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Accuracy of Pedicle Screw Reinsertion in Revision Spine Surgery

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Abstract

Objective: The goal of this study was prospectively to evaluate the accuracy of placement of new Pedicle Screws (new-PSs) in revision surgery.

Methods: A total of 181 new-PSs inserted in 31 consecutive patients undergoing posterior fixation in the thoracic or lumbar spine were evaluated. Placement of these screws was analyzed on postoperative Computed Tomography (CT) and compared with that of previously inserted Pedicle Screws (pre-PSs) on preoperative CT. Placement positions were classified as Grade 0: No perforation and screw completely contained in the pedicle, Grade 1: Perforations <2 mm, Grade 2: perforations ≥ 2 to <4 mm, and Grade 3: perforations ≥ 4 mm.

Results: New-PSs were inserted with a free hand from Th6 to S1 for a broken rod, non-union, adjustment for segmental degeneration or proximal junctional kyphosis, and other conditions. There were 16 screws inserted into the thoracic spine and 165 into the lumbar spine. Three of the 10 new-PSs in the thoracic spine that had a larger diameter than the pre-PS resulted in a Grade 1 medial breach of the screw. In the lumbar spine, two new-PSs resulted in Grade 3 lateral breach, and 7 new-PSs resulted in breaches of Grade 2. The rate of Grades 2 and 3 new-PSs in the lower lumbar spine was significantly higher than that of pre-PSs in the upper lumbar spine. The mean depth from the skin to the position of screw insertion in MRI of the lower lumbar spine was significantly deeper than that of the upper lumbar spine. There was no neurovascular injury as a result of insertion of the new-PSs.

Conclusion: New-PSs have a potential for malposition in revision surgery. In particular, reinsertion in the lumbar spine has a higher perforation rate and a tendency for an unintentional trajectory change, which might be due to limitations of the posterior and lateral back muscles during screw insertion. Therefore, new-PSs should be inserted carefully.

Keywords: Spinal fusion surgery; Revision surgery; Pedicle screw; Accuracy; Screw replacement

Key Points

- The accuracy of placement of new-PSs on CT to provide more detailed information on malpositioning of new-PSs in revision surgery was evaluated.
- Three of the 10 new-PSs in the thoracic spine that had a larger diameter than the pre-PS resulted in a Grade 1 medial breach of the screw.
- In the lumbar spine, two new-PSs resulted in Grade 3 lateral breach, and 7 new-PSs resulted in breaches of Grade 2.
- The rate of Grades 2 and 3 new-PSs in the lower lumbar spine was significantly higher than that of pre-PSs in the upper lumbar spine.
- The mean depth from the skin to the position of screw insertion in MRI of the lower lumbar spine was significantly deeper than that of the upper lumbar spine.

Abbreviations

Pre-PS: Previously inserted Pedicle Screw; new-PS: new Pedicle Screws

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Introduction

In the past few decades, use of the Pedicle Screw (PS) technique has become widespread and instrumentation for spinal surgery has been developed, since the reports by Boucher and Roy-Camille et al. [1,2]. Such instrumentation provides better rigid fixation by insertion of a screw into each segmental vertebra, and results in a better fusion rate [3,4]. There are many techniques for PS insertion, including free hand and fluoroscopy- or navigation-assisted. These methods may improve accuracy [5,6], but the reported PS malposition rates are [7]. 3% to 29.5% in the lumbar spine and 4.4% to 54.4% in the thoracic spine [5,8-11].

Due to the recent expansion of rigid spinal fusion surgery, the rates of implant failures, adjacent segmental diseases, proximal junctional kyphosis, and pseudoarthrosis have risen, and this has increased the need for revision surgeries. PSs inserted during a previous surgery require additional procedures, including replacement by a new PS system or a screw of increased diameter, and screw removal, depending on the case. However, there have been few reports on the accuracy of reinserting a PS (hereinafter referred to as a new-PS) in revision spine surgery. Kim et al. [12] determined the perforation rate of new-PSs for a total of 60 screws replaced with new screws, for which the malposition rate was 0% on evaluation by plain X-ray and triggered electromyography [4]. However, Computer Tomography (CT) was not used, which may have limited the accuracy and safety evaluation [12]. Therefore, in the current study, we evaluated the accuracy of placement of new-PSs on CT to provide more detailed information on malpositioning of new-PSs in revision surgery.

