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Functional recovery after laminoplasty versus staged anterior–posterior fusion for multilevel cervical ossification of the posterior longitudinal ligament

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Abstract

Background Ossification of the posterior longitudinal ligament (OPLL) causes progressive narrowing of the cervical canal and neurological deficits. Cervical laminoplasty (LP) and staged anterior–posterior fusion (APF) are widely used, but their comparative outcomes remain controversial. This study compared clinical and radiographic outcomes of LP and APF for multilevel OPLL, with analysis according to OPLL subtype.

Methods We retrospectively reviewed 217 patients with cervical OPLL who underwent LP ($n = 135$) or APF ($n = 82$) between 2014 and 2023. All patients had ≥ 3 operated levels and ≥ 1-year follow-up. Clinical outcomes included Japanese Orthopaedic Association (JOA) score, Neck Disability Index (NDI), visual analog scale (VAS) for pain, and subjective improvement rate (IR). Radiographic outcomes included C2–7 lordosis and sagittal vertical axis (SVA). Assessments were performed preoperatively and at 6 months, 1 year, and 2 years. Between-group comparisons and longitudinal analyses were performed using t-tests, chi-square tests, and repeated-measures ANOVA.

Results Baseline characteristics were comparable between groups. Both LP and APF significantly improved neck and arm pain and JOA scores, with no group difference at 2 years. APF achieved greater correction of sagittal alignment, with larger improvements in C2–7 lordosis across all OPLL types ($p < 0.001$). However, APF patients had consistently higher NDI scores during early follow-up ($p < 0.001$), particularly in domains requiring cervical motion (personal care, lifting, work, driving). Subgroup analysis showed that patients with segmental-type OPLL experienced the greatest postoperative disability after fusion due to higher preoperative motion. These differences gradually decreased by 2 years, indicating functional adaptation. Although the difference did not reach statistical significance ($p = 0.0719$), there was a trend toward higher IR in the APF group.

Conclusion Both LP and APF provided significant neurological recovery and pain relief in multilevel OPLL. APF yielded superior sagittal alignment but was associated with higher early postoperative disability, most pronounced in segmental-type OPLL. Differences diminished by the second postoperative year, suggesting patient adaptation.

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Surgical decision-making should consider OPLL subtype, preoperative mobility, and the trade-off between motion preservation and alignment correction.

Keywords Ossification of the posterior longitudinal ligament, Cervical laminoplasty, Posterior cervical laminectomy and fusion, Spinal surgery, Clinical outcomes, Neck disability index

Introduction

Ossification of the posterior longitudinal ligament (OPLL) is a progressive, degenerative condition that predominantly affects the cervical spine. This leads to the gradual narrowing of the spinal canal and subsequent spinal cord compression [1, 2]. Its prevalence is notably higher in East Asian populations, with rates reported up to 2–4% in countries such as Japan and Korea [3–5]. Clinically, OPLL may manifest a wide spectrum of symptoms ranging from mild neck pain to severe myelopathy characterized by motor weakness, sensory deficits, and autonomic dysfunction [1–6].

Surgical decompression is generally indicated in patients with progressive neurological deterioration [7]. Among the posterior surgical approaches, cervical laminoplasty (LP) and staged anterior and posterior fusion (APF) are the most commonly employed techniques [8]. Laminoplasty aims to expand the spinal canal while preserving the posterior osseoligamentous structures, thereby maintaining cervical motion. This approach has been associated with favorable neurological recovery in appropriately selected patients, particularly those with preserved cervical lordosis. In contrast, laminectomy with fusion involves the removal of the lamina combined with posterior instrumentation to stabilize the cervical spine, which is advantageous in patients presenting with preoperative kyphotic deformity or extensive OPLL, as it facilitates the restoration and maintenance of sagittal alignment [9–11].

Despite the effectiveness of both surgical techniques in achieving spinal cord decompression, controversy remains regarding their relative impact on postoperative sagittal balance, neurological improvement, and disability progression, especially when outcomes are analyzed according to different OPLL subtypes (continuous, segmental, and mixed) [2].

This study aimed to conduct a comparative analysis of posterior LP and APF in patients with OPLL. We assessed the postoperative sagittal alignment, functional recovery (using the Japanese Orthopedic Association (JOA) score) [12, 13], and neck disability (using the Neck Disability Index (NDI)) [14] over a 2-year follow-up period. In addition, subgroup analyses based on OPLL morphology were conducted to elucidate whether its specific subtypes may benefit preferentially from one surgical approach over the other. The ultimate goal was to provide evidence-based recommendations that can enhance surgical planning and improve patient outcomes.

