Original Article

Unprecedented journey to 650 transpedicular screws using freehand technique and intraoperative C-arm imaging with technical nuances

ABSTRACT

Introduction: Pedicle screw placement plays a crucial role in treating various cases such as fractures, scoliosis, degenerative spine issues, and kyphosis, reinforcing all three spinal columns simultaneously. While three-dimensional navigation-assisted pedicle screw placement is considered superior, the freehand technique relies on anatomical landmarks and tactile feedback, with observed low complication rates.

Materials and Methods: This was a prospective single-center study conducted over a period of 3 years. It included all patients of dorsal, lumbar, and sacral spinal instability of myriad etiology. Previously operated patients and sick obtunded patients were excluded from the study.

Results: In our study, we included 102 patients including 62 (60.7%) males and 40 (39.2%) females. More than half of patients were young in the age group of 20–50 years. Our study population had a varied etiology with 43.1% of patients having vertebral column instability due to trauma. The other etiologies were spondylolisthesis and lumbar canal stenosis (39.2%), Pott's spine (11.7%), tumors (2.9%), and osteoporotic fractures (2.9%). Majority of patients (44.1%) presented with lower backache with radiculopathy. All the transpedicular screws inserted were evaluated by C-arm to assess for screw fixation. In the first year of our study, an average of 4 anteroposterior (AP) and 4 lateral C-arm X-ray shots were taken per screw placement. In the next year, an average of 3 AP and 3 lateral shots and finally in the last year of our study only 2 AP and 2 lateral C-arm X-ray shots were taken per screw placement. Out of 650 screws placed, 4 screws were identified to cause breach with maximum breaches in the lumbar spine fixation. In dorsal spine fixation, there was 1 lateral breach at D10. In lumbar spine fixation, there were 3 breaches: two medial one each at L4 and L5 and one anterior at L2 level. The various complications include wound infection, temporary and permanent neurological deficit, screw breakage, screw misplacement, cerebrospinal fluid leaks, nonunion, and spinal epidural hematoma.

Conclusions: Our study has provided strong encouragement to persist with the freehand technique in transpedicular fixation surgeries after a certain number of cases given the minimal breaches and complications observed. There are subtle technical nuances as we increase the number of cases with less exposure of anatomical landmarks and X-rays. Success hinges on experience, adherence to technique, and thorough preoperative planning. Further research and extended follow-up periods are necessary to firmly establish this technique as the gold standard.

Keywords: C-arm, intraoperative X-ray, pedicle screw, transpedicular

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INTRODUCTION

The introduction of transpedicular screw spinal fixation in 1963 by Roy-Camille marked a significant advancement in spine surgery.[1,2] Pedicle screw placement plays a crucial role in treating various cases such as fractures, scoliosis, degenerative spine issues, and kyphosis, reinforcing all three spinal columns simultaneously. Complications arising from misplacement include dural tears, neurological deficits, broken screws, screw loosening, screw-rod disconnections,

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vertebral fractures, vessel injuries, hematomas, wound infections, and cerebrospinal fluid (CSF) leakage.[3] Surgeons must carefully consider pedicle width, length, screw diameter, trajectory, and entry point to minimize complications.[4,5] Screw parameters should be selected based on anatomical landmarks and tactile feedback for each case.[6] The use of image guidance devices during surgery may provide a safer and more accurate method for placing thoracic pedicle screws, reducing radiation exposure.[7] While three-dimensional (3D) navigation-assisted pedicle screw placement is considered superior, the freehand technique relies on anatomical landmarks and tactile feedback, with observed low complication rates.[8]

Radiological methods' limitations have led to varying reports on screw loosening rates, with some papers indicating <1% on X-rays[9,10] and others showing significant rates.[11,12] Radiographic factors such as osteoporosis, osteopenia, nonfusion surgery, and long segment fixation contribute to screw loosening.[13] Surgeon experience also plays a crucial role, with experienced surgeons demonstrating lower screw misplacement rates in thoracolumbar procedures using traditional techniques.[6] While navigation systems ease surgeons' tasks, they come with challenges like a steep learning curve, calibration errors, instrument bending, occasional surgical field obstruction, and issues with reference frame connections.[14,15] Studies comparing fluoroscopy-assisted pedicle screw insertion accuracy to computed tomography (CT) navigation vary in their conclusions due to differences in population characteristics and assessment methods.[16,17] In the present study, we described our experience of the placement of pedicle screws in dorsal, lumbar, and sacral spine using a freehand technique via intraoperative C-arm imaging and its technical nuances.

