Journal of Taibah University Medical Sciences (2026) 21(4), 651–662

Taibah University

Journal of Taibah University Medical Sciences

www.sciencedirect.com

Original Article

Association between pedicle screw dimensions and pedicle morphometry in computed tomography scans

Anusha Shetty, MS, Shyamasunder N. Bhat, MS *, Raghuraj S. Kundangar, MS and Madhava Pai K, MS

Department of Orthopaedics, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, Karnataka, 576104, India

Received 26 October 2025; revised 19 February 2026; accepted 22 May 2026; Available online 11 June 2026

الملخص

أهداف البحث: تتناول العديد من المقالات قياسات الفقرات ومفهوم اختراق العنيقة بشكل عام. ومع ذلك، لم يتم إثبات وجود علاقة مباشرة بين قياسات العنيقة وأبعاد البراغي. هدفت هذه الدراسة إلى تحديد العلاقة بين حجم واتجاه براغي العنيقة المستخدمة، بالإضافة إلى قياسات عنيقات الفقرات الصدرية القطنية، والتي تم تقييمها بواسطة التصوير المقطعي المحوسب.

طرق البحث: شