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Distal adding-on phenomenon in adolescent idiopathic scoliosis patients with thoracolumbar vertebra fusion

A case–control study

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Abstract

The adding-on phenomenon is a common complication in adolescent idiopathic scoliosis (AIS) patients after correction surgery. However, the risk factors of previous studies and the optimal treatment strategies remain controversial. The aim of this study was to identify new risk factors for the adding-on phenomenon after posterior correction surgery in AIS patients and compare different treatment strategies to guide the selection of the lowest instrumented vertebra (LIV).

All types of Lenke AIS patients who received correction surgery at our center from January 2009 to July 2014 were analyzed. The anteroposterior and lateral films were evaluated before surgery, at the 2-week follow-up, and at the 2-year or later follow-up. The patients were divided into 2 groups according to whether adding-on was observed at the last follow-up. The factors predictive of the adding-on phenomenon were identified in a multivariate binary logistic regression model. Different methods for LIV selection were compared in both the adding-on group and the control group (no adding-on).

Out of the 346 patients reviewed, 92 met the inclusion criteria; 22 of these met the definition for distal adding-on, and were included in adding-on group. The remaining 70 patients were included in the no adding-on group. The average follow-up was 3.6 years. Touch classification ($P < .000$), Dnfs ($P = .005$), and vertebra number between LIV and angle velocity (AV) ($P = .001$) were significantly different between the 2 groups. Age, gender, Risser sign, and screw density were not found to be affiliated with the presence of adding-on. The results of the Scoliosis Research Society (SRS)-22 were not significantly different between the adding-on group and the control group for any section or overall ($P > .05$). Binary logistic regression results indicated that postoperative LAV deviation from the CSVL and Touch classification were independent predictive factors. Among the 4 methods, only choosing touch type A as LIV shows satisfactory outcome.

The Touch classification is an important risk factor that is highly correlated with the incidence of the adding-on phenomenon. The best LIV choice to preserve the lumbar activity segment as much as possible is Touch type C, and no significant difference was observed in the SRS-22 scores between the Touch type C group and the control group in the short-term follow-up.

Abbreviations: AIS = adolescent idiopathic scoliosis, AV = angle velocity, CSVL = center sacrum vertical line, Dnfs = the number of vertebrae from the first non-fused vertebra to the L5 vertebra, DV = the first vertebra in the cephalad direction from the sacrum with a deviation from the CSVL of more than 10 mm, LAV = lumbar apical vertebral, LIV = lowest instrumented vertebra, LIV-CSVL = vertebrae-central sacral vertical line, LTV = last touching vertebra, NV = neutral vertebra, SV = stable vertebra, SV-1 = the first segment above the stable vertebra.

Keywords: adding-on phenomenon, adolescent idiopathic scoliosis, CSVL, risk factor, treatment strategy

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1. Introduction

In younger and progressive patients with adolescent idiopathic scoliosis (AIS), surgery often becomes the only choice because brace treatment cannot control the development of the deformity. However, in surgical cases, after spinal fusion control, the deformity continues to develop, and the spine continues to grow, thus producing the distal postoperative adding-on phenomenon.[1] Adding-on often leads to the progressive loss of curve correction, unsatisfactory clinical outcomes, and a high risk of reoperation, the incidence of which has been reported to be 2% to 13%[2–4] and is a great concern among patients and surgeons.[5]

Many previous studies have focused on this phenomenon. Although many risk factors are associated with adding-on, such as age, skeletal immaturity, increases in the lowest instrumented vertebrae-central sacral vertical line (LIV-CSVL) distance of 10 mm in the postoperative period, the number of vertebrae from the first nonfused vertebra to the L5 vertebra (Dnfs), the postoperative scoliosis of the lumbar curve, and shoulder balance,[3,4,6–8] the selection of the LIV is the most important factor. Wang et al[1] suggested choosing the DV (the first vertebra in the cephalad direction from the sacrum with a deviation from the CSVL of more than 10 mm) because the LIV may provide the best outcome; it not only prevents adding-on but also conserves more lumbar motion and growth potential. However, these previous studies have used Lenke 1, 2 AIS patients as study subjects, and most were treated with thoracic vertebra fusion. Few studies have focused on thoracolumbar vertebra fusion and took Lenke5 or Lenke6 AIS patients as study subjects. In addition, no consensus has been reached regarding the main causes of the adding-on phenomenon, and the method to determine the LIV is also unclear.

The purpose of this study was to identify new risk factors for the adding-on phenomenon after posterior correction surgery in AIS patients with thoracolumbar vertebra fusion and compare different treatment strategies to guide the selection of the LIV.

2. Methods

2.1. Patient population

Thoracolumbar vertebra fusion, double-curved, AIS patients who received posterior pedicle screw instrumentation at our center from January 2009 to July 2014 were retrospectively analyzed. The inclusion criteria consisted of thoracolumbar vertebra fusion AIS patients with no operation history and treatment with posterior pedicle screw instrumentation. All of the patients received posterior correction surgery under controlled hypotension. The fusion material was a freeze-dried bone allograft. Scoliosis was corrected with a combination of translation and rod derotation techniques. The common criterion of proximal fixed vertebra selection was the neutral vertebra (NV), and the distal end was the stable vertebra (SV) or the first segment above the SV (SV-1). All of the patients included were followed up for at least 2 years. Other scoliosis types, such as neuromuscular scoliosis and degenerative scoliosis, as well as patients without sufficient radiological parameters, were excluded. This study was approved by the Institutional Review Board at our university, and all of the patients in our study provided written informed consent.

2.2. Data collection

General information, including age, gender, Lenke classification, Risser sign, fusion range, number of screws, and follow-up period, were recorded. Standing posteroanterior radiographs before surgery and standing posteroanterior and lateral radiographs at 2 weeks after surgery (initial) and at the 2-year follow-up were obtained. Radiological parameters were measured and analyzed, including the gap difference of the AV-LIV (the vertebrae in the lumbar region with the largest deviation from the CSVL was chosen as the AV; e.g., if the AV was at L3 and the LIV was at T12, the gap difference of AV-LIV was 3, "+": the LIV was distal to the EV and "-": the LIV was proximal to the AV); the screw density (screw number/fusion number); the positional relationship between the LIV and CSVL (the vertical line that bisects proximal sacrum), called the Touch classification, which was divided into 3 categories: A, the CSVL was located in the LIV pedicle of the lateral side and did not touch the pedicle; B, the CSVL touched the LIV pedicle; C, the CSVL was located between the LIV bilateral pedicles (Fig. 1); the number of nonfused segments on the distal end of the LIV (Dnfs, the number of vertebra from the first nonfused vertebra to the L5 vertebra; e.g., if the first nonfused vertebra was T12, the number of remaining segments was 6); the deviation of the lumbar apical vertebrae from the CSVL; and the SRS-22 scores (Scoliosis Research Society questionnaire). These scores were evaluated by focusing on the

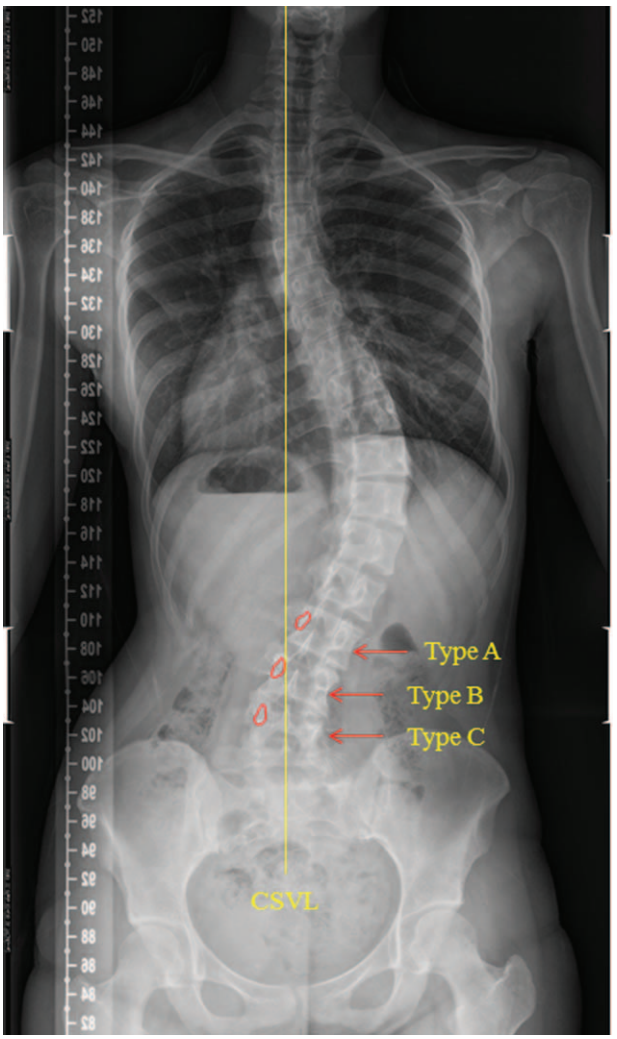

Figure 1. Touch type diagram.

patient-centered outcome, groups of different Touch classifications, and the adding-on and no adding-on groups with regard to pain, appearance, activity, mental health, and satisfaction. All of the parameters were obtained by 2 independent surgeons with 2 replications, and the average value of 4 repetitions was calculated.

