A Clinical Comparison of Robotic-Assisted and Navigated Screw Placement Accuracy to Planned Screw Trajectory

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INTRODUCTION: Pedicle screw fixation can be an effective solution to address spinal stability and correct deformity, but close proximity to sensitive soft tissues, such as nerves, vasculature, and dura introduces the potential to impart subsequent clinical complications.[1] The use of image-guided enabling technologies such as navigation and robotic-assisted screw placement may reduce the risk of misplaced screws.[2] This study quantified the accuracy of executed pedicle screw placement compared to intraoperatively planned trajectories in navigated and robotic-assisted procedures.

METHODS: Anonymized machine data was exported from the computer guidance platform at five hospitals for 83 clinical cases utilizing CT-based navigation (42 procedures) or robotic-assisted (RA) pedicle screw placement (41 cases) in spine thoracolumbar surgical procedures that occurred between October 2024 and June 2025. Workflow data and screw placement were recorded for 271 navigated screws. Workflow data was captured for 204 RA screws, and screw placement was logged for 180 RA screws. Intraoperative CT imaging was imported to the guidance platform where surgeons identified and selected the operative levels for the procedure. Surgeons reviewed the screw size and trajectory suggested by the guidance system and either accepted or modified the suggested screw plan during intraoperative pre-planning prior to beginning the surgical workflow. Alternatively, surgeons were able to execute virtual screw placement during the surgical procedure without pre-planning. Final executed screw positioning was recorded in the guidance platform's coordinate system relative to the patient tracker and was compared to the pre-planned trajectory. Linear displacement of planned versus executed screw placement was measured in the pedicle, 20 mm beneath the executed screw head. Workflow data comparing navigated to RA surgical procedures and planned versus executed screw placement were statistically analyzed using the Chi-square test ($p<0.05$).

RESULTS: A minimally invasive (MI) surgical approach was utilized more frequently in RA procedures (52% MI, 48% open) versus navigated cases (15% MI, 85% open) ($p<0.0001$). The number of operative levels per case was similar for both RA and navigated procedures, with ≥80% of cases consisting of ≤3-levels (RA: 85%, navigated: 80%). Seventy-one percent of RA procedures utilized intraoperative pre-planning to select screw size and trajectory prior to the start of the surgical workflow versus 58% for navigation ($p=0.0025$). Surgeons modified the platform's suggested screw trajectory (i.e., position and angle) during intraoperative pre-planning for 92% of RA screws and modified angle or position from the suggested trajectory in 78% and 81% of planned navigated screws, respectively. Surgeons were more likely to introduce changes to the software's suggested screw diameter and length when using the robotic-assisted technique in comparison to navigation and accepted the suggested screw size, both diameter and length, without change for 39% of all navigated versus 17% of all RA screws ($p<0.0001$). When changes were introduced, surgeons tended to increase the screw diameter and decrease the screw length from the platform's suggested screw size (**Table 1**).

A comparison of executed screw position to planned screw placement showed similar position deviation for both robotic-assisted and navigated screws, with 71% of robotic-assisted and 76% of navigated screws demonstrating ≤2.5mm deviation from plan (**Figure 1**). Quantification of transverse angle deviation in the medial-lateral plane demonstrated differences for robotic-assisted and navigated techniques, with a tighter distribution observed for RA screws relative to navigated screws (**Figure 2**). Eighty percent of RA screws were placed within ±1.5° of plan versus 41% for navigated screws ($p<0.0001$).

DISCUSSION: This clinical data demonstrated greater utilization of a minimally invasive surgical approach when using robotic-assistance in comparison to navigated techniques. Surgeons conducting RA procedures were more likely to intraoperatively pre-plan and more likely to tailor the planned screw trajectory and screw size relative to the initial screw suggestion offered by the guidance software. Screws placed using both robotic-assisted and navigated techniques demonstrated close alignment of planned and executed screw position, which may suggest the potential of these enabling technologies to allow for surgeon confidence in executing screw placement to plan. While position deviation was similar across platforms, robotic-assisted screws showed less variability in transverse angle deviation in comparison to navigated screws. This may possibly be attributed to the design of the robotic-arm system which holds a guide tube in place to facilitate pedicle preparation and pedicle screw insertion by the surgeon along a haptically-guided trajectory. The greater predictability of screw head placement with robotic-assistance may influence subsequent efficiency of rod placement through the final construct for fixation.

SIGNIFICANCE/CLINICAL RELEVANCE: Both navigation and RA techniques demonstrated accurate and repeatable screw placement relative to planned trajectories in spine thoracolumbar surgery.

REFERENCES: [1] Beisemann N, et al. *Sci Rep* **12**, 12344 (2022). [2] Fan Y, et al. *Sci Rep* **8**, 890 (2018).

IMAGES AND TABLES:

Table 1. Change in screw size from platform-suggested to surgeon-selected size.

Diameter Change	Nav	RA	Length Change	Nav	RA
-3 mm	0%	0%	-20 mm	1%	0%
-2.5 mm	0%	0%	-15 mm	4%	4%
-2 mm	0%	0%	-10 mm	9%	17%
-1.5 mm	0%	0%	-5 mm	18%	37%
-1 mm	8%	5%	0 mm	51%	37%
-0.5 mm	1%	1%	5 mm	15%	4%
0 mm	56%	36%	10 mm	2%	1%
0.5 mm	3%	1%	15 mm	1%	0%
1 mm	8%	19%	20 mm	0%	0%
1.5 mm	17%	17%			
2 mm	5%	8%			
2.5 mm	4%	12%			
3 mm	0%	2%			

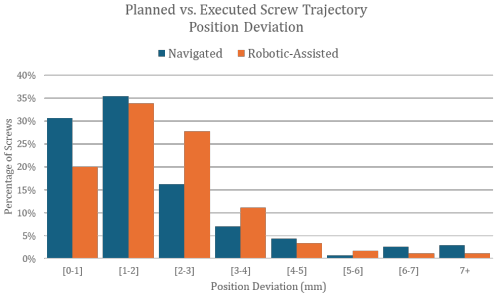

Figure 1. Position deviation in planned versus executed screw placement.

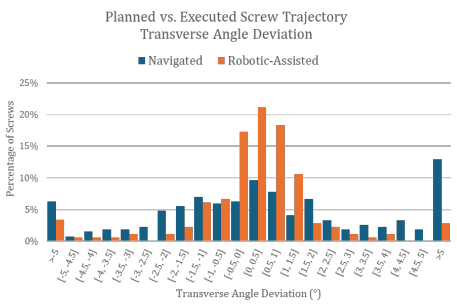

Figure 2. Transverse angle deviation in planned versus executed screw placement.

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