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Pedicle Screw Insertion for Concave Side of Proximal Thoracic Curve in Adolescent Idiopathic Scoliosis

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Abstract

Background: Insertion of the pedicle screws (PS) into the proximal thoracic spine is occasionally challenging owing to the small size of the pedicles and the proximity to the spinal cord. An appropriate anchor placement method for the concave side of the proximal thoracic curve has not been established yet. This study aimed to evaluate the pedicle size and position of PS on the concave side of the proximal thoracic curve in patients with adolescent idiopathic scoliosis (AIS). **Methods:** Forty consecutive patients with AIS who underwent correction and fusion with all PS constructs, including the proximal thoracic curve in the fusion area, were included. After identifying the screws inserted on the concave side of the proximal thoracic curve, the preoperative morphology and postoperative position of the inserted PS, including the end vertebrae, were analyzed using computed tomography (CT). Screw perforations were categorized into four grades depending on the degree of perforation from the pedicle wall on postoperative CT and were classified using an outcome-based classification. **Results:** A total of 109 screws were inserted on the concave side of the proximal thoracic curve. The average width of all pedicles was 3.5 ± 1.1 mm. The width of 90 pedicles (83%) was <4.5 mm. Based on categorization by the degree of perforation, there were only 17 screws with Grade 0 (no perforation). Perforation was found in 92 pedicles (84%), including Grade 1 in 76 screws, Grade 2 in nine screws, and Grade 3 in seven screws. In the outcome-based classification, 101 screws (93%) were classified as Type I (acceptable) and eight screws as Type II (unacceptable). None of the screws were classified as Type III (grievous). **Conclusion:** Perforations were found in 84% of the PS on the concave side of the proximal thoracic curve; however, 93% of the PS were considered acceptable in the outcome-based classification. Thus, we conclude that the in-out-in technique may be both feasible and effective.

Keywords

Pedicle Screw, Proximal Thoracic Curve, Adolescent Idiopathic Scoliosis

1. Introduction

Pedicle screw (PS) insertion has become the gold standard for correcting adolescent idiopathic scoliosis (AIS) since its introduction by Abe *et al.* in 1994 [1]. Segmental PS insertion in multiple vertebrae across multilevel fusion has been shown to provide desired deformity correction [2] [3] [4]. Morphological studies of the pedicle have verified the feasibility and safety of PS insertion [5].

PS insertion into the proximal thoracic curve plays an important role in correcting the proximal curve and anchoring the upper end of instrumentation, especially in Lenke types 1, 2, and 4. However, insertion of the PS into the proximal thoracic spine is occasionally challenging owing to the small size of the pedicles and the proximity to the spinal cord [6] [7] [8] [9]. In a recent study, Guzek *et al.* reported that almost half of all concave pedicles of the proximal thoracic curve have morphological characteristics that make them too small to accommodate PS [6]. Conversely, studies have shown that PS for the proximal thoracic spine can be inserted safely without misplacement with a free hand [8]. Thus, an appropriate anchor placement method for the concave side of the proximal thoracic curve has not been established yet. The present study was undertaken to assess PS insertion by evaluating the pedicle size and PS position on the concave side of the proximal thoracic curve in AIS using two different classification types.

2. Methods

2.1. Patients

Seventy-two consecutive patients underwent correction and fusion for AIS between 2010 and 2016 in our hospital. We enrolled the patients with the curve type of Lenke 1, 2, and 4 in which the proximal thoracic curve was included in the fusion area. Then, 40 patients were identified as applicable. Following a comprehensive explanation of the procedures, risks, and benefits of the study, the participants provided written informed consent, which was approved by the institutional review board (IRB).

2.2. Procedures

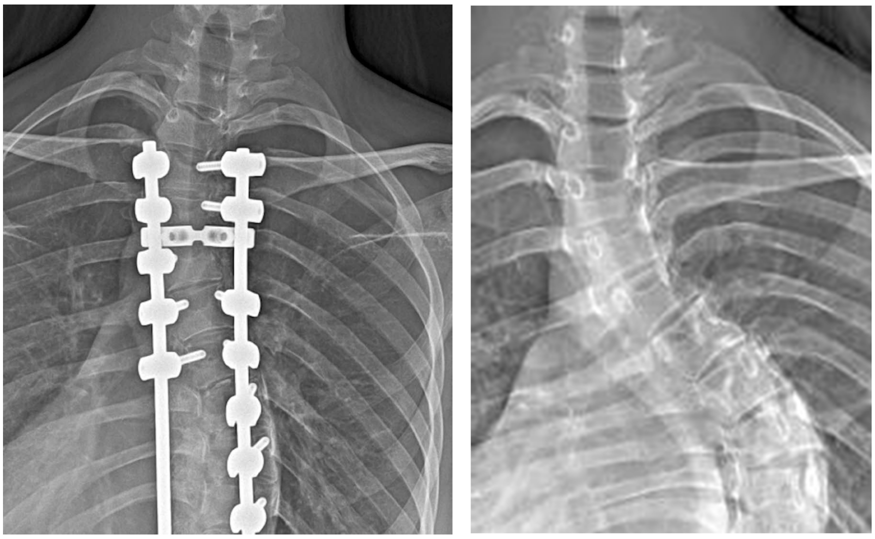
Posterior instrumentation with all PS constructs was performed in all patients. The PS was inserted with an anteroposterior (AP) view of C-arm fluoroscopy using techniques similar to those described by Lee *et al.* [10]. Briefly, the C-arm was adjusted such that each vertebral body had the correct AP image. When the pedicle probe was inserted to approximately 20 - 25 mm, and simultaneously, the tip of the probe touched the inner wall of the pedicle in a fluoroscopic image, the probe proceeded at that angle to create an advanced hole. Subsequently, a screw of an appropriate size was inserted using the hole. Coronal and sagittal curves were corrected using a rod rotation maneuver followed by in situ bending.

