Original Article

Do low-density screws influence pelvic incidence in adolescent idiopathic scoliosis correction?

ABSTRACT

Background: Low-density screw constructs yield significant radiographic and clinical improvements with reduced risk of neurological complications. This study aimed to investigate the relationship between coronal Cobb angle and pelvic incidence (PI) in the correction of adolescent idiopathic scoliosis (AIS) using a low-density construct, as well as the association between PI and functional outcomes.

Patients and Methods: This prospective cohort study involved 60 posteriorly instrumented AIS patients, aged 10–16 years, with Cobb angles ranging from 45 to 90 of various Lenke types. Radiological assessments were conducted pre- and postsurgery at 1, 3, 6, 12, and 24 months. Functional evaluation utilized the Scoliosis Research Society score form (SRS-30).

Results: A positive correlation was observed between screw density and operation time, blood loss, and degree of correction with SRS change ($P = 0.004$). No correlation was found between screw density and hospital stay, loss of correction, correction rate, SRS change, change in PI, or Cobb angle.

Conclusions: Correction of AIS through a posterior approach using a low-density construct can lead to satisfactory curve correction, impacting spinopelvic parameters. However, PI alone does not directly influence patient functional outcomes assessed by SRS-30. Low-density implant constructs reduce operative time, blood loss, costs, and complication risks.

Keywords: Adolescent idiopathic scoliosis, coronal Cobb angle, deformity correction, high-density screws, low-density screws, pelvic incidence, pelvic tilt, sacral slope, scoliosis, scoliosis research society-30 score

INTRODUCTION

Improvements in surgical instruments for treating spine deformities have resulted in increased use of implants. Careful use of pedicle screws has enabled effective correction of severe spinal deformities.[1] However, the impact of screw density on the outcomes of treating adolescent idiopathic scoliosis (AIS) is still debated.[2] Reducing the number of implants can cut down surgical time, lower the risk of screw misplacement, and decrease costs. The ideal implant density for successful treatment is still unknown.[3] The relationship between pelvic indices and sagittal profile has been extensively studied.[4,5] Pelvic incidence (PI) is a fixed anatomical parameter that significantly influences the spine's sagittal balance, calculated by combining two variable parameters: sacral slope (SS) and pelvic tilt (PT). A mismatch between PI and lumbar lordosis (LL) can disrupt the overall sagittal balance in patients. The impact of adult spinal deformity is assessed using the Scoliosis Research Society (SRS)-Schwab classification. There is a notable link between

Access this article online	
	Quick Response Code
Website: www.jcvjs.com	
DOI: 10.4103/jcvjs.jcvjs_52_24	

Ahmed Maher Sultan, Walid El Nawawy[1], Mohammed Ahmad Dawood[2], Wael Tawfik Koptan, Yasser Elmiligui, Ahmed Samir Barakat, Khaled Ahmed Fawaz

Department of Orthopedic Surgery and Traumatolgy, Cairo University, [2]Agouza Spine Centre, Giza, [1]Department of Orthopedic Surgery, Alexandria University Hospitals, Alexandria, Egypt

Address for correspondence: Prof. Ahmed Samir Barakat, Cairo University, Giza, Egypt.
E-mail: ahmedsamir222222@live.com

Submitted: 27-Mar-24 **Accepted:** 01-May-24
Published: 12-Sep-24

How to cite this article: Sultan AM, El Nawawy W, Dawood MA, Koptan WT, Elmiligui Y, Barakat AS, *et al*. Do low-density screws influence pelvic incidence in adolescent idiopathic scoliosis correction? J Craniovert Jun Spine 2024;15:315-20.

the lumbopelvic alignment mismatch (PI-LL) and the degree of disability. Individuals with spinal deformities characterized by positive sagittal alignment and inadequate LL tend to have poorer physical and social functioning, self-perception, and higher pain levels.[6,7] Maintaining or restoring normal sagittal alignment is crucial in all types of spinal reconstructive surgery. Therefore, addressing various spinal abnormalities such as posttraumatic deformities, Scheuermann's kyphosis, and AIS requires a comprehensive evaluation of spinopelvic parameters.[8] Currently, there is no universal agreement on the impact of altered spinopelvic parameters in scoliosis surgery. Nonetheless, some studies in the literature have addressed the impact of surgical correction on spinopelvic parameters.[9] This study aimed to assess the correlation between the Coronal Cobb angle and PI after correcting deformities in AIS using a low-density construct, as well as the relationship between PI and the patient's functional outcome.