Material and Methods

This prospective evaluation included 31 consecutive patients who underwent posterior fixation for the thoracic or lumbar spine between December 2006 and December 2019 in two hospitals. There were 31 patients (33 surgeries, 21 women, 12 men) with a mean age of 65.8 years at the time of revision surgery. The study was approved by the institutional review board at our hospital. Placement of 181 new-PSs inserted with a free hand was evaluated on postoperative CT and compared with pre-PS placement on preoperative CT. Placement positions were classified as Grade 0, no perforation and screw completely contained in the pedicle (Figure 1a); Grade 1, perforations <2 mm (Figure 1b); Grade 2, perforations ≥ 2 to <4 mm (Figure 1c), and Grade 3, perforations ≥ 4 mm (Figure 1d). New-PSs that were inserted to achieve a different trajectory from the pre-PS and cases in which the pedicle diameter was smaller than the previous screw diameter were excluded from analysis. If preoperative CT in revision surgery showed a clear zone around a pre-PS or screw loosening was found during revision surgery, we inserted a new-PS that was 0.5 mm or 1.0 mm larger than the pre-PS. We speculated that the posterior muscle and wound retractor might cause a different trajectory for a new-PS. Depth was compared for new-PSs with the same and different trajectories using MRI.

Statistical analysis

Statistical analysis was performed by unpaired two-tailed Student t test for single comparisons and one-way ANOVA with a post hoc Bonferroni test for multiple comparisons. All analyses were conducted in SPSS for Windows ver. 22 (SPSS Inc., Chicago, IL, USA), with $P<0.05$ considered significant. Data are presented as mean ± SD.

Results

In total, 181 new-PSs were inserted into the pedicles of vertebrae from the Th6 to S1 levels in 31 patients (33 surgeries) for the following reasons: broken rod (n=5), non-union (n=7), and adjustment for segmental degeneration or proximal junctional kyphosis (n=21) (Table 1). The numbers of new-PSs inserted at each level were as follows: 16 in the thoracic spine at Th6 (n=1), Th10 (n=3), Th11 (n=6), and Th12 (n=6); and 163 in the lumbar spine at L1 (n=7), L2 (n=22), L3 (n=31), L4 (n=51), L5 (n=42), and S1 (n=12) (Table 2, Figure 2).

In the thoracic spine, all screws that were the same size as the previous screw followed the same trajectory. Three of the 10 new-PSs in the thoracic spine with a larger diameter than that of the pre-PS resulted in a Grade 1 medial breach of the screw, but all had the same trajectories as the pre-PSs (Figure 3).

In the lumbar spine, 86.1% (142/165) of reinserted screws were placed into the previous screw holes with the same trajectory, and 13.9% (23/165) had changes in trajectory. Two new-PSs resulted in a Grade 3 lateral breach (Table 1, Figure 1d & 3), and 8 new-

Table 1: Summary of patient characteristics.

Item	Value
Number of patients	31 (33 surgeries)
New pedicle screws	181
Sex (male/female)	21/10
Age (years)	65.8 ± 11.0 (37–80)
Diagnosis at revision surgery	
ASD or PJK	21
Non-union	7
Rod breakage	5

Age is shown as mean ± standard deviation followed by the range
ASD: Adjustment for Segmental Degeneration; PJK: Proximal Junctional Kyphosis

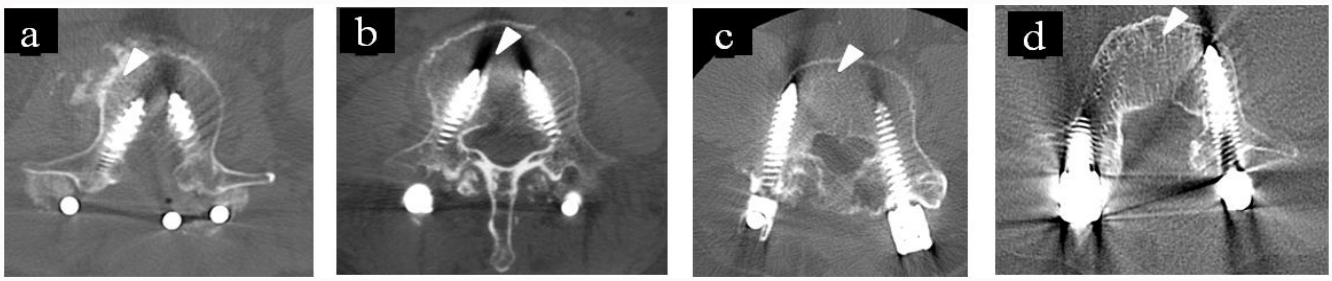

Figure 1: Evaluation of pedicle screw placement on Computed Tomography (CT), using an example of an axial CT image of an inserted pedicle screw (pre-PS). Grade 0: no perforation and screw completely contained in the pedicle (a), Grade 1: perforations <2 mm (b), Grade 2; perforations ≥ 2 to <4 mm (c), Grade 3: perforations ≥ 4 mm (d).

Table 2: Accuracy of screw placement in revision surgery.

Category	T4-9	T10-12	L1-3	L4-5	S1	Total
Total screws	1	15	60	93	12	181
Same-size diameter screws	0	6	7	3	2	18
Grade 0	0	6	7	3	2	18
Larger diameter screws	1	9	53	90	10	153
Grade 0	0	7	45	75	10	138
Breach						
Medial grade 1	1	2	0	2	0	5
Lateral grade 1	0	0	7	4	0	11
Medial grade 2	0	0	0	1	0	1
Lateral grade 2	0	0	0	7	0	7
Lateral grade 3	0	0	1	1	0	2

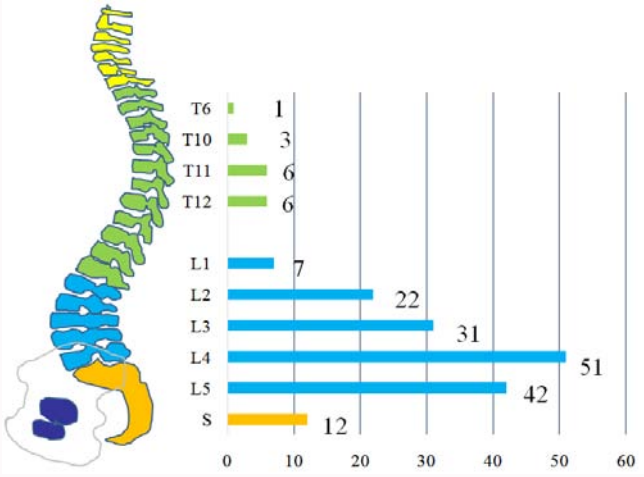

Figure 2: Number of new-PSs inserted at each level.

