A novel technique to correct kyphosis in cervical myelopathy due to continuous-type ossification of the posterior longitudinal ligament

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OBJECTIVE Although posterior decompressive surgery is widely used to treat patients with cervical myelopathy and multilevel ossification of the posterior longitudinal ligament (OPLL), a poor outcome is anticipated if the sagittal alignment is kyphotic (or K-line negative). Accordingly, it is mandatory to perform anterior decompression and fusion in patients with cervical kyphosis. However, it can be difficult to perform anterior surgery because of the high risk of complications. This present report proposes a novel “greenstick fracture technique” to change the K-line from negative to positive in patients with cervical myelopathy, OPLL, and kyphotic deformity.

METHODS Four patients with cervical myelopathy, continuous-type OPLL, and kyphotic sagittal alignment (who were K-line negative) were indicated for surgery. Posterior laminectomy and lateral mass screw insertions using a posterior approach were performed, followed by anterior surgery. Multilevel discectomy and thinning of the OPLL mass by bur drilling was performed, then an intentional greenstick fracture at each disc level was made to convert the cervical K-line from negative to positive. Finally, posterior instrumentation using a rod was carried out to maintain cervical lordosis.

RESULTS MRI showed complete decompression of the cord by posterior migration in all cases, which had been caused by cervical lordosis. Restoration of neurological defects was confirmed at the 1-year follow-up assessment. No specific complications were identified that were associated with this technique.

CONCLUSIONS A greenstick fracture technique may be effective and safe when applied to patients with cervical myelopathy, continuous-type OPLL, and kyphotic deformity (K-line negative). However, further studies with more cases will be required to reveal its generalizability and safety.

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KEY WORDS cervical myelopathy; kyphosis; K-line; anterior surgery; surgical technique

CERVICAL myelopathy is a common disease that is associated with hand clumsiness, gait disturbance, and/or weakness of the limbs. The mainstay of treatment for cervical myelopathy has involved surgery because conservative management may only be applicable to mild stenosis and has not generally been considered to be effective in moderate to severe stenosis.^{14,16,18} However, many surgical options exist, including anterior decompression and fusion, posterior laminoplasty, posterior laminectomy and fusion, and/or combined surgery.^{12,21} Levels of compression and the maintenance of cervical lordosis have been considered to be two important parameters for the selection of appropriate procedures.^{5,11} In patients with multilevel cord compression with a lordotic cervical spine, a posterior approach may be effective. However, poor clinical outcomes have been reported when posterior

decompressive surgery was performed in patients with a kyphotic cervical spine.^{17,19,20} Therefore, adequate correction of the cervical sagittal alignment by an anterior approach is considered to be important in cases of multilevel cervical cord compression with kyphotic deformity.²⁰ To restore cervical lordosis, anterior support achieved by intervertebral cage insertion may be effective.

However, an anterior approach can be associated with many problems if the cervical myelopathy is caused by continuous-type ossification of the posterior longitudinal ligament (OPLL). A risk of CSF leakage, longer operative duration, and/or technical difficulties has been reported to represent a challenge in patients with multilevel OPLL undergoing anterior decompression. Accordingly, we suggest herein a novel approach, the “greenstick fracture technique,” that is relatively easy, safe, and clinically effective

ABBREVIATIONS HRQOL = health-related quality of life; JOA = Japanese Orthopaedic Association; NDI = neck disability index; OPLL = ossification of the posterior longitudinal ligament; VAS = visual analog scale.

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TABLE 1. Baseline characteristics of the 4 patients with cervical myelopathy and continuous-type OPLL

Case No.	Age (yrs), Sex	Symptom Onset (mos)	Major Symptoms	Nurick Grade	JOA Score	C2–7 Lordosis*			Levels of OPLL	Follow-Up Period
						Neutral	Flexion	Extension		
1	68, M	24–36	Hand clumsiness, arm pain	1	13	4	–14	20	C3–4, C5–6	1yr 6 mos
2	55, M	4	Hand clumsiness	1	14	4	–14	15	C4–7	1 yr
3	68, M	120	Gait disturbance, hand clumsiness	2	11	–3	–18	0	C2–5	1 yr
4	62, F	24	Hand clumsiness, arm pain	1	14	–1	–26	3	C2–6	1 yr

The preoperative K-line was negative in all cases.

* A negative value indicates kyphosis.

for restoring cervical lordosis. We aimed in this study to establish a new technique for the treatment of patients with cervical myelopathy that results from multilevel OPLL and kyphosis.