PATIENTS AND METHODS

This prospective cohort study included 60 patients at Cairo University Hospitals and Agouza Spine Center who underwent posterior low-density screw fusion for AIS of various Lenke types with a Cobb angle ≥45°–90°, aged between 10–16 years. The study was conducted between December 2016 and May 2019 after obtaining approval from the relevant Ethical Committee of Cairo University Hospitals. Written informed consent was obtained from the patients' caregivers. Excluded were patients with other types of scoliosis, previous spine surgeries, sacralized lumbar vertebrae, and other spinal pathologies.

All patients underwent a thorough history, routine laboratory tests, physical and detailed neurological examinations, and magnetic resonance imaging of the entire spine to assess for cord pathology. The coronal Cobb angle, PI, PT, and SS were measured using Surgimap software (Nemaris Inc., Methuen, MA, USA).

During general anesthesia, patients were positioned prone with neutral or extended hips to achieve lumbar spine lordosis and with flexed knees to ensure proper venous return.

All cases were instrumented through a posterior approach using titanium monoaxial screws at levels near the apex and titanium polyaxial screws at the remaining levels. Titanium rods of G5 strength were used to maintain the correction. Pedicle screws were placed using a freehand technique, and neuromonitoring was employed in all cases. The derotation and direct vertebral derotation techniques were utilized on the concave side, followed by the application of the convex rod. Finally, segmental compression, distraction, and *in situ* bending were employed to enhance correction. Operative time, blood loss, and the need for blood transfusion were documented. The radiological assessment involved evaluating the relationship between the change in Cobb angle and PI values after surgical correction. Regular functional (SRS-30) and radiological follow-up at 1, 3, 6, 9, 12, and 24 months were conducted. Functional assessment compared preoperative and final follow-up patient satisfaction using the SRS-30 form to pre/postoperative Cobb angle and pre/postoperative PI values. Implant density was defined as the number of fixation screws divided by the number of available anchor sites within the main curve. Intra- or postoperative complications were also recorded [Figure 1].

Statistical analysis

Version 26 of SPSS (IBM Inc., Armonk, NY, USA) was utilized for statistical analysis. Repeated measures ANOVA was employed to compare the measurements of quantitative variables, which were expressed as the mean and standard deviation (SD). The frequency and proportion of qualitative factors were defined (%). The Pearson moment correlation equation was employed to determine the correlation between different variables when the variables followed a linear relationship such as normal distribution. For variables with nonnormal or nonlinear monotonic relationships, the Spearman rank correlation equation was utilized. Considered statistically significant was a two-tailed $P = 0.05$.

RESULTS

The mean age was 14.6 ± 2.68 SD years. There were 5 males (8.33%) and 55 females (91.67%).

Types of curves were type I in 28 (46.67%) patients, II in 2 (3.33%) patients, III in 4 (6.67%) patients, IV in 3 (5%) patients, V in 19 (31.67%) patients, and VI in 4 (6.67%) patients. The mean operation time was 259.1 ± 38.59 SD min. The mean blood loss was 857.8 ± 330.22 SD ml. Blood transfusion was required in 22 (36.67%) patients.

The mean screw density was 1.2 ± 0.23 SD. The mean loss of correction was 1.8 ± 1.11 SD. The mean correction degree was 43.9 ± 15.39 SD. The mean correction rate was 71.6 ± 9.12 SD %. The mean hospital stay was 3.4 ± 0.72 SD days [Table 1].

