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Basic Science

Preliminary experience with a novel facet-based lateral mass drill guide for the placement of lateral mass screws compared to freehand technique: a cadaveric study

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Abstract

BACKGROUND CONTEXT: Lateral mass screw fixation is the standard for posterior subaxial cervical fixation. Several freehand surgical techniques for placing lateral mass screws have been described which rely on anatomical landmarks and surgeon mastery of the technique to safely place screws. The accuracy of these freehand techniques is inherently variable and can be influenced by a surgeon's level of clinical experience. A novel technique was developed that utilizes the plane of the facet joint to create lateral mass screw pilot holes parallel with the joint line to improve the safety and accuracy of lateral mass screw placement regardless of experience.

PURPOSE: To assess the safety and accuracy of lateral mass screw placement using a novel lateral mass drill guide instrument (LM Guide), compared to standard freehand technique.

STUDY DESIGN: Randomized cadaveric study utilizing multiple surgeon evaluators to compare the safety and accuracy of guided cervical lateral mass placement compared to traditional freehand techniques.

MATERIALS AND METHODS: Lateral mass screws were placed from C3 to C7 in 20 cadaver specimens by 8 spine surgeons of varying levels of clinical experience (4 attendings, 4 fellows). Screws were placed bilaterally using standard anatomic landmarks ("freehand") randomly allocated on one side and using the LM Guide on the other. Cadaveric specimens were imaged with high-resolution CT to assess screw placement. Zone grading for safety was conducted based on screw tip position and clinical severity of screw breach was based on proximity to surrounding neurovascular

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anatomy. Screws were graded as safe, at-risk, or critical, with at-risk and critical screws considered malpositioned. To assess the accuracy of screw trajectory placed using the LM Guide compared to freehand, sagittal screw angle was measured and compared to an "ideal" screw path parallel to the facet joint line. Freehand and LM Guide groups were compared using Pearson's chi-square correlation.

RESULTS: Screw placement using the LM guide yielded a significantly lower rate of screw malpositioning, with 7 of 91 (7.7%) compared with 18 of 99 (18.2%) screws placed in the At-Risk or Critical Zones, p<.05. Of the 91 screws inserted using the LM Guide, 84 (92.3%) were in the Safe Zone, 7 (7.7%) were At-Risk, and 0 were in Critical zones. There was no incidence of neural or transverse foramen breaches with the LM Guide. In comparison, for the 99 screws inserted freehand, 81 (81.8%) were Safe, 14 (14.1%) were At-Risk, and 4 (4.1%) were in Critical zones. The 4 Critical zone freehand screw breaches included 1 neural foramen breach, 2 transverse foramen breaches, and 1 facet breach. The LM Guide also resulted in higher accuracy of screw trajectory, as indicated by a significant reduction in sagittal screw angle compared with freehand, p<.01. Notably, in the less-experienced surgeon cohort, the LM Guide significantly reduced the sagittal screw angle and resulted in no critical screw breaches compared to 3 critical breaches with freehand technique suggesting there might be a benefit in decreasing the learning curve associated with lateral mass screw placement.

CONCLUSIONS: Lateral mass screw placement with a novel LM Guide that uses the facet joint to control screw trajectory improved the accuracy and reproducibility of screw placement with a significant reduction in screw breach rate and sagittal screw angle compared to freehand techniques regardless of surgeon experience level.

CLINICAL SIGNIFICANCE: The inherent variability of freehand lateral mass screw placement can increase the risk of clinical complications associated with screw malpositioning. The technique presented in this cadaveric study may be a viable alternative to standard freehand technique that can improve the overall safety of lateral mass screw placement.

Keywords: Breach; Cervical spine; Facet joint; Lateral mass screw; Posterior cervical fixation; Screw guide; Screw trajectory

Introduction

Lateral mass screw fixation has become the standard method for performing posterior cervical spine instrumented fusions. Lateral mass fixation is effective for managing cervical spine instability caused by disorders such as degenerative disease, tumors, infection, and trauma. The safety profile and effectiveness of lateral mass fixation has been reported as more favorable than other stabilization techniques such as wiring, with low risk of complications and a high fusion rate of 97% across multiple studies [1−5].

Numerous freehand lateral mass screw placement techniques have been adopted, with "ideal" screw positions defined relative to patient anatomy. The overall aim of lateral mass screw placement is to maximize the biomechanical fixation of the lateral mass screw while avoiding damage to neurovascular structures (eg, the exiting nerve root, vertebral artery). Anatomic studies have evaluated the screw trajectories associated with common insertion techniques and reported on the optimal screw length and angulation for reduced complication rates [6−10]. The most common surgical techniques can be generally categorized into those in which the screw trajectory is perpendicular to the posterior lateral mass surface (ie, the Roy-Camille technique) [11] and those in which the screw trajectory is parallel to the facet joint and angling lateral on the axial plane (eg, Magerl, Anderson, An and others) [12−18]. Regardless of which specific technique is used, the screw entry point and trajectory angle are defined relative to anatomic landmarks and rely on surgeon experience and mastery to avoid screw malpositioning.