Methods

Patient Population

Patients with cervical myelopathy, continuous-type OPLL, and kyphotic sagittal alignment (who were K-line negative) were indicated for surgery. A total of 4 patients were retrospectively reviewed in this study. All patients exhibited cervical myelopathy–related symptoms upon cord compression with continuous-type OPLL and sagittal kyphotic alignment. A visual analog scale (VAS) was used to measure neck pain and arm pain. A neck disability index (NDI) and Japanese Orthopaedic Association (JOA) score were used to assess the degree of disability. Health-related quality of life (HRQOL) was measured using SF-36 scores. All patients were followed-up for 1 year postoperatively. Basic patient demographic data, symptoms, and radiological characteristics are summarized in Table 1. All cases exhibited cord compression by multilevel OPLL and the loss of cervical lordosis. Among the 4 patients, 2 (Cases 3 and 4) did not show cervical lordosis in the extension position. An example (Case 1) is shown in Fig. 1. This study was approved by the institutional review board of our institution, which waived the requirement for informed consent due to the retrospective nature of the study.

Surgical Technique

In general, posterior surgery was initially performed. Then, anterior and posterior surgeries were planned 1 week later. Using a posterior midline approach, a total laminectomy was performed from C-3 to C-6. An additional partial laminectomy (undercutting) was performed in C-2 or C-7. Then, lateral mass screws were inserted from C-3 to C-6 and laminar and pedicle screws were inserted in C-2 and C-7, respectively. At 1 week after the initial posterior surgery, anterior surgery was performed. Using a Smith-Robinson approach, the C3–7 disc space was exposed. At each disc level, thinning of the OPLL mass was achieved by bur drilling following discectomy. Without attempting complete excision of the OPLL mass, an incomplete fracture was created in the shallow OPLL mass with a laminar spreader. A lordotic allograft was then inserted at each disc level to restore cervical lordosis. This procedure, termed the “greenstick fracture technique,” is illustrated

in Fig. 2. On the same day, posterior rod insertion with a compression maneuver between screws was conducted to maintain cervical lordosis. After the second stage of surgery, patients were cared for in the intensive care unit for 1 day to monitor airway function and to assess whether it was compromised.

Results

All 4 patients exhibited improvement of both subjective symptoms and clinical scores. Arm pain VAS scores decreased (from 6 to 0, from 3 to 0, from 5 to 3, and from 8 to 5) and JOA scores improved (from 13 to 16, from 14 to 17, from 11 to 13, and from 14 to 17) in the postoperative 1-year period. HRQOL also showed overall improvement in all patients (Table 2). In 1 patient (Case 1), C-5 nerve palsy was observed after the first stage of surgery. Additional total foraminotomy was performed on the left C4–5 level and bilateral C5–6 level at the second stage of the operation. However, deltoid power in this patient fully recovered by 1 month postoperatively. Otherwise, no specific complications were identified. The mean operative time was 128.5 and 265.0 minutes in the first and second stages of the operation, respectively. The mean estimated blood loss was 200 and 350 ml in the first and second stages of the operation, respectively. None of the patients received a blood transfusion.

Radiological parameters regarding cervical sagittal alignment improved postoperatively. C2–7 lordosis was restored in the 4 patients from 4° to 27°, from 4° to 18°, from –3° to 23°, and from –1° to 26°. Postoperative lateral radiographs revealed cervical lordosis that was K-line positive in all cases and postoperative MRI showed no compressive lesions. Examples (Cases 3 and 4) are shown in Figs. 3 and 4.

Discussion

Cervical myelopathy resulting from OPLL is a common condition that can lead to cervical cord compression and requires surgical decompression.^{1,3} Although the selection of an anterior or posterior approach has been the subject of debate, multilevel cord compression by OPLL and preoperative lordotic sagittal alignment are conditions that favor a posterior approach.¹¹ However, many studies have shown that poor clinical and radiological outcomes may occur if posterior laminoplasty or laminectomy is performed in patients with cervical kyphosis.^{4,19,20} Thus, it is predicted that favorable outcomes should be expected

FIG. 1. Case 1. Images obtained in a 68-year-old man who exhibited clumsiness in both hands as well as pain with numbness in both hands for 2–3 years. **A:** Preoperative plain lateral radiographs showing that an OPLL mass (*dashed line*) touched the K-line. **B:** Flexion and extension lateral radiographs. **C:** A lateral reconstructed CT image showing an OPLL mass. **D:** A double-layer sign (*arrow*) shown on an axial CT scan.

FIG. 2. Illustration of the mechanism underlying the greenstick fracture technique. **A:** Huge OPLL mass (*gray area*) with a kyphotic deformity that was K-line negative. **B:** Thinning of the OPLL mass at each disc level. **C:** A greenstick fracture with an interbody cage results in restoration of cervical lordosis (K-line positive). Figure is available in color online only.

