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ORIGINAL ARTICLE

Curve progression in de novo degenerative lumbar scoliosis combined with degenerative segment disease after short-segment fusion

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Abstract

Purpose To validate the reliability of Berjano and Lamartina classification system of surgical planning in cases of de novo degenerative lumbar scoliosis (DNDLS) combined with degenerative segment disease and identify factors contributing to curve progression.

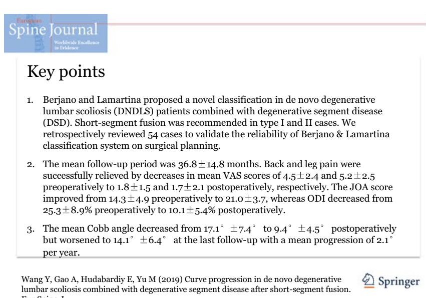
Methods Fifty-four cases of type I or II DNDLS were retrospectively reviewed. Health-related quality of life (HRQOL) was assessed using visual analogue scale (VAS) scores for the back and leg, Oswestry Disability Index (ODI), and Japanese Orthopaedic Association (JOA) scores. Radiographic parameters were obtained from X-rays. Improvements in HRQOL were confirmed by a paired *t* test. Changes in radiographic parameters were confirmed by paired *t* test and Wilcoxon signed-rank test. Clinical relevance between spinopelvic parameters and Cobb angle progression was analyzed by Spearman correlation coefficient.

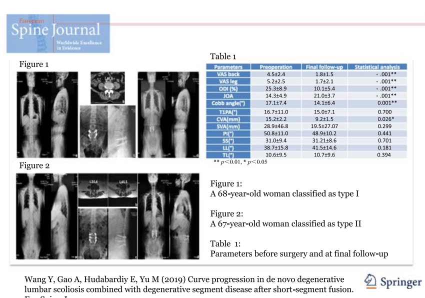
Results The mean follow-up period was 36.8 ± 14.8 months. The scores taken preoperatively versus at the last follow-up were as follows: mean VAS back score, 4.5 ± 2.4 versus 1.8 ± 1.5 ($p < 0.01$); and mean VAS leg score, 5.2 ± 2.5 versus 1.7 ± 2.1 ($p < 0.01$). The ODI score improved from 25.3 ± 8.9% to 10.1 ± 5.4% ($p < 0.01$), whereas the mean JOA score improved from 14.3 ± 4.9 to 21.0 ± 3.7 ($p < 0.01$). The mean Cobb angle decreased from 17.1° ± 7.4° to 9.4° ± 4.5° postoperatively but worsened to 14.1° ± 6.4° at the last follow-up with a mean progression of 2.1° per year. Cobb angle correction was lost at a mean 2.1° ± 3.3° per year with correlation to T1 pelvic angle and sagittal vertical axis preoperatively.

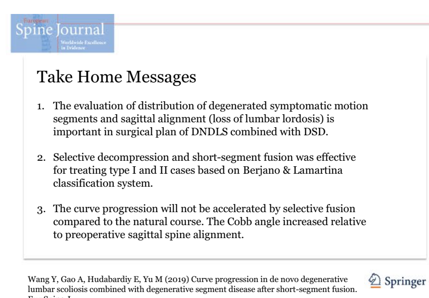
Conclusions Selective decompression and short-segment fusion were effective for treating type I and II cases DNDLS. The Cobb angle increased relative to preoperative sagittal spine alignment.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.







Yongqiang Wang and Ang Gao contribute equally to this work.

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Keywords De novo degenerative lumbar scoliosis · Degenerative segment disease · Spinopelvic parameter · Cobb angle · Short fusion · Curve progression

Introduction

De novo degenerative lumbar scoliosis (DNDLS), a primary adult degenerative scoliosis with an incidence of 13.3% in the Chinese Han population and 8.85% in western countries, is attracting attention in our ageing society [1, 2]. DNDLS usually arises from asymmetrical degenerative disc and/or facet joint arthritis and eventually progresses to degenerative segment disease (DSD). Pain and disability, such as neurogenic claudication, are the most relevant findings indicative of surgical treatment [3]. Decompression alone, dynamic stabilization, indirect decompression, decompression with short fusion, and long fusion with curve correction are widely used [4–6]. However, the ideal surgical strategy for DNDLS combined with severe symptoms caused by DSD remains controversial.