2.3. Evaluation

First, the screws inserted into the concave side of the proximal thoracic curve were identified (**Figure 1(a)**). Preoperative computed tomography (CT) scans were retrospectively evaluated for pedicles with the inserted PS (**Figure 1(b)**).

Preoperative pedicle morphology and postoperative position of the inserted PS on the concave side of the proximal curve, including the end vertebrae, were analyzed using a CT scan. Preoperative CT scans were used to evaluate the transverse width of the pedicle. CT scans obtained approximately 6 months postoperatively were evaluated for the position of the PS at the pedicles using two classification methods [11] [12]. The interpretation of preoperative and postoperative CT scans was performed by one of the authors (MH), who had more than 10 years of clinical experience in the management of scoliosis.

Screw perforations were categorized into four grades depending on the degree of perforation from the pedicle wall on postoperative CT [11]: Grade 0 (no perforation), Grade 1 (<2 mm of perforation-medial or lateral), Grade 2 (2 - 4 mm, medial or lateral), and Grade 3 (>4 mm, medial or lateral) (**Figure 2**).



(a) (b)

Figure 1. Evaluated screws. (a) First, screws inserted to the concave side of the proximal thoracic curve were identified. (b) Then preoperative CT was retrospectively evaluated for the pedicles with the pedicle screws inserted. CT: Computed Tomography.

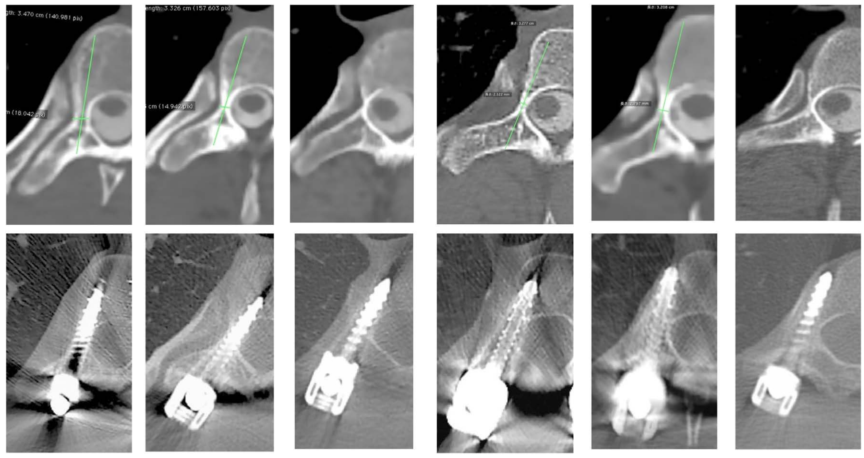


Figure 2. Classification of screw perforations. Inserted screws were categorized to four grades depending on the degree of perforation from the pedicle wall on postoperative CT. CT: Computed Tomography.

The screw perforations were then classified using the outcome-based classification proposed by Upendra *et al.* [12]: Type I (acceptable placement, screws were completely within the pedicle medullary canal encroaching on any cortex of the pedicle but still within the pedicle or <2 mm penetration through any of the cortices contained within the pedicle rib unit); Type II (unacceptable placement without neurovascular complications—screws with anterior cortex perforation or >2 mm penetration); and Type III (with clinical neurovascular complications).

2.4. Statistical Analyses

For patient characteristics and screw perforation rates, we examined variables using descriptive analysis. The values of pedicle diameter are represented as mean and standard deviation.

3. Results

Of the 40 patients, 31 were women. The mean age of the patients was 15.2 years (range, 10 - 18 years). Of the patients, 26 had Lenke type 1 curve, and 14 had Lenke type 2 curve. The Cobb angles were 37.5˚ ± 9.5˚ for the proximal thoracic curve and 62.7˚ ± 10.9˚ for the main thoracic curve. The mean follow-up period was four years (range, 2 - 9 years).