MATERIALS AND METHODS

This was a prospective single-center study conducted over a period of 3 years. It included all patients of dorsal, lumbar, and sacral spinal instability of myriad etiology. Previously operated patients and sick obtunded patients were excluded from the study. Detailed history and clinical examination of all the patients was followed by preoperative radiological assessment using X-rays, magnetic resonance imaging, and CT scan with 3D reconstruction. All the fixations were done by a single surgeon. Freehand technique was used for screw insertion using anatomical landmarks as a guide for entry under intraoperative C-arm imaging. During the first year of our study, complete exposure of facet joint and transverse process was done; however, during subsequent 2 years, only the facet joint was exposed. The entry point for dorsal spine was taken at the junction of upper border of transverse process and pars lateral superior articular process. For lumbar spine, entry point was taken at the junction of midpoint of transverse process and pars lateral superior articular process. For sacral spine, entry point was taken at the junction of sacral ala and sacral ala superior articular process. C-arm images and naked eye examination were used to confirm the accuracy of transpedicular fixation intraoperatively. The patients were followed for a period of 1 year.

RESULTS

In our study, we included 102 patients including 62 (60.7%) males and 40 (39.2%) females. More than half of patients were young in the age group of 20–50 years. Our study population had a varied etiology [Table 1] with 43.1% of patients having vertebral column instability due to trauma. The other etiologies were spondylolisthesis and lumbar canal stenosis (39.2%), Pott's spine (11.7%), tumors (2.9%), and osteoporotic fractures (2.9%). Majority of patients (44.1%) presented with lower backache with radiculopathy. The other presentations were paraplegia, flaccid paraparesis, spastic paraparesis, and severe back pain with tingling and numbness [Table 1].

In the first year of our study, 31 patients were operated after exposing both the facet joint and transverse process. However,

Table 1: Varied etiology and diverse presentation of our presentation

Etiology	Percentage	Presentation	Percentage
Trauma	43.1	LBA with radiculopathy	44.1
Spondylolisthesis and spinal canal stenosis	39.2	Severe back pain with tingling and numbness	33.3
Pott's spine	11.7	Flaccid paraparesis	7.8
Tumor	2.9	Paraplegia	7.8
Osteoporotic fractures	2.9	Spastic paraparesis	6.8

LBA - Low back ache

Table 2: Number and percentage of screws used at different spinal levels

Level	*n* (%)
D7	12 (1.8)
D8	12 (1.8)
D9	8 (1.2)
D10	68 (10.4)
D11	78 (12)
D12	60 (9.2)
L1	62 (9.5)
L2	75 (11.5)
L3	35 (5.3)
L4	92 (14.1)
L5	92 (14.1)
S1	56 (8.6)

in subsequent 2nd and 3rd years, only the facet joint was exposed, while junction was only palpated in rest 71 cases. Over time, the proficiency in performing transpedicular fixation using freehand technique steadily increased. This growth in experience was marked by enhanced tactile feedback after 30 cases, resulting in improved outcomes over time. We placed 650 screws in our study, with lumbar spine being the most common site of placement including 356 screws followed by thoracic spine (238 screws) and sacral spine (56 screws) [Table 2].

Out of total, 626 screws were self-drilling polyaxial titanium screws and 24 were cannulated cement screws. The screw dimensions were different for different levels. The length and breadth of screw for dorsal spine ranged from 40 to 45 mm and 4.5–5.5 mm, respectively. The same dimensions for lumbar spine were 45 mm and 5.5 mm and for sacral spine were 50 mm and 6.5 mm, respectively [Table 3].

