinous process and lamina is inevitable. While C2DEL technique was also available which cause less destruction to the structures associated with C2. Nevertheless, it is still not confirmed whether it can achieve similar outcomes as C2EL. This study aimed to compare the clinical and radiographic outcomes of C2 dome-like expansive laminoplasty technique(C2DEL) and C2 extended laminoplasty technique(C2EL) applied in the treatment of cervical ossification of posterior longitudinal ligament (OPLL)involving C2 segment.

Methods: Data of 56 patients with OPLL involving C2 segment who underwent cervical laminoplasty were retrospectively reviewed. 26 patients received C2EL technique while C2DEL technique was applied in another 30 patients. Functional outcomes evaluated by visual analog scale score for neck pain (VASSNP), Neck Disability Index (NDI), Japanese Orthopedic Association (JOA) score and Health-Related Quality-of-Life Short Form-36 Physical Component Summary (SF-36 PCS) were recorded and compared pre- and postoperatively. The radiographic outcomes assessed by the Cobb angle and range of motion (ROM) of cervical spine at C2-C7, as well as decompression effect at C2 level evaluated by space available for spinal cord (SAC) were measured in two groups. The intraoperative parameters including total blood loss and operation time were documented and compared between 2 groups.

Results: At the final follow-up, JOA scores, NDI, and SF-36 PCS were significantly improved in both groups(all $P<0.05$), but no significant differences were identified between two groups. VASSNP was reduced significantly in both groups($P<0.05$), but the cases in C2EL group experienced more severe neck pain than that of C2EL group($P<0.05$). Cobb angle at C2 and C7 and the cervical ROM in both groups reduced greatly, the SAC at C2 improved postoperatively and no significant difference was identified intergroup. No serious complications related to the surgical approach and instrumentation were observed in either group.

Conclusion: C2DEL was comparable to C2EL for treating OPLL involving C2 segment. C2DEL was an ideal alternative treatment strategy for OPLL involving the C2 segment.

Introduction

Ossification of the posterior longitudinal ligament (OPLL) is one of the etiologies that result in myelopathy, and surgical intervention is indicated for patients with neurological deficiencies[1]. Various surgical techniques have been historically applied to treat OPLL, and each technique has individual indications, advantages, and disadvantages[2, 3]. Anterior decompression and fusion for OPLL is technically demanding due to the potential risk of complications such as cerebrospinal fluid leakage and neurological deterioration, especially for patients with multilevel OPLL accompanied by high spinal canal occupying ratio. For cervical OPLL extending across more than three intervertebral disc levels, a posterior surgical approach is safer in terms of the development of surgery-related complications[4]. Cervical laminoplasty is considered an ideal technique with satisfactory efficacy and favorable clinical safety[2]. Additionally, it is beneficial for maintaining a relatively intact posterior cervical structure and preserving cervical range of motion (ROM) theoretically[5].

Although OPLL is usually identified in the subaxial cervical spine, its extension upward to the C2 segment has also been observed in clinical practice[6]. However, there are controversies about the surgical indications and strategies for OPLL involving the C2 segment. Direct decompression via anterior cervical approach is challenging due to the complex anatomical structures around the upper cervical spine[7]. Although laminoplasty has been performed for OPLL involving the C2 segment, many surgeons are concerned about postoperative kyphosis and neck axial pain due to the excessive destruction of posterior structures, especially deep extensors attached to C2[8]. In order to preserve the integrity of C2, some surgeons prefer to perform posterior decompression only for patients with severe spinal cord compression with signal changes in the spinal cord at C2 due to OPLL, excluding patients without severe spinal cord compression at C2, but the progression of OPLL may increase the potential deterioration of cervical myelopathy[9-11].

In response to these technical limitations, Matsuzaki *et al.*[12] first contrived dome-like expansive laminoplasty (C2DL) for C2 decompression by removing the ligamentum flavum and ventral cortex of the C2 lamina with satisfactory preliminary clinical outcomes. The advantage of this technique is that the dorsal musculature attachments at the C2 spinous process and lamina can be preserved. However, few studies have analyzed the mid-to long-term outcomes of C2OL and C2DL for treating multilevel cervical OPLL involving C2. Therefore, this retrospective study was conducted to compare the clinical outcomes of the two techniques for treating multilevel cervical OPLL involving C2.

Materials And Methods

Patient population

This study was approved by the ethical committees of our hospital and every patient provided informed consent. Seventy-six consecutive patients with myelopathy due to multilevel cervical OPLL involving C2 who underwent laminoplasty were retrospectively reviewed. All patients had neck pain and neurological deficiencies to varying degrees preoperatively. To minimize the selection bias and increase the validity, only patients with multilevel cervical OPLL with C2 involvement and underwent C2–C7 laminoplasty were included. Patients with any of the following criteria precluding laminoplasty were excluded: (1) K-line(-); (2) cervical spine instability; (3) cervical neoplasm, trauma or inflammatory diseases; (4) previous cervical surgery; (5) cervical kyphosis; (6) cervical ossification of the ligamentum flavum or OPLL of the thoracic spine simultaneously; (7) lack of complete clinical and radiographic data; or (8) follow-up duration of less than 36 months. The included patients were divided into 2 groups according to surgical techniques; 36 patients were allocated to the C2OL group (Figure 1A–I), while 40 patients were allocated to the C2DL group (Figure 2A–K).

Radiological Assessment

We retrospectively reviewed the pre- and postoperative plain cervical radiographs, magnetic resonance imaging (MRI), and computed tomography (CT) scans with 3-dimensional reconstruction, and plain cervical radiographs at 3, 6, and 12 months postoperatively and annually thereafter. The space available for the spinal cord (SAC) at C2 were measured based on CT scans. The pre- and postoperative C2–C7 Cobb angles were measured on plain cervical radiographs. The C2–C7 Cobb angle is formed by the inferior endplates of C2 and C7, as observed on cervical neutral plain radiographs. The cervical ROM was calculated by subtracting the maximum flexion Cobb angle from the maximum Cobb extension angle.

Clinical outcome assessment

The Japanese Orthopedics Association (JOA) score was used to evaluate neurological function, and the neurological recovery rate (RR) was calculated as follows: RR = (final JOA score−preoperative JOA score)/(17−preoperative JOA score) × 100%. The visual analog scale score for neck pain (VASSNP) was used to evaluate neck pain.[13] The 36-Item Short Form Health Survey (SF-36)[14] and Neck Disability Index (NDI)[15] were applied to assess the patients' quality of life. All the aforementioned variables were evaluated preoperatively and at the final follow-up. Perioperative parameters between the two groups were compared. Postoperative complications including C5 palsy, cerebrospinal fluid leakage, neck axial pain, wound infection, neurological deterioration, implant failure, and door reclosure were also investigated.

Surgical Procedures

Patients were placed in slight flexion prone position on a tailored gypsum bed under general anesthesia. Cervical posterior elements were exposed from C3 to T1 with preservation of the musculature attachments at the C2 spinous process and lamina in patients in the C2DL group and exposure from C2 to T1 was performed in patients in the C2OL group. At the junction of the lamina and lateral mass, a high-speed burr and Kerrison rongeur were used to create a bilateral partial-thickness groove, and close attention was paid to preserve the inner cortex of the laminae. The open-door side was achieved by removing the residual ventral cortex bone and ligamentum flavum along the longitudinal gutter and separating the adhesions of dura mater. The laminae from C2 to C7 were lifted by about 7–10 mm, and the ventral cortex bone of the hinge-side were preserved integrally. Mini-plates (Centerpiece, Medtronic Sofamor Danek Corporation, Memphis, TN) were used to fix the laminae and lateral masses at the open-door side in order to maintain the open laminae. The cephalad partial lamina of T1 was also removed in order to preclude the potential risk of incarceration due to spinal cord posterior shift. For the patients in the C2DL group (Figure 3)[12], after achieving laminoplasty of C3–C7 and removal of the ligamentum flavum between C2 and C3, a high-speed burr was used to remove the partial ventral lamina of C2 to enlarge SAC in the context of preserving the dorsal musculature attachments at the C2 spinous process and lamina. The wound was closed in a standard fashion with a suction drain. Postoperatively, the patients were immobilized in a Philadelphia type collar for 2–3 weeks.