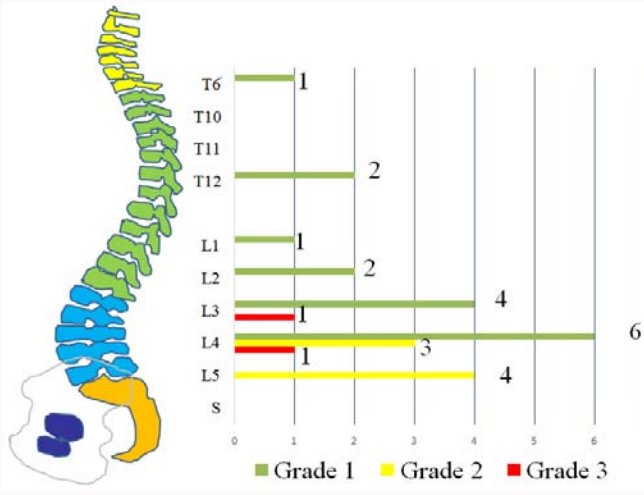

Figure 3: Number of new-PSs inserted with a different trajectory. In the thoracic spine, all screws that were the same size as previous screws followed the same trajectory. Three of the 10 new-PSs in the thoracic spine with a larger diameter than that of the pre-PS resulted in a Grade 1 medial breach of the screw, but all had the same trajectories as the pre-PSs. In the lumbar spine, 86.1% (142/165) of reinserted screws were placed into the previous screw holes with same trajectory. Thus, 13.9% (23/165 screws) had a change in trajectory. Two new-PSs resulted in a Grade 3 lateral breach, and 8 new-PSs resulted in Grade 2 breaches (one screw medially and 7 screws laterally).

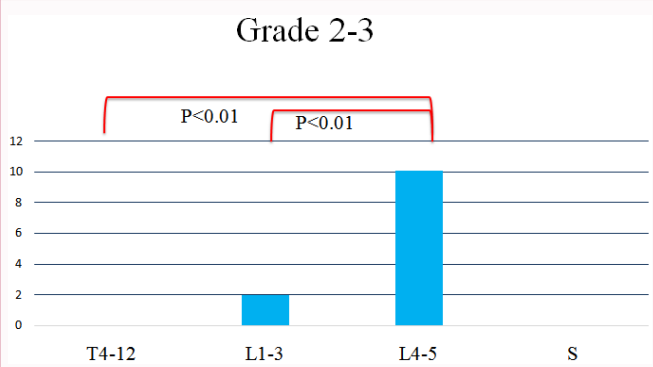

Figure 4: Number of new-PSs inserted with a different trajectory. The rate of Grades 2 and 3 new-PSs in the lower lumbar spine was significantly higher than that of pre-PSs in the upper lumbar spine.

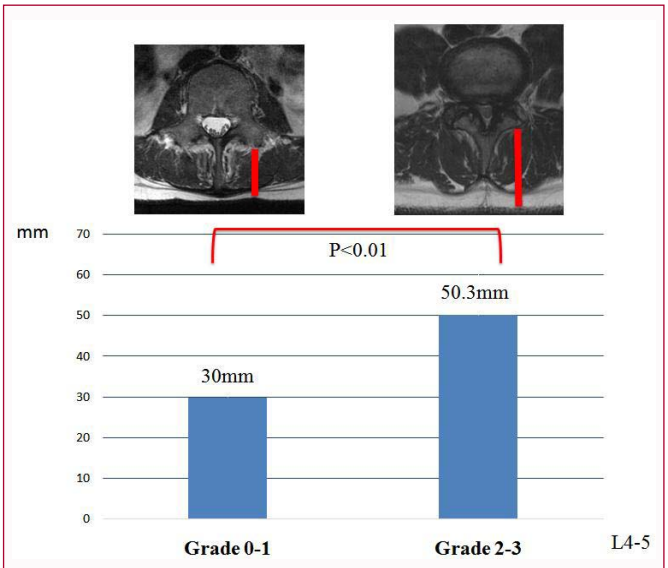

Figure 5: The mean depth from the skin to the position of screw insertion on MRI in the lower lumbar spine was significantly deeper than that in the upper lumbar spine.

PSs resulted in Grade 2 breaches (one screw medially and 7 screws laterally) (Table 1, Figure 1c & 3). The rate of Grade 2 and 3 new-PSs in the lower lumbar spine was significantly higher than that for pre-PSs in the upper lumbar spine (Figure 4). The mean depth from skin to the position of screw insertion on MRI in the lower lumbar spine was significantly deeper than that for the upper lumbar spine (Figure 5). Neurovascular injury due to insertion of the new-PSs did not occur.

Discussion

Previous reports have shown malposition rates of PSs of 8.3% to 29.5% in the lumbar spine and 4.4% to 54.4% in the thoracic spine [5-11]. Revision surgeries are likely to increase due to aging of society and performance of surgeries with PS systems. Thus, it is important to know the malposition rate of new-PSs. Replacement of PSs in revision surgery should be easier and of lower risk compared to primary screw insertion because all that is required is to insert the new-PS into the previous screw holes. To our knowledge, only one study has examined malposition of PS replacement in revision surgery, and this was based on plain radiographs [12]. The current study provides more detailed information on placement of new-PSs using CT.