The most recognized classification systems for adult deformity are SRS-Schwab and Aebi, which are based on curve severity and etiology in cases of adult scoliosis [3, 7]. However, these systems lack a surgical strategy for treating DNDLS combined with DSD. Berjano et al. [8] advocated a novel treatment-oriented classification for DSD in adults with deformity affecting the lumbar and thoracolumbar spine. Categories are graded by distribution of degenerated symptomatic motion segments and sagittal alignment (loss of lordosis). Type I was defined as localized non-apical DSD with a balanced spine. Type II was defined as localized apical DSD, in which symptomatic DSD is present at the apical segments of the main coronal curve with a balanced spine. Based on the Berjano and Lamartina classification system, selective decompression and short fusion were allowed. We aimed to validate the classification's reliability, investigate scoliosis progression after short-segment fusion, and identify risk factors for curve progression.

Materials and methods

Inclusion criteria

Our hospital's electronic database was retrospectively reviewed. Patients treated between 2011 and 2015 who met the following criteria were included: (1) age > 50 years; (2) presence of DNDLS with Cobb angle > 10°; (3) concomitant DSD; (4) conservative therapy failure; (5) minimum 2-year follow-up; and (6) availability of complete radiographs.

Exclusion criteria

The exclusion criteria were: (1) adult idiopathic scoliosis; (2) spine deformity caused by infection, trauma, or tumour; or (3) history of spinal surgery.

Surgical procedure

All patients underwent a modified posterior lumbar inter-body fusion surgery in the prone position under general anaesthesia. The spinous processes, lamina, facet joints, and transverse processes were exposed in a midline incision. The 2/3 of superior lamina, 1/2 inferior lamina, half of bilateral facet joints were resected. Material for bone graft was harvested from the resected spinous processes, lamina and facet joints and morselized. Discectomy was performed with gentle retraction of neural elements. Bone graft mass was packed into the intervertebral space and followed by insertion of single inter-body cage, which was rotated horizontally. Posterolateral fusion was also performed with residual bone graft. Pedicle screws and rods were placed to stabilize lumbar spine.

In the type I group, patients underwent thorough neural element decompression followed by lumbar inter-body fusion (inter-body fusion cage and autologous bone) and posterolateral fusion at the affected level. In the type II group, patients underwent decompression, inter-body fusion (inter-body fusion cage and autologous bone), and posterolateral fusion at the affected level(s) and asymmetrical compression of pedicle screws at the convex side to partially restore spinal alignment. It was unnecessary to extend fusion segments above and below the apical vertebra.

Health-related quality of life measurements

The visual analogue scale (VAS) scores for the back and leg, Oswestry Disability Index (ODI), and Japanese Orthopaedic Association (JOA) scoring system were used to assess the patients' health-related quality of life (HRQOL).

Radiographic parameter measures

Scoliosis progression was evaluated by Cobb angle. Radiographic spinopelvic parameters including coronal vertical axis (CVA), sagittal vertical axis (SVA), pelvic incidence (PI), sacral slope (SS), lumbar lordosis (LL), thoracolumbar kyphosis (TK), and T1 pelvic angle (T1PA) were obtained from anteroposterior and lateral X-rays. Inter-crest line, lateral listhesis, lateral osteophyte difference (LOD), disc index, and apical vertebral rotation were obtained from anteroposterior X-rays as described by Seo et al. [9]. Lateral listhesis was defined as the distance from the reference line of a laterally translated vertebral body to that of the lower vertebra (Fig. 1). LOD was the difference between lateral osteophyte length on each side, which were the sums of the perpendicular distances measured from the reference line to the lateral ends of the osteophytes on the upper and lower endplates (Fig. 2). Disc index was the ratio of disc height on the decreased side to the disc height on the opposite side (Fig. 3). All parameters were measured separately by two expert spine surgeons.

Statistical analysis

Clinical and radiographic data were analyzed using the Statistical Package for the Social Sciences version 22.0 (SPSS, Inc., Chicago, IL, USA). The inter-rater reliability of the classification was tested by intraclass correlation coefficient (ICC). A paired t test was utilized to compare pre- and post-operative HRQOL. A Wilcoxon signed-rank test was used to check pre- and post-operative TK and SS, while a paired t test was used to measure other radiographic parameters. Clinical relevance between spinopelvic parameters and Cobb angle progression was analyzed by Spearman correlation. p values < 0.05 were considered statistically significant.