Statistical Analysis

SPSS statistical analysis software for Windows Version 21.0 (SPSS Inc., Chicago, IL, USA) was utilized to analyze the data. The data were analyzed using the independent-sample *t*-test, chi-square test. Statistical significance was defined as $P < 0.05$.

Results

Patients’ General Information and Complications

General patient information is summarized in Table 1. There were no significant differences in all preoperative information between the two groups. Neither severe deterioration of myelopathy nor catastrophic neurological complications related to surgery were identified in either group. One patient in each group experienced C5 palsy, and neurological function recovered after hyperbaric oxygen therapy for one month and rehabilitation exercise for 3 months. One patient in the C2OL group underwent debridement and intravenous antibacterial therapy for 1 week because of wound infection, and satisfactory prognosis was finally achieved. Cerebrospinal fluid leakage resulting from dura tear occurred in one patient of the C2DL group, and continuous lumbar drainage was performed; healing of the incision was achieved well without the development of meningitis. No patients experienced hematoma, implant failure, door reclosure, or severe late-stage neurological function deterioration. The perioperative parameters of both groups are also presented in Table 1. There was no significant difference in operation times ($P > 0.05$), but the volume of blood loss in the C2OL group was significantly greater than that in the C2DL group ($P < 0.05$).

Functional Outcomes

Functional outcomes of the patients in both groups are presented in Table 2. There were no significant differences in the pre- and postoperative JOA scores, NDI, and SF-36 scores between the two groups ($P > 0.05$), and great improvements were identified in both groups at the final follow-up ($P < 0.05$). Although there was no significant difference in the preoperative VASSNP between the two groups ($P > 0.05$), the postoperative VASSNP and incidence rate of neck axial pain in the C2OL group were significantly higher than those in the C2DL group ($P < 0.05$). The RR of both groups demonstrated that satisfactory neurological function outcomes were achieved in most patients postoperatively, and no obvious difference was identified between the two groups ($P > 0.05$).

Radiographical Results

The radiographical outcomes are summarized in Table 3. There were no significant differences in the distribution of OPLL types (P0.05). The results demonstrated that the preoperative C2–C7 Cobb angle and cervical ROM were comparable between the two groups (P0.05). However, patients in both groups showed a decrease in the C2–C7 Cobb angle and cervical ROM postoperatively (P0.05), and the C2–C7 Cobb angle and cervical ROM of patients in the C2OL group decreased more than those in the C2DL group at the final follow-up (P0.05). In addition, the SAC at the C2 segment improved significantly in both groups (P0.05), and no obvious difference was identified between the two groups (P0.05).

Discussion

In this study, we compared the outcomes of 76 patients who underwent laminoplasty combined with C2DL or C2OL for treating multilevel cervical OPLL involving C2. C2DL was comparable to C2OL in terms of the functional outcomes evaluated by the NDI, SF-36 score, JOA score, neurological RR. However, the volume of blood loss, postoperative VASSNP and incidence rate of neck axial pain in the C2OL group were higher than those in the C2DL group. Additionally, C2DL was superior to C2OL in terms of maintaining the C2–C7 Cobb angle and cervical ROM postoperatively.

Nowadays, there are controversies regarding the surgical intervention indications for treating OPLL involving C2[16-18]. Liu *et al.*[5] considered that the spinal canal at the C2 segment was larger than the spinal canal in the subaxial spine, which may tolerate slight neural elements compression, and only patients with the spinal cord severely compressed at C2 or obvious kyphosis at the C2–C3 segment were surgically indicated. However, the authors only focused on the local region of C2, ignoring whether the C2 segment would affect the overall decompression effect after surgery. Hirabayashi *et al.*[19] introduced two mechanisms of neural decompression because of laminoplasty: dorsal shift of the spinal cord and local decompression effect. Therefore, Matsuzaki *et al.*[12] proposed the following surgical indications for OPLL involving C2. First, patients with severe stenosis of the spinal canal at C2 due to OPLL must undergo decompression surgery. Second, patients with a relatively stenotic spinal canal at C2 and obviously narrow spinal canal from C3 downward, as well as a narrow spinal canal from C3 downward combined with obvious cervical lordosis, were recommended for surgical interventions because C3 downward decompression alone may affect the spinal cord posterior shift. Anyway, any elements precluding spinal cord posterior shift will compromise the decompression effect. In the current study, the mean SAC at the C2 spinal canal was about 10 mm, and the OPLL extended upward to C2 with spinal canal stenosis at C2 caudal side. We predicted that C3 downward decompression alone would compromise the spinal cord posterior shift; so C2 segment decompression was performed in all patients, and satisfactory spinal cord posterior shift was achieved.

