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Choice of Lowest Instrumented Vertebras for Lenke I Adolescent Idiopathic Scoliosis Orthopedics

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Abstract: To discuss the impact of different lowest instrumented vertebras on the effect of posterior spinal pedicle screw-rod orthopedics for treatment of Lenke I adolescent idiopathic scoliosis. 45 patients with adolescent idiopathic scoliosis (AIS) who received posterior pedicle screw-rod orthopedics from July 2011 to September 2015 were analyzed retrospectively. All patients were divided into touched vertebra group (n=21 cases; 6 M and 15 F) and stable vertebra group (n=24 cases; 7 M and 17 F) according to the choice of different lowest instrumented vertebras. The indexes of the coronal and sagittal spinal imaging before and after operation as well as in the last follow-up were analyzed and SRS-22 questionnaire was performed to evaluate the curative effect. Through a 6-36-month follow-up visit, no significant difference was found in the pre-operative indexes (Cobb angle and pre-operative TS, SVA, TK and LL) of the coronal and sagittal spinal imaging between the two groups ($P>0.05$). Meanwhile, there was no statistical difference in the spinal coronal parameters (i.e., Cobb angle, TS, pre-operative thoracic-waist/waist scoliosis, pre-operative flexibility of thoracic scoliosis, correction rate and loss rate) after operation and in the last follow-up visit between the two groups ($P>0.05$). In touched vertebra group, the coronal spinal parameters (e.g., thoracic-waist/waist scoliosis) after operation and in the last follow-up visit were significantly higher than those of stable vertebra group ($P<0.05$) while there was no statistical difference in postoperative SVA between the two groups ($P>0.05$). In the aspect of fusion segments, the touched vertebra group saved one centrum relative to stable vertebra group ($P<0.05$). The postoperative SRS-22 scores for living quality of both groups were significantly decreased compared with the pre-operative, in which the score was decreased from the preoperative 51.0 to 29.0 in touched vertebra group and from 50.9 to 28.7 in stable vertebra group (both $P<0.05$), but both the pre- and post-operative scores were not significantly different between the two groups ($P>0.05$). In order to treat Lenke I AIS patients with posterior pedicle screw-rod orthopedics, touched vertebra should be used as lowest instrumented vertebra as it can not only obtain the similar therapeutic effect to stable vertebra, but also shorten the fixed segments.

Keywords: Idiopathic Scoliosis, Lowest Instrumented Vertebra, Stable Vertebra, Touched Vertebra

1. Background

Adolescent idiopathic scoliosis (AIS) is a three-dimensional deformity of spine characterized by the scoliosis on the coronary plane, losing normal physiological curvature on the sagittal plane and the vertebral rotation on the horizontal plane [1, 2]. Scoliosis Research Society defines the scoliosis as follow: Cobb's method was used to measure the spinal curvature on an erect position by anteroposterior X-ray film and the angle > 10° was regarded as scoliosis [3]. The incidence of AIS is 1%～3% in risk populations aged 10～16 years old [4]. It can cause a variety of severe physical deformities. For spine, lateral curvature can cause the growth imbalance of spine, thus affecting the height and leading to slant trunk, unequal height of shoulders, chest deformity, razorback and other physical abnormalities, and even might result in dysfunction of circulation, respiratory and nervous system to severely affect the child' appearance, spirit and social activities, etc. Therefore, it is necessary to deepen the cognition of this disease in the clinical practice to achieve early detection and early treatment. The surgical therapy is generally required for patients with severe scoliosis (Cobb angle ≥ 40°) accompanied by thoracic spinal lordosis, thorax rotation, razorback, slant trunk and obvious decompensation [5].

The surgical therapy for scoliosis requires to correct the coronal, sagittal and axial deformities and perform bone graft fusion based on the internal fixation in order to prevent deformity development, thereby improving the appearance and preventing back pain and dysfunction. Currently, the effective treatment methods for AIS are the surgical therapies, of which posterior approach operation is applied most in the clinical practice, including Cotrel-Dubousset spine internal fixation system, Harrington system, AO-USS spinal fixation system and pedicle screw-rod system [6]. Nowadays, the orthopedics with pedicle screw-rod system is regarded as the most effective method for the treatment of AIS. However, there is a big controversy for choice of fusion range of the spine, which focus on the choice of lowest instrumented vertebra (LIV) (stable vertebra or touched vertebra). Some research believed that touched vertebra as LIV can retain more movement segments [7].

