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# Accuracy of pedicle screw fixation in lumbar spine by freehand technique studied postoperatively by computed tomography

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## Abstract

**BACKGROUND:** Spinal stabilization using pedicle screw has been widely used in spinal surgery for the management of various pathologies.

**AIMS:** We aimed to assess the accuracy of pedicle screw fixation in the lumbar spine by freehand technique studied by postoperative computed tomography (CT) scan.

**SETTING AND DESIGN:** This prospective observational study was carried out in a tertiary healthcare facility specializing in managing spine deformities.

**MATERIALS AND METHODS:** The study involved 55 patients with 253 pedicle screws. The accuracy of pedicle screws is determined by calculating breaches in the cortex based on a postoperative CT scan done on three weeks' postoperative follow-up (on suture removal) and confirming by the index surgeon. Postoperative CT was done in all the patients to evaluate implant position within the first month after surgery.

**STATISTICAL ANALYSIS:** Chi-squared test was used to find the statistical significance.

**RESULTS:** In this study, the accuracy of the pedicle screw in the fixation of the lumbar spine was 95.25%, and the incidence of pedicle breaches was 4.75%. The left breach was comparatively higher than the right breach (5.51% vs. 3.96%). Among 12 breaches of the pedicle trajectory, 7 (58.33%) breaches as compared to the 5 (41.66%) on the left side ($P$ = 0.99).

**CONCLUSION:** In conclusion, CT scan is a reliable and effective method for postoperative assessment of spinal pedicle screw placement.

**Keywords:**

Accuracy, CT scan, lumbar spine, misplacement, pedicle breach, pedicle screw

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## Introduction

Pedicle screw fixation is the widely used surgical modality for the entire vertebral column due to its efficacy in stabilizing all three spine columns.[1,2] For this merit, this technique manages spine trauma, instability, deformity, and neoplastic spinal destruction. In the past decade, this technique gaining much attention, and it was first used during lumbar spine surgeries followed by thoracic and cervical spine surgeries.[3] However, its accuracy and complication of pedicle screw position is on debate and has been reported in various studies.[4] Perforation of pedicle cortex during pedicle screw fixation may impose the risk of dural tearing, neural damage, and vascular or visceral complications. Further, pedicle screw misplacement or malpositions may lead to loss of fixation, particularly if it forms at the lower end of the construct.



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Misplaced screws might lead to altered biomechanics or pedicle cortical breaches precisely at the medial position and prelude to worse clinical outcomes. Earlier reports show the accuracy of this technique with the incidence of pedicle wall breaches in the range from 5% to 31%.[5-7] Thus, accurate positioning of pedicle screw placement is required for reducing neurological injury and spinal stability for an extended period.[8]

The freehand pedicle screw insertion method depends on the surgeon's physical response and expertise to point out accurate anatomical marks for the correct screw entry point, without the need of intraoperative imaging tools or with minimal requirement of intra-operative fluoroscopy. Meanwhile, the freehand methods are highly reliable and frequently used, but the main demerit is that they require a long learning curve since practical placements of screws rely on surgeons' skills and experience to achieve good clinical outcomes.[9,10]

Various imaging modalities have been used to determine the accuracy of pedicle screw fixation. Intraoperative fluoroscopy and serial radiography only measures the penetration of screw depth but cannot detect screw malpositioning.[11] Albeit, reports suggest that computed tomography (CT) imaging is the most reliable and accurate modality compared to conventional radiography in determining pedicle screw location, precisely in medial and lateral pedicel perforation.[12] Earlier, the postoperative CT evaluation is used in patients where the condition worsens postoperatively and in many clinical setups, CT is not routinely performed after surgery.[13] Albeit the emergence of new modalities, the incidence of pedicle screws misplacement in lumbar spine surgeries is still a significant drawback in the clinical scenario.[14]

As a result, this study was conducted to determine the accuracy of pedicle screw fixation by freehand technique in the lumbar spine, as assessed by a postoperative CT scan. The placement (trajectory) of pedicle screws and bridges in the trajectory was also assessed.

## Subjects and Methods

This prospective observational study was done from June 2018 to May 2019 at the Department of Orthopaedics, Seth Nandlal Dhoot Hospital, Aurangabad, India. The study population included 55 patients with a total of 253 pedicle screws which had who underwent pedicle screw fixation in the lumbar spine using the freehand technique.

The inclusion criteria for the present were the patients who underwent pedicle screw fixation in the lumbar spine for the degenerative spine, spondylolisthesis, traumatic spine, infective pathology, revision spine cases, inflammatory pathology, and malignancy. Patients with severe spinal deformity and pediatric cases were excluded from the study. A written, informed consent was obtained from all the study participants.