Nevertheless, there is no consensus over optimal surgical strategies for the treatment of cervical OPLL involving C2 because C2 occupies a pivotal position for maintaining the cervical spine alignment and stability[12]. There are several extensors attached to the C2 lamina and spinous process, including the semispinalis cervicis, obliquus capitis inferior, and rectus capitis posterior major. Biomechanical experiments have demonstrated that these extensors and C2 combined with ligaments act as the main dynamic stabilizers that are beneficial for maintaining static and dynamic equilibria of the cervical spine and play a major role in maintaining the lordosis and alignment of the cervical spine[20, 21]. Inoue *et al.* [22]noted that a kyphotic deformity in the upper cervical spine and compensatory lordosis of the lower cervical spine developed in patients who underwent C2 lamina removal. In traditional cervical laminoplasty, many patients have suffered from neck axial pain and neck stiffness due to destruction of the posterior cervical deep extensors[23]. Therefore, modified laminoplasty that preserves the deep extensors has been developed, such as C4–C7 laminoplasty combined with C3 laminectomy, or laminoplasty with preservation of the C2 and C7 spinous processes achieved better clinical outcomes. The authors considered that protection of the anatomical structures around the cervical spine such as the extensors and ligaments resulted in better cervical ROM and alleviation of neck axial pain[8, 24, 25].

There are various surgical strategies for cervical OPLL involving C2 with individual advantages and disadvantages. Liu *et al.*[5] preferred C2–C7 open-door laminoplasty due to the satisfactory functional outcomes, but the incidence of neck axial pain and volume of blood loss were significantly greater than those in patients who underwent C3–C7 laminoplasty alone. The clinical results were consistent with our study; the higher incidence of postoperative neck axial pain and increased volume of blood loss in the C2OL group might be attributable to extended destruction and additional injury of significant musculature attachments at C2[26]. Takeshita *et al*[27]. applied French-door laminoplasty for C2 decompression. Although the musculature attachments at C2 were reconstructed intraoperatively, the C2–C7 Cobb angle decreased significantly. Wang *et al.*[28] applied C2–C7 open-door laminoplasty combined with instrumented fusion to prevent cervical alignment loss, but cervical spine fusion resulted in cervical ROM reduction. When OPLL involves the C2 segment, adequate posterior decompression and preservation of the musculature attachments at C2 seems to be contradictory, and achieving both is technically demanding for clinicians. However, Matsuzaki *et al.*[12] invented open-door laminoplasty combined with C2 dome-like decompression for cervical OPLL involving C2 that fully preserved the C2 dorsal structure intact and can be performed safely. During the procedures, a dome-like cavity was created on the ventral cortex of the C2 lamina using a high-speed burr; moving the burr in a semicircular motion to prepare a well-proportioned groove according to the configuration of the dura mater was crucial to generate sufficient space available for spinal cord posterior shift. The authors applied this novel technique in 33 patients, and improvements in clinical symptoms were observed in all patients without catastrophic complications[12]. Sun *et al.*[29] applied C2DL for the treatment of cervical spinal stenosis in 28 patients. The neurological function improved significantly, mean cervical ROM decreased slightly, and incidence of neck axis pain was 14.29%. In our study, we applied open-door laminoplasty combined with C2 dome-like decompression in the C2DL group with satisfactory functional outcomes. The incidence of neck axis pain in the C2DL group was 15.0%, which was similar to that reported by Sun *et al.*[29] Compared with those in the C2OL group, the lower incidence of neck axial pain and volume blood loss in the C2DL group may be attributable to preservation of the musculature attachments at C2[5].