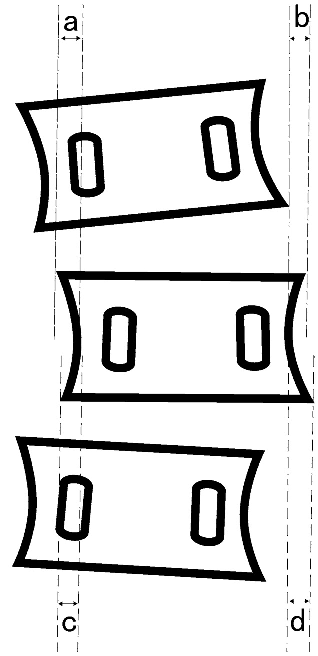
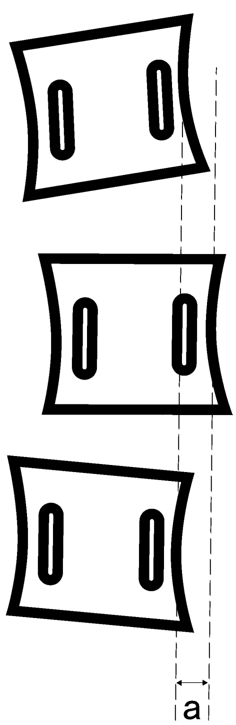


Fig. 2 Definition of lateral osteophyte differences (LOD). The difference between the length of the lateral osteophytes on each side. Lateral osteophyte difference $= (a + b) - (c + d)$

Fig. 1 Definition of lateral listhesis. The distance from the reference line of the laterally translated vertebral body to that of the lower vertebra



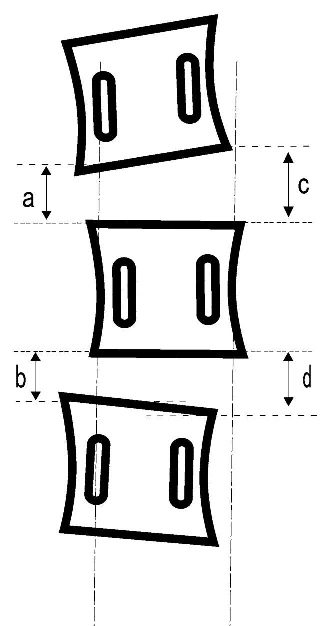


Fig. 3 Definition of disc index. The ratio of disc height on the decreased side to disc height on the opposite side. Disc index $= (a + b)/(c + d)$

Results

Patient characteristics

Between January 2011 and December 2015, 54 patients (16 men, 38 women) with a mean age of 61.6 ± 5.2 (range, 52–73) years were enrolled. The mean follow-up period was 36.8 ± 14.8 (range, 24–61) months.

Among this population, 36 patients were classified as type I and 18 were classified as type II.

Reliability of classification showed excellent agreement (ICC = 0.833, $p < 0.01$). In the type I group, the apical vertebra was L2 in 9 cases, L2/3 in 11 cases, L3 in 9 cases, L3/4 in 5 cases, and L4 in 2 cases. In the type II group, the apical vertebra was L2/3 in 4 cases, L3 in 1 case, L3/4 in 9 cases, L4 in 2 cases, and L4/5 in 2 cases.

Table 1 Parameters before surgery and at final follow-up

Parameters	Preoperation	Final follow-up	Statistical analysis
VAS back	4.5 ± 2.4	1.8 ± 1.5	< .001**
VAS leg	5.2 ± 2.5	1.7 ± 2.1	< .001**
ODI (%)	25.3 ± 8.9	10.1 ± 5.4	< .001**
JOA	14.3 ± 4.9	21.0 ± 3.7	< .001**
Cobb angle (°)	17.1 ± 7.4	14.1 ± 6.4	0.001**
T1PA (°)	16.7 ± 11.0	15.0 ± 7.1	0.700
CVA (mm)	15.2 ± 2.2	9.2 ± 1.5	0.026*
SVA (mm)	28.9 ± 46.8	19.5 ± 27.07	0.299
PI (°)	50.8 ± 11.0	48.9 ± 10.2	0.441
SS (°)	31.0 ± 9.4	31.21 ± 8.6	0.701
LL (°)	38.7 ± 15.8	41.5 ± 14.6	0.181
TL (°)	10.6 ± 9.5	10.7 ± 9.6	0.394

$^{**}p < 0.01$, $^{*}p < 0.05$

Surgical parameters and clinical outcomes

Back and leg pain were successfully relieved (Table 1) as evidenced by decreases in mean VAS scores of 4.5 ± 2.4 (range, 0–8) and 5.2 ± 2.5 (range, 1–10) preoperatively to 1.8 ± 1.5 (range, 0–5) and 1.7 ± 2.1 (range, 0–6) postoperatively, respectively. The neurological deficit improved (Table 1) as indicated by a JOA score that improved from 14.3 ± 4.9 (range, 6–25) preoperatively to 21.0 ± 3.7 (range, 14–28), whereas ODI decreased from 25.3 ± 8.9% (range, 11–39%) preoperatively to 10.1 ± 5.4% (range, 1–21) postoperatively.

In type I patients, limited decompression and fusion were performed at affected levels (Fig. 4). 1-level fusion was performed in 18 patients, and 2-level fusion was performed in 18 patients with an estimated mean blood loss of 329.4 ± 195.0 mL (range, 50–600 mL). A 1-level fusion was done at L3/4 in 3 cases, L4/L5 in 11 cases, and L5/S1 in 4 cases. A 2-level fusion was done at L4/L5 and L5/S1 in 12 cases and at L3/L4 and L4/L5 in 6 cases.

In type II patients, the limited decompression and fusion were performed at affected levels without extensive fusion above and below the apex (Fig. 5). 2-level fusions were performed in 13 cases and 3-level fusions were performed in 5 cases with an estimated mean blood loss of 534.1 ± 217.8 mL (range, 260–800 mL). A 2-level fusion was done at L2/L3 and L3/L4 in 6 cases and at L3/L4 and L4/L5 in 7 cases. A 3-level fusion was done at L2/L3, L3/L4, and L4/L5 in 5 patients.

The average Cobb angle decreased from 17.1° ± 7.4° (range, 10°–36.6°) to 9.4° ± 4.5° (range, 2.6°–19.6°) after

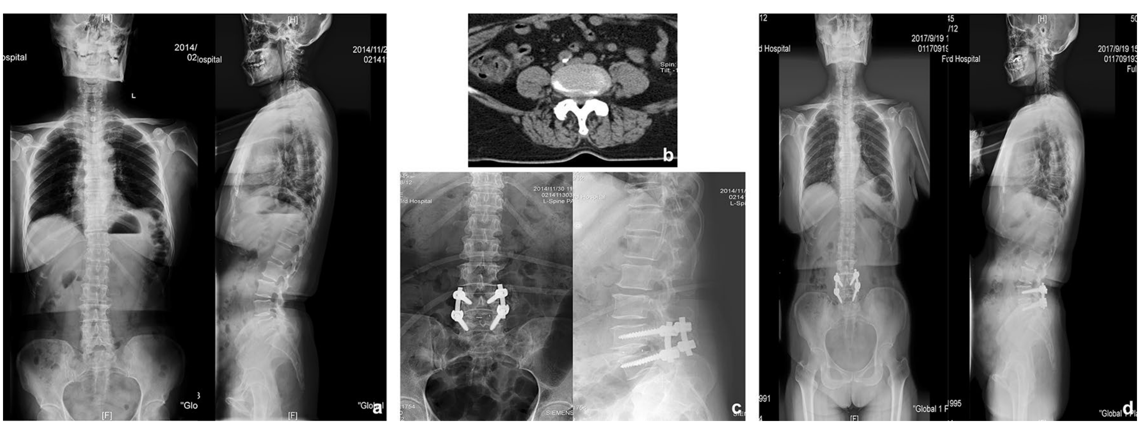


Fig. 4 A 68-year-old woman classified as type I. **a** The standing long-cassette anteroposterior and lateral radiographs of spine demonstrating a Cobb angle of 12.1° and L3 as the apical vertebra with a balanced spine. **b** Axial computed tomograph image showing disc herniation and lateral recess stenosis at L4/L5. **c** Post-operative lateral and anteroposterior X-rays. **d** The standing long-cassette anteroposterior and lateral radiographs of spine demonstrating a post-operative Cobb angle of 2.6° that increased to 5.9° at 33-month's follow-up

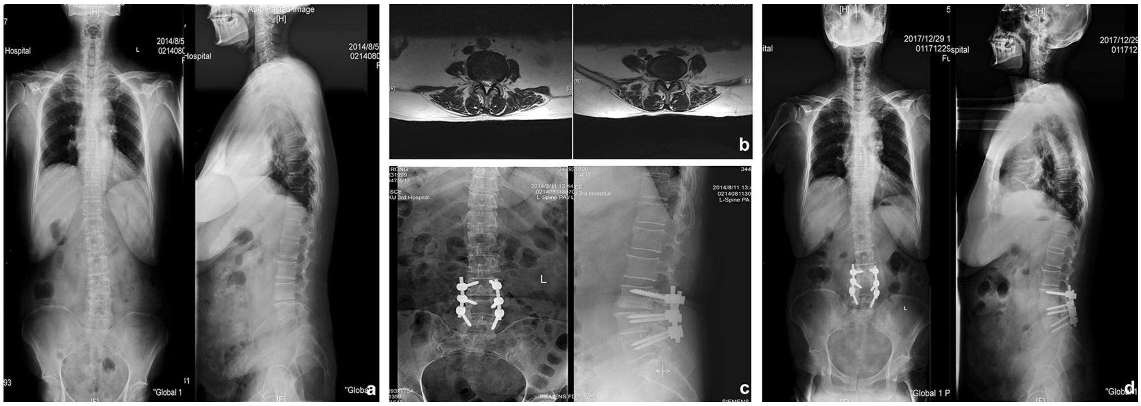


Fig. 5 A 67-year-old woman classified as type II. **a** The standing long-cassette anteroposterior and lateral radiographs of spine demonstrating a Cobb angle of 14.9° and L3/L4 as the apical vertebra with a balanced spine. **b** Axial T2-weighted magnetic resonance imaging showing disc herniation and lateral recess stenosis at L3/L4 and L4/L5. **c** Post-operative lateral and anteroposterior X-rays. **d** Lateral and anteroposterior X-ray demonstrating a post-operative Cobb angle of 4.2° that increased to 11.9° at 3-year's follow-up

Table 2 Correlation between Cobb angle progression and factors

Factor	*P* value	Correlation
CVA	0.769	–
Age	0.539	–
Follow-up period	0.331	–
SVA	0.048*	0.384
T1PA	0.046*	0.387
LL	0.361	–
TL	0.632	–
SS	0.961	–
PI	0.157	–
PT	0.166	–
PI-LL	0.127	–
Inter-crest line	0.418	–
Lateral listhesis	0.271	–
Lateral osteophyte differences	0.117	–
Disc index	0.178	–
Apical vertebral rotation	0.553	–

**$p<0.01$, *$p<0.05$

surgery but worsened to 14.1° ± 6.4° (range, 3.6°–25.9°) at the final follow-up. CVA decreased from 15.2 ± 2.2 mm (range, 1.86–37.36 mm) to 9.2° ± 1.5 mm (range, 1.2–25.41 mm). The differences in pre- and post-operative SVA, T1PA, LL, and other spinopelvic parameters were not significant (Table 2).

One patient underwent debridement surgery due to wound dehiscence. Cerebral spinal fluid leakage was recorded in 3 patients. No adjacent segment disease, internal fixation failure, or other complications requiring further surgery were recorded.

Progression of Cobb angle

The mean curve progression was 2.1° per year. The correlation analysis demonstrated that the sagittal parameters (SVA, T1PA) were significantly correlated with Cobb angle progression (Table 2). Age, follow-up period, inter-crest line, lateral listhesis, disc index, apical vertebral rotation, and other spinopelvic parameters were not correlated with Cobb angle progression (Table 2).

In the type I group, the apical vertebra at last follow-up was L2 in 9 cases, L2/3 in 11 cases, L3 in 9 cases, L3/4 in 5 cases, and L4 in 2 cases. The post-operative apical vertebra, upper vertebra, and lower vertebra were unchanged.

In the type II group, the apical vertebra was changed at the last follow-up to L1 in 2 cases, L1/2 in 6 cases, L2 in 2 cases, L2/3 in 3 cases, and L3 in 5 cases. An apical vertebra moving from L2/3 to L1/2 or L4 to L3 was defined as a 1-segment alteration, while one that moved from L3 to L2/3 or L2/3 to L2 was defined as a 0.5-segment alteration. A mean 1.2 ± 0.7 segments (range, 0.5–3 segments) were changed.

Discussion

Decompression with short fusion in DNDLS

Multiple techniques were used to manage DNDLS, including decompression alone [4, 10–12], decompression with short fusion [4, 6, 11–14], and decompression with long corrective fusion [4, 6, 11–14]. The surgical strategy for DNDLS remains controversial, while the reported clinical outcomes are ambiguous. Compared to correction surgery, short fusion was recommended by many surgeons due to its lower incidences of motor deficits and internal fixation failure [11, 12]. However, many surgeons worried about post-operative Cobb angle progression, adjacent segment disease, and other complications requiring further surgery [4, 5, 15, 16].

We speculate that the causes of the controversy were the scoliosis severity of the cohorts included in previous studies and the scoliosis assessments being heterogeneous. Fewer investigators used SRS-Schwab classification as a guideline to treat DNDLS combined with DSD despite its proven comprehensive nature and validity. Berjano et al. [8] emphasized that a good classification should express the severity gradient and guide surgical planning and introduced a novel treatment-oriented classification. Type I and II cases can be treated by selective fusion limited to the degenerated and symptomatic segment because of the absence of global spinal malalignment. Some investigators may describe types I and II as mild scoliosis [7], while others may define them as spinal stenosis with balanced de novo degenerative lumbar scoliosis without substantial sagittal imbalance [14]. We advocate that a widely accepted classification should be used to describe the severity and clinical outcomes of DNDLS, and the Berjano and Lamartina classification system shows good performance.

Many surgeons may have treated patients as described in the Berjano and Lamartina classification system regardless of whether they accept the classification system. A meta-analysis reported decreased blood loss and shorter operative time in the short fusion group than that in the long fusion group in cases with balanced spinal alignment. However, there was no significant difference in improvement of ODI between two groups [14]. Other investigators advocated that decompression with short limited fusion was appropriate when patients have smaller curves (< 30°), no deformity progression, and no sagittal malalignment [11, 17, 18]. In the present study, good outcomes were observed: VAS and ODI scores decreased notably, while the mean JOA score significantly improved from 14.3 ± 4.9 preoperatively to 21.0 ± 3.7 postoperatively, which indicates the efficacy of decompression with limited fusion. Regarding HRQOL improvement, we agree with Berjano and Lamartina's suggestion that selective decompression and fusion would be optimal for type I and II cases. Transfeldt [4] and Kleinstueck [12] compared the 3 mentioned surgical procedures separately but denied the attempt to compare these procedures and achieved mixed results: Those of the short fusion group had better outcomes compared to those of the long fusion group and inferior to the decompression alone group considering the operation duration, blood loss, complications, and reoperation rate. However, the scoliosis severities and general health conditions of their study cohort were heterogeneous, which may have affected the results. Variation of the curve apex was observed in our study. It was a classical surgery to perform fixation and fusion above and below the apex vertebra in DNDLS patients. To reserve segment motion, inter-body fusion and fixation was ended at the apex vertebra in type II cases, and asymmetrical compression was performed at the site of the vertebra below the apex vertebra rather than at the apex vertebra itself. We speculated that the cause of the observed variation in curve apex included instrumentation ending at the apex vertebra and asymmetrical compression below the apex vertebra.

The difference of PI value was recorded in our study despite this was not statistical significance. It was once widely accepted that PI was static if no pelvic and sacral osteotomies are performed in adulthood. But this theory has been questioned in recent years. Cecchinato et al. [19] found that a statistically significant change of PI was observed in patients who underwent sacral fixation plus pelvis fixation after adult spinal deformity surgery. Similarly, change of PI was observed in aged group (age > 65 years) who underwent sacral fixation alone. The author postulated change of sacroiliac joint mobility was attributed to position with hips and lumbar spine and rotation of sacrum altered by surgical manoeuvers. The pelvis adjusted and fixed with corresponding changes. However, it was a study based on early post-operative data and a further study with long-term follow-up was needed to prove the accuracy of this hypothesis.

Progression of Cobb angle in DNDLS

Faldini et al. [6] reported a mean preoperative coronal Cobb angle of 24° that changed to 12° after short fusion surgery after 2–5 years of follow-up. Masuda [11] also reported that the Cobb angle decreased from 14.8° ± 4.0° to 10.0° ± 8.5° after surgery in the limited fusion group versus increasing from 14° ± 2.9° preoperatively to 14.3° ± 6.4° at the final follow-up in the decompression alone group.

Post-operative curve progression occurring in short fusion is one factor that confuses surgeons, and it is essential to compare the curve progression in the present study with the natural course of DNDLS to validate the efficiency of the Berjano and Lamartina classification system. This study indicated that curve correction was statistically significant between the preoperative point and the last follow-up with a mean curve progression of 2.1° per year. Pritchett et al. [20] reported a mean curve progression of 3° per year over a 5-year period among 73% of their patients, equivalent to that observed in our study. Many authors have focused on curve progression among patients with degenerative lumbar stenosis treated by short-segment fusion. Lee [21] found that the Cobb angle progressed 3.38° after short fusion during a mean follow-up period of 28 months, but only 50 of 540 patients (9.3%) had coronal Cobb angles > 10°. Likewise, Hasogene [10] reported a mean progression of 3.4° after decompression alone during a mean follow-up of 2.8 years, while 50 of 852 patients (5.9%) had a lumbar curve > 10° at the final follow-up. Although the Cobb angle continued to progress, no correlation between HRQOL decline and Cobb progression was observed in these studies. The cohorts in their studies were degenerative lumbar stenosis cases, and details of scoliosis were not mentioned, whereas the present study included only cases of DNDLS diagnosed preoperatively. Compared to preoperative Cobb angle, curve progression was observed in 10 cases (18.5%) at last follow-up, which was higher compared to the 2 studies mentioned above [10, 21]. We inferred that the deviation was caused by different inclusion criteria. Patients with a preoperative Cobb angle > 10° were selected as potential candidates in this study, whereas the inclusion criteria of other studies were a Cobb angle > 10° at the final follow-up. However, our findings suggest that curve progression will not be accelerated by selective fusion compared to the natural course. Thus, worries about curve progression should not be considered in the treatment of type I and II cases.

Risk factors for curve progression

To date, little has been revealed about the prognostic factors of curve progression in DNDLS patients without powerful correction. A systematic review [22] presented strong evidence that increased intervertebral disc degeneration, the inter-crest line through L5, and apical lateral vertebral translation ≥ 6 mm are associated with DNDLS curve progression. Moderate evidence was found for apical vertebral rotation as a risk factor for curve progression. Based on previous studies, we tried to identify some prognostic factors for curve progression. Age, follow-up period, inter-crest line, lateral listhesis, LOD, disc index, apical vertebral rotation, and coronal and sagittal parameters were analyzed [9, 10, 21–23].

In this study, we determined that only SVA and T1PA were correlated with curve progression (Table 2). Likewise, risk factors, including age, follow-up duration, and number of decompression level were also not identified by Hasogene [10]. Lee [21] demonstrated that loss of lumbar lordosis and a Cobb angle > 30° were risk factors for curve progression, which were insignificant in our study. Xu [24] conducted a survey comprised of 284 subjects diagnosed with lumbar degeneration disc disease and drew the conclusion that SVA value was positively correlated with overall lumbar disc degeneration degree. However, SVA is compensated for by knee flexion and pelvic retroversion. Protopsaltis [25] introduced the T1 pelvic angle, a novel measure of sagittal alignment that simultaneously accounts for both spinal inclination and pelvic retroversion to reflect the entire sagittal spine alignment. Here, we found that SVA and T1PA were correlated with post-operative curve progression, while the curve progression after short fusion was similar to the natural history in DNDLS patients. We speculated that the augmentation of sagittal spinopelvic parameters may be correlated with lumbar degeneration, while short fusion would not end this natural degeneration process. Meanwhile, Sebaaly et al. [26] postulated that the whole spine evolved into global kyphosis eventually, which was generated by degeneration of the lumbar disc and facet joints. As a consequence, the C7 plumb line was forward, which reflected a larger value of SVA. Thus, DNDLS patients with a higher SVA and T1PA were more likely to suffer from curve progression.

Limitations

This study has several limitations. First, it was retrospective and conducted at a single centre. Second, bias in complications and curve progression may have been introduced due to its relatively small sample size and short follow-up period. Furthermore, we did not validate the reliability of the Berjano and Lamartina classification focusing on type III or IV cases. Further studies are needed that include such cases of spinal malalignment.

Conclusion

This novel classification is effective to plan surgical treatment for DNDLS combined with DSD. Cobb angle and CVA improved with surgery. However, Cobb angle progressed at a mean 2.1° per year, and this progression correlated with the preoperative sagittal spine alignment.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent was not required.

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