At the final follow-up, the patients were divided into 2 groups based on whether the adding-on phenomenon occurred, according to the definition by Wang et al,[1] which specifies a progressive increase in the number of vertebrae included within the primary curve distally combined with either an increase of more than 5 mm in the deviation of the first vertebra below the instrumentation from the CSVL or an increase of more than 5° in angulation of the first disc below the instrumentation at the 1-year follow-up.

2.3. Statistical analysis

The SPSS 18.0 software package (SPSS Inc., Chicago, IL) was used for all statistical analyses. Descriptive statistics are presented as means and standard deviations. Independent 2-sample *t* tests were used to compare the differences in variables between the 2 groups. A χ^2 test was used to compare the differences in count data. The Spearman correlation test was used to test the correlation between various factors and the presence of adding-on. Binary logistic regression models with forward elimination (conditional) were constructed using variables that were found to be significant in a comparison study. A value of $P < .05$ was considered to be a significant difference.

2.4. Treatment strategy comparison

We employed 4 commonly used parameters to determine the LIV before surgery: classification of the LIV at the vertebra exhibiting the Touch A criterion; classification of the LIV at the vertebra exhibiting the Touch B criterion; classification of the LIV at the vertebra exhibiting Touch C criterion; and classifying the LIV at the DV, which was the first vertebra in the cephalad direction from the sacrum for which the deviation from the CSVL was more than 10 mm. All 4 methods were compared in the adding-on group to identify which strategies could better prevent distal adding-on, and the methods were also compared in the control (no adding-on) group to identify the strategies that could more effectively conserve mobility in the lumbar spine.

3. Results

Of the 346 patients reviewed, 92 [14 males (15%), 78 females (85%)] met the inclusion criteria; 22 of these patients met the definition for adding-on [20 females (25.6%), 2 males (14.3%)]. The average follow-up was 3.6 years. The average age at surgery was 14.4 years (ranging from 10 to 20 years), and the average Risser sign was 3.3. The study included 48 Lenke 1 patients (14 with adding-on, 29.2%), 18 Lenke 2 patients (6 with adding-on, 30%), 8 Lenke 3 patients (2 with adding-on, 25%), 16 Lenke 5 patients (no adding-on), and 2 Lenke 6 patients (no adding-on). Regarding the Touch Classification, 33.7%, 37.0%, and 29.3% of these AIS patients were classified as type A, B, and C, respectively. In addition, 18 type A (58%) and 4 type B (12%) patients exhibited adding-on, and no adding-on occurred for type C patients. The distribution of the measurements is summarized in Table 1.

Table 1

General information of patients.

	Case (n)	Percentage (%)	Adding-on case	Adding-on percentage (%)
Gender				
Female	78	85	20	25.6
Male	14	15	2	14.3
Risser sign				
0	5	5	2	40
1	6	6	0	0
2	19	21	0	0
3	21	23	9	42.8
4	9	10	3	33.3
5	32	35	8	25
Lenke classification				
1	48	52.2	14	29.2
2	18	19.5	6	30
3	8	8.7	2	25
4	0	0	0	0
5	16	17.4	0	0
6	2	2.2	0	0
Touch classification				
A	31	33.7	18	58
B	34	37.0	4	12
C	27	29.3	0	0

3.1. Univariate analysis

Significant differences in the parameters between these 2 groups were found for the following: Touch classification ($P < .000$), Dnfs ($P = .005$), and vertebra number between LIV and AV ($P = .001$). The Spearman correlation test revealed a significant correlation with the Touch classification for Dnfs, deviation from the LAV (lumbar apical vertebral) to the CSVL in the postoperative follow-up, and vertebra number between LIV and AV. The data are summarized in Table 2. Furthermore, the scores for pain, appearance, activity, mental health, and satisfaction and the total score were 4.4 ± 0.5, 4.2 ± 0.7, 4.1 ±

Table 2

Risk factor identification test.