Cobb angle and SS were significantly lower at 1 m, 3 m, 6 m, 12, and 24 m than preoperative ($P < 0.001$). PT and SRS were significantly higher at 1 m, 3 m, 6 m, 12 m, and 24 m than preoperative ($P < 0.001$). PI was insignificantly different at 1 m, 3 m, 6 m, 12 m, and 24 m compared to preoperative.

Figure 1: (a and b) Preoperative standing X-ray of a 12-year-old girl with Lenke type six adolescent idiopathic scoliosis with a thoracic Cobb angle 45° and a main lumbar curve with a Cobb angle of 50°, PI =38°, PT =8°, SS =30°. (c and d) Immediate postoperative x-rays showed good correction of the thoracic Cobb's angle to 20° and a lumbar Cobb's angle of 23° and PI =40°, PT =17°, SS =23°. (e and f) At 16 months postoperatively the thoracic Cobb angle remains 20° and the main lumbar curve remains the Cobb angle of 23° with PI of 40°. (g and h) Preoperative and postoperative clinical pictures of the patient, respectively

Table 1: Demographic and operative data (n=60)

Age (years)	14.6±2.68
Sex	
Male	5 (8.33)
Female	55 (91.67)
Types of curves	
I	28 (46.67)
II	2 (3.33)
III	4 (6.67)
IV	3 (5)
V	19 (31.67)
VI	4 (6.67)
Operation time (min)	259.1±38.59
Blood loss (mL)	857.8±330.22
Blood transfusion	22 (36.67)
Screw density	1.2±0.23
Loss of correction (°)	1.8±1.11
Correction (°)	43.9±15.39
Correction rate (%)	71.6±9.12
Hospital stay (days)	3.4±0.72

Data are presented as absolute values, mean±SD, or frequency (%). SD - Standard deviation

The change value of SRS at 1 year was −52.3 ± 5.54, and the change value of PI at 1 year was −0.2 ± 0.29.

There was a positive correlation between screw density and operative time and blood loss ($P < 0.05$) and between the degrees of correction and change of SRS ($P = 0.004$). Yet, there was no correlation between screw density and hospital stay, loss of correction, correction rate, and change of SRS. Furthermore, there was no correlation between the change of SRS and the change of PI and between the Cobb angle and change of PI.

Acute anemia occurred in 4 (6.67%) cases for which they received adequate blood transfusion. Persistent vomiting occurred in 2 (3.33%) patients, which improved after 2 days of medical treatment. Loosening of a screw nut occurred in 1 (1.67%) patient after 6 months and was managed conservatively. Two cases (3.33%) suffered from postoperative ileus, in which one of them proved to be a superior mesenteric artery syndrome. Both cases were managed conservatively. Both cases were managed conservatively. Out of the total, three cases (5%) experienced superficial wound infections, which were also treated with oral antibiotics. In addition, two cases (3.33%) presented with lower limb numbness and mild weakness, showing improvement with conservative measures after a 3-month period [Tables 2-4].

DISCUSSION

Pedicle screws provide excellent outcomes for correcting major curves in AIS patients due to their mechanical strength and rigid fixation of the vertebrae. However, there are limitations to using a high-density screw technique, such as longer operations, increased blood loss, risks of screw misplacement, and higher costs.

Debates among spine surgeons persist regarding the relationship between screw density and three-dimensional curve correction, aiming to determine the minimum safe screw density needed for effective and sustainable curve correction in the long term.