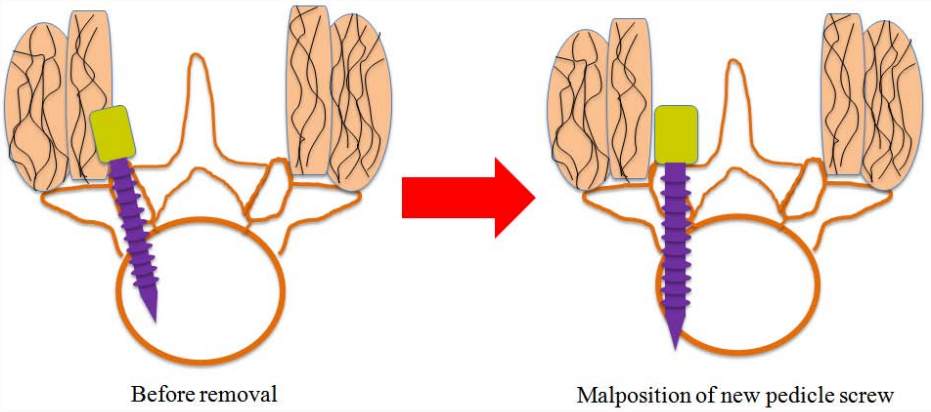

Figure 6: The lumbar posterolateral muscle in the lower lumbar spine (L4-L5 vertebrae) may have caused a lateral trajectory of new-PSs. The vertebrae are also positioned lower and deeper for screw insertion due to lumbar lordosis, the posterior muscle, and fat.

In the thoracic spine, all screws that were the same size as previous screws followed the same trajectory. In contrast, three larger new-PSs (30%, 3/10) had medial breaches. Most thoracic pedicle diameters were smaller than those in the lumbar spine, so a larger screw diameter may have had a greater risk of causing a breach. These screws did not evoke neurovascular complications, which suggest that screws with larger diameters do not cause severe complications. However, we only examined a small number of screws, and data from more revision surgeries are needed to validate this conclusion. Spinal cord electromyography is also important for avoidance and detection of neurological complications in new-PS insertion. In the thoracic spine, there were no screws with lateral trajectories, which indicate that insertion of new-PSs in the thoracic spine may not be affected by the posterior muscle.

In the lumbar spine, 86.1% (142/165) of reinserted screws were placed into the previous screw holes with the same trajectory. Thus, 13.9% (23/165 screws) had changes in trajectory. The lumbar posterolateral muscle in the lower lumbar spine (L4-L5 vertebrae) may have caused a lateral trajectory for new-PSs. These vertebrae are also positioned lower and deeper for screw insertion due to lumbar lordosis, the posterior muscle, and fat (Figure 6). Moreover, the lower lumbar vertebrae require screw insertion at a more acute angle compared with thoracic or upper lumbar vertebrae. These factors might have increased the malposition rate of new-PSs in the lower lumbar spine. In the lumbar spine, 20% (18/90) of larger new-PSs had trajectory changes with or without pedicle perforation. Thus, reinserting larger screws may increase the risk for an incorrect trajectory in this region. Thus, when reinserting screws in the lumbar spine, the posterolateral muscle should be exposed sufficiently during the procedure to ensure safe and accurate screw insertion.

Limitations

This study has some limitations. There was a small number of patients, and this may have limited cases with new-PSs with larger diameters. However, this report includes the largest number of new-PSs evaluated using postoperative CT to date. Therefore, the results are important in emphasizing the risk of malposition of a replacement pedicle screw.

Conclusion

New-PSs have the potential for malposition in revision surgery. Reinsertion in the lumbar spine has a particularly high perforation rate and a tendency for unintentional trajectory change, which might be due to effects of the posterior and lateral back muscles during screw insertion. Therefore, new-PSs should be inserted carefully, particularly in this region.

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