Although the original intention of laminoplasty was to preserve the cervical ROM, It has been reported that 30%–70% of patients experienced loss of cervical ROM during the follow-up[30, 31]. According to study by Hyun *et al.* [31], the overall cervical ROM decreased by 38.5% compared to the baseline after laminoplasty, 77.7% of patients with OPLL developed autofusion, and the mean cervical ROM decreased by 52.8% five years postoperatively. In the current study, the ROM of the cervical spine in the C2OL and the C2DL groups decreased by 57.2% and 40.0% at the final follow-up, respectively. We suggest that the overall reduced cervical ROM is attributed to alterations in tissue elasticity after posterior neck muscle dissection. Laminoplasty including the C2 lamina also resulted in worsening of cervical alignment. An analysis conducted by Kawaguchi *et al.*[32] showed that the alignment decreased by 7.3° after *en bloc* laminoplasty in 16 patients. In the study by Takeshita *et al.*,[27] the mean C2–C7 Cobb angle decreased in the French-door laminoplasty group and dome-like expansive laminoplasty group were 8.3° and 5.2°, respectively, which were similar to that in our study. The authors insisted that laminoplasty including the C2 lamina resulted in worsening of cervical alignment compared with cases in which the C2 lamina was retained. In our study, the mean C2–C7 Cobb angle decreases in the C2OL and C2DL groups was 9.2°and 6.9°, respectively. Based on the radiographical outcomes, the patients who underwent C2DL achieved better cervical alignment and ROM than those who underwent C2OL. We suggest that the cervical deep extensors attached to C2 spinous process and lamina play an important role. Therefore, we can conclude that preserving the attachment of the extensors at C2 facilitates the maintenance of cervical ROM and cervical lordosis preliminarily.

Although satisfactory outcomes were obtained in both groups and there were no severe complications in our study, complications associated with C2DL should be noted. Shimizu *et al.*[33] reported a case of fracture of the C2 lamina that occurred after dome-like expansive laminoplasty and caused neural compression due to excessive lamina grinding. Therefore, preoperative feasibility and safety evaluation of C2DL based on CT is required. Additionally, care should be taken to avoid excessive lamina removal, and the possibility of axial fracture occurring after the procedure should be considered. In our study, we implemented the following strategies to preclude insufficient decompression or excessive C2 lamina removal. First, we measured the thickness of the C2 lamina accurately on CT scans and predesigned the decompression area preoperatively. Second, it was necessary to explore the residual thickness of C2 the lamina during grinding. The principle of decompression is to ensure that there is no obvious pressure on the dura mater and to avoid an excessively wide scope of bilateral decompression and inordinate lamina removal.

Our study has some limitations. First, this was a single-institution retrospective study with a small sample size, this limits the external validity and conclusions that can be drawn. Second, although we reviewed cases using the same inclusion criteria, the selection bias with retrospective studies may have an impact on the conclusions. Third, the factor of OPLL progression was not considered, potentially affecting the final functional outcomes. Therefore, further prospective multi-institutional studies with larger sample size and long-term follow-up should be conducted to achieve a more reliable conclusion.

Conclusions

Both C2OL and C2DL are effective for treating multilevel cervical OPLL involving C2. C2DL is not only less traumatic, but also beneficial for maintaining the cervical curvature and ROM and reducing neck axial pain. It is a favorable alternative to C2OL for treating multilevel cervical OPLL involving C2.

Declarations

Acknowledgements

Not applicable

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Availability of data and materials

The datasets generated and analyzed during the present study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study was approved by the Changzheng Hospital ethics committee (IRB, 2020182). All methods were performed in accordance with the relevant guidelines and regulations. And all patients included in this study gave their informed consent.

Consent for publication

All data published here are under the consent for publication. Written informed consent was obtained from all individual participants included in the study.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1

Patients’ general information.

Characteristic	C2OL Group (n=36)	C2DL Group (n=40)
Sex (n, %) *		
Male	20 (55.6)	25 (62.5)
Female	16 (44.4)	15 (37.5)
Age at operation (years)†	54.9 ± 8.6	55.8 ± 8.3
Active smoker (n, %) *	16 (44.4)	17 (42.5)
Patients with diabetes (n, %) *	11 (30.6)	14 (35.0)
SDP (months)†	14.7 ± 6.6	13.6 ± 6.4
Blood loss (ml)‡	291.9 ± 63.0	243.5 ± 49.2
Operation time (minutes)†	138.2 ± 26.6	132.2 ± 23.9
Follow-up time (months)†	46.4 ± 8.8	46.4 ± 7.4
Postoperative complication (n, %)		
Wound infection	1 (2.7)	0
C5 palsy	1(2.7)	1(2.5)
Cerebrospinal fluid leakage	0	1(2.5)

Data are expressed as mean ± SD unless otherwise indicated.

DM, diabetes mellitus; SDP, symptomatic duration preoperative; C2OL, C2 open-door laminoplasty; C2DL, C2 dome-like laminoplasty.

*P□0.05, comparison between groups using c^2test.

†P□0.05, comparison between groups using Student *t* test.

‡P□0.05, comparison between groups using Student *t* test.

Table 2

Functional outcomes of two groups.

Variable	C2OL group (n=36)	C2DL group (n=40)
JOA score		
Pre-operation†	7.4 ± 1.1	7.1 ± 0.9
Final visit†	12.2 ± 1.6#	11.9 ± 1.4#
RR (%)†	50.4 ± 13.9	47.9 ± 14.8
VASSNP		
Pre-operation†	4.8 ± 1.2	4.6 ± 1.3
Final visit‡	2.3 ± 0.8#	1.5 ± 0.6#
Neck axial pain (n, %) *	14 (38.9)	6 (15.0)
NDI (%)		
Pre-operation†	36.9 ± 10.4	37.2 ± 9.8
Final visit†	13.8 ± 3.0#	13.7 ± 3.4#
SF-36 PCS (score)		
Pre-operation†	24.6 ± 6.1	24.0 ± 5.0
Final visit†	35.4 ± 7.5#	35.7 ± 7.2#

Data are expressed as mean ± SD unless otherwise indicated. JOA, Japanese Orthopedic Association; VASSNP, visual analog scale score for neck pain; NDI, Neck Disability Index; SF-36, 36-Item Short Form Health Survey;

RR, recovery rate; C2OL, C2 open-door laminoplasty; C2DL, C2 dome-like laminoplasty.

†P□0.05, comparison between groups using Student *t* test.

‡P□0.05, comparison between groups using Student *t* test.

*P□0.05, comparison between groups using c^{2}test.

#P□0.05, compared with preoperative variable within group using Student *t* test.

Table 3

Radiographical outcomes of two groups.

Variable	C2OL group (n=36)	C2DL group (n=40)
OPLL type (n, %) *		
segmental	9 (25.0)	11 (27.5)
continuous	15 (41.7)	16 (40.0)
mixed	12 (33.3)	13 (32.5)
C2-C7 Cobb angle		
Preoperative†	14.6° ± 4.8°	14.7° ± 4.7°
Final visit‡	5.4° ± 2.3°$^{\#}$	7.9° ± 2.4°$^{\#}$
Cervical ROM		
Preoperative†	30.2° ± 10.2°	32.3° ± 9.6°
Final visit‡	11.0° ± 4.8°$^{\#}$	14.1° ± 6.6°$^{\#}$
SAC at C2 (mm)		
Preoperative†	9.8 ± 1.2	10.2 ± 1.3
Final visit†	19.0 ± 2.6$^{\#}$	19.4 ± 2.0$^{\#}$

Data are expressed as mean ± SD unless otherwise indicated. OPLL, ossification of posterior longitudinal ligament; SAC, space available for the spinal canal; ROM, range of motion; C2OL, C2 open-door laminoplasty; C2DL, C2 dome-like laminoplasty.

†P□0.05, comparison between groups using Student *t* test.

‡P□0.05, comparison between groups using Student *t* test.

*P□0.05, comparison between groups using c^2test.

$^{\#}$P□0.05, compared with preoperative variable within group using Student *t* test.