Clinical complication rates of lateral mass screw fixation are low, with a reported clinical incidence of 0.6% vertebral artery injury (VAI) and 1.8%-per-screw risk of radiculopathy [19,20]. However, the rate of radiographic screw malpositioning in lateral mass screw fixation are significantly higher. Screw malpositioning has been reported at rates as high as 37 to 41.5% with Magerl and Roy-Camille techniques [20,21]. Reduced medial-lateral angulation of the lateral mass screw can cause vertebral artery breach or contact, which has been reported in up to 9.6% (44/457 screws) of lateral mass screw placements [22]. Similarly, malpositioning of screws leading to transverse foramen breach also puts the vertebral artery at risk of injury, with a breach rate (in cadaveric studies) between 7.3% and 26.8% [9,21]. Finally, sagittal misangulation of the screw can violate the facet joint of the adjacent lateral mass, with elevated risk of clinical consequences of neck pain or unintended fusion particularly at the caudal end of the construct. The clinical incidence of facet joint violation varies between 0.6 and 16.7% and is reported to be more common for the Roy-Camille technique compared to the Magerl technique [5,23,24]. Fortunately, most malpositioned screws do not lead to clinical complications. Nevertheless, there is a need to improve screw trajectory and reproducibility of the surgical technique.

The level of training and experience of the surgeon may also affect the safety and accuracy of LM screw placement. Several studies have suggested there is a learning curve associated with lateral mass screw placement, with higher rates of screw malpositioning found across less experienced surgeons [21,25]. Safe placement of screws was significantly improved with focused educational training on the specific technique [25].

A novel lateral mass drill guide (LM Guide) has been developed that uses the facet joint to control both medial-lateral and sagittal screw trajectory and provide a reproducible means of placing lateral mass screws. The LM Guide instrument contains shims to access the facet joint and fixed parallel channels for screw pathway preparation. This radiographic study compares the safety and accuracy of lateral mass screw placement using the lateral mass drill guide, compared to a standard freehand technique using anatomic landmarks, across surgeons of varying experience levels.

Materials and methods

Twenty cadaver specimens (12 male, 8 female) were used in this study, with an average age of 79.1±10.7 years at time of death, and no gross deformities such as scoliosis or kyphosis (Table 1). Eight spine surgeons with varying levels of clinical experience participated (4 attendings, 4 fellows). Each surgeon operated on 2 to 4 cadavers, depending on specimen availability at the time of the procedure, for a total of 20 to 40 screws placed per surgeon.

Lateral mass screws were placed bilaterally in each specimen from C3 to C7, with screw trajectory establishment and screw placement performed freehand using standard anatomic landmarks on one side of the spine and utilizing the LM Guide on the other. The left and right sides of each specimen were randomized to the LM Guide or freehand cohort. Cadaver specimens were placed in the prone position with the cervical spine in a neutral position. A standard midline posterior exposure was performed, with dissection of soft tissue off the posterior aspect of the cervical vertebrae from C1 to T2. Surgeons removed gross osteophytes and exposed facet joint lines per their standard surgical practice. Screws were inserted in each lateral mass using either freehand or LM Guide surgical technique in accordance with the cohort randomization scheme. For the freehand approach, surgeons performed pilot hole drilling, tapping, and screw insertion according to their preferred technique, typically targeting a sagittal trajectory parallel to the facet joint at each level, and lateral angulation to avoid vertebral artery injury. Fluoroscopy was used as needed based on surgeon preference. For the LM Guide technique, the instrument was positioned on the facet joint line at each level with the medial fork aligned with the medial border of the lateral mass and angled laterally 10 to 20˚ from the sagittal plane to avoid the spinal canal and transverse foramen. The instrument was advanced into the joint until the positive stop on the instrument contacted the cranial lateral mass. Once seated within the joint, the LM Guide could be adjusted medial to lateral within the joint utilizing laser markings to achieve the desired medial to lateral screw trajectory (Fig. 1A). The screw pilot hole was then drilled through the guide at a fixed trajectory parallel to the joint, using one of two offsets depending on specimen anatomy (Fig. 1B and C). A standard screw length of 3.5 mm diameter X 14 mm length was used across all cohorts and specimens. Postoperatively, cadaveric specimens were imaged with high-resolution CT. Axial sequences and sagittal reconstructions were used to evaluate screw placement.