All the operated cases of lumbar spine pedicle screw fixation for various pathologies satisfying inclusion and exclusion criteria, operated by a single Surgeon by Magrel technique studied. All the pedicle screws are inserted from the right side after proper exposure and visualization of the pedicles. Accuracy of pedicle screws measured in terms of the breaches in the cortex calculated on the postoperative CT scan done on three weeks followed up (on suture removal) and reconfirmed by the index surgeon.

### Surgical procedure

It was identified using anatomical landmarks that located the intersection of the spine of the transverse process with the corresponding facet, and the screw trajectory was confirmed by fluoroscopy in lateral projections. During surgery, fluoroscopy in the only lateral plane was used. The cortex overlying this site was removed with a rongeur, and an awl 4 mm in diameter was used to drill the pedicle screw pilot hole, and the pathway was opened with a pedicular probe. The probe then was advanced manually 30 to 35 mm, and its position was checked with fluoroscopy. The hole was tapped, and then a pedicle tester was used to determine if the pedicle wall had been breached. A pedicle feeler was used to confirm the presence of bone in all four quadrants. This situation would have necessitated changing the entry point or moving the entry point up or down until the intact pedicle wall was prepared. For correct placement of a pedicle screw, the screw must be directed down the cancellous tunnel of the vertebral pedicle. Finally, the screw inserted using fingertip pressure only. After each screw had been placed, fluoroscopy was used to confirm the pedicle screw trajectory. After screws inserted into the pedicles, they connected with a titanium rod. If a laminectomy or a broad exposure was performed, the screws were also inserted by direct pedicle visualization and palpation. All of the implants used in this study were made entirely of titanium. No intraoperative neurophysiological monitoring was performed. After surgery, the patients were examined neurologically by an independent observer to assess neurological deficits preoperatively not present.

### Postoperative evaluation

Postoperative CT was performed in all cases to evaluate implant position within the first month after surgery. The CT scans were obtained with 2-mm axial slices of the instrumented levels. These images were then inspected for evidence of pedicle violation. Three independent observers performed all accuracy evaluations. In this

study, the screw placement was evaluated according to the criteria published by Gertzbeins and Learch.[15] The screw placement was considered correct when the screw was completely surrounded by the pedicle and no portion of the screw penetrated the cortex. Using the scale on the CT image, we measured the penetration depth of the pedicle screw in millimeters. If the penetration depth was more than 2 millimeters along the pedicle inferiorly, superiorly, laterally, medially, or anywhere from the corpus, the screw was considered misplaced. Penetration was further subdivided— based on measurement of the distance that the edge of the screw thread extended outside the pedicle cortex—into minor (≤2.0 mm), moderate (2.1–4 mm), and severe (>4 mm). In accordance with the direction of the pedicle violation, screw misplacement was classified as lateral, medial, inferior, or superior, and right or left.

Screw position was analyzed qualitatively for placement on CT examination within or outside the pedicle. A quantitative analysis was also developed to determine the accuracy of screw entry and trajectory. The data from screw positions were subdivided according to error measurement ideal, 0–2 mm, 2.1–4 mm, and greater than 4 mm, error direction (medial, lateral, caudal, cephalic), pedicle side (right or left), and vertebral level.

### Statistical analysis

The accuracy of pedicle screw fixation in the lumbar spine is considered a primary outcome variable. Other outcomes include a breach in the trajectory of the pedicle wall, that is, anterior, superior, lateral medial, inferior and superior endplate on the right and left side. For all the parameters, the results were expressed as mean ± standard deviation (SD). Chi-squared test was used to determine statistical significance, and a $P$ =.05 level of significance was considered significant.

## Results

In this study, a total of 55 cases were studied with different operative indications, of which 20 (36%) of lumbar canal stenosis, 19 (34%) of the prolapsed intervertebral disc, 7 (13%) of spondylolisthesis, 4 (4%) of neoplasm, 2 (4%) of infective pathologies, 2 (4%) of revision spine surgery, and 1 (2%) case of trauma. Two hundred fifty-three pedicle screws were inserted by freehand techniques in selected cases and studied postoperatively for accuracy of insertion.

Among the 253 pedicle screws, ten were in the L1 pedicle, five on each side, 22 were in L1 pedicle, 11 on each side, 45 were in the L3 pedicle, 22 on the right side and 23 on the left, 84 were in L5 pedicle 42 on each side. Ninety-two are in L5 pedicle 46 on each side. Thus out of 253 screws, 126 screws were inserted on the right side, and 127 screws were inserted on the left side, respectively.