Figures

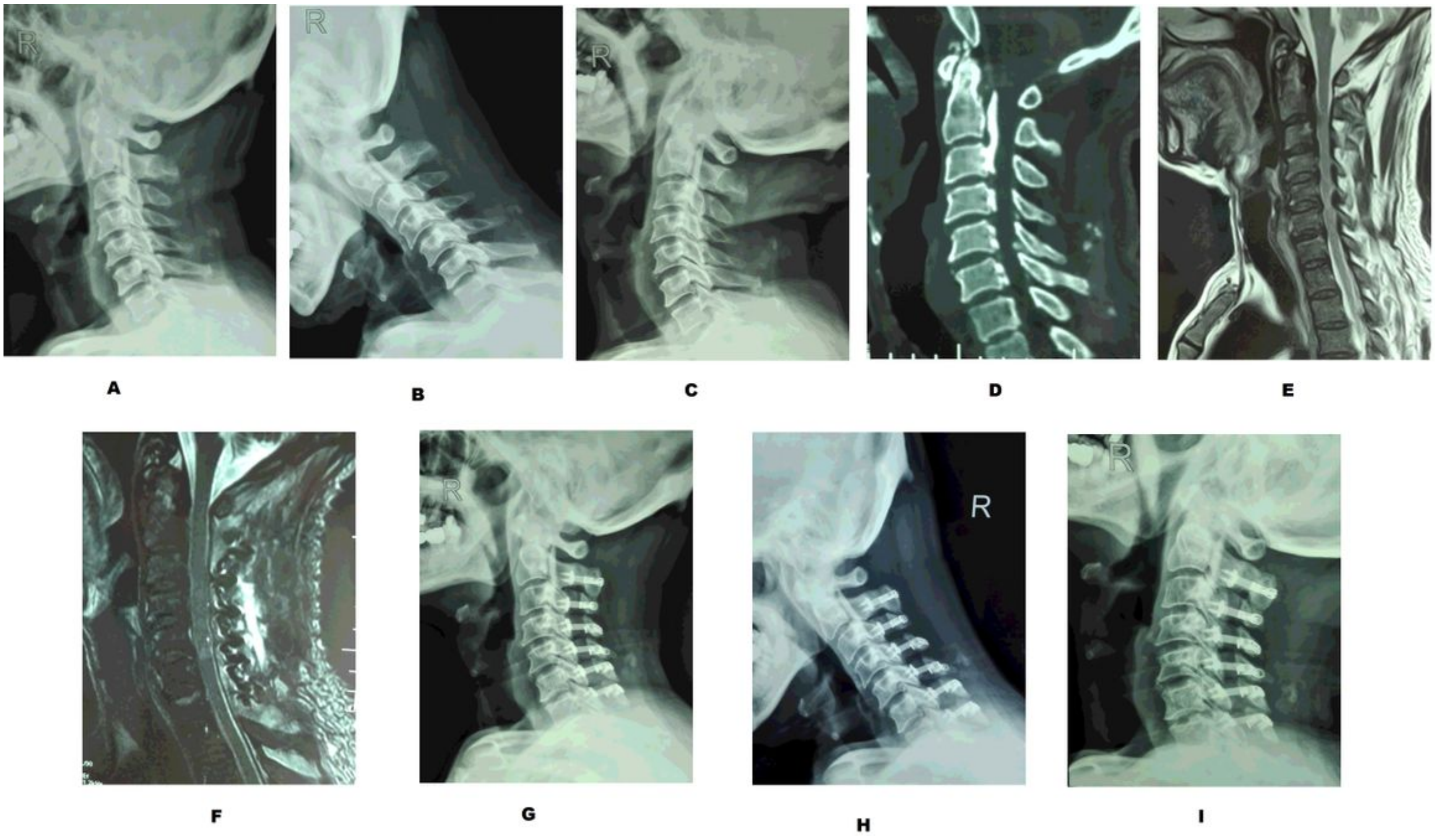

Figure 1

A case with mixed type of OPLL managed with C2-7 open-door laminoplasty. Preoperative lateral radiographs of the cervical spine in neutral (A), flexion (B) and extension position (C) showing OPLL involving C2. Preoperative CT with sagittal reconstruction (D) and MRI (E) showing the spinal cord compression from C2 to C7. Postoperative sagittal MRI (F) showing the spinal cord decompressed sufficiently. Lateral radiographs of the cervical spine in neutral (G), flexion (H) and extension (I) at 36 months postoperatively showing no cervical instability and kyphosis.