The surgery for Lenke I scoliosis should make sure the satisfaction of orthopedics while try to retain the movement segments of the spine, especially the lumbar motility. In this study, we retrospectively analyzed the data of 45 patients with AIS who treated with posterior pedicle screw-rod orthopedics from July 2011 to September 2015 and discussed the effect of different lowest instrumented vertebras on the effect of posterior pedicle screw-rod orthopedics for Lenke I adolescent idiopathic scoliosis, providing a reference for more scientifically choosing the surgical programs of AIS.

2. Methods

2.1. Participants

Inclusion criteria: (1) the patients were definitely diagnosed with AIS; (2) the patients aged 10-18 years; (3) AIS patients with Cobb angle ≥ 40° on anteroposterior X-ray of the scoliosis; (4) the preoperative forced vital capacity was 40%～85% of normal predicted value; (5) the patients who had no serious heart and lung disease and could tolerate the surgery. Exclusion criteria: (1) the patients were not conformed to the diagnosis of AIS; (2) the patients aged < 10 years or > 18 years; (3) AIS patients with Cobb angle < 40° on anteroposterior X-ray of the scoliosis; (4) the patients who had serious heart and lung disease and other organ functional lesion and could not tolerate the surgery; (5) AIS combined with spinal tuberculosis, spinal tumor, syringomyelia and tethered cord syndrome.

We retrospectively analyzed the data of the lenke I AIS patients who treated with posterior pedicle screw-rod orthopedics from July 2011 to September 2015 and a total 45 cases were included in this study. All patients were divided into touched vertebra group and stable vertebra group according to the choice of different lowest instrumented vertebras (Table 1).

Table 1. *Patient information.*

Groups	Number of cases	Age (years, x̄±s)	Sex (n)		Lenke types (n)	
			Male	Female	IA	IB
Touched vertebra group	21	15.1±2.8	6	15	12	9
Stable vertebra group	24	15.0±1.3	7	17	10	11
t value		0.103	3.943		4.000	
P value		0.919	0.783		0.406	

2.2. Surgical Methods

Preoperative examinations were completed, including preoperative evaluation of heart and lung function. The positions of Apical Vertebra (AV), End Vertebra (EV), Neutral Vertebra (NV), Stable Vertebra (SV) and Touched Vertebra (TV) were determined according to Harrington's Principle, of which TV was the first centrum touched at the lowest scoliosis in the sacral midline and located between bilateral pedicles of touched vertebra. Risser index was divided into grade 0~IV. The rotation of touched vertebra was measured by Nash-Moe method. The vertebra to be implanted with the screw was conformed and designed based on the imaging results before operation and pre-operative SRS-22 scoring was accomplished in a quiet environment. (1) The electrophysiological monitoring was performed during operation and the patient adopted a prone position on the operating bed adjusting curvature while nothing was filled under the abdomen after general anesthesia with tracheal intubation worked; (2) A longitudinal incision was made on the middle of vertebral segment designed before operation; and the skin, subcutaneous tissue, fascia and supraspinous ligament were cut, followed by stripping the surrounding soft tissues along the perispinous process to expose the bilateral zygapophyseal joint, and placement of pedicle screw with an appropriate length, and confirming the internal fixation position in place by intraoperative fluoroscopy; (3) A longitudinal connecting rod of appropriate length was chosen and pre-bended following the pedicle screw tail direction. After placing the screw tail and screwing the nut, the longitudinal connecting rod was rotated. The scoliosis was transformed into thoracic kyphosis, and the tail of screw was locked after completing correction and the longitudinal connecting rod with same radian and nut were contralaterally implanted, followed by rotating and locking. (4) Intraoperative spinous process was removed and retained for use in bone grafting and the post- vertebral plate cortical bones in bone grafting segments were removed to expose cancellous bones and the retained cancellous bones were implanted into the space between vertebral plates and cross-linkage was installed. Then, fluoroscopy was conducted again to make sure the internal fixation position in place. (6) The incision was washed while one drainage tube was indwelt. The incision was sutured layer by layer. The bleeding was recorded during the operation.