Numerous authors have demonstrated a significant correlation between the correction of the coronal curve and the increased density of screws. Nevertheless, further research has shown promising results with low-density screw techniques in surgical interventions for AIS.[10-14]

In this study, the average screw density was 1.2 ± 0.23 screws per fused level, with an average correction angle of 43.9° ±15.39°, a correction rate of 71.6% ±9.12%, and a loss of correction of 1.8 ± 1.11. A positive and statistically significant relationship was found between screw density and operative time ($r = 0.343$, $P = 0.007$), as well as a more significant correlation with blood loss ($r = 0.499$, $P < 0.001$). No statistically significant associations were observed between screw density and the length of hospital stay ($r = 0.147$), loss of correction ($r = 0.229$, $P = 0.078$), correction rate ($r = 0.224$, $P = 0.084$), or changes in SRS scores ($r = -0.125$, $P = 0.341$).

In line with our findings, Yeh *et al*.[1] reported an average screw density of 1.60 in their patient cohort. Kilinc *et al*.[15] also mentioned a mean screw density of 1.3 with an average of 9.6 fused levels. In addition, Tannous *et al*.[16] illustrated that the average construct density observed was 1.2 screws perfusion level. Moreover, Vora *et al*.[17] confirmed that lower screw density was linked to reduced operative time and decreased blood loss. They concluded that using lower density compared to higher density constructs, as evaluated by SRS-30 scores, led to similar outcomes with significantly less blood loss and operative time.

Over the past decade, several studies have extensively discussed the relationship between implant density and correction of coronal balance in AIS patients, yielding conflicting results. Yeh *et al*.[1] found no correlation between anchor density and correction of the coronal curve or apical vertebral rotation in all AIS patients. Similarly, Sariyilmaz *et al*.[18] observed no significant differences in curve correction between early postoperative and final follow-up periods, regardless of screw density. Rushton *et al*.[18] also showed no association between screw density and correction of coronal curve, dorsal kyphosis, or LL.

Li *et al*.[19] confirmed a mild negative relationship between screw density and loss of correction of the main thoracic curve, with correlation coefficients of −0.25 in the nonstructural region at 2 weeks postoperatively and −0.09 for correction ratio and screw density. They suggested that lower screw density was mildly associated with decreased correction of the main thoracic curve, as indicated by a correlation coefficient of −0.27 ($P = 0.036$). Gebhart *et al*.[20] found no correlation between correction of the main thoracic curve and implant density. In contrast to our results, other authors have shown positive relationships between anchor density and AIS coronal curve correction. Mac-Thiong *et al*.[12] determined that implant density is a significant predictor of

Table 2: Correlation between Cobb's angle, pelvic tilt, sacral slope, scoliosis research society-30, and pelvic incidence

	Preoperative	1 m	3 m	6 m	12 m	18 m	24 m
Cobb (°)	60.2±13.78	22.5±5.96	22.9±5.97	23.4±4.69	21.9±4.84	22.4±4.91	24.2±5.02
P		<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
PT (°)	10.6±7.76	11.7±7.77	12.1±7.73	12.6±7.93	13.1±8.02	13.7±7.82	14.2±7.78
P		<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
SS (?)	39.9±8.49	36.3±8.71	35.8±8.53	35.2±8.47	32.8±8.6	33.8±8.73	35.7±8.72
P		<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
SRS-30 score	73.6±6.71	81±6.9	90.1±6.91	101.2±6.71	125.9±7.56	128.3±7.86	136.5±7.93
P		<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
PI (°)	52.8±11.55	52.8±11.55	52.9±11.74	53±12	53.1±11.25	53.1±11.84	53.2±11.91
P		0.668	0.393	0.402	0.075	0.081	0.628

*Significant as $P \leq 0.05$. Data are presented as mean±SD. PI - Pelvic incidence; SRS - Scoliosis research society; SD - Standard deviation; SS - Sacral slope; PT - Pelvic tilt

Table 3: Change value of scoliosis research society score and pelvic incidence of the studied patients

	Change value at 24 m
SRS	−52.3±5.54
PI	−0.2±−0.29

*Significant as $P \leq 0.05$. Data are presented as mean±SD. PI - Pelvic incidence; SRS - Scoliosis research society; SD - Standard deviation

Table 4: Correlation between screw density and other variables, correction degree and change of scoliosis research society, change of scoliosis research society, and change of pelvic incidence and between Cobb and change of pelvic incidence