To assess the safety of screw placement by the LM Guide compared to freehand, a zone grading system was adapted from the method described by Heller et al. [21] and Graham et al. [20]. The zone grading system divides the cervical lateral mass into three zones in the sagittal plane and three zones in the axial plane based on anatomical landmarks. Each zone was then graded for safety by classifying each of the nine zones as Safe, At-Risk, or Critical based on clinical risk and severity of clinical consequences of breaching nearby neurovascular structures (Fig. 2, Table 2). These were used to quantify the percentage of malpositioned screws, using criteria adapted from Barrey et al. [9]. The zones marked as “Safe” include the Central and Lateral Zones of both Sagittal Zone I and II, since these encompass

Table 1
Specimen information and cohort summary

Surgeon Experience	Cadaver details		Total cadavers	Levels per surgical technique	
	Sex (male/female)	Age (years)		LM Guide	Freehand
Attending	6/5	Male: 80.0 ± 6.5 Female: 79.4 ± 10.4	11	49	54
Fellow	6/3	Male: 71.7 ± 12.0 Female: 92.7 ± 2.5	9	42	45
Study Total	12/8	79.1 ± 10.7	20	91	99

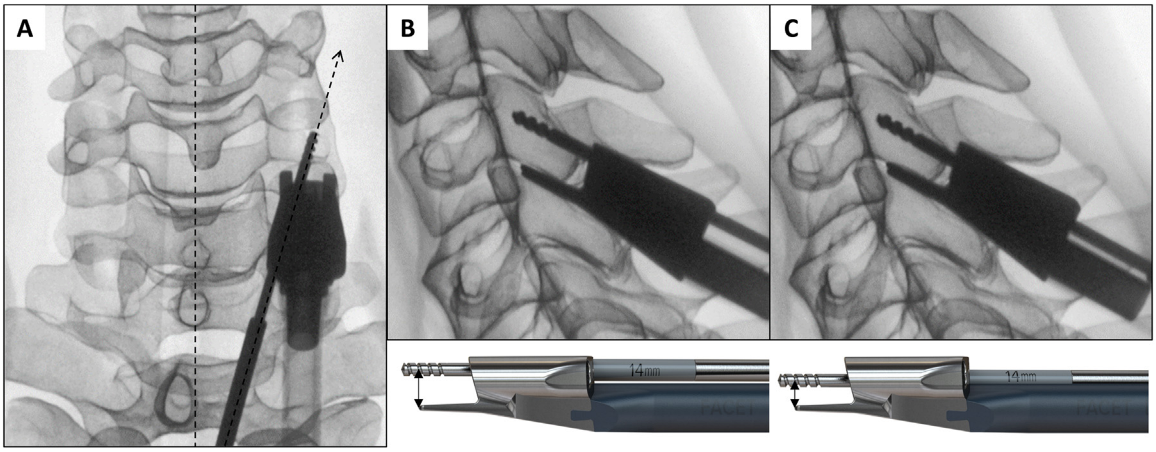

Fig. 1. Fluoroscopic images demonstrating the drill pilot hole trajectory of the LM Guide. (Left) Posteroanterior view showing the instrument inside the facet joint with the medial fork positioned inside the medial border of the lateral mass and angled laterally from the sagittal plane. There is a fixed cephalad/caudad trajectory for the drill in the LM Guide but the trajectory can be modified by angling the LM Guide medially or laterally from the midline while the forks are engaged in the facet joint. (Middle and Right) Lateral views showing the sagittal angle of the drill in the LM Guide that is fixed parallel with the forks. The forks engage in the facet joint and facilitate a screw trajectory parallel with the facet joint line. The head of the LM Guide is designed with a positive stop to prevent over insertion of the instrument into the facet joint. Two offsets (Middle and Right) allow the surgeon to select the optimal screw positioning based on the patient's lateral mass height.

appropriate locations of the LM screw tips, with no structures at risk. In contrast, the "Critical" zones include the Medial region of Sagittal Zones I to III, due to risk of breaching the neural foramen, and the Central region of Sagittal Zone III, due to transverse foramen breach risk. The remaining Sagittal Zone III Lateral region is marked "At-Risk" due to potential violation of the facet joint. Any screw tips placed in the "Critical" and "At-Risk" zones were considered malpositioned screws.

To assess the accuracy and reproducibility of screws placed using the LM Guide technique compared to freehand, screw trajectory was measured and compared to an "ideal" screw trajectory parallel to the facet joint line. According to Magerl's screw trajectory recommendations, the ideal screw trajectory would be parallel to the facet joint, yielding a sagittal screw angle measurement of 0°. Thus, the mean sagittal screw angle was used as an indicator of accuracy, whereas the range and standard deviation was used to assess repeatability. Using sagittal reconstructions, three blinded observers evaluated screw trajectory by measuring screw angle relative to the adjacent inferior facet joint. The final screw trajectory angle was presented as a mean of all three observers.

Statistical analyses were performed using Minitab (Minitab, PA). Freehand and LM Guide Groups were compared using Pearson's chi-square correlation. Statistical significance was assumed at $p<.05$.