2.3. Observation Index

All AIS patients underwent the full-length spinal anteroposterior-lateral and left-right Bending X-ray on an erect position before operation, and were asked to return to the hospital for review by the full-length spinal anteroposterior-lateral X-ray on an erect position 6 months-1 year after the surgery. The coronal balance and forms of spine were measured: (1) Cobb angle for main thoracic (MT); (2) trunk shift (TS), measured based on the distance from the midline of the 7th cervical vertebra to the midline of the sacrum (C7-CSVL); (3) bending position measuring: flexibility of thoracic scoliosis = (Cobb's angle on the anteroposterior X-ray of thoracic scoliosis before operation - Cobb's angle on bending X-ray of thoracic scoliosis)/Cobb's angle on the anteroposterior X-ray of thoracic scoliosis before operation. As shown in Figure 1, the sagittal form of the spine was measured: (1) the distance from C7 plumb line to the posterior superior border of the sacrum was measured; (2) thoracic kyphosis (TK): the included angle between the superior endplate of T5 vertebral body and inferior endplate of T12 vertebral body; (3) lumbar lordosis (LL): the included angle between the superior endplate of L1 vertebral body and superior endplate of S1 vertebral body. Fused segments counting: fused segments were counted after operation.

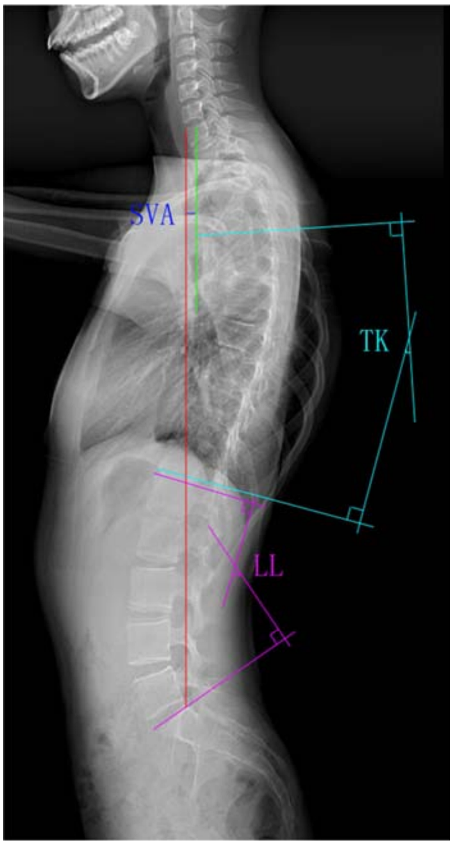

Figure 1. Schematic diagram of measurement indexes on coronal view and sagittal view.

2.4. Score of Quality Life

Scoliosis Research Society-22 (SRS-22) was used and included a total of 22 questions covering movement function, pain status, self-assessment, mental health and treatment satisfaction scale. 5 options were set for each and corresponded to score 1 to 5, with total score of 110.

2.5. Statistical Methods

The data were analyzed using SPSS 19.0 statistical software. *t* test was used to compare the age, Risser indexes, flexibility of lumbar vertebra, Cobb's angle, SVA, TK and LL between the two groups, in which the data were expressed as $\overline{x} \pm s$ ($\overline{x}$ was mean value and s was standard deviation) and the difference with $P < 0.05$ was statistically significant.

3. Results

In all included 45 patients with AIS, the operation were all performed by the same group of physicians. The average operation time was (180 ± 30) min and the intraoperative amount of bleeding was (548 ± 195) mL, and the duration of follow-up was 6 months to one year.

3.1. Comparability of Baseline Information Between the Touched Vertebra Group and Stable Vertebra Group (hereinafter Inclusive)

There was no statistical difference in pre-operative Cobb angle [(54.2 ± 7.7) vs. (49.0 ± 8.2); *t*= 1.466, *P* = 0.160 > 0.05], TS [(8.3 ± 17.6) vs. (16.3 ± 13.0); *t*=0.290, *P* = 0.775 > 0.05], SVA [(14.0 ± 11.0) vs. (10.3 ± 11.6); *t*= 0.733, *P* = 0.473>0.05], TK [(29.7 ± 15.4) vs. (29.0 ± 13.6); *t*= 0.108, *P* = 0.915 > 0.05], LL [(45.1 ± 5.9) vs. (48.4 ± 6.9); *t*= -2.183, *P* = 0.242 > 0.05], and flexibility of thoracic scoliosis [(0.49 ± 0.13) vs. (0.38 ± 0.10); *t* = 2.074, *P* = 0.0.053 > 0.05] between the two groups (Table 2). These results indicated that the pre-operative basic information and baseline information were comparable between the two groups.

