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A new perspective of evaluation of the relationship between spinal pedicle screw malposition and surgical experience

Halil GÖK [1], Olgun BİNGÖL [2]*

[1]Department of Orthopedics and Traumatology, Ankara Etlik City Hospital, Ankara, Türkiye
[2]Department of Orthopedics and Traumatology, Ankara Bilkent City Hospital, Ankara, Türkiye

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Abstract

The computed tomography scans of patients who underwent posterior instrumentation for thoracolumbar vertebral fractures were retrospectively reviewed. The aim of this study is to present a single surgeon's experience in the placement of pedicular screws in the thoracic, lumbar, and sacral spine using the two-way fluoroscopy-assisted freehand technique. The directions of screw malposition were classified as anterior, medial, lateral, superior, and inferior; screws with malposition in more than one direction were recorded. Patients' neurological symptoms were recorded and their compatibility with the direction and amount of screw malposition was assessed. The effect of surgical experience on thoracic, lumbar, and sacral pedicle screw placement and the amount of screw experience required for correct pedicle screw placement were investigated. The study evaluated 1112 pedicle screws in 147 patients with thoracolumbar fractures. Screw malposition was found in 206 (18.52%) screws. Medial malposition was found to be statistically higher in the lumbar spine ($p<0.001$). A significant correlation was found between inferior malposition and neurological deficit ($p=0.012$). Thoracic and sacral pedicle screw malposition was statistically higher than lumbar ($p<0.001$). It was found that 386 pedicle screws were required for the learning curve in lumbar fractures ($p=0.004$). Surgical experience is an important factor in correct screw placement. It was found that 386 pedicle screws were required for the learning curve in the lumbar spine.

Keywords: thoraco-lumbo-sacral spine, pedicular screw, malposition, learning curve

1. Introduction

Traditional pedicle screw fixation technique is largely dependent on personal clinical experience (1). The three-dimensional anatomy of the spine can challenge even the most experienced surgeon (2). Despite advances in instrument design and attention to placement technique, cortical perforation is observed.

Rates of malalignment have been reported to range from 5% to 41% in the lumbar spine and from 3% to 55% in the thoracic spine (3). Neurological deficits are not seen in most cases of malalignment. Malalignment is usually asymptomatic (4). Although malalignment is often asymptomatic, spine surgeons are trying to reduce the rate of malalignment. It is thought that the rate of malalignment decreases as surgeon experience increases. However, to our knowledge, no study has examined the amount of malalignment with surgeon experience.

This study hypothesizes that as spine surgeon experience increases, malposition rates will decrease, and a certain number of screws will be required in terms of the learning curve. The aim of this study is to present a single surgeon's 18-year experience of placing pedicle screws in the thoracic, lumbar, and sacral spine using the two-way fluoroscopy-assisted freehand technique and to evaluate malposition, possible causes, and clinical outcomes.

2. Material and Methods

Patients with thoracolumbar vertebral fractures who underwent transpedicular titanium screw fixation with a posterior approach by the same surgeon between June 2002 and March 2020.

Patients with thoracolumbar vertebral fractures aged over 18 years, of both sexes, with at least 2 years of follow-up, and with available radiological and clinical data were included in the study. For homogeneity of technical difficulty, patients with a diagnosis of congenital or acquired rotational deformity, patients under 18 years of age, patients with less than two years of follow-up, and patients whose data could not be reached were not included in the study.

Patients underwent postoperative computed tomography (CT) scans within 48 hours. Screw placements were measured by the authors, malalignment was determined, and clinical outcomes were assessed by reviewing axial, sagittal, and coronal images, with attention to cortical integrity.

The amount of screw overflow was measured, and the overflow directions of the screws were classified as the anterior, medial, lateral, superior, and inferior, overflow of more than 2 mm was considered malalignment. Screws with overflow in more than one direction were recorded. As current

*Correspondence: olgunbingol@gmail.com

classifications do not specify screw malposition in two or three directions and their clinical implications, the level, side, direction, amount, and presence of neurological and vascular pathology were specified for each screw malposition. For example, lumbar 5 (left); anterior overflow 0, lateral overflow 0, medial overflow 5 mm, inferior overflow 4 mm, superior overflow 0, sensorimotor deficit (-), vascular pathology (-), radicular pain (+) in a patient with only positive findings at L5 (L); formulated as M5I4R (+) (Fig. 1). In this way, the overshoot of each pedicle screw in one, two, or three directions, if any, and its clinical implications can be expressed.