Results

Total 190 lateral mass screws were placed in 20 cadaver specimens: 99 using the freehand technique and 91 using the LM Guide. Fig. 3 shows a sample CT image of lateral mass screws inserted bilaterally with two different techniques, freehand on the left and LM Guide on the right. The majority of screws (165/190) were positioned with the screw tips in the central and lateral zones of Sagittal Zone 2 (Table 3), corresponding to ideal screw position for maximal screw purchase and safety. There was 1 screw tip placed in the medial axial zone, breaching the neural foramen. Three screws were placed in the central axial zone in Sagittal Zone 3, breaching the transverse foramen and placing the vertebral artery and nerve root at risk. Twenty-five of the 190 (13.2%) screws were malpositioned screws, either breaching or at risk of breaching nearby structures such as the neural or transverse foramen or the facet joint (Table 4).

The LM Guide significantly reduced the percentage of malpositioned screws placed to 7.7% compared with 18.2% for the freehand technique, $p<.05$ (Fig. 4). Of the 91 screws inserted using the LM Guide, 84 (92.3%) were in the Safe Zone, 7 (7.7%) were At-Risk, and 0 were in Critical zones (Table 4). There was no incidence of neural or transverse foramen breaches with the LM Guide. The 7 At-Risk LM Guide screws included 4 facet joint breaches and 3 screws in potential violation of the facet joint. In comparison, for the 99 screws inserted freehand, 81 (81.8%) were Safe, 14 (14.1%) were At-Risk, and 4 (4.1%) were Critical breaches. The 4 Critical zone freehand screw breaches included 1 neural foramen breach, 2 transverse foramen breaches, and 1 facet breach (Table 5). The 14 At-Risk freehand screws include 9 facet joint breaches and 5 screws close to breaching.

The LM Guide significantly reduced the rate of screw malpositioning in the less-experienced surgeon cohort, $p<.05$ (Table 4). Within the residents and fellows cohort, the rate of malpositioned screws was significantly reduced to 2.4% of screws placed with the LM Guide, compared to