Table 2. *Baseline information.*

	Preoperative Cobb angle (°, x̄±s)	Preoperative TS (°, x̄±s)	Preoperative SVA (mm, x̄±s)	Preoperative TK (°, x̄±s)	Preoperative LL (°, x̄±s)	Flexibility of thoracic scoliosis (x̄±s)%
Touched vertebra group	54.2±7.7	18.3±17.6	14.0±11.0	29.7±15.4	45.1±5.9	0.49±0.13
Stable vertebra group	49.0±8.2	16.3±13.0	10.3±11.6	29.0±13.6	48.4±6.9	0.38±0.10
t value	1.466	0.290	0.733	0.108	2.183	2.074
P value	0.160	0.775	0.473	0.915	0.242	0.053

3.2. Comparison of Cobb Angle, Correction Rate and Loss Rate Between Touched Vertebra Group and Stable Vertebra Group

There was no statistical difference in preoperative Cobb angle [(54.2 ± 7.7) vs. (49.0±8.2)] (*t*=1.466, *P* = 0.160 > 0.05), postoperative Cobb angle [(9.7 ± 7.2) vs. (6.7 ± 3.9)] (*t*=1.152, *P* = 0.264 > 0.05), the last Cobb angle [(9.8 ± 7.5) vs. (7.3 ± 4.1)] (*t*=0.922, *P* = 0.369 > 0.05), correction rate of Cobb angle [(0.81 ± 0.13) vs. (0.85 ± 0.07)] (*t*=-0.748, *P* = 0.464 > 0.05), and loss rate of Cobb angle [(0.03 ± 0.03) vs. (0.04 ± 0.04)] (*t*=-0.235, *P* = 0.817 > 0.05) (Table 3). These results showed similar correction effect obtained in the two groups and no obvious loss of Cobb angle in the postoperative follow-up visit.

Table 3. *Variation of Cobb angle, correction rate and loss rate before and after operation.*

Parameters	Touched vertebra group	Stable vertebra group	*t*	*P*
Preoperative Cobb angle (°, x̄±s)	54.2±7.7	49.0±8.2	1.466	0.160
Postoperative Cobb angle (°, x̄±s)	9.7±7.2	6.7±3.9	1.152	0.264
Last Cobb angle (°, x̄±s)	9.8±7.5	7.3±4.1	0.922	0.369
Correction rate of Cobb angle (x̄±*s*)%	0.81±0.13	0.85±0.07	-0.748	0.464
Loss rate of Cobb angle (x̄±*s*)%	0.03±0.03	0.04±0.04	-0.235	0.817

The count of upper end vertebra to stable vertebra (11 ± 1) in touched vertebra group was not statistically different than that (12 ± 1.7) in stable vertebra group (*t*= 0.972, *P* = 0.386 > 0.05). A statistical difference was found in the actually fused vertebral body count between touched vertebra group and stable vertebra group [(10 ± 1) vs. (12 ± 1.7)] (*t*= -6.061, 0.000 < 0.05). The mean difference between the count from upper end vertebral body to stable vertebra and the actually fused vertebral body count was one.

Table 4. *The count of fused vertebral body.*

Parameters	Touched vertebra group (number, x̄±s)	Stable vertebra group (number, x̄±s)	*t*	*P*
The count of upper end vertebra to stable vertebra	11±1	12±1.7	0.972	0.386
The count of actually fused vertebra	10±1	12±1.7	-6.061	0.000*

The pre-operative thoracic-waist/waist scoliosis was not significantly different in the touched vertebra group from that in stable vertebra group [(28.8 ± 8.2) vs. (21.8 ± 8.2)] (*t*=1.907, *P* = 0.073 > 0.05), but the postoperative value was statistically different between them [(11.9 ± 5.2) vs. (5.5 ± 3.9)] (*t*=3.101, *P*= 0.006 < 0.05). Moreover, there was statistical significance in the last thoracic-waist/waist scoliosis between the two groups [(10.2 ± 5.7) vs. (5.0 ± 3.8)] (*t*=-2.414, 0.027 < 0.05) (Table 5). All the results above indicated that the corrective effect of stable vertebra was superior to touched vertebra.

Table 5. *Comparison of thoracic-waist scoliosis/waist scoliosis.*

Parameters	Touched vertebra group	Stable vertebra group	*t*	*P*
Preoperative thoracic-waist scoliosis/waist scoliosis (°, x̄±s)	28.8±8.2	21.8±8.2	1.907	0.073
Postoperative thoracic-waist scoliosis/waist scoliosis (°, x̄±s)	11.9±5.2	5.5±3.9	3.101	0.006*
Last thoracic-waist scoliosis/waist scoliosis (°, x̄±s)	10.2±5.7	5.0±3.8	2.414	0.027*

There was no statistical difference in preoperative TS [(13.1 ± 13.3) vs. (16.3 ± 13.0)] (*t*= 0.544, *P* = 0.593 > 0.05), postoperative TS [(9.7 ± 7.2) vs. (6.7 ± 3.9)] (*t*=1.152, *P* = 0.264 > 0.05), and the last TS [(5.3 ± 3.8) vs. (2.5 ± 2.7)] (*t*=0.655, *P*

= 0.521 > 0.05) (Table 6). These suggested that both groups achieved an improvement of TS after operation and no obvious shift was found in the last follow-up visit.