	Adding-on N = 22	NO-Adding-on N = 70	$P^{\dagger}$	Correlation coefficient	P^{*}
Age	14.4 ± 2.5	14.5 ± 2.2	.939	−0.031	.772
Gender			.365	0.096	.365
Risser sign	3.5 ± 1.5	3.2 ± 1.57	.291	0.131	.214
Touch classification			<.000‡	−0.489	<.000‡
Screw density	64 ± 7%	67 ± 7%	.171	−0.151	.152
Dnfs	2.1 ± 0.6	1.6 ± 1.1	.005‡	0.210	.044‡
Postoperative LAV	11.1 ± 6.3	14.2 ± 8.0	.070	−0.153	.046‡
Deviation from CSVL vertebra	0.4 ± 0.5	−0.13 ± 0.8	.001‡	0.278	.007‡
SRS-22					
Pain	4.4 ± 0.5	4.4 ± 0.6	.67		
Appearance	4.2 ± 0.7	4.3 ± 0.5	.52		
Activity	4.1 ± 0.4	4.1 ± 0.5	.61		
Mental health	4.2 ± 0.7	4.3 ± 0.6	.42		
Satisfaction	4.3 ± 0.6	4.4 ± 0.5	.25		
Total score	4.3 ± 0.4	4.2 ± 0.6	.56		

CSVL = central sacral vertical line, Dnfs = the number of vertebrae from the first nonfused vertebra to the L5 vertebra, LAV = lumbar apical vertebral, SRS-22 = scoliosis research society-22.

* Spearman correlation test was performed.

† Continuous variables were presented as mean ± standard deviation and tested by using independent 2-sample *t* test; categorical variables were presented as frequency and tested by using x^2 test.

‡ Significantly correlated with the presence of adding-on, $P < .05$.

Table 3

Touch classification SRS-22.

SRS-22	Type A	Type B	Type C	*P*
Pain	4.4±0.3	4.5±0.2	4.4±0.5	.72
Appearance	4.3±0.1	4.2±0.8	4.2±0.7	.50
Activity	4.1±0.5	4.1±0.4	4.2±0.2	.21
Mental health	4.2±0.6	4.3±0.4	4.2±0.7	.42
Satisfaction	4.3±0.5	4.4±0.1	4.3±0.4	.33
Total score	4.3±0.4	4.2±0.5	4.3±0.6	.46

Continuous variables were presented as mean ± standard deviation and tested by using independent 2-sample *t* test.

Table 4

Binary logistic regression analysis for risk factor of adding-on.

Valuable	B	S.E.	Wald	Df	*P*	OR	95% CI
Postoperative LAV Deviation from CSVL	−1.828	0.665	7.557	1	.006*	0.161	0.044–0.592
Touch classification	−2.274	0.586	15.047	1	<.000*	1.137	0.039–1.478
Constant	5.454	1.600	11.613	1	.001*	223.665	

95% CI = 95% confidence interval; OR = odds ratio; S.E. = standard error.
* Statistically significant.

0.4, 4.2±0.7, 4.3±0.6, and 4.3±0.4 in patients with adding-on and 4.4±0.6, 4.3±0.5, 4.1±0.5, 4.3±0.6, 4.4±0.5, and 4.2±0.6 in patients without adding-on, and no significant differences were found between the 2 groups (all $P > .05$, Table 2).

3.2. Multivariate analysis

On the basis of the results of the risk factor identification analysis, the Touch classification, Dnfs, LIV-AV difference, and postoperative LAV deviation from the CSVL were used to establish a binary logistic regression model (Table 3). The results indicated that postoperative LAV deviation from the CSVL and Touch classification were independent predictive factors for adding-on. However, other variables were not included in the regression equation (Dnfs: $P = .103$, vertebra number between LIV and AV; $P = .325$), as summarized in Table 3.

The 4 previously mentioned strategies used to determine the LIV were compared within the adding-on group (Table 4). Using type C to specify the LIV produced the best outcome, use of type B and the DV produced a similar outcome. In all of the adding-on cases, the type A criterion was used to select the LIV. The 4 treatment strategies were also evaluated within the control group (Table 5). An unsatisfactory outcome was observed when type C was used. At least 1 vertebra was added to the fusion extent. However, type A showed the best outcome (Figs. 2–5).

4. Discussion

The adding-on phenomenon is a common complication after surgery in AIS patients that occurs during the long-term follow-up.[9] Initially, Lenke found that the incidence of decompecation and imbalance will increase after surgery while AIS patients employed selective thoracic fusion, the apical vertabra of lumbar curve deviated CSVL, for Lenke1C cases.[10,11] Suk et al[12,13] also discovered this phenomenon in some Lenke 1 AIS patients in whom the original main thoracic curve extended toward the overcorrected lumbar curve, which was termed the adding-on phenomenon, and considered that NV is an important factor for the determination of fusion level. Adding-on often leads to the

Table 5

Comparison of the 4 methods within adding-on group.