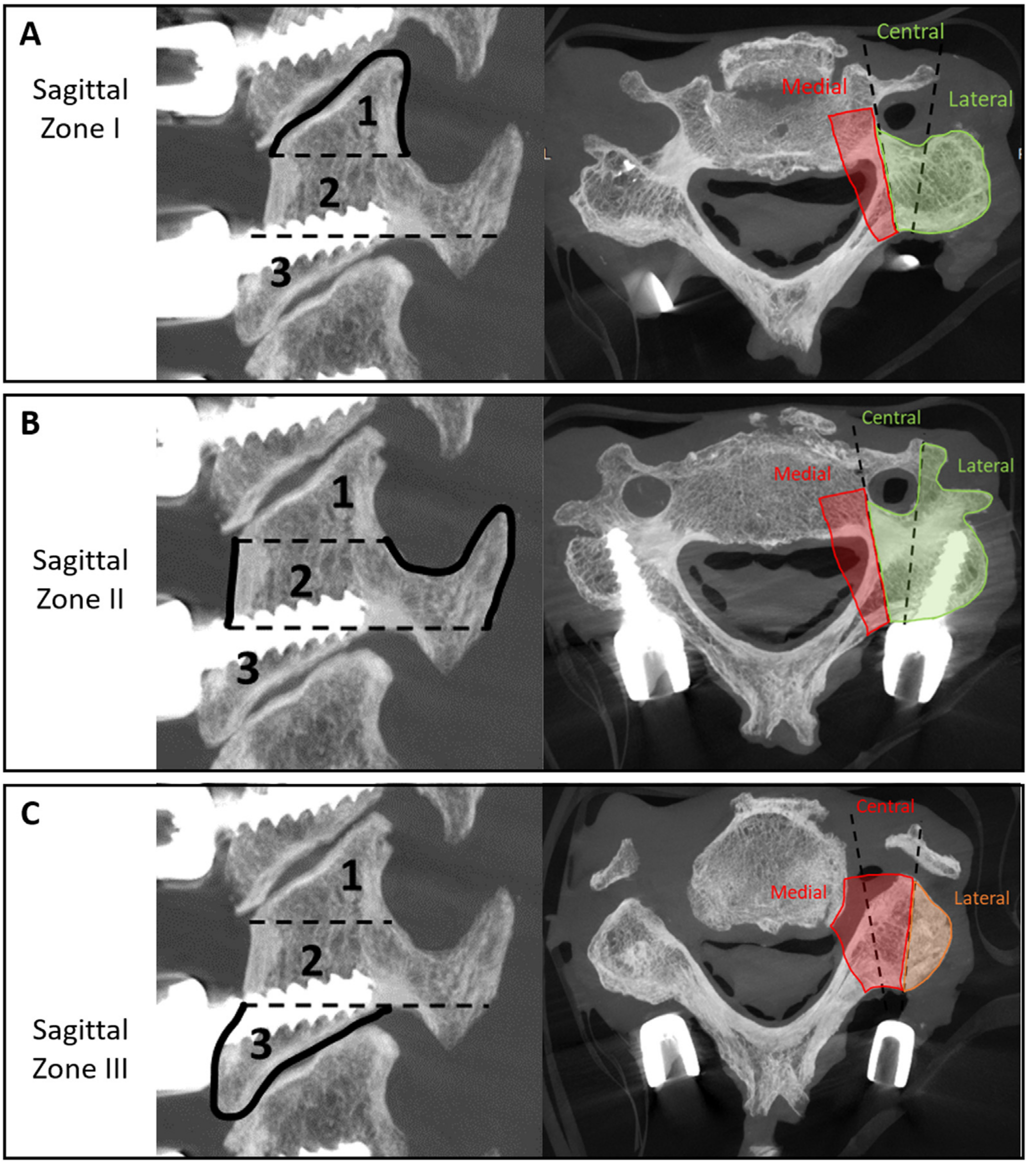

Fig. 2. Zone grading system divides the lateral mass into three zones in the sagittal and axial planes. (Upper) Sagittal Zone I starts from the superior margin of the superior articular process and extends to the superior origin of the transverse process. (Middle) Sagittal Zone II encompasses the ventral portion of the lateral mass, from the superior portion of the transverse process to the inferior portion of the transverse process (Lower) Sagittal Zone III extends from the inferior margin of the transverse process to the tip of the inferior articular process. Axial Zones of Medial, Central, and Lateral Zones are defined within each sagittal zone to allow for three-dimensional localization of the screw tip. The "Safe" zones (Green) include the Central and Lateral Zones of both Sagittal Zone I and II, since these encompass appropriate locations of the LM screw tips, with no structures at risk. The "Critical" zones (Red) include the Medial region of Sagittal Zones I to III, due to risk of breaching the neural foramen, and the Central region of Sagittal Zone III, due to transverse foramen breach risk. The remaining Sagittal Zone III Lateral region is marked "At-Risk" (Orange) due to potential violation of the facet joint.

Table 2
Safety Grading of LM Screw Tips in Each Sagittal and Axial Zone, based on risk of breaching nearby neurovascular structures. Screw tips in the Critical and At-Risk Zones were considered malpositioned

	Axial zone		
Sagittal Zone	Medial	Central	Lateral
1	*Critical*	Safe	Safe
2	*Critical*	Safe	Safe
3	*Critical*	*Critical*	*At-Risk*

17.7% with freehand technique. The more experienced (attending) surgeon cohort had a similar though less pronounced effect of reducing the rate of malpositioned screws, with 12.2% in the At-Risk and Critical zones screws when using the LM Guide compared to 18.5% with freehand.

Consistency and accuracy of lateral mass screw trajectory was enhanced by using the LM Guide, yielding significant reduction in sagittal screw angle compared with freehand technique, p<.01 (Fig. 5). Deviation from the ideal

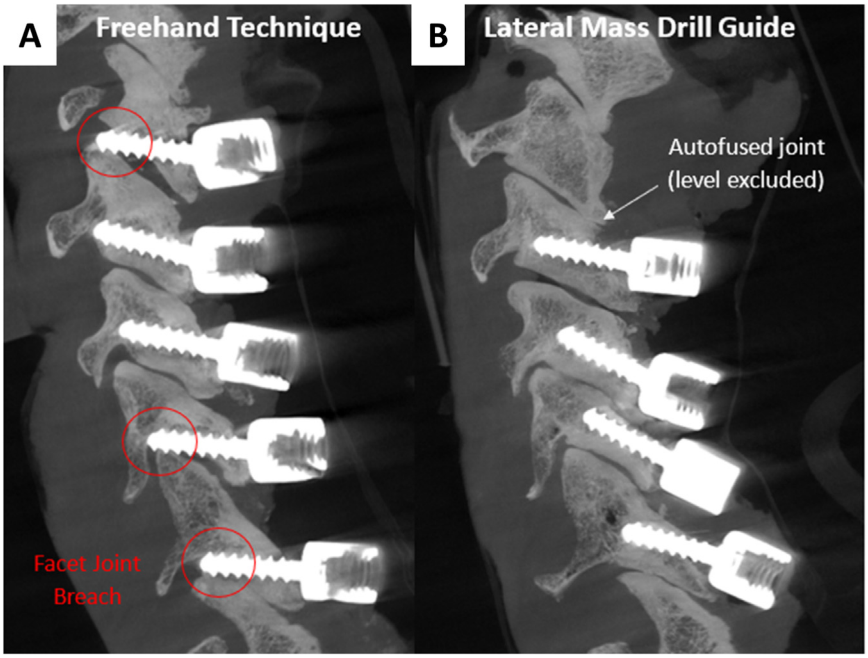

Fig. 3. Sample CT image of lateral mass screws inserted bilaterally by the same surgeon using two different techniques, freehand on the left (Left) and LM Guide on the right (Right). On the freehand side, three instances of facet joint breach are visible (red circles).

sagittal trajectory was significantly reduced to a 12.3° sagittal screw angle for LM Guide screws compared to for 15.8° for freehand, p<.01. Additionally, the LM Guide group had a smaller range and tighter distribution of sagittal screw angle, demonstrating that the surgeons were more consistent in the angle of their screw trajectory when using the LM Guide. Notably, for the less-experienced surgeon cohort, there was a statistically significant (p<.05) reduction in sagittal screw angle from 16.36°±8.09° for freehand technique to 10.56°±7.05° when using the LM Guide. The more experienced surgeon cohort exhibited a similar trend of reduced sagittal screw angle with LM Guide, but the difference did not reach statistical significance.

Table 3
Screw position in lateral masses of C3 to C7, for freehand and LM guide. Italics indicate screws considered malpositioned

Surgical Technique	Sagittal Zone	Axial zone		
		Medial	Central	Lateral
Freehand	I	*0*	0	0
	II	*1*	19	62
	III	*0*	*3*	*14*
LM Guide	I	*0*	0	0
	II	*0*	15	69
	III	*0*	*0*	*7*

Discussion

The current study demonstrates the safety, accuracy and reproducibility of lateral mass screw placement using a novel lateral mass drill guide technique, compared to a standard freehand technique based on anatomical landmarks. Use of the LM Guide for screw placement resulted in significantly reduced screw breach rates and more accurate sagittal screw trajectory, across surgeons of varying experience levels.

A novel zone safety grading system for screw position was developed to evaluate safety outcomes by an anatomical, clinically relevant, and quantitative measurement.

Table 4
Safety Zones for screws inserted by surgeons with varying levels of experience, using freehand and LM Guide techniques. Screws considered malpositioned included screws placed in the Critical and At-Risk safety zones

Surgeon experience	Number of levels	Surgical technique	Safety zones			Malpositioned	p value
			Critical	At-Risk	Safe		
Attending	54	Freehand	2	8	44	10 (18.5%)	.380
	49	LM Guide	0	6	43	6 (12.2%)	
Fellow	45	Freehand	2	6	37	8 (17.7%)	**.018**
	42	LM Guide	0	1	41	1 (2.4%)	

The bolding was used to highlight values that were statistically significant at $p < 0.05$.

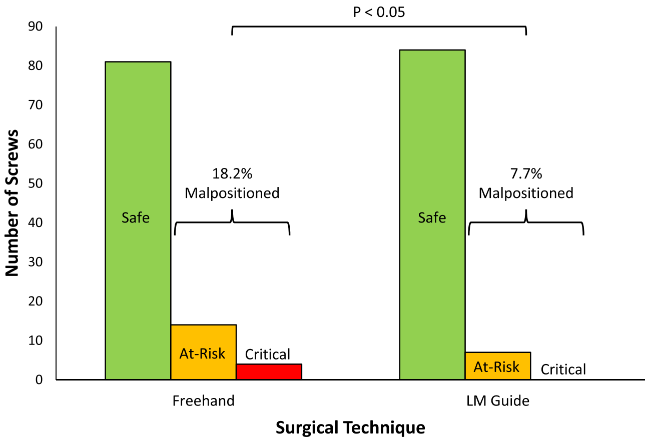

Fig. 4. Safety Zones of Lateral Mass Screws inserted using freehand and LM Guide surgical techniques. Safe zones correspond to the screw tip being in appropriate locations with no structures breached. At-Risk zones correspond to screw tips in potential violation of the facet joint. Critical zones correspond to the screw tips breaching the neural foramen or transverse foramen. Screw tips placed in the Critical and At-Risk zones were considered malpositioned.

Using criteria established by Heller et al. [21] and expanded by Graham et al. [20] and Barrey et al. [9], screw tip position was classified as Safe, At-Risk, or Critical based on proximity to breaching nearby neurovascular structures, and associated level of clinical risk. This offers the advantage of distinguishing between a critical breach, such as vertebral artery injury, and a noncritical breach, such as a facet joint violation in the middle of a construct. Previously, zone grading systems have been used to compare screw position and breaches for different screw trajectories, such as Roy-Camille and Magerl techniques [9,21]. In the current study, the safe anatomical zones were uncoupled from any particular screw insertion technique and generalized to any technique for screw placement.

The screw breach rates reported in this study are consistent with reported incidence from previous clinical and cadaveric studies [5,9,19−24,26]. In the current study, the freehand technique resulted in 1 breach of the neural foramen and 3 breaches of the transverse foramen, putting the vertebral artery and nerve roots at risk. The LM Guide

Table 5
Screw breaches of neural foramen, transverse foramen, and facet joint, across varying surgeon experience, using freehand and LM Guide techniques

Surgeon experience	Number of levels	Surgical technique	Screw breaches				
			Neural foramen	Transverse foramen	Facet joint	Total	p value
Attending	54	Freehand	0	1	5	*5 (9%)	.553
	49	LM Guide	0	0	3	3 (6%)	
Fellow	45	Freehand	1	1	5	7 (16%)	**.034**
	42	LM Guide	0	0	1	1 (2%)	
Combined	99	Freehand	1	2	10	13 (13%)	**.037**
	91	LM Guide	0	0	4	4 (4%)	

The bolding was used to highlight values that were statistically significant at $p < 0.05$.
* Note: One screw in the freehand group breached both the facet joint and the transverse foramen. This was considered a single breach in the total.