Table 6. *Comparison of TS.*

Parameters	Touched vertebra group	Stable vertebra group	*t*	*P*
Preoperative TS (mm, x̄±*s*)	13.1±13.3	16.3±13.0	0.544	0.593
Postoperative TS after operation (mm, x̄±*s*)	5.3±3.8	2.5±2.7	0.655	0.521
Last TS (mm, x̄±*s*)	2.5±2.7	2.7±1.9	-0.187	0.854

No statistical difference was found in the preoperative SVA [(14.0 ± 11.0) vs. (10.3 ± 11.6)] (t = 0.733, P = 0.473 > 0.05), postoperative SVA [(10.8 ± 8.7) vs. (11.9 ± 8.8)] (t = -0.282, P = 0.781 > 0.05), and last SVA [(8.5 ± 6.6) vs. (7.2 ± 6.0)] (t = 0.460, P = 0.651 > 0.05) (Table 7). All the results above reflected that both groups achieved an improvement of sagittal balance after operation and no obvious shift was found in the last follow-up visit.

Table 7. *Sagittal vertical axis.*

Parameters	Touched vertebra group	Stable vertebra group	*t*	*P*
Preoperative SVA (°, x̄±s)	14.0±11.0	10.3±11.6	0.733	0.473
Postoperative SVA (°, x̄±s)	10.8±8.7	11.9±8.8	-0.282	0.781
Last SVA (°, x̄±s)	8.5±6.6	7.2±6.0	0.460	0.651

No statistical difference was found in the preoperative TK [(29.7 ± 15.4) vs. (29.0 ± 13.6)] (t = 0.108, P = 0.915 > 0.05), postoperative TK [(21.1 ± 10.2) vs. (17.0 ± 6.9)] (t = 1.053, P = 0.306 > 0.05), and last TK [(22.6 ± 8.7) vs. (17.9±7.0)] (t = 1.332, P = 0.200 > 0.05) (Table 8), suggesting that the postoperative TK of both groups was slightly decreased after operation but there was no statistical difference, and the findings in last follow-up visit were the same as those after operation.

Table 8. *Kyphotic angle of thoracic vertebra.*

Parameters	Touched vertebra group	Stable vertebra group	*t*	*P*
Preoperative TK (°, x̄±s)	29.7±15.4	29.0±13.6	0.108	0.915
Postoperative TK (°, x̄±s)	21.1±10.2	17.0±6.9	1.053	0.306
Last TK (°, x̄±s)	22.6±8.7	17.9±7.0	1.332	0.200

No statistical difference was found in the preoperative LL [(45.1±5.9) vs. (48.4±6.9)] (t = -2.183, P = 0.242>0.05), postoperative LL [(39.4±8.3) vs. (40.3±4.7)] (t = 0.298, P = 0.769 > 0.05), and last LL [(39.4±8.3) vs. (40.3±4.7)] (t = 0.298, P = 0.200 > 0.05) (Table 9), demonstrating that the postoperative LL of both groups was slightly reduced after operation but there was no statistical difference, and the findings in last follow-up visit were the same as those after operation.

Table 9. *Lumbar lordosis angle.*

Parameters	Touched vertebra group	Stable vertebra group	*t*	*P*
Preoperative LL (°, x̄±s)	45.1±5.9	48.4±6.9	-2.183	0.242
Postoperative LL (°, x̄±s)	39.4±8.3	40.3±4.7	0.298	0.769
Last LL (°, x̄±s)	39.4±8.3	40.3±4.7	0.298	0.769

3.3. There was no Significant Difference in Living Quality Before and After Operation

As shown in Figure 2, the pre-operative SRS22 score of touched vertebra group was significantly different from that of stable vertebra group (P > 0.05); the postoperative score of both groups dropped obviously compared with the preoperative, from (51.0 ± 6.4) to (29.0 ± 6.4) in touched vertebra group (t = 15.360, P < 0.05) while (50.9 ± 6.1) to (28.7 ± 5.8) (t = 12.800, P < 0.05). The postoperative score was not significantly different between the two groups (P > 0.05).