Patient no.	Fusion extent	Touch classification							
		A	B	C	DV	A*	B*	C*	DV*
1	T4-L2	L2	L3	L4	L3	0	1	2	1
2	T4-L3	L3	L4	L5	L4	−1	0	1	−1
3	T3-L3	L3	no	L4	L3	0	no	1	0
4	T3-L2	L2	no	L4	L3	0	no	2	1
5	T3-L3	L3	no	L4	L3	0	1	1	0
6	T3-L3	L3	L4	L5	L4	−1	0	1	0
7	T2-L4	L4	L5	S1	L5	0	1	2	1
8	T5-L3	L3	L4	L5	L3	0	1	2	0
9	T3-L3	L3	L4	L5	L4	0	1	2	1
10	T4-L3	L3	L4	L5	L4	−1	0	1	0
11	T2-L4	L4	L5	S1	L5	0	1	2	1
12	T3-L3	L3	no	L4	L3	0	no	1	0
13	T3-L3	L3	no	L4	L3	0	no	1	0
14	T4-L2	L2	L3	L4	L3	0	1	2	1
15	T4-L2	L2	L3	L4	L3	0	1	2	1
16	T3-L3	L3	L4	L5	L4	−1	0	1	2
17	T3-L3	L3	L4	L5	L4	0	1	2	1
18	T2-L4	L4	L5	S1	L5	0	1	2	1
19	T2-L4	L4	L5	S1	L5	0	1	2	1
20	T3-L2	L2	no	L4	L3	0	no	2	1
21	T5-L3	L3	L4	L5	L3	0	1	2	0
22	T4-L2	L2	L3	L4	L3	0	1	2	1
Total						−4	13	**36**	12

"A*" represents choosing touch type A as LIV. "B*" represents choosing touch type B as LIV. "C*" represents choosing touch type C as LIV. "DV*" represents choosing touch type DV as LIV.
DV indicates the first vertebra in cephalad direction from sacrum whose deviation from CSVL is more than 10 mm.

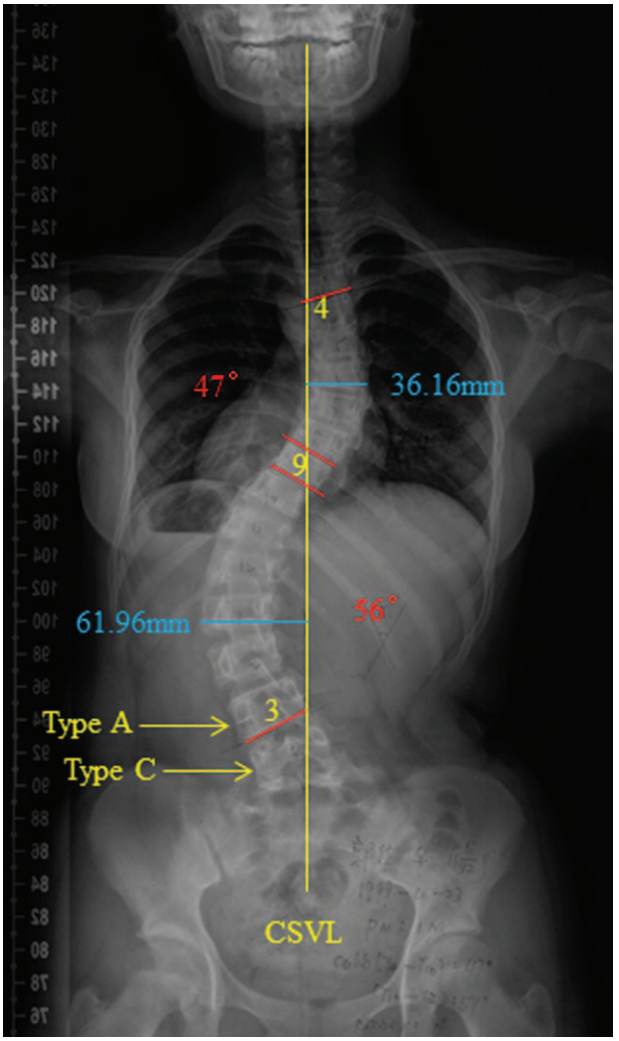

Figure 2. Typical cases, anterioposterior film in pre-operation.