Among five right L1 pedicle screws, all are accurately placed, one superior endplate breach out of 11 pedicle screws at right L2 (9% breach), one medial breach out of 22 pedicle screws at right L3 (4.54% breach), one lateral breach out of 42 pedicle screws at right L5 (2.27%) and one lateral and 1inferior breach out of 46 pedicle screws at right L4 (4.34% breach). Thus, out of 126, 5(3.96%) pedicle violations found on the right side and 121 (96.03%) screws were accurately placed and in these 1 (0.79%) medial breach,2 (1.58%) lateral breach, no superior breach,1 (0.79%) inferior breach, no anterior breach,1 (0.79%) superior endplate breach noted. The results are shown in Table 1. Among five left L1 pedicle screws, all are accurately placed, one superior endplate breach and one lateral breach out of 11 pedicle screws at left L2 (18.18% breach), one anterior breach out of 23 pedicle screws at left L3(4.34% breach), one inferior breach out of 42 pedicle screws at left L5(2.27%) and two medial and 1lateral breach out of 46pedicle screws at left L4 (6.52% breach). Thus, out of 127,7(5.51%)pedicle violation found on left side and 120(94.48%) screws were accurately placed, thus 2 (1.5%) medial breach,2 (1.5%) lateral breach, no superior breach,1 (0.75%) inferior breach,1 (0.75%) anterior breach,1(0.75%) superior endplate breach were noted. The results are shown in Table 2.

Among 10 L1 pedicle screws, all were accurately placed,2(9%) superior endplate breach and 1(4.5%) lateral breach out of 22 pedicle screws at L2 (13.6% breach),1(2.22%) anterior breach and 1(2.22%) medial breach out of 45 pedicle screws at L3(4.44%

**Table 1: Level and breaches studied by postoperative CT scans on right side**

| Level of pedicle screw insertion | Number of pedicle screws inserted (right side) | Cortical breaches | | | | | |
|---|---|---|---|---|---|---|---|
| | | M | L | S | I | A | SE |
| L1 | 05 | 0 | 0 | 0 | 0 | 0 | 0 |
| L2 | 11 | 0 | 0 | 0 | 0 | 0 | 1 |
| L3 | 22 | 1 | 0 | 0 | 0 | 0 | 0 |
| L4 | 46 | 0 | 1 | 0 | 1 | 0 | 0 |
| L5 | 42 | 0 | 1 | 0 | 0 | 0 | 0 |
| Total | 126 | 1 | 2 | 0 | 1 | 0 | 1 |

M = medial, L = lateral, S = superior, I = inferior, A = anterior, SE = superior end

**Table 2: Level and breaches studied by postoperative CT scans on left side**

| Level of pedicle screw insertion | Number of pedicle screws inserted (left side) | Cortical breaches | | | | | |
|---|---|---|---|---|---|---|---|
| | | M | L | S | I | A | SE |
| L1 | 05 | 0 | 0 | 0 | 0 | 0 | 0 |
| L2 | 11 | 0 | 1 | 0 | 0 | 0 | 1 |
| L3 | 23 | 0 | 0 | 0 | 0 | 1 | 0 |
| L4 | 46 | 2 | 1 | 0 | 0 | 0 | 0 |
| L5 | 42 | 0 | 0 | 0 | 1 | 0 | 0 |
| Total | 127 | 2 | 2 | 0 | 1 | 1 | 1 |

M = medial, L = lateral, S = superior, I = inferior, A = anterior, SE = superior end

**Table 3: Total number of breaches in the cortex on both sides (right and left combined)**

| Level of pedicle screw insertion | Number of pedicle screws inserted | Cortical breaches | | | | | |
|---|---|---|---|---|---|---|---|
| | | M | L | S | I | A | SE |
| L1 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| L2 | 22 | 0 | 1 | 0 | 0 | 0 | 2 |
| L3 | 45 | 1 | 0 | 0 | 0 | 1 | 0 |
| L4 | 92 | 2 | 2 | 0 | 1 | 0 | 0 |
| L5 | 84 | 0 | 1 | 0 | 1 | 0 | 0 |
| Total | 253 | 3 | 4 | 0 | 2 | 1 | 2 |

M = medial, L = lateral, S = superior, I = inferior, A = anterior, SE = superior end

breach),1 (1.19%) inferior breach and 1(1.19%) out of 84 pedicle screws at L5(2.38%) and 2(2.17%) medial and 2(2.17%) lateral breach and 1(1.08%) inferior breach out of 92 pedicle screws left L4(4.34% breach) were noted. Thus, out of 253,12(4.74%) pedicle violation was observed, and 241(95.25%) screws were accurately placed, thus 3(1.24%) medial breach,4 (1.58%) lateral breach, no superior breach, 2 (0.79%) inferior breach,1 (0.39%) anterior breach,2 (0.79%) superior endplate breach were noted. The results are shown in Table 3.