Methods

Study design and patient selection

This retrospective cohort study included patients who underwent posterior cervical surgery for OPLL between March 2014 and December 2023. The patients were categorized into two groups based on the surgical approach: LP ($n = 135$) and posterior APF ($n = 82$) groups. All patients included in the study underwent surgery involving three or more levels. The inclusion criteria were as follows: patients diagnosed with cervical myelopathy due to OPLL, with a minimum follow-up duration of 1 year. The exclusion criteria included focal-type OPLL, previous cervical surgery, laminoplasty combined with anterior cervical surgery, trauma, infection, congenital abnormalities, Radiographic degenerative instability (> 3 mm translation or > 11° angulation on flexion–extension view) also led to exclusion and a follow-up duration of less than 1 year. Of the initially screened 268 patients, 21 were excluded for focal-type OPLL, 9 for prior cervical surgery, 7 for trauma, 4 for infection, and 10 for follow-up less than 1 year, leaving 217 patients included in the final analysis. This study was approved by the appropriate Institutional Review Board and Ethics Committee, which waived the need for informed consent (3–2021-0398).

Surgical protocol

Laminoplasty (LP)

All patients underwent expansive open-door laminoplasty using buttress plates. The level of LP was determined based on the degree of spinal cord compression and the presence of cord signal changes on MRI. In most cases, the right side was used to open the laminae. In other cases with left-sided symptoms, the laminae were opened on the left side. Dome-shaped undercutting (dome laminoplasty) was performed for decompression at the C2 and C7 levels. All patients were required to wear a Miami J cervical collar for 6 weeks postoperatively.

Staged anterior and posterior fusion (APF)

In principle, multilevel anterior cervical discectomy and fusion (ACDF) using allogeneic bone without anterior plate fixation was performed at each level included in the planned posterior fusion. However, the C3/4 level was selectively addressed anteriorly depending on individual pathology and surgeon judgment; in such cases, posterior decompression and instrumented fusion still spanned the involved levels. Posteriorly, neural decompression and instrumentation were performed using lateral mass screws proximal to C6 and pedicle screws at C7–T1, followed by posterolateral fusion with autogenous spinous-process and lamina grafts. All patients wore a Miami J collar for 3 months (Fig. 1).

Radiological and clinical outcome measures

All radiographs were reviewed, and the radiographic parameters were measured using Centricity (Enterprise Web ver. 3.0; GE Healthcare, Chicago, IL, USA). Standing lateral radiographs were used to measure the C2-7 Cobb lordotic angle, defined as the angle between the inferior endplates of C2 and C7, and the C2-7 sagittal vertical axis (cSVA), defined as the distance between the vertical line from the center of the C2 body and the posterosuperior corner of C7. Utilizing preoperative CT sagittal view, the OPLL subtypes were sorted into segmental, continuous, and mixed types [15, 16].

Neck and arm pain were evaluated using a 10-point visual analog scale (VAS). The NDI was used to assess neck pain and functional impairment, with scores expressed as a percentage (0–50). Additionally, detailed NDI scores for ten functional domains were evaluated, each scored on a 5-point scale. Functional impairment was further assessed using a modified JOA scale, ranging from 0 to 17. The subjective improvement rate (IR), as reported by the patient, using a 0–100 scale. The clinical and radiographic outcomes were assessed preoperatively and at 6 months, 1 year, and 2 years postoperatively, and analyses included all available 2-year data. Two independent observers (senior resident, attending surgeon) performed measurements twice, 4 weeks apart; intra- and inter-observer ICCs for cSVA and lordosis were 0.91 and 0.88, respectively.

Statistical analysis

Between-group comparisons were performed using an independent two-sample t-test for continuous variables and the chi-square test (or Fisher's exact test) for categorical variables. Normality of continuous variables was assessed using the Shapiro–Wilk test. If normality assumptions were violated, non-parametric tests (Mann–Whitney U test) were applied, yielding results consistent with the primary analyses. Given the imbalance in OPLL subtype distribution, we additionally performed multivariable logistic regression adjusting for surgical method, OPLL subtype, age, and sex. Longitudinal changes over time were analyzed using a linear mixed model and repeated-measures analysis of variance. Missing data $<$ 5% were handled with maximum-likelihood estimation in the mixed model; no imputation was required. Sensitivity analyses excluding cases with missing 2-year