	Screw density (*r*)	*P*
Operation time (min)	0.343	0.007*
Blood loss (mL)	0.499	<0.001*
Hospital stay (days)	0.147	0.259
Loss of correction	0.229	0.078
Correction rate (%)	0.224	0.084
Change of SRS	−0.125	0.341
	Correction in degree (*r*)	***P***
Change of SRS	0.365	0.004*
	Change of SRS (*r*)	***P***
Change of PI	**−0.022**	**0.861**
	Cobb (*r*)	***P***
Change of PI	0.008	0.945

*Significant as P≤0.05. PI - Pelvic incidence; SRS - Scoliosis Research Society

major coronal curve correction in AIS patient surgery. Having more anchors within the main curve can lead to increased coronal curve correction. They also noted that adding more implants when density is ≥70% within the main curve does not affect coronal curve correction. However, Sudo *et al*.[21] established that changes in dorsal kyphosis were significantly associated with screw density on the concave side but not the convex side.

Across these various studies on surgically treated AIS patients focusing on implant density, there were notable differences in outcomes, primarily radiologically (curve correction), which did not correspond to clinical outcomes (SRS 30). This confirms that achieving maximum curve correction without improving clinical outcomes is futile.

Before surgery, adequate planning is essential to ensure proper thoracic kyphosis and LL, taking into account sagittal pelvic measurements. While there has been extensive research on coronal curve balance, the differences in sagittal spinopelvic profile between nonscoliotic adolescents and those with AIS post-PSF have not been thoroughly explored.[22]

These results align with the findings of this study. The mean pre- and postoperative PI values were 52.8 ± 11.55 and 53.1 ± 11.25 at 12 months and 53.2 ± 11.91 at 24 months, respectively. While the pre- and postoperative SS mean values were 39.9° ±8.49° and 35.7° ±8.72° at 24 months, respectively, showing a reduction of 4.2°. Mean PT showed an increase of 3.6° postoperatively at the last follow-up. The changes in the SS and PT values were statistically significant. Farshad *et al*.[23] reported that PI was 50° ±12°, PT 12° ±7°, and the SS 38° ±10°. Roussouly and Pinheiro-Franco.[24] found that postoperatively, SS and LL decreased, PT increased, and PI remained the same. Data regarding the relationship between coronal balance and pelvic parameters are not yet fully validated. Ito *et al*.[25] observed that different spinal and pelvic parameters showed that PI, LL, and TK were correlated, whereas Cobb angle had no influence on pelvic parameters. Yang *et al*.[26] indicated that there was no significant correlation between preoperative coronal imbalance and preoperative sagittal imbalance. Furthermore, no notable correlation was observed between patients exhibiting final coronal imbalance and those with final sagittal imbalance. Moreover, Ma *et al*.[27] identified a correlation between coronal and sagittal parameters, whereas the sagittal vertical axis did not show any correlation with coronal parameters. Consequently, it was deduced that coronal balance plays a role in influencing sagittal balance in instances of AIS. In this study, we found a significant correlation between the change of Cobb angle and the change of the PI value, i.e., the coronal curve and the PI are affected by each other. However, the percentage of change in both measurements was statistically insignificant. Upon analyzing this study's findings, a positive and statistically significant correlation was found between the percentage change in the Cobb angle and the SRS-30 score. A positive correlation was also observed between the degree of correction and the variation in the SRS score. However, the magnitude of change in the Cobb angle did not exhibit a correlation with the overall SRS-30 score. In addition, there was no statistically significant relationship between the SRS-30 score and PI, nor was there a correlation between changes in the Cobb angle and alterations in PI. Ghandehari *et al*.[28] highlighted a significant positive correlation between the percentage of curve correction and the overall SRS score ($r = 0.52$, $P < 0.001$). While no correlation was found between preoperative coronal balance and the total SRS score, a significant positive relationship was identified between the rate of coronal balance correction and the overall SRS score. In this study, functional outcome was evaluated using the SRS-30 score on 60 patients after AIS correction and correlated to PI as an individual parameter. The results revealed an insignificant correlation between the functional outcome and both the change and the percentage of change in PI value. However, the limitations of this study included the small number of patients and the single-center nature of the research.