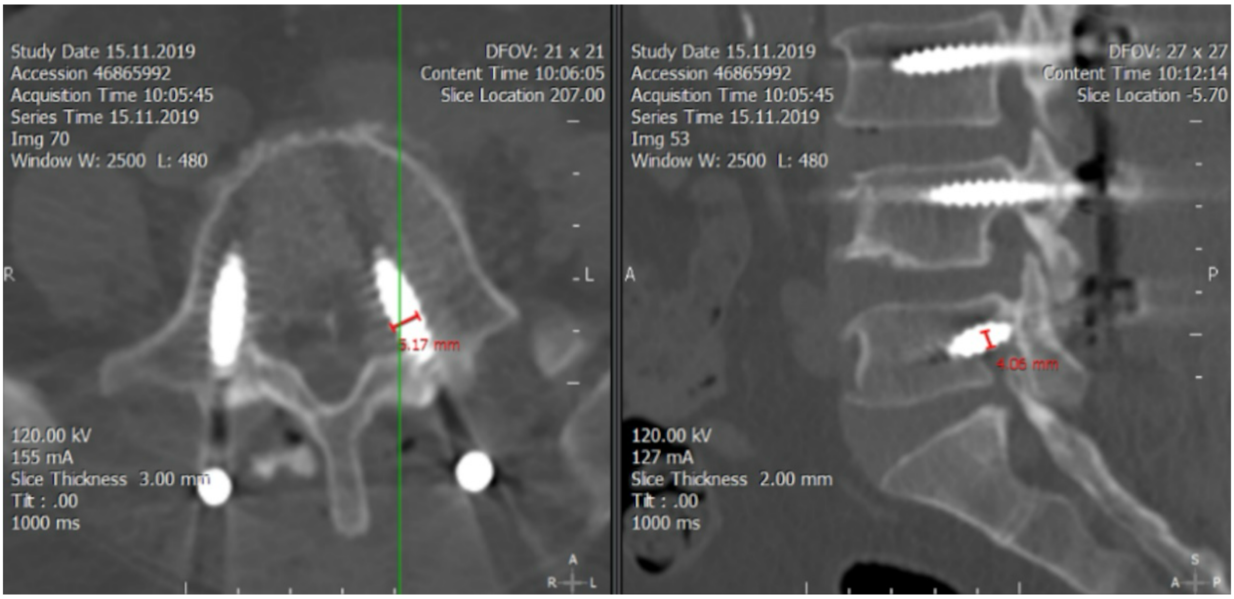

Fig. 1. Screw malposition formulation example: Lumbar 5 (left); anterior overflow 0, lateral overflow 0, medial overflow 5 mm, inferior overflow 4 mm, superior overflow 0, sensorimotor deficit (-), vascular pathology (-), radicular pain (+) in a patient with only positive findings at L5 (L)); formulated as M5I4R (+)

2.1. Preoperative plan

The number of screws to be used, their length and diameter, and the axial and transverse pedicle angles were determined preoperatively for each screw based on the patient's preoperative radiographs and computed tomography (CT) scans. Titanium alloy pedicle screws with diameters of 5.5 mm for T1-T10, 6.5 mm for T11-L5, and 7.5 mm for S1-S2 were used.

2.2. Surgical technique

Patients received prophylaxis against infection and venous thromboembolism. Surgery began with a posterior incision in the prone position on a radiolucent table under general anesthesia. Screws of the pre-planned number, length, and diameter were inserted under fluoroscopic control at the specified axial and transverse pedicle angles. Care was taken to ensure that the tip of the screw did not cross the midline of the vertebral body. Two opposing rods of appropriate angulation and length were placed and fixed to the screws. Once all the implants were in place, a final check was performed using anteroposterior and lateral fluoroscopy. After bleeding control and stability, a haemovac drain was placed in the surgical area. Neuromonitoring was not used in any of the patients.

2.3. Postoperative follow-up

Patients were evaluated postoperatively with neurological examination, x-ray, and 3 mm thin slice CT. The haemovac drain was removed within 24-48 hours postoperatively and the patients were mobilized. Sutures were removed at the end of the second week.

2.4. Statistical analysis

Statistical analysis was performed using SPSS version 22.0 for Windows. Descriptive statistics for numerical variables are mean, standard deviation, median, and min-max. Expressed as values. The chi-square test was used for the analysis of categorical data. The Fisher-Freeman-Halton exact test was used to examine the relationship between the percentage of learning and the presence of malocclusion, and whether this relationship was significant or not. The results were evaluated within the 95% confidence interval and a value of $p<0.05$ was considered significant.

3. Results

A total of 147 patients were included in the study. The mean age of the patients was determined as 53.85 ± 14.85 (min:18, max:79). There were 83 female and 64 male patients. 1112 pedicle screws were inserted for thoracolumbar fractures. Screw malposition was found in 206 (18.52%) screws in 128 (87.07%) patients.

No statistically significant difference was found between gender and pedicle screw malposition ($p=0.578$). Medial malalignment was found to be statistically significantly higher in the lumbar spine ($p<0.001$). A statistically significant correlation was found between inferior malalignment and neurological deficit ($p=0.012$). Thoracic and sacral pedicle screw malposition was statistically higher than in the lumbar spine (p<0.001). In the lumbar spine, a significant correlation was found between the learning percentage and the presence of malalignment (p=0.042). There was a decrease in malalignment rates from 50% and it was found that 386 pedicle screws were required for the learning curve (p=0.004).