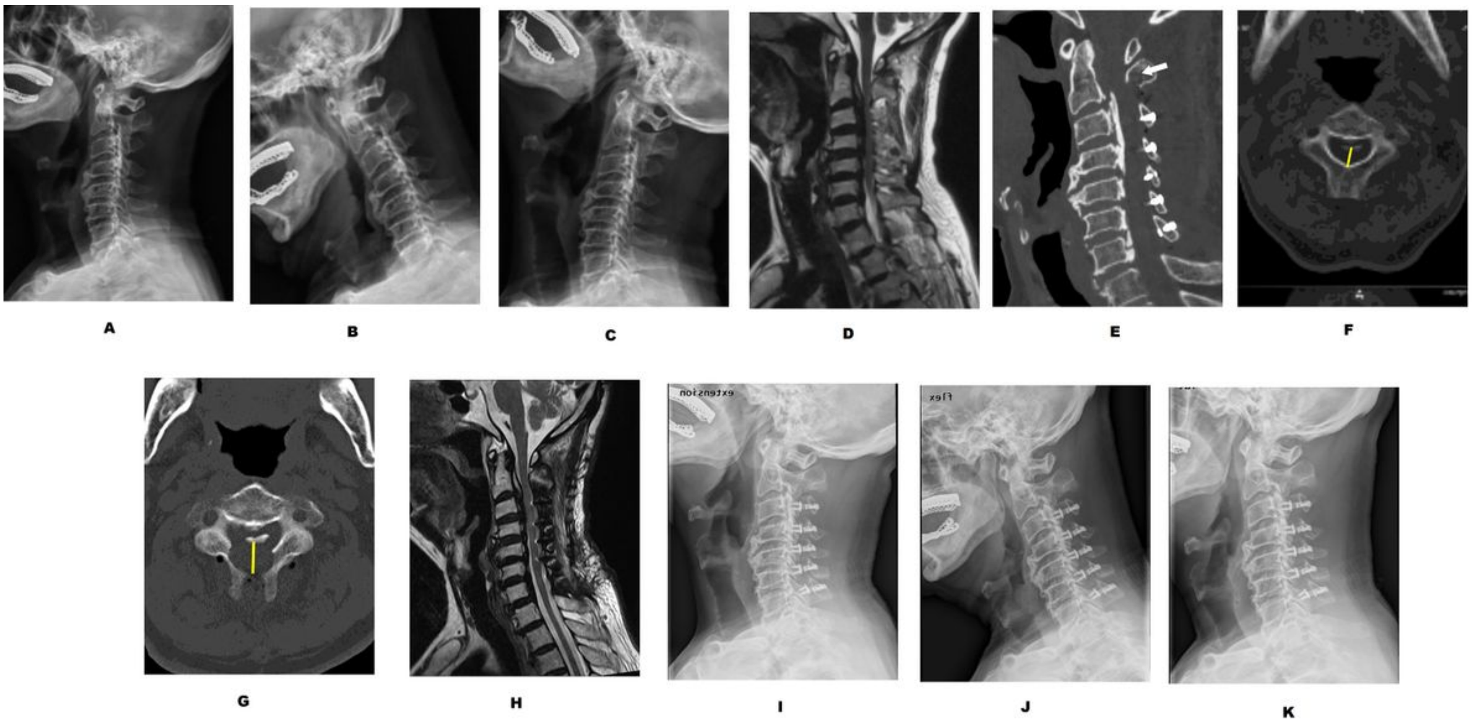

Figure 2

A case with mixed-type of OPLL managed with C2-7 laminoplasty combined with C2DL. Preoperative lateral radiographs in neutral (A), flexion (B), and extension (C) positions showing multilevel cervical OPLL. Preoperative sagittal MRI (D) showing the spinal cord compression from C2 to C7. Postoperative CT and sagittal reconstruction (E) showing C3-C7 laminoplasty being performed with partial C2 ventral lamina removal (white arrow). Preoperative (F) and postoperative (G) axial CT images at C2 level demonstrating SAC increment from 10 mm to 19 mm after C2 partial ventral lamina removal and postoperative sagittal MRI (H) showing the spinal cord decompression completely from C2-C7. Lateral radiographs of the cervical spine in neutral (I), flexion (J) and extension (K) showing no instability and cervical kyphosis 36 months postoperatively.