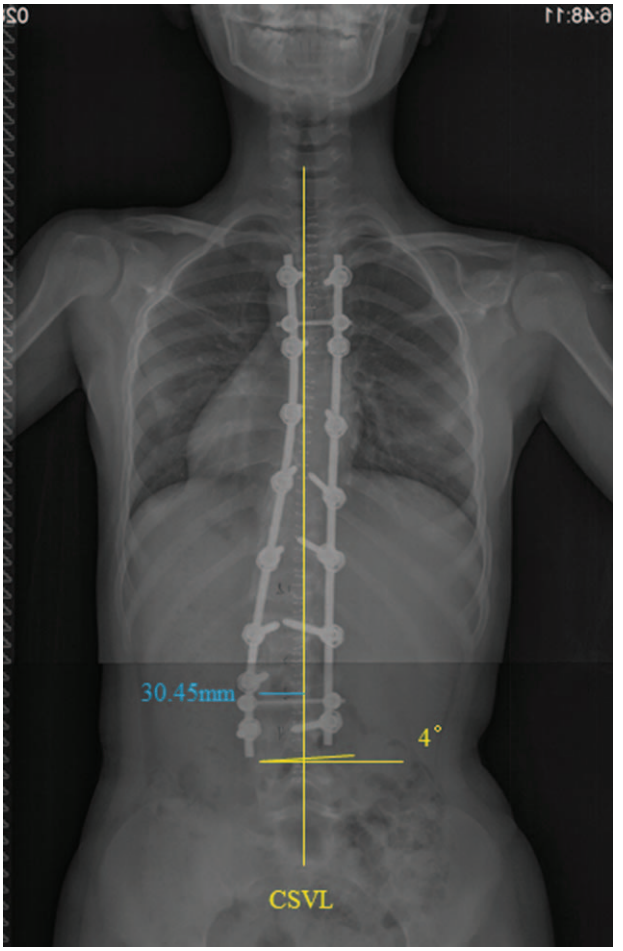

Figure 3. Typical cases, anterioposterior film 2 weeks in postoperation.

progressive loss of curve correction and unsatisfactory clinical outcomes, as well as a high risk of reoperation.[1] Later, Parisini et al[14] and Sponseller et al[5] both verified the adding-on phenomenon after selective thoracic surgery.

Thus, several authors have focused on this phenomenon and have found that skeletal immaturity and the selection of the LIV are highly correlated with distal adding-on.[1,4,8] Skeletal immaturity is indicated by an earlier and smaller Risser sign. Risser sign is the most common method to predict the development degree of AIS patients.[15,16] Doctor Risser[17] proposed using the different situation of iliac bone epiphyseal fusion to predict the growth potential of AIS, and put forward the Risser sign classification. It is generally assumed that only patients with the Risser sign 0-2 occurred Adding-on,[18] but some studies suggest that even patients with Risser sign 4–5 have an actively growing ability in vertebral growth plate,[19] so focusing on the growth factor alone is not enough. And Wang et al[9] concluded that less mature patients were more likely to experience adding-on. Yang et al[8] stated the same conclusion. However, a contradiction exists between increased spine fusion to prevent scoliosis progression and preservation of more of the segment to obtain better lumbar activity; thus, the selection of the LIV was subjected to more in-depth research. Wang et al[1] suggested selection of the DV, as the LIV produced the best outcomes and fewer complications because this method maintains more lumbar motion and decreases the incidence of adding-on. Matsumoto et al[3] suggested that the remaining apical vertebra deviation of the main thoracic curve and the last touching vertebra (LTV) in the cephalad direction of the LIV were significantly correlated with adding-on. Lakhal et al[4] concluded that the choice of the LIV influenced the deterioration of the lumbar curve and the development of adding-on.

In clinical research, it is difficult to decide which vertebra should be classified as the LIV, especially in AIS patients with lumbar fusion. Because waist activity depends mainly on the function of L4, L5, and S1, if lumbar fusion includes L5 or S1, waist motion is mostly lost. Although the functional activity can be compensated by a bilateral hip, the quality of life is obviously different for patients who have more active segments.[20] Thus, for patients with lumbar fusion, LIV selection is critical. The low corrective and satisfaction rates are the result of an insufficient fusion range, which can easily result from the postoperative occurrence of the adding-on phenomenon, which frequently requires revision surgery. In contrast, the postoperative quality of life is decreased due to an extended fusion range, and a suitable LIV may resolve this condition. The choice of the LIV based on an analysis of the anteroposterior (coronal) and lateral (sagittal) ranges of motion seems to prevent the development of adding-on. Although many risk factors have been found, the incidence of