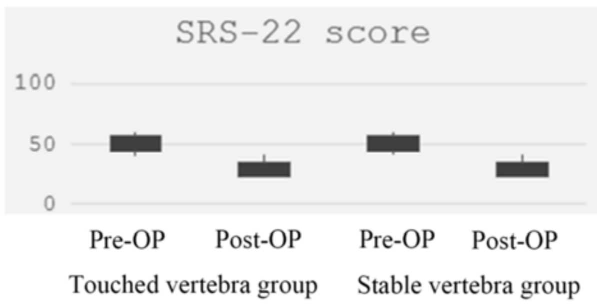

Figure 2. *Comparison of SRS22 score in patients treated with posterior pedicle screw-rod orthopedics between the two groups (score, x̄±s).*

4. Discussion

The aim of the surgical treatment for AIS is to correct the angle of scoliosis and try to keep the physiological equilibrium of the spine and reduce the fusion range, thus reserving the original function of the spine. Elective fusion surgery has become the most identified and respected operation way by scholars so far. The emergence of Leken classification system has a great guiding significance for the choice of preoperative fusion treatment [7]. It has been the controversial focuses whether the choice of fusion range can keep a long-term corrective effect and that the complications such as decompensation, extend of scoliosis and pain in lower back occur [8, 9]. When the spine surgeons choose the fusion range during operation, they always try to retain as more movement segments as possible on the premise that the curative effect is kept.

In the present study, all the patients received the surgery completed by the same group of spine surgeons so as to minimize the disputes on end vertebra, neutral vertebra, stable vertebra and touched vertebra. According to the statistical results, the correction rate of coronary Cobb angle reached a satisfactory result, whether TV or SV was chose as LIV. It meant that their abilities to correct scoliosis are similar and the regimens were feasible. As for the fused segments, touched vertebra group can averagely save one movement segment relative to stable vertebra group. In one-year follow-up visit, no loss of angle was found in both groups. Based on the postoperative and last follow-up findings, there was significant difference in coronal and sagittal balance as well as postoperative SRS-22 score between the two groups, indicating a similarity of the curative effect in both groups. Therefore, in order to treat Lenke I AIS, TV can be chosen as LIV, which can reduce the fusion segments and maintain the patients' activity as compared with SV.

For Lenke IA or IB AIS, left bendings stable vertebra (LBSV) could chosen as the LIV (Salah *et al.*) [10]. If there were ≤ 2 segments between EV and NV, NV was recommended as LIV, but there were > 2 segments, the upper adjacent segment of NV (NV-1) was suggested [11]. When Wang Yan *et al* treated the patients with Lenke I AIS, the fusion range was subject to the distance from CSVL to C7 vertical line, location of NV and EV. They determined LIV according to the lumbar rotation and the centrums that CSVL passes through. If the CSVL only passes through NV, it can be chosen as LIV, and if CSVL was between NV and EV, the middle centrum was used as LIV. If CSVL passes through EV and NV simultaneously, EV can be taken as LIV [12]. Cao *et al.* compared the postoperative scoliosis extension when the upper adjacent vertebra of touched segment, touched segment and lower adjacent vertebra as LIV, and found that the upper adjacent vertebra was used as LIV, the extension of scoliosis arc was more obvious. Hence, the present study concluded that touched vertebra relative to stable vertebra as LIV is safer. In this study, the vertebras were fused to TV and the postoperative efficacy was similar to those from Cao *et al.*, and there was no postoperative decompensations [13].

In the present study, a small sample size is used and the follow-up time is not long enough. Furthermore, it is designed to be a retrospective case study with low evidence-based index and the cases can be further expanded. It is necessary to prolong the follow-up time appropriately or design a prospective cohort study or randomized controlled trials to further enhance evidence-based medical level and improve the conclusion of research. In choosing of LIV, there is no a unified standard clinically. By prolonging the follow-up time for fused segments in these patients appropriately, the expected clinical effect is reached. However, clear quantitative indicators and in-depth researches are needed to evaluate the relationship between LIV and low end vertebra, neutral vertebra, stable vertebra when the growth potential is obvious and to determine the standard for choosing of lowest instrumented vertebras.

5. Conclusion

In order to treat Lenke I AIS patients with posterior pedicle screw-rod orthopedics, touched vertebra should be used as lowest instrumented vertebra as it can not only obtain the similar therapeutic effect to stable vertebra, but also shorten the fixed segments.

Acknowledgements

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