CONCLUSIONS

AIS correction through a single posterior approach using a low-density construct leads to substantial curve correction. The PI value exhibits minimal, insignificant changes postcurve correction in AIS cases, attributed to pelvis compensation through PT and SS adjustments. PI and Cobb angle are interrelated, with PI alone not directly influencing patient functional outcomes assessed by the SRS-30 score. Low-density implant constructs decrease operative time, blood loss, costs, and complication risks.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Yeh YC, Niu CC, Chen LH, Chen WJ, Lai PL. The correlations between the anchor density and the curve correction of adolescent idiopathic scoliosis surgery. BMC Musculoskelet Disord 2019;20:497.
2. Wang F, Xu XM, Lu Y, Wei XZ, Zhu XD, Li M. Comparative analysis of interval, skipped, and key-vertebral pedicle screw strategies for correction in patients with lenke type 1 adolescent idiopathic scoliosis. Medicine (Baltimore) 2016;95:e3021.
3. Shen M, Jiang H, Luo M, Wang W, Li N, Wang L, *et al*. Comparison of low density and high density pedicle screw instrumentation in Lenke 1 adolescent idiopathic scoliosis. BMC Musculoskelet Disord 2017;18:336.
4. Burkus M, Schlégl ÁT, O'Sullivan I, Márkus I, Vermes C, Tunyogi-Csapó M. Sagittal plane assessment of spino-pelvic complex in a Central European population with adolescent idiopathic scoliosis: A case control study. Scoliosis Spinal Disord 2018;13:10.
5. Duval-Beaupère G, Schmidt C, Cosson P. A barycentremetric study of the sagittal shape of spine and pelvis: The conditions required for an economic standing position. Ann Biomed Eng 1992;20:451-62.
6. Celestre PC, Dimar JR 2nd, Glassman SD. Spinopelvic parameters: Lumbar lordosis, pelvic incidence, pelvic tilt, and sacral slope: What does a spine surgeon need to know to plan a lumbar deformity correction? Neurosurg Clin N Am 2018;29:323-9.
7. Chen HF, Zhao CQ. Pelvic incidence variation among individuals: Functional influence versus genetic determinism. J Orthop Surg Res 2018;13:59.
8. Mehta VA, Amin A, Omeis I, Gokaslan ZL, Gottfried ON. Implications of spinopelvic alignment for the spine surgeon. Neurosurgery 2012;70:707-21.
9. Roussouly P, Pinheiro-Franco JL. Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. Eur Spine J 2011;20 Suppl 5:609-18.
10. Bharucha NJ, Lonner BS, Auerbach JD, Kean KE, Trobisch PD. Low-density versus high-density thoracic pedicle screw constructs in adolescent idiopathic scoliosis: Do more screws lead to a better outcome? Spine J 2013;13:375-81.
11. Chen J, Yang C, Ran B, Wang Y, Wang C, Zhu X, *et al*. Correction of lenke 5 adolescent idiopathic scoliosis using pedicle screw instrumentation: Does implant density influence the correction? Spine (Phila Pa 1976) 2013;38:E946-51.
12. Mac-Thiong JM, Ibrahim S, Parent S, Labelle H. Defining the number and type of fixation anchors for optimal main curve correction in posterior surgery for adolescent idiopathic scoliosis. Spine J 2017;17:663-70.
13. Garcia EB, Garcia LF, Garcia EB Jr., Gonçalves RG, Giesbrecht ST, Oliveira FH, *et al*. Adolescent idiopathic scoliosis: Evaluation on the effect of screw density in the correction. Coluna Columna 2016;15:17-21.