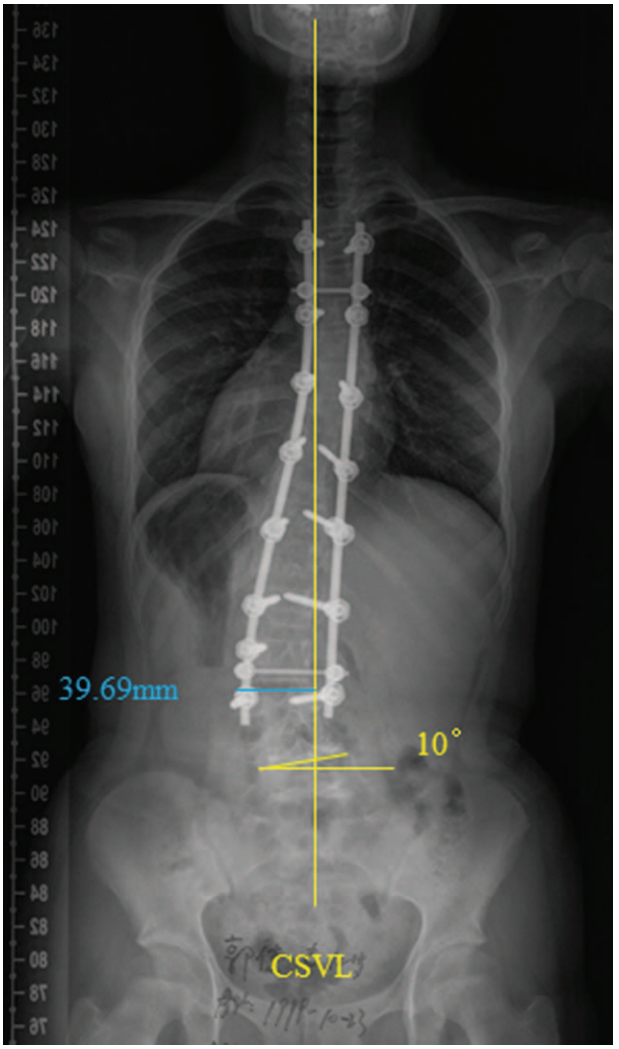

Figure 4. Typical cases, anterioposterior film 1 year in postoperation.

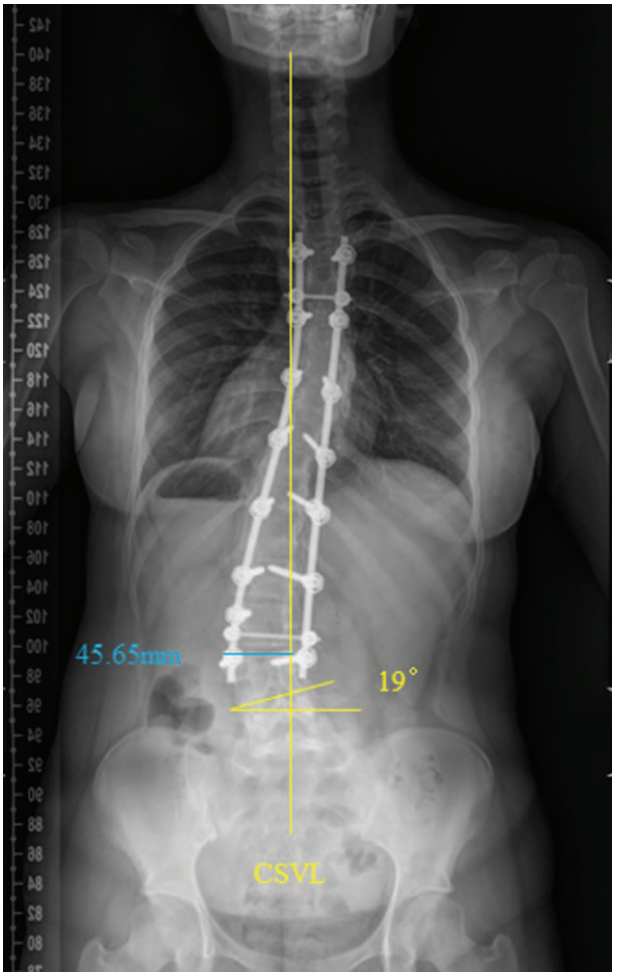

Figure 5. Typical cases, anterioposterior film 2 years in postoperation.

adding-on is low, ranging from 2% to 13%.[2–4] We generally believe that some cases of adding-on may be avoided. As found in clinical observation, the relationship between the CSVL and the LIV has an important guiding significance for the choice of the LIV.