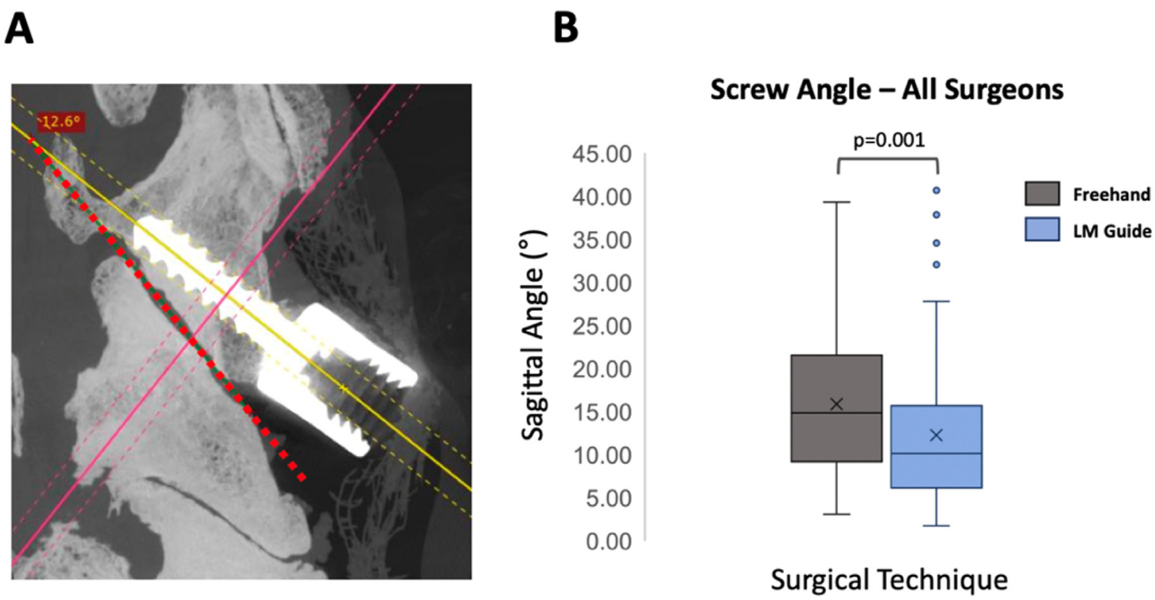

Fig. 5. Sagittal Screw Angle to measure accuracy of LM screw trajectory. (Left) Screw trajectory was measured and compared to an “ideal” screw trajectory parallel to the facet joint line (dotted red line). (Right) Mean Sagittal Angle for screws inserted freehand and with the LM Guide by all surgeons. The lower mean sagittal angle, as well as smaller range and narrower distribution for the LM Guide indicates greater accuracy, consistency and reproducibility of screw placement, compared to the freehand technique.

technique resulted in zero critical breaches. The critical breach rate of 0 to 4% from this study (across techniques) is within the range of reported breach rates from 0% up to 9.6% [22]. Similarly, the rates of facet joint breach from this study of 10% (10/99) for freehand and 4% for LM Guide (4/91) are within the range of 0.6 to 16.7% clinical incidence of facet joint violation [5,23,24]. Although facet breaches typically have less clinically serious adverse effects, they can be significant at the most caudal level of the construct because the breach will disrupt the adjacent unoperated joint and could result in an unintended fusion.

The LM Guide provided greater accuracy and consistency, as evidenced by less deviation from the ideal screw trajectory as well as tighter distribution of the sagittal screw angle, compared to freehand technique. The sagittal trajectory of the LM Guide was designed in accordance with the Magerl surgical technique, to direct screws into Sagittal Zone I or II, depending on which drill offset is used and on the height of the lateral mass (Fig. 1B and C). The axial trajectory was designed with fixed medial-lateral angle to direct screws into Central or Lateral Axial zones (Fig. 1A). The surgeon can control the medial-lateral angle to his or her preference by changing the angle of the instrument when constrained sagittally in the joint. In the present study, 92.3% of screws placed with the LM Guide were in the Safe/Optimal zones per the instrument design, while there were 4 (4.4%) facet breaches that occurred. One facet breach was associated with osteophyte overgrowth over the facet joint, which changed the angle of the LM Guide and affected the sagittal trajectory of the screw (Fig. 6). This facet joint breach could be avoided with minor burring of the osteophyte to allow for correct instrument angulation (Fig. 6C). The other screw breaches were attributed to challenging patient anatomy (ankylose joints) and the learning curve for the surgical technique.

In the current study, the level of training and experience of the surgeon did not have a significant impact on screw malpositioning rates for either the freehand or LM Guide technique. Indeed, the attending and fellow surgeon cohorts had the same rates of critical screw breach (4% for freehand, 0% for LM Guide) and similar rates of overall screw breach (encompassing neural foramen, transverse foramen, and facet joint breaches) when using the freehand technique. The improvement in safe and accurate screw placement with use of the LM Guide was especially pronounced in the less-experienced surgeon cohort, demonstrating the potential utility of this instrument as a teaching aide for LM screw placement. For more experienced surgeons, there was a slight improvement in screw safety with the LM Guide compared to freehand but the effect was smaller. It is possible that the more experienced surgeons are more tolerant of positioning screws in the "at-risk" safety zones which would not result in clinical complications of critical screw breach. This study did not assess other measures of surgical technique such as operative time, use of fluoroscopic imaging, or unicortical or bicortical screw purchase.

The present study evaluated the safety and accuracy of screws placed with the LM Guide across all subaxial cervical levels. One potential limitation of the LM Guide surgical technique is that it may not be suitable for placing screws at the lower instrumented vertebra without disrupting facet joints of the adjacent level. However, this is typically not a concern with long fusion constructs where surgeons commonly extend screw fixation to T1 or T2 utilizing freehand techniques.

One limitation of this study is that the anatomical variation and pathology of the cadaveric specimens used may not fully represent the challenging congenital or degenerative deformities of the cervical spine often treated in posterior cervical fusion procedures. The LM Guide relies on access to the facet joint to accurately target the lateral mass, so deformities that disrupt the facet joint may require an adjustment in surgical technique or additional preparative steps, such as burring the joint down, to accommodate these pathologies. This was outside the scope of the present study but warrants investigation in future work.

Freehand lateral mass screw placement techniques that rely on anatomical landmarks and surgeon proficiency are

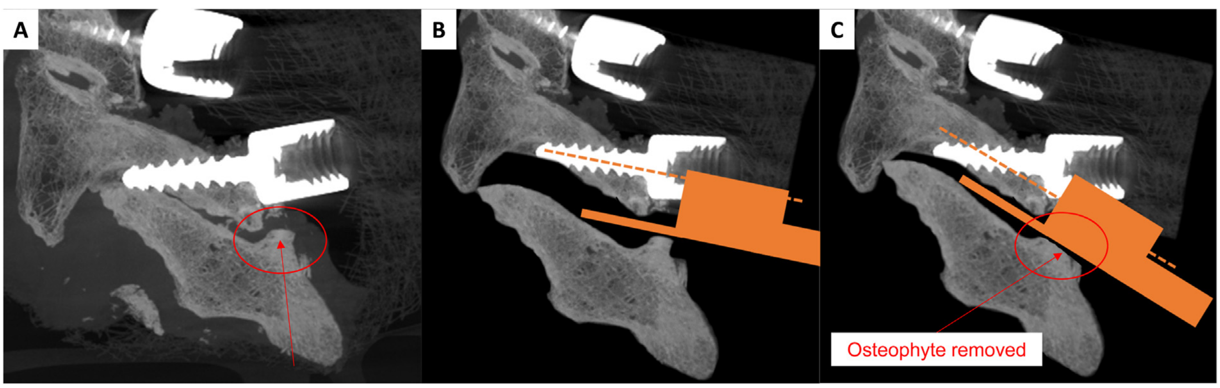

Fig. 6. (Left) Screw breach of facet joint due to osteophyte overgrowth over the joint (red circle and arrow) (Middle) Osteophyte led to distraction of the joint and changed the angle of the instrument and lateral mass trajectory (dotted line) (Right) This can be prevented with minor burring of joint line before LM Guide insertion.

inherently variable and can increase the risk of clinical complications associated with screw malpositioning. This study presented a novel LM Guide technique that utilizes the fixed orientation of the patients own facet joint to accurately and reproducibly place lateral mass screws across subaxial levels. This technique may remove the influence of surgeon experience on screw accuracy and improve the overall safety of lateral mass screw placement compared to standard freehand technique across surgeons of all experience levels.

Conclusion

This study demonstrated the increased safety and accuracy of a novel technique that utilizes the plane of the facet joint to create lateral mass screw pilot holes parallel with the joint line to place lateral mass screws, compared to a standard freehand technique using anatomic landmarks. More studies are needed to reinforce the clinical safety and accuracy of using the LM Guide instrument for placement of lateral mass screws, and to assess long-term clinical outcomes of screw malpositioning.

Declaration of Competing Interest

One or more of the authors declare financial or professional relationships on ICMJE-TSJ disclosure forms.

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Disclosure

The manuscript submitted does not contain information about medical device(s)/drug(s).

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