Among 12 breaches of the pedicle trajectory, 7 (58.33%) breaches on the left side, which is slightly higher as compared to the 5 (41.66%) on the left side, and it was not significant (Chi square = 0.065; $P = 0.99$).

Among 55 cases studied for pedicle screws ($n = 253$) insertions, 4(1.5%) were found to have postoperative complications. Among these, 1(0.39%) had screw loosening, 2(0.79%) cases had postoperative neuropraxia, and 1 case showed postoperative radiculopathy.

## Discussion

Recently, pedicle screw fixation has been a routinely used method in surgeries involving the thoracic, lumbar and sacral spine for the management of different pathologies.[16] The important role of this technique is to stabilize the unstable spine and augment the arthrodesis for complete bony fusion and the correction of pathologic segment. Enhancing the screw placement accuracy leads to minimal adverse effects by entirely fixing the screw in bone without affecting the anatomical structures such as nerve roots blood vessels and increasing the strength of the device and its resistance to pullout, thus improving the long term outcome. Accurate screw placement is when the screw is entirely surrounded by the pedicle, and none of the screw portions is perforated outside the cortex. Pedicle screw penetration is measured in millimeters (mm) using a scale on the CT, and it is considered as a gold standard technique in determining the pedicle screw placement accuracy.[17] The misplacement of the pedicle screw is stated when the penetration is 2 mm or higher along the pedicle inferiorly, superiorly, laterally, medially, or anywhere from the corpus. Based on the pedicle screw violation, the misplacement of screws was stated as lateral, medial, inferior, or superior, and right or left.

In this study, the accuracy of pedicle screw placement is 95.25% which is in line with the recent study conducted by Aigner *et al.*,[18] where the accuracy rate is 95.2%. In our study, the incidence of pedicle screw misplacement is 4.74%, and the previous studies reported the incidence range of screw violation between 0–42%.[19] This wide range might be due to various clinical reasons such as surgery type, spinal level, surgeons experience, intraoperative variability and methods used for the post-operative assessment. Laine *et al.*[20] reported 35.22% of screw violation, and Castro *et al.*[21] detected cortical penetration in 40% of their patients, which is lower as compared to this study. In another study done by Salem *et al.*,[22] the incidence of misplaced screws was evaluated using CT scan to detect cortical breach even 33.33%, higher than this study.

However, this study identified some differences in outcome in accordance with pedicle levels. These differences are usually associated with the different pedicle morphology and different indications for surgery. In this study, the main finding was that the screws

positioned tend to perforate the cortex laterally. The distribution of perforation must be in medial or lateral or at other possible sites. The reason for the preponderance of lateral perforations is might be due to the variations in longitudinal midline axis of the pedicle and the anatomically feasible axis.

This study results showed breach rate of the L4 pedicle is slightly higher than that of L3 and L5. In fact, the L5 pedicle is less sizeable than projected value. The morphological characteristics of L5 are somehow different from other lumbar pedicles. Zindrick *et al*.[23] reported that the narrowest widths of the pedicles in the transverse plane from L3 to L5 were 10.3, 12.9, and 18.0 mm, respectively. As the pedicles of L3 L4 are narrower in the transverse plane than that of L5, higher screw breach rates in L3 and L4 may be reasonable.

In our study, all the pedicle screws were inserted by a single surgeon from the right side; there is a difference between the breaches on the right and left sides. On the right side total of 5(41.62%) breaches were observed, among them 2 (16.16%) at L4 and 1(8.33%) at L2, L3, and L5 levels each. Out of 52 screws laterally beached, the pedicle and 1screw were breached medially, superior endplate, and inferiorly each. On the Left side total of 7(58.33%) breaches were observed, among them 3 (25%) at L4, 2(16.16%) at L2,1(8.33%) at L3 and L5 level each. Out of 72 screws laterally and medially beached, the pedicle and 1screw breached anterior, superior endplate, and inferiorly each, and it was not significant. According to Agarwal *et al*.,[24] the resident had a rate of 7.69% significant medial and 10.76% significant lateral breaches with the freehand technique. The expert surgeon had a rate of 6.15% significant medial and 1.53% significant lateral breaches with the freehand technique.

## Conclusion

Freehand technique is an effective method in lumbar pedicle screws fixation with around 95.25% of accuracy rates and 4.75% pedicle breaches, which is most important in the institutes where there is no source of newer methods of pedicle screws insertion such as O arm technique and CT-guided pedicle screws insertion.

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### Conflicts of interest
There are no conflicts of interest.

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