TABLE 2. Pre- and postoperative HRQOL scores

Case No.	NDI		SF-36 PCS		SF-36 MCS	
	Preop	Postop	Preop	Postop	Preop	Postop
1	13	11	33.8	45.2	47	49.9
2	0	4	41.4	57.7	48	52.9
3	17	7	18.2	27.4	40.5	54.6
4	5	17	37.6	39.1	40.6	44.1

MCS = mental component summary; PCS = physical component summary.

when cervical lordosis is maintained because it can permit a backward shift of the cord.⁴ However, the cutoff value of kyphosis for a favorable outcome is also the subject of debate. According to one study, a good outcome may be anticipated when posterior laminoplasty is performed if the degree of kyphosis is less than 10°.²⁰

In this context, the K-line concept has been proposed to

be a reliable indicator that may predict outcomes following posterior surgery in patients with cervical myelopathy and OPLL.⁷ The K-line is the line that connects the midpoint of the vertebral canal at the levels of C-2 and C-7 on the lateral radiograph.⁷ It has been suggested that a sufficient posterior shift of the cord will not be obtained after posterior decompressive surgery in the K-line negative group.⁷ Accordingly, if the protruding OPLL mass touches the K-line (K-line negative), even with a lordotic cervical spine, patient outcomes following posterior laminoplasty will not be favorable because cord compression can remain. However, the K-line itself represents a modifiable parameter. Thus, we proposed to change the K-line itself in our present study by restoring cervical lordosis.

To convert cases from K-line negative to positive, an anterior approach is recommended in cases with multilevel OPLL. Anterior decompression with fusion has been associated with improved postoperative neurological function when used for patients with multilevel cervical

FIG. 3. Case 3. Images from a 68-year-old man who exhibited hand clumsiness and slowly progressive gait disturbance for 10 years. **A:** Preoperative lateral radiograph showing that the patient was K-line negative. *Dashed line* indicates the OPLL mass. **B:** Dynamic lateral radiographs showing an inability to extend the neck. **C:** A huge continuous OPLL mass (*arrows*) shown on a sagittal CT reconstruction image. **D:** Severe cord compression revealed on a sagittal T2-weighted MR image. **E:** A postoperative lateral radiograph showing that this patient was K-line positive. **F:** Sagittal CT reconstruction image showing the remaining thin OPLL mass (*arrows*). **G:** A well-decompressed state was revealed by sagittal MRI.

compressive myelopathy.^{9,12} However, for anterior surgery in patients with OPLL, it has been reported that this approach is technically demanding and associated with a higher incidence of operation-related complications.^{1,9} These complications included the risk of a dural tear or CSF leakage, which was difficult to repair in anterior cervical surgery.^{2,13} The incidence of dural tear and CSF leakage has been reported to be 13.7-fold greater in patients with OPLL compared with patients affected by other conditions.⁸ It has also been reported that CSF leakage frequently occurs when a double-layer sign can be identified by a CT scan, which also occurred in our cases (Fig. 1D).²² Thus, aggressive attempts to remove a whole OPLL mass may increase the risk of a dural tear, which could hinder the delicate surgical process and lead to secondary complications, such as infections or wound problems. Our greenstick fracture technique has been developed to convert the K-line by restoring cervical lordosis without the risk of a dural tear or CSF leakage. Previously, an anterior floating method combined with corpectomy has been used, which may be suitable for cases with massive

OPLL and preoperative kyphotic alignment.¹⁵ However, this technique was associated with many complications, such as nonunion, graft trouble, and a difficult learning curve.^{6,10} These disadvantages can be overcome by our novel technique, which does not require corpectomy or complete anterior decompression; thus, it is technically easier than the conventional floating technique. Furthermore, a 2-stage operation also has advantages because longer operative time itself can be a risk factor for perioperative complications, and some procedures such as additional foraminotomy can be added in the second stage of the operation if arm pain persists or neurological deficit such as C-5 nerve palsy develops. However, this technique has been performed in only 4 patients, so its generalizability is questionable. Furthermore, possible complications related to long operative time and deformity correction should be considered, although fortunately they were not found in these cases.

To summarize, a greenstick fracture technique represents a relatively easy and safe procedure that can be used in patients with cervical myelopathy, continuous-type

FIG. 4. Case 4. Images obtained in a 62-year-old woman who exhibited hand clumsiness and right-sided arm pain for 2 years. **A:** Preoperative lateral radiograph showing an OPLL mass (dashed line) and kyphotic deformity that was K-line negative. **B:** Dynamic lateral radiographs showing an inability to extend the neck. **C:** Continuous-type OPLL mass at the C2–6 level shown on a sagittal CT reconstruction image. **D:** Postoperative lateral radiograph showing the lordotic alignment, K-line positive. **E:** Sagittal CT reconstruction image demonstrating the remaining thin OPLL mass (arrows).

OPLL, and kyphotic alignment. Both complete decompression of the cord and restoration of cervical lordosis can be achieved using this technique. However, further studies with more cases will be required to reveal its generalizability and safety.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Cho, DH Lee. Acquisition of data: Joo. Analysis and interpretation of data: Joo. Drafting the article: Cho. Critically revising the article: Cho, DH Lee, Hwang, CS Lee. Reviewed submitted version of manuscript: DH Lee, CS Lee. Approved the final version of the manuscript on behalf of all authors: Cho. Statistical analysis: Joo. Administrative/technical/material support: DH Lee, Hwang, CS Lee. Study supervision: Hwang, CS Lee.

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