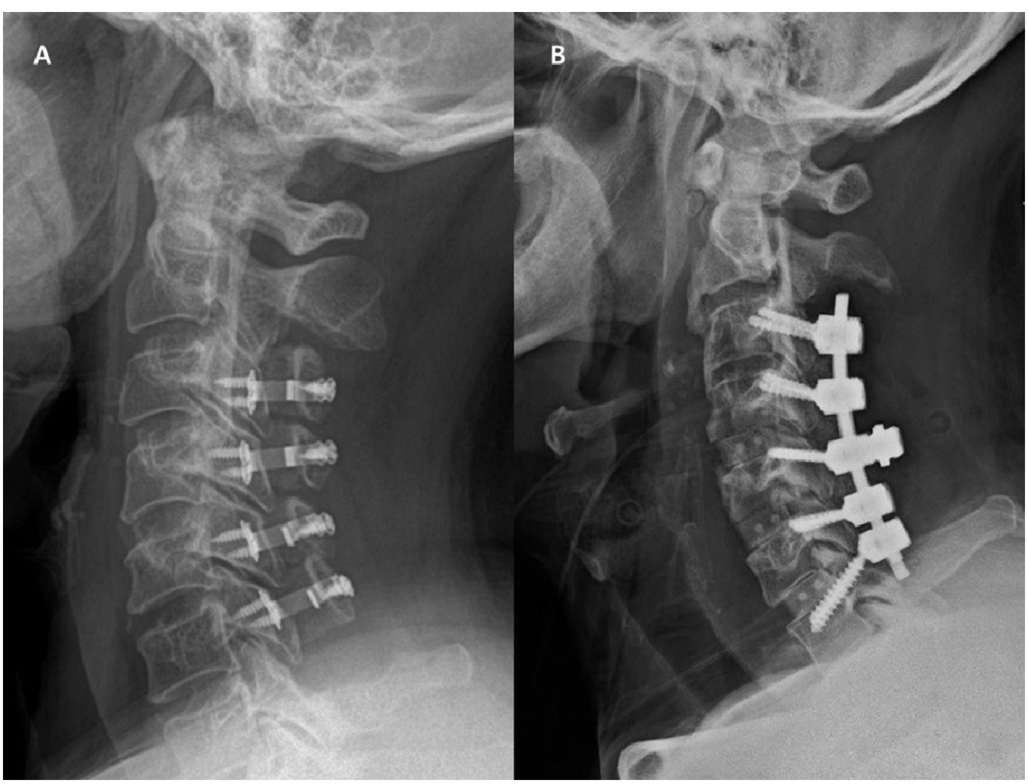

Fig. 1 Postoperative lateral cervical spine radiographs of patients with ossification of the posterior longitudinal ligament (OPLL) following posterior cervical surgery. **A** Cervical laminoplasty (LP), **B** Staged anterior and posterior fusion (APF). LP, cervical laminoplasty; APF, Staged anterior and posterior fusion; OPLL, ossification of the posterior longitudinal ligament

Table 1 Demographic and clinical characteristics of LP and APF groups

Variables	Total (N = 217)	LP (N = 135)	APF (N = 82)	p-value
	Mean ± SD or N (%)	Mean ± SD or N (%)	Mean ± SD or N (%)	
Gender				0.261
Male	160 (73.7)	96 (71.1)	64 (78.1)	
Female	57 (26.3)	39 (28.9)	18 (21.9)	
Age	60.26 ± 12.43	59.54 ± 12.61	61.92 ± 11.88	0.076
Follow-up duration (Months)	27.75 ± 16.75	28.27 ± 15.12	26.56 ± 20.01	0.398
Surgical level				0.064
3	60 (27.6)	47 (34.8)	13 (15.8)	
4	131 (60.4)	78 (57.8)	77 (64.6)	
5	26 (11.9)	10 (7.4)	25 (19.5)	
OPLL type				0.010
Continuous	43 (19.8)	32 (23.7)	11 (13.4)	
Mixed	75 (34.6)	54 (40.0)	45 (54.9)	
Segmental	99 (45.6)	45 (33.3)	26 (31.7)	

Data are presented as mean ± standard deviation (SD) or N (%). P-values were calculated using the chi-square test for categorical variables and the t-test for continuous variables

OPLL, ossification of the posterior longitudinal ligament; LP, laminoplasty; APF, anterior–posterior fusion

Table 2 Comparison of the sagittal vertical axis (SVA) and C2-7 lordosis between LP and APF groups, stratified by the OPLL type

Variables		LP	APF	*p*-value
		MEAN ± SD	Mean ± SD	
Total				
SVA	Pre	23.87 ± 10.34	23.31 ± 12.33	0.718
	Post	27.60 ± 12.23	24.75 ± 11.58	0.091
C2-7 lordosis	Pre	8.82 ± 10.15	4.77 ± 10.09	0.005
	Post	4.59 ± 11.29	15.89 ± 10.24	< 0.001
Continuous-type OPLL				
SVA	Pre	25.93 ± 11.54	24.42 ± 8.60	0.693
	Post	29.67 ± 12.52	25.71 ± 9.07	0.341
C2-7 lordosis	Pre	9.14 ± 10.46	2.79 ± 5.63	0.063
	Post	4.93 ± 11.01	14.94 ± 6.08	0.007
Mixed-type OPLL				
SVA	Pre	22.58 ± 10.35	27.75 ± 12.24	0.058
	Post	24.96 ± 13.07	27.25 ± 10.92	0.448
C2-7 lordosis	Pre	8.42 ± 8.33	6.07 ± 10.60	0.295
	Post	2.69 ± 12.37	16.48 ± 9.35	< 0.001
Segmental-type OPLL				
SVA	Pre	23.83 ± 9.56	20.47 ± 12.56	0.135
	Post	28.77 ± 11.02	23.07 ± 12.39	0.017
C2-7 lordosis	Pre	8.99 ± 11.54	4.50 ± 10.69	0.049
	Post	6.12 ± 10.34	15.77 ± 11.59	< 0.001

Values are presented as mean ± standard deviation (SD). P-values were calculated using the independent *t*-test

OPLL, ossification of the posterior longitudinal ligament; SVA, sagittal vertical axis; Pre, preoperative; Post, postoperative; LP, laminoplasty; APF, anterior–posterior fusion

PROs showed consistent results. (ANOVA). All statistical analyses were conducted using SAS statistical software (version 9.4; SAS Inc., Cary, NC, USA). A *p*-value of < 0.05 was considered statistically significant.

Results

Baseline characteristics

There were no significant differences in demographic factors between LP and APF groups. Sex distribution was similar, with 96 males (71.1%) and 39 females (28.9%) in the laminoplasty group and 64 males (78.1%) and 18 females (21.9%) in the APF group ($p = 0.261$). The mean patient age was 59.54 ± 12.61 years in the laminoplasty group and 61.92 ± 11.88 years in the APF group ($p = 0.076$). The mean follow-up duration was comparable between the groups ($p = 0.398$).

The average operated levels was 3.9 ± 0.6 (LP) vs. 4.1 ± 0.7 (APF) (p = 0.064). The OPLL type distribution showed a statistically significant difference ($p = 0.010$), with continuous-type OPLL more common in the LP group (23.7% vs. 13.4%) and mixed-type OPLL more frequent in the APF group (54.9% vs. 40.0%). Segmental-type OPLL was similarly distributed between the 2 groups (33.3% vs. 31.7%) (Table 1). Of the 217 patients, 127 (58.5%) had complete 2-year NDI follow-up, while the remaining 90 patients had shorter follow-up with last available PROs at earlier time points. Baseline characteristics of included and excluded patients were broadly comparable, with no significant differences except a nonsignificant trend toward younger age in the included group ($p = 0.073$).

Radiographic outcomes

The postoperative SVA increased in the laminoplasty group (27.60 ± 12.23 mm) compared to the APF group (24.75 ± 11.58 mm, $p = 0.091$). C2-7 lordosis improved significantly more in APF (15.89 ± 10.24°) than in the LP group (4.59 ± 11.29°, $p < 0.001$). Among the OPLL subtypes, the postoperative SVA remained higher in the LP group for continuous (29.67 ± 12.52 mm vs. 25.71 ± 9.07 mm, $p = 0.341$) and segmental types (28.77 ± 11.02 mm vs. 23.07 ± 12.39 mm, $p = 0.017$). However, the mixed-type SVA showed no significant difference (24.96 ± 13.07 mm vs. 27.25 ± 10.92 mm, $p = 0.448$). C2-7 lordosis consistently improved more in the APF group across all subtypes, with significant differences observed in the continuous (14.94 ± 6.08° vs. 4.93 ± 11.01°, $p = 0.007$), mixed (16.48 ± 9.35° vs. 2.69 ± 12.37°, p < 0.001), and segmental types (15.77 ± 11.59° vs. 6.12 ± 10.34°, $p < 0.001$) (Table 2).

Clinical outcomes

Pain outcomes

Both groups showed significant improvements in neck and arm pain following surgery. The mean preoperative neck pain VAS score was 4.39 ± 2.45 in the LP group and 4.59 ± 2.82 in the APF group (p = 0.594). At 2 years postoperatively, the intensity of neck pain decreased significantly in both groups, with no statistically significant difference between them (LP: 0.48 ± 1.31 vs. APF: 0.21 ± 0.63; p = 0.0976). Similarly, the intensity of arm pain improved markedly, but at 2 years postoperatively, the APF group reported significantly lower arm pain compared to the LP group (0.37 ± 1.17 vs. 0.98 ± 1.93; p = 0.0165).

Table 3 Comparison of the clinical outcomes between LP and APF groups at different postoperative time points

Outcomes		LP (N = 135) Mean ± SD	APF (N = 82) Mean ± SD	*p*-value	Overall *p*-value
Neck pain (0–10)	Pre	4.39 ± 2.45	4.59 ± 2.82	0.5944	group: 0.5546 time: < 0.0001 group*time: 0.7151
	POD 6 M	0.63 ± 1.27	0.47 ± 1.03	0.3733	
	POD 1 Y	0.5 ± 1.24	0.34 ± 0.98	0.3273	
	POD 2 Y	0.48 ± 1.31	0.21 ± 0.63	0.0976	
Arm pain (0–10)	Pre	4.1 ± 2.16	4.48 ± 2.66	0.2805	group: 0.4303 time: < 0.0001 group*time: 0.082
	POD 6 M	0.82 ± 1.53	0.76 ± 1.85	0.8192	
	POD 1 Y	0.9 ± 1.77	0.48 ± 1.39	0.0681	
	POD 2 Y	0.98 ± 1.93	0.37 ± 1.17	0.0165	
JOA score (0–17)	Pre	12.5 ± 3.6	12.05 ± 2.81	0.3199	group: 0.355 time: < 0.0001 group*time: 0.3597
	POD 6 M	15.53 ± 2.17	15.1 ± 2.16	0.1816	
	POD 1 Y	15.72 ± 2.01	15.54 ± 1.64	0.5242	
	POD 2 Y	15.61 ± 2.23	15.89 ± 2.05	0.4518	
NDI score (0–50)	Pre	17.11 ± 10.17	19.96 ± 8.33	0.0377	group: < 0.0001 time: < 0.0001 group*time: 0.1899
	POD 6 M	10.1 ± 7	14.67 ± 8	< 0.0001	
	POD 1 Y	9.39 ± 7.08	14.19 ± 8.25	< 0.0001	
	POD 2 Y	8.89 ± 7	11.63 ± 8.41	0.0429	
IR (0–100)	POD 6 M	78.02 ± 21.67	80.29 ± 13.91	0.3775	group: 0.4661 time: 0.1648 group*time: 0.5286
	POD 1 Y	78.63 ± 21.85	79.23 ± 19.1	0.8474	
	POD 2 M	77.6 ± 23.19	83.08 ± 13.33	0.0719	

Values are presented as mean ± standard deviation (SD). P-values represent comparisons between groups at each time point using the independent t-test. The overall p-values for group, time, and group × time interaction were obtained using repeated-measures analysis of variance

POD, postoperative day; NDI, Neck Disability Index; Pre, preoperative; M, Months; Y, Years; LP, laminoplasty; APF, anterior–posterior fusion

Neurological function (JOA score)

The preoperative JOA scores were comparable between the groups (LP: 12.5 ± 3.6 vs. APF: 12.05 ± 2.81; p = 0.3199). Both groups demonstrated significant improvement over time (p < 0.0001), with no significant difference in the JOA scores at 2 years postoperatively (LP: 15.61 ± 2.23 vs. APF: 15.89 ± 2.05; p = 0.4518).

Functional disability (NDI)

The NDI scores showed significant improvements postoperatively in both groups. However, the APF group consistently exhibited higher disability scores compared to the LP group throughout the follow-up period. Preoperatively, the fusion group had a significantly higher mean NDI score (19.96 ± 8.33) compared to the LP group (17.11 ± 10.17; p = 0.0377). At 6 months postoperatively, this difference remained significant (14.67 ± 8.00 vs. 10.1 ± 7.00; p < 0.0001), as well as at 1 year (14.19 ± 8.25 vs. 9.39 ± 7.08; p < 0.0001) and 2 years (11.63 ± 8.41 vs. 8.89 ± 7.00; p = 0.0429). Repeated-measures ANOVA confirmed a significant effect of the surgical group (p < 0.0001) and time (p < 0.0001), though the interaction between group and time was not significant (p = 0.1899). Thus, temporal differences observed between groups should be regarded as descriptive trends rather than evidence of divergent trajectories.

Patient-reported IR

The subjective IR did not significantly differ between the groups at any postoperative time point. At 2 years postoperatively, the IR was 77.6 ± 23.19% in the LP group and 83.08 ± 13.33% in the APF group (p = 0.0719), indicating comparable subjective satisfaction (Table 3).

Postoperative complications were recorded for all patients. Superficial wound infection occurred in 5 patients (2.3%), transient neurological worsening in 3 patients (1.4%), and implant-related complications such as screw loosening or breakage in 4 patients (1.8%). No cases of pseudarthrosis were identified during the mean follow-up of 27.8 months.

Subdomain analysis of the NDI

Further analysis of the NDI subdomains revealed that the APF group experienced significantly higher disability in activities requiring cervical motion, including personal care, lifting, work, driving, and recreation. Notably, the fusion group showed worse scores for personal care at 1 year (1.55 ± 1.29 vs. 0.76 ± 0.94; p < 0.0001) and for lifting at 6 months (2.72 ± 1.51 vs. 1.45 ± 1.41; p < 0.0001). These differences gradually diminished over time but

Table 4 Comparison of detailed Neck Disability Index (NDI) scores between LP and APF groups at different postoperative time points

Outcomes (0–5		LP (N = 135)	APF (N = 82)	*p*-value	Overall *P*-value
		Mean ± SD	Mean ± SD		
Pain intensity	Pre	1.98 ± 1.13	2.3 ± 1.09	0.0527	group: 0.0499 time: < .0001 group*time: 0.7759
	POD 6 M	1.24 ± 0.92	1.41 ± 1.02	0.258	
	POD 1 Y	1.14 ± 0.9	1.45 ± 0.99	0.0381	
	POD 2 Y	1.16 ± 0.9	1.26 ± 1.05	0.5848	
Personal care	Pre	1.71 ± 1.41	2.08 ± 1.22	0.055	group: < .0001 time: < .0001 group*time: 0.0462
	POD 6 M	1 ± 1.08	1.83 ± 1.27	< .0001	
	POD 1 Y	0.76 ± 0.94	1.55 ± 1.29	< .0001	
	POD 2 Y	0.77 ± 0.91	1.13 ± 1.01	0.0357	
Lifting	Pre	1.98 ± 1.58	2.69 ± 1.39	0.0012	group: < .0001 time: < .0001 group*time: 0.0041
	POD 6 M	1.45 ± 1.41	2.72 ± 1.51	< .0001	
	POD 1 Y	1.34 ± 1.38	2.22 ± 1.57	0.0002	
	POD 2 Y	1.15 ± 1.3	1.46 ± 1.45	0.2047	
Reading	Pre	1.9 ± 1.45	2.1 ± 1.21	0.3043	group: 0.0654 time: < .0001 group*time: 0.8951
	POD 6 M	1.31 ± 1.12	1.49 ± 1.17	0.3147	
	POD 1 Y	1.28 ± 1.1	1.63 ± 1.18	0.0574	
	POD 2 Y	1.21 ± 1.08	1.46 ± 1.21	0.2091	
Headaches	Pre	1.23 ± 1.24	1.1 ± 1.19	0.4614	group: 0.7732 time: < .0001 group*time: 0.5335
	POD 6 M	0.63 ± 0.91	0.68 ± 1.02	0.7193	
	POD 1 Y	0.68 ± 0.95	0.57 ± 0.7	0.3957	
	POD 2 Y	0.58 ± 0.88	0.59 ± 0.79	0.9094	
Concentration	Pre	1.38 ± 1.22	1.7 ± 1.3	0.0698	group: 0.0084 time: < .0001 group*time: 0.9652
	POD 6 M	0.76 ± 0.81	1.01 ± 0.96	0.0687	
	POD 1 Y	0.78 ± 0.85	1.09 ± 0.97	0.0325	
	POD 2 Y	0.71 ± 0.77	0.98 ± 0.84	0.0631	
Work	Pre	1.63 ± 1.39	2.04 ± 1.12	0.0212	group: 0.0004 time: < .0001 group*time: 0.7407
	POD 6 M	0.89 ± 0.91	1.36 ± 1.11	0.0029	
	POD 1 Y	0.89 ± 0.94	1.37 ± 0.92	0.0012	
	POD 2 Y	0.85 ± 1.02	1.15 ± 1.09	0.1158	
Driving	Pre	1.44 ± 1.61	1.52 ± 1.56	0.7146	group: 0.0013 time: < .0001 group*time: 0.0595
	POD 6 M	0.81 ± 1.11	1.3 ± 1.81	0.0471	
	POD 1 Y	0.55 ± 0.77	1.36 ± 1.64	0.0003	
	POD 2 Y	0.63 ± 0.92	0.98 ± 1.38	0.1083	
Sleeping	Pre	1.89 ± 1.39	2.05 ± 1.16	0.4025	group: 0.0037 time: < .0001 group*time: 0.0562
	POD 6 M	0.89 ± 1.1	1.2 ± 1.38	0.1198	
	POD 1 Y	0.68 ± 0.83	1.3 ± 1.23	0.0005	
	POD 2 Y	0.68 ± 0.85	0.89 ± 0.98	0.2132	
Recreation	Pre	1.95 ± 1.39	2.38 ± 1.32	0.0322	group: 0.0002 time: < .0001 group*time: 0.8992
	POD 6 M	1.1 ± 1.02	1.59 ± 1.35	0.0109	
	POD 1 Y	0.99 ± 1.02	1.55 ± 1.23	0.0018	
	POD 2 Y	0.9 ± 0.93	1.37 ± 1.25	0.023	

Values are presented as mean ± SD. P-values represent comparisons between groups at each time point using the independent t-test. The overall p-values for group, time, and group × time interaction were obtained using repeated-measures ANOVA

POD, postoperative day; NDI, Neck Disability Index; Pre, preoperative; M, months; Y, years; LP, laminoplasty; APF, anterior–posterior fusion

remained statistically significant in certain domains after 2 years (Table 4).

Subgroup analysis by OPLL type

When stratified by the OPLL type (continuous, mixed, and segmental), the segmental OPLL group exhibited the most pronounced differences in NDI scores between the surgical techniques. Patients with segmental-type OPLL, who had greater motion preoperatively, experienced a higher degree of functional impairment after fusion surgery. However, the disparity in NDI scores between the two groups decreased over the 2-year follow-up period. This finding should be interpreted as a possible trend rather than definitive evidence of functional adaptation (Fig. 2).

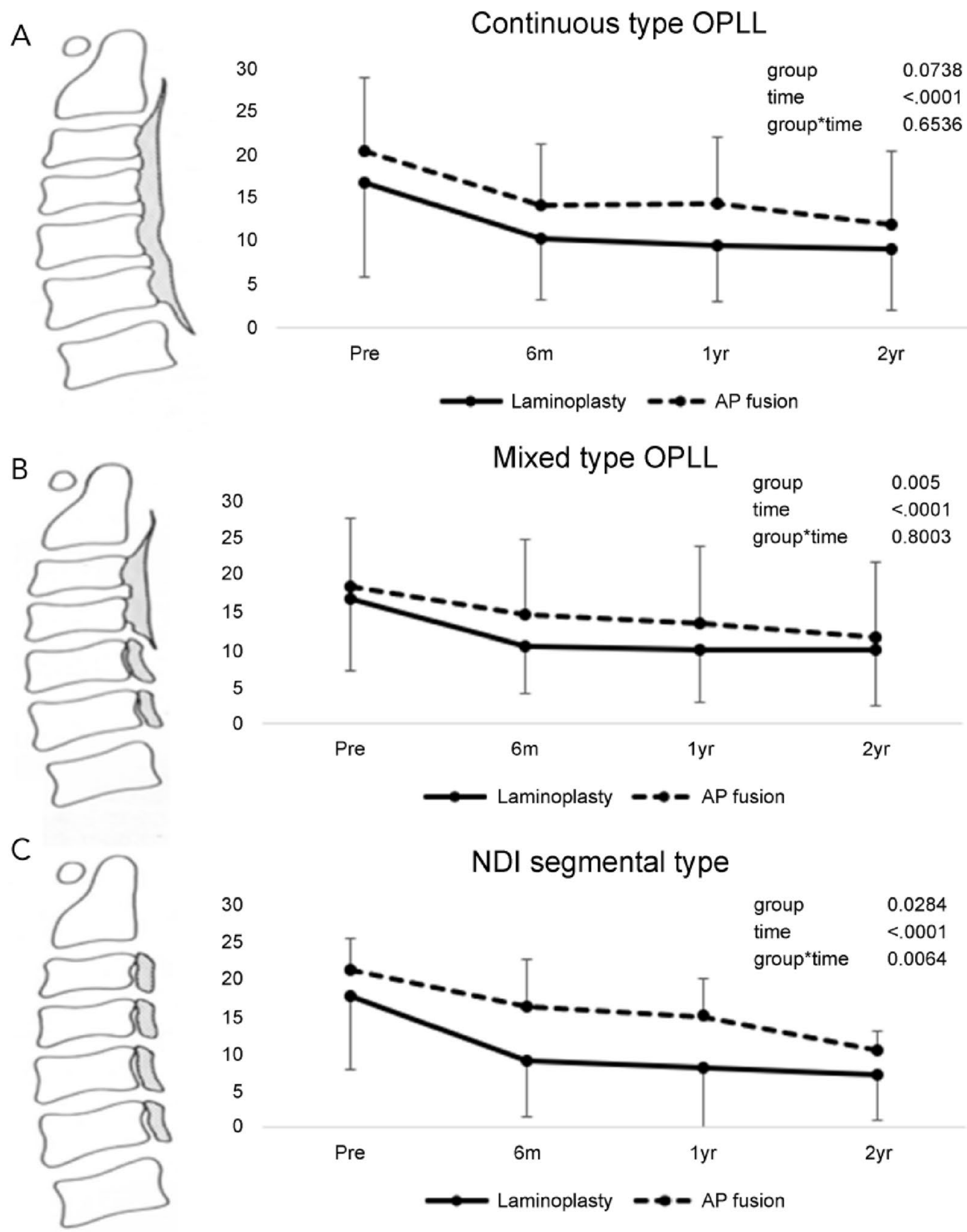

Fig. 2 Changes in the neck disability index (NDI) scores over time in LP and APF groups, stratified by the OPLL type. **A** Continuous-type OPLL, **B** Mixed-type OPLL, **C** Segmental-type OPLL. The mean NDI scores at preoperative, 6-month, 1-year, and 2-year follow-ups are plotted with error bars representing standard deviations. Solid lines indicate the laminoplasty group, while dashed lines represent the APF group. *P*-values for group, time, and group × time interaction were obtained using repeated-measures analysis of variance. OPLL, ossification of the posterior longitudinal ligament; NDI, Neck Disability Index; AP, anterior–posterior

Given the imbalance in OPLL subtype distribution between groups, we additionally performed multivariable logistic regression adjusting for surgical method, OPLL subtype, age, and sex. As shown in Supplementary Table 1, OPLL subtype itself was not an independent predictor of adverse outcomes, indicating that the main results remained robust after adjustment.

Discussion

This study compared the clinical outcomes of LP and APF in patients with OPLL. After adjusting for baseline disability, functional gains (ΔNDI, ΔJOA) were comparable between techniques. Both surgical techniques resulted in significant neurological improvements and pain relief, as evidenced by comparable gains in JOA scores and reductions in the intensities of neck and arm pain [17–19].

However, distinct differences were observed in radiographic correction and functional disability. Although the APF group achieved superior restoration of cervical lordosis, these benefits were tempered by higher NDI scores, particularly in the early postoperative period.

The greater improvement in the C2–7 lordotic angle in the APF group indicates better restoration of sagittal alignment, which is particularly valuable in patients with preoperative kyphotic deformity [20]. Nonetheless, the associated loss of cervical motion contributed to higher NDI scores, especially in functional domains such as personal care, lifting, work, driving, and recreation [21–23]. This trade-off suggests that while improved alignment is important, preserving cervical mobility may be equally crucial for patient function.

From a clinical perspective, the choice between LP and APF reflects this fundamental trade-off between motion preservation and sagittal alignment correction. Segmental-type OPLL, characterized by greater preoperative mobility, may benefit more from motion-preserving laminoplasty, whereas continuous-type OPLL, with inherently limited motion, may derive greater advantage from alignment correction with fusion. For mixed-type OPLL, individualized decision-making is essential. These findings underscore that surgical planning should consider OPLL subtype, cervical alignment, and patient mobility, while recognizing that our results are exploratory and hypothesis-generating.

Moreover, irrespective of the OPLL subtype, our study found that the NDI scores progressively decreased over time following surgery. In both the LP and APF groups, the initially observed differences in NDI scores diminished considerably by the 2-year follow-up, suggesting that patients gradually adapted to the postoperative changes in cervical mobility. This convergence in NDI outcomes implies that long-term functional recovery may be more similar between the two techniques than early postoperative assessments might indicate, highlighting the importance of considering patient adaptation and long-term recovery trajectories when selecting the optimal surgical approach for OPLL.

The choice between LP and APF is influenced by several patient- and pathology-related factors. LP is generally favored in patients with preserved cervical lordosis and *K*-line (+) alignment, where motion preservation can be achieved with adequate decompression. In contrast, APF is more often indicated in cases with preoperative kyphosis, *K*-line (−), or instability, where sagittal correction and stabilization are essential [9, 20]. Although APF is associated with greater surgical trauma, higher cost, and slower recovery [10], it may provide superior alignment in select patients. Our study did not aim to redefine surgical indications; rather, it focused on comparing postoperative outcomes between LP and APF. Nonetheless, these contextual factors should be considered when applying our findings to clinical decision-making.

Recent studies have similarly emphasized this balance between motion preservation and sagittal alignment correction. Large cohort and meta-analytic data report that LP achieves reliable neurological recovery with motion preservation in patients with lordotic alignment and K-line (+) status, while APF offers superior correction of sagittal deformity and stability in patients with kyphosis or *K*-line (−) alignment [9, 11, 18–20]. Our results are consistent with these contemporary findings, supporting the concept that optimal surgical strategy for multilevel cervical OPLL should be individualized according to baseline alignment and OPLL subtype.

This study has several limitations. First, because it is a single-center retrospective study with a follow-up period limited to 2 years, there is a potential for selection bias and limited external generalizability, and the ability to address long-term outcomes remains restricted. Second, the distribution of OPLL subtypes differed significantly between groups, which may reflect selection bias in surgical decision-making. Although we adjusted for subtype in regression models, residual confounding cannot be excluded. Third, the subgroup analyses by OPLL morphology involved modest sample sizes, and thus the findings should be interpreted as exploratory and hypothesis-generating. Future research should adopt a prospective, multicenter design with larger cohorts and longer follow-up (≥ 5 years) to validate these findings. In addition, comprehensive preoperative assessments—including K-line status, sagittal parameters, dynamic instability, and comorbidity indices—should be systematically incorporated to better control for baseline confounders and clarify the long-term impact of motion preservation versus fusion on patient quality of life. [24]

Because OPLL is particularly prevalent in Asian populations, large single-center cohorts such as ours provide important evidence that complements existing literature, much of which is derived from Western cohorts where OPLL is relatively rare. Although regional epidemiology differs, the principle of balancing sagittal alignment against motion preservation is universally relevant, and our findings may therefore inform surgical decision-making not only in Asia but also in global practice.

Conclusions

Both LP and APF improved the neurological function and pain in patients with OPLL. Although fusion achieved better sagittal alignment, it was associated with higher early postoperative disability, with a trend particularly observed in patients with segmental-type OPLL. These findings should be considered hypothesis-generating and warrant confirmation in larger cohorts

Abbreviations

APF	Anterior–posterior fusion
IR	Improvement rate
JOA	Japanese orthopedic association
LP	Laminoplasty
NDI	The neck disability index
OPLL	Ossification of the posterior longitudinal ligament
VAS	Visual analog scale

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13018-025-06504-6.

Supplementary file 1 (DOCX 19 kb)

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None.

Author contribution
J.W.S. and K.S.S. wrote the main manuscript text, and J.W.S. prepared the visualizations. K.S.S. conceptualized and supervised the project, acquired funding, administered the project, and provided resources. J.W.S. curated the data, developed the software, and conducted the investigation and methodology together with K.S.S. Formal analysis was conducted by K.S.S., H.S.K., S.H.M., S.Y.P., B.H.L., and J.W.K. Supervision and review/editing were carried out by K.S.S., H.S.K., S.H.M., S.Y.P., B.H.L., and J.W.K. All authors reviewed the manuscript.

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Data availability
The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval
This retrospective review was done with the approval of the corresponding institutional review board of our medical college (IRB No. 3-2021-0398).

Consent for publication
Not applicable.

Consent to participate
The requirement for informed consent was waived due to the retrospective nature of this study.

Conflicts interests
The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article

Competing interests
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