The Cobb angle of the coronal curve was corrected to 14.4˚ ± 6.2˚ (56% correction) for the proximal thoracic spine and to 14.1˚ ± 8.9˚ (77%) for the main thoracic spine at the final follow-up. There were no major perioperative complications such as neurological deterioration, vascular injury, or death.

A total of 109 screws were inserted on the concave side of the proximal thoracic curve.

Table 1 shows the morphological evaluation of preoperative CT, retrospectively measured for the pedicles with PS insertion. The average width of all pedicles was 3.5 ± 1.1 mm. The width of 90 pedicles (83%) was <4.5 mm. More than 80% of pedicles from T3 to T6 had width <4.5 mm.

Based on the categorization by the degree of perforation, there were only 17 screws with Grade 0. Perforation was found in 92 pedicles (84%), including Grade 1 in 76 screws, Grade 2 in nine screws, and Grade 3 in seven screws (Table 2).

In the outcome-based classification, 101 screws (93%) were classified as Type I (acceptable) and eight screws as Type II (unacceptable). None of the screws were classified as Type III (grievous). No major complications associated with screws were observed.

4. Discussion

In this study, 83% of the pedicles on the concave side of the proximal thoracic curve were thinner than the screws. Additionally, a high rate of screw perforation

Table 1. Width of the pedicle of concave side evaluated with preoperative CT scan.

Spinal levels	N	Pedicle width (mm)	Under 4.5 mm
T1	2	6.4 ± 1.3	0 (0%)
T2	18	4.2 ± 1.0	12 (67%)
T3	19	3.0 ± 0.7	19 (100%)
T4	25	2.9 ± 0.8	23 (92%)
T5	28	3.6 ± 0.9	24 (86%)
T6	11	3.6 ± 1.2	9 (82%)
T7	6	3.8 ± 1.0	4 (67%)
Total or Average	109	3.5 ± 1.1	90 (83%)

Table 2. Grading by degree of perforation from pedicle wall with postoperative CT scan.

Level	N	Grade 0	Grade 1			Grade 2	Grade 3
			Medial	Lateral	Both	All lateral	All lateral
T1	2	2	0	0	0	0	0
T2	18	8	1	2	3	3	1
T3	19	0	1	7	5	2	4
T4	25	0	3	15	4	2	1
T5	28	4	2	8	11	2	1
T6	11	2	1	6	2	0	0
T7	6	1	1	3	1	0	0
Total	109	17	9	41	26	9	7

was observed. In contrast, 93% of the screws were classified as acceptable based on the outcome-based classification for PS placement without clinical complications [12]. The uniqueness of this study lies in its comprehensive assessment of morphological data, puncture rates, and clinical outcomes. Although 84% of the screws were perforated, our screw insertion method provided safe and good correction without complications. We found that the use of fluoroscopy with an AP view, which avoided excessive inward penetration, and the accurate measurement of screw length with preoperative CT allowed us to safely insert the screws.

A noteworthy aspect of the study is its focus on the concave side of the proximal thoracic curve. Although the pedicle is small at this site, there are no large blood vessels in its vicinity. Therefore, care should be taken to prevent spinal cord injuries due to inward perforation and organ damage due to anterior violation. In this study, the majority of perforations were found on the lateral or both lateral and medial walls of the pedicles within 2 mm. Approximately half of the screws (57 screws, 52%) were classified as lateral perforations. Favorably though, even a considerable outward deviation would not cause serious problem. However, deviated screws may not have sufficient pull-out strength and obtaining a stronger anchor may necessitate ingenuity.

If the screw tip is inserted into the vertebral body or lateral wall, the screw trajectory is considered an in-out-in insertion [13]. A biomechanical study showed that perforation of the PS did not significantly alter screw stability [14]. Pull-out testing showed that an extrapedicular screw had inferior pull-out strength compared with a transpedicular screw [15]. In a clinical study, in-out-in insertion was utilized for extremely small pedicles [10]. The current study used a technique similar to that described above, which is considered safe and effective for pedicles smaller than the screws on the concave side of the proximal thoracic curve. In addition, based on the clinical findings of this study, a screw perforation of up to 2 mm is considered acceptable.

A limitation of this study is that the extent to which the screws can contribute to correction has not been verified. Further research is needed to analyze the frequency and correction rate of screw insertion or to compare other fixation devices, such as hooks or sublaminar tape. Exposure to fluoroscopy is necessary for safe screw insertion but should be kept minimal. Therefore, it is essential to use template guides or navigation systems.

5. Conclusion

Perforations were found in 84% of the PS on the concave side of the proximal thoracic curve; however, 93% of the PS were considered acceptable in the outcome-based classification. Thus, we conclude that the in-out-in technique may be both feasible and effective.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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