All the transpedicular screws inserted were evaluated by C-arm to assess for screw fixation. In the first year of our study, an average of 4 anteroposterior (AP) and 4 lateral C-arm X-ray shots were taken per screw placement. In the next year, an average of 3 AP and 3 lateral shots and finally in last year of our study only 2 AP and 2 lateral C-arm X-ray shots were taken per screw placement.

Out of 650 screws placed, 4 screws were identified to cause breach with maximum breaches in the lumbar spine fixation. In dorsal spine fixation, there was 1 lateral breach at D10. In lumbar spine fixation, there were 3 breaches: two medial one each at L4 and L5 and one anterior at L2 level. There was no breach in sacral spine fixation.

The complication rate after freehand screw placement was low for lumbar spine fixation. The various complications include wound infection, temporary and permanent neurological deficit, screw breakage, screw misplacement as shown in Figure 1. Figure 2 shows percentage of different complications encountered.

The functional results after surgery were assessed by modified Macnab criteria. 62.7% of patients had excellent outcome, 19.6% had good outcome, 14.7% had fair outcome, and 2.9% had poor outcome. Even the modified Macnab criteria indicated an improvement in results over 3 years.

Table 3: The screw parameters at different levels

Level	Screw length	Screw width (mm)
D7	40	4.5
D8	45	4.5
D9	45	4.5
D10	45	5.5
D11	45	5.5
D12	45	5.5
L1	45	5.5
L2	45	5.5
L3	45	5.5
L4	45	5.5
L5	45	5.5
S1	50	6.5

DISCUSSION

Pedicle screw fixation offers the benefit of engaging all three spinal columns without intruding into the spinal canal, leading to potentially better clinical outcomes in treating fractures and correcting deformities.[8] As concerns about radiation exposure grow, many surgeons prefer the freehand technique for placing pedicle screws across various conditions, from trauma to tumors.[18] Mastering this technique based on fundamental anatomy is crucial for both new surgeons and in settings where neuronavigation tools are limited.[19] While image-guided techniques have enhanced safety margins, they require additional equipment and increase radiation exposure. The freehand method relies on visible and palpable anatomical landmarks, including the lateral border of the pars interarticularis, the entire transverse process, and the adjacent facet joints, for precise screw placement[20] as shown in Figures 3-5.

We conducted a 3-year study involving 102 patients, where 650 screws were utilized for spine fixations, with an average patient age of 46 years. The majority of patients suffered spine fractures due to trauma, and all fixations were performed by a single surgeon using the freehand technique. Proficiency in transpedicular fixation improved steadily over the study period, predominantly focusing on the dorsal spine. The vast majority (96%) of screws employed were self-drilling polyaxial titanium screws. Our study identified four instances of screw breaches, with the lumbar spine experiencing the most breaches, including two medial breaches at L4 and L5, one lateral

Figure 1: Axial computed tomography scan showing medial breach of right pedicle screw into the canal

breach at D10, and one anterior breach at L2. We defined a safe zone for pedicle screw breach of vertebral bodies ranging from 2 to 4 mm. Baaj *et al*.[21] observed in their study of 720 screws that 97 screws were misplaced, with lateral misplacements being more common than medial misplacements.

In our study, the average accuracy was 95.5%, defined as successfully placing the entire screw within the cortices of each respective pedicle as shown in Figure 5. According to a previous research, accuracy rates have ranged from a low of 87.4%[22] to a high of 98.3%.[23] Modi *et al*.[24] also assessed accuracy for various spine pathologies, reporting rates of 86.1% for adolescent idiopathic scoliosis, 91.7% for cerebral palsy, 95.9% for Duchenne's muscular dystrophy, 90.2% for spinal muscular atrophy, and 84.4% for polio. Weinstein *et al*.[25] found an overall accuracy of 93.8% in a study involving five surgeons.