Previous studies have mainly included Lenke 1 and 2 AIS patients. There are 2 reasons for this choice: lumbar curve unfusion is easy to perform for the majority of Lenke 1 and 2 AIS patients treated with thoracic curve correction surgery and adding-on rarely occurs in Lenke 3, 4, 5, and 6 AIS patients due to the lumbar curve structure. Thus, the lumbar curve should be included in the fusion range because little possibility of progression exists; the literature also support this idea.[21] However, no relevant reports exist regarding the postoperative adding-on phenomenon in AIS patients with thoracic-lumbar curve fusion. This retrospective study with thoracic-lumbar curve fusion patients was conducted to explore new risk factors for the adding-on phenomenon and to determine a better method to guide the choice of the LIV.

Regarding the 92 patients included in this study, the LIV was lower than L2, the adding-on group consisted of 22 patients, the control group consisted of 70 patients, and the general data trend showed that adding-on did not occur in Lenke 3, 4, and 5 AIS patients, indicating that the structure of the lumbar curve was fused. In addition, no adding-on occurred in patients classified according to Touch type C. This result indicated that the Touch classification has important clinical significance.

In the adding-on group, a lower Touch type and Dnfs were observed, as well as a higher segment number between the LIV and DV. The Touch classification is a new risk factor that requires verification. We classified the region between the CSVL and LIV pedicle into 3 types depending on whether the CSVL touched the LIV pedicle: A, B, or C (Fig. 1). This classification was inspired by the lumbar modification of the Lenke classification.[22] CSVL Touch Type can evaluate long-term follow-up in a simple way; compared with LIV-CSVL, it is more qualitative other than quantitative. The CSVL is an important parameter used to evaluate spinal coronal balance.[23] In Touch type A, the LIV pedicle does not touch the CSVL, indicating that the LIV deviates from the center vertical line of the body. Patients with a large lumbar curve often have an L5 tilt, a large lumbar vertebra rotation, and a large AV deviation.[24] In our research, the adding-on incidence of patients with an LIV classified as Touch type A is as high as 58%, indicating that more than half of these patients showed the adding-on phenomenon. In addition, if the fusion segment is too short, the incidence of adding-on will increase.[8] Thus, the choice of the LIV can influence the Dnfs and adding-on. Furthermore, clinical observation showed that an

enlarged fusion segment can prevent adding-on. The DV is the vertebra that starts to deviate from the CSVL, indicating the boundary between the deviation and the center.

Regarding the questionnaire, the mean follow-up period was 3.6 years. The results of the SRS-22 were not significantly different between the adding-on group and the control group for any section or overall ($P > .05$); thus, our research is consistent with that of Matsumoto et al[3] and Yang et al.[8] However, a long-term study is needed. Moreover, the same result was obtained when grouping by Touch type. This shows that in the short-term follow-up period (<5 years), the quality of life of patients classified as Touch type C was not different from that of Type A and B patients, but the incidence rates of adding-on for type A and B patients were 58% and 12%, respectively.

The parameters of the scoliosis of the main thoracic curve and lumbar curve were not included in the logistic correlation analysis because they were part of the inclusion criteria of the adding-on group. Spearman correlation analysis showed that the Touch classification and postoperative deviation from the LAV to the CSVL were negatively correlated, while the Dnfs and vertebra number between the LIV and AV were positively correlated. The correlation with the Touch classification was highest (correlation coefficient = −0.489). Binary logistic regression analysis showed that the Touch classification and postoperative LAV deviation from the CSVL are independent impact factors, both showing negative correlations. The following logistic equation was used: $P = 5.454 – 1.828$ Deviation-2.274 Touch. Therefore, when the Touch type was classified as C, the deviation was very negligible, and the incidence of adding-on was lowest.

Regarding the classification of a long or short fusion range, a high or low correction effect and the absence or presence of the adding-on phenomenon will depend on the study aims; thus, different surgeons will choose different classifications. Regarding the LIV hypothesis, our study referenced the method of Wang et al,[1] in which the LIV will exhibit a decreased adding-on incidence and more lumbar activity. In the adding-on group, a more appropriate LIV will extend the fusion range, which is the theoretical basis of our hypothesis. Four choices of LIV were compared between the adding-on and control groups. We found that using the Touch C classification was the best method to prevent adding-on, and the fusion range increased by at least one segment in the adding-on group. In addition, we recommend choosing L4 as the LIV when L5 is Touch type C and L4 is Touch type B, and the LIV should be classified as Touch type C if it is above L4.

5. Conclusion

The Touch classification is an important risk factor that is highly correlated with the incidence of the adding-on phenomenon, and it is more qualitative way. The best LIV choice to preserve the lumbar activity segment as much as possible is Touch type C, and no significant difference was observed in the SRS-22 scores between the Touch type C group and the control group in the short-term follow-up.

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