14. Li Y, Yang C, Zhu X, Li M. Analysis of correlation between regional implant density and the correction rate in treatment of Lenke 1A and 1B adolescent idiopathic scoliosis with pedicle screws. Medicine (Baltimore) 2018;97:e9488.
15. Kilinc BE, Tran DP, Johnston C. Comparison of implant density in the management of Lenke 1b and 1c adolescent idiopathic scoliosis. Acta Ortop Bras 2019;27:33-7.
16. Tannous OO, Banagan KE, Belin EJ, Jazini E, Weir TB, Ludwig SC, *et al*. Low-density pedicle screw constructs for adolescent idiopathic scoliosis: Evaluation of effectiveness and cost. Global Spine J 2018;8:114-20.
17. Vora V, Crawford A, Babekhir N, Boachie-Adjei O, Lenke L, Peskin M, *et al*. A pedicle screw construct gives an enhanced posterior correction of adolescent idiopathic scoliosis when compared with other constructs: Myth or reality. Spine (Phila Pa 1976) 2007;32:1869-74.
18. Sariyilmaz K, Ozkunt O, Karademir G, Gemalmaz HC, Dikici F, Domanic U. Does pedicle screw density matter in Lenke type 5 adolescent idiopathic scoliosis? Medicine (Baltimore) 2018;97:e9581.
19. Li M, Shen Y, Fang X, Ni J, Gu S, Zhu X, *et al*. Coronal and sagittal plane correction in patients with Lenke 1 adolescent idiopathic scoliosis: A comparison of consecutive versus interval pedicle screw placement. Clin Spine Surg 2009;22:251-6.
20. Gebhart S, Alton TB, Bompadre V, Krengel WF. Do anchor density or pedicle screw density correlate with short-term outcome measures in adolescent idiopathic scoliosis surgery? Spine (Phila Pa 1976) 2014;39:E104-10.
21. Sudo H, Abe Y, Kokabu T, Ito M, Abumi K, Ito YM, *et al*. Correlation analysis between change in thoracic kyphosis and multilevel facetectomy and screw density in main thoracic adolescent idiopathic scoliosis surgery. Spine J 2016;16:1049-54.
22. Pasha S, Ilharreborde B, Baldwin K. Sagittal spinopelvic alignment after posterior spinal fusion in adolescent idiopathic scoliosis: A systematic review and meta-analysis. Spine (Phila Pa 1976) 2019;44:41-52.
23. Farshad M, Catanzaro S, Schmid SL. The spinopelvic geometry in different lenke curve types of adolescent idiopathic scoliosis. Spine Deform 2016;4:425-31.
24. Roussouly P, Labelle H, Rouissi J, Bodin A. Pre- and post-operative sagittal balance in idiopathic scoliosis: A comparison over the ages of two cohorts of 132 adolescents and 52 adults. Eur Spine J 2013;22 Suppl 2:S203-15.
25. Ito K, Imagama S, Ito Z, Ando K, Kobayashi K, Ukai J, *et al*. The relationship between spinal and pelvic parameters in the Japanese patients with adolescent idiopathic scoliosis. Scoliosis 2015;10:O42.
26. Yang X, Hu B, Song Y, Liu L, Zhou C, Zhou Z, *et al*. Coronal and sagittal balance in Lenke 5 AIS patients following posterior fusion: Important role of the lowest instrument vertebrae selection. BMC Musculoskelet Disord 2018;19:212.
27. Ma Q, Wang L, Zhao L, Wang Y, Chen M, Wang S, *et al*. Coronal balance versus sagittal profile in adolescent idiopathic scoliosis, are they correlated? Front Pediatr 2019;7:523.
28. Ghandehari H, Mahabadi MA, Mahdavi SM, Shahsavaripour A, Seyed Tari HV, Safdari F. Evaluation of patient outcome and satisfaction after surgical treatment of adolescent idiopathic scoliosis using scoliosis research society-30. Arch Bone Jt Surg 2015;3:109-13.