In our research, we encountered few issues such as wound infections, neurological deficits, and screw-related problems. Kim *et al*.'s study, involving 3204 screws over a decade, demonstrated the technique's safety without neurological or vascular complications.[26] Parker *et al*.'s comparison of multiple surgeons also showed a low complication rate, affirming the technique's safety across different practitioners.[27-34] Another study reported a low complication rate of 4.3%, primarily durotomies, in thoracic spine screw placements.[22] Functional outcomes were evaluated using modified Macnab criteria, revealing mostly positive results with improvements observed over 3 years.

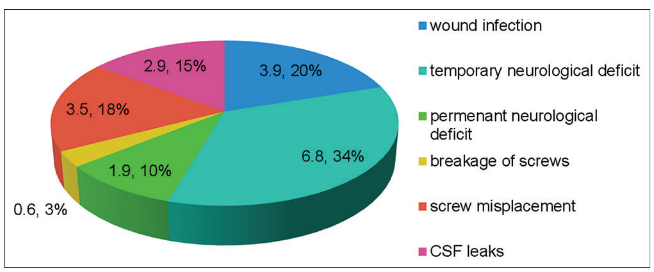

Figure 2: Percentage of different complications encountered. CSF: Cerebrospinal fluid

CONCLUSIONS

Our study has provided strong encouragement to persist with the freehand technique in transpedicular fixation surgeries after a certain number of cases given the minimal breaches and complications observed. There are subtle technical nuances as we increase the number of cases with less exposure of anatomical landmarks and X-rays. Success hinges on experience, adherence to technique, and thorough preoperative planning. Further research and extended follow-up periods are necessary to firmly establish this technique as the gold standard.

Figure 3: Awl and screw hitting the bulls eye (pedicle) in anteroposterior view on intraoperative C-arm

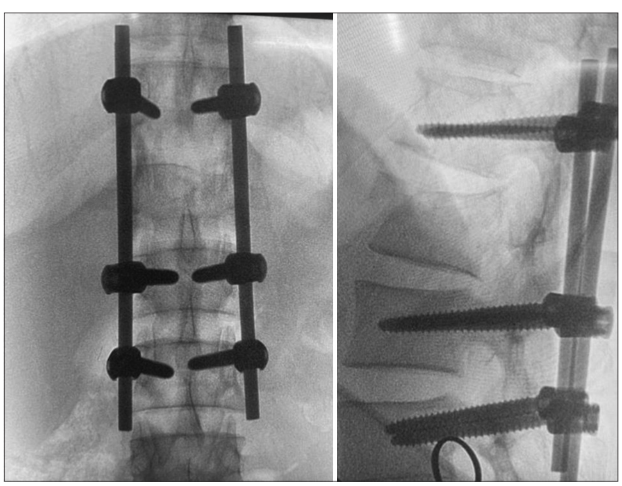

Figure 4: Sagittal X-ray anteroposterior/lateral view showing transpedicular fixation at L2, L4, L5 level

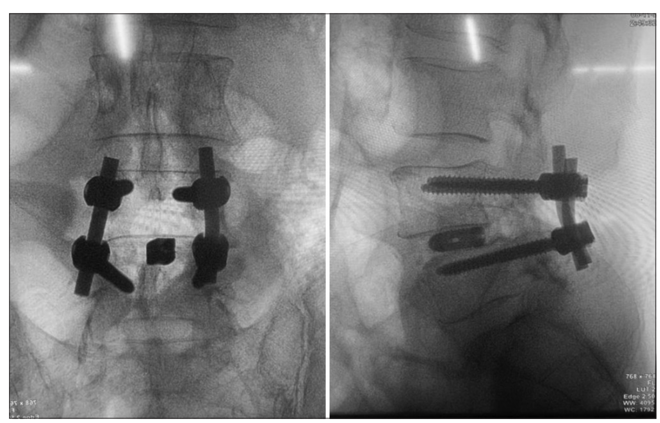

Figure 5: Sagittal X-ray anteroposterior/lateral view showing the transforaminal lumbar interbody fusion

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Conflicts of interest

There are no conflicts of interest.

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