It was observed that one screw malposition in three directions and 28 screws in both directions. Radicular pain was noted in 3 (2.04%) patients with malposition. The first patient was re-operated within 24 hours and the malposition screw was corrected. In the second patient, the pain partially resolved with medical treatment. When fusion was achieved in the first postoperative year, the patient's implants were removed. The third patient's radicular pain completely resolved with medical treatment at 6 months postoperatively. No sensorimotor deficits, vascular pathologies, or screw fractures were found in any of the patients.

4. Discussion

The main finding of the present study was that one screw encroached in three directions (inferior, medial, and anterior), and 28 screws encroached in both directions (inferior, medial). In addition, the need for 386 pedicle screws or the learning curve for lumbar pedicle screw placement was determined by the experience of a single surgeon.

Malposition rates have been reported in the literature to range from 5% to 41% in the lumbar spine and from 3% to 55% in the thoracic spine (5-9). In the current study, 1112 pedicle screws were placed for thoracolumbar fractures and 206 (18.52%) screw malposition were identified.

The larger the vertebral canal, the lower the risk of neurological complications (10). Griffith et al. (11) reported that although males have a greater spinal canal cross-sectional area (CSA) and vertebral body CSA than females, the spinal canal CSA relative to the vertebral body CSA is greater in females. There are no studies in the literature comparing malposition and gender. In the current study, no statistically significant difference was found between gender and pedicle screw malposition (p=0.578).

The ideal pedicle screw should converge and have the maximum diameter and length that will not fracture the cortical layer of the pedicle or vertebral body (12). The highest degree of surgical accuracy should be the goal, as incorrect placement of the pedicle screw can lead to undesirable consequences. Accuracy is defined by the ratio of screws completely within the pedicle to screws penetrating the corpus and pedicle cortex (13). Due to the proximity of the thoracic pedicles, which are relatively smaller than the lumbar and sacral pedicles, to the vessels and nerves, screw protrusion, especially inferior and medial, can easily cause serious damage (14). In the case of the lumbar and sacral pedicles, the protrusion of the screws into the vertebral body can cause serious damage.

There is no consensus in the literature regarding the safe zone in case of screw malposition from the pedicle. Kim et al. (15) rated screws as 0 to 2 mm deviation (absolutely safe), 2 to 4 mm deviation (probably safe), > 4 mm (questionably safe), or possibly dangerous medial overflow. Roy-Camille et al. (16) stated that the safe zone between the medial border of the pedicle and the spinal cord is 2-3 mm. Gertzbein and Robins (17) stated that the penetration of 4 mm medially and 6 mm laterally is an acceptable "safe zone". In most clinical trials (37 clinical trials), pedicle infringement of less than 2 mm was not considered to be misplaced on the grounds that it was not responsible for complications (18). In our study, more than 2 mm was accepted as malposition.

In his cadaver study published in 2017, Sarwahi stated that anterior screw overflow of up to 4 mm seen on CT is still found in the periosteum after anatomical dissection (19). The first sacral segment has been extensively analyzed and the bicortical sacral attachment has been found to be extremely safe and widely accepted (20). In the current study, the bicortical sacral attachment was aimed at. This may explain the high rate of anterior overflow in sacral screws.

Fig. 2. MRI image of the patient with malposition formulated as L5(L)M6I5R(+)

Iatrogenic neurological deficits following lumbar spine surgery are rare but important complications to recognize and manage. Complications such as radiculopathy, spinal cord compression, motor deficits, and new-onset radiculitis are rare but can occur. A review study by Ghobrial et al in 2015 reported that 37 (1.9%) of 2052 patients had neurological damage after posterior decompression and fusion, and screw malposition was responsible for 11 of these complications (21). Rauschning (22) stated that screw penetration of the inferior and medial walls of the pedicle can easily cause severe injury to the nerve roots. In our study, infero-medial overflow was found in three patients with radicular pain. One case with L5(L)M6I45R (+) was re-operated within 24 hours and the screw malposition was corrected. (Fig. 2)

The current study has several limitations, and our results should be interpreted in light of these issues. First, this was a retrospective study, and the results should be further verified in randomized controlled trials. In addition, this retrospective design introduces a potential bias in patient selection by the authors. Secondly, the surgeon's experience in terms of the number of pedicle screws placed during residency or prior to the study was not calculated before the first pedicle screw placement measured for this study.

Surgical experience is an important factor in correct screw placement. It has been found that 386 pedicle screws are required for the learning curve in the lumbar spine. Differences in classification and scoring result in a wide range of statistical results. The presentation of each clinically significant screw malposition is necessary to standardize results and to identify screw malposition in two or three directions.

Conflict of interest
The authors declared no conflict of interest.

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None to declare.

Authors' contributions
Concept: H.G., O.B. Design: H.G., O.B., Data Collection or Processing: H.G., Analysis or Interpretation: H.G., Literature Search: O.B., Writing: H.G., O.B.

Ethical Statement
Approval was obtained from Ankara City Hospital Clinical Research Ethics Committee, the study started. The ethics committee decision date is 23/02/2022 and the number of ethical committee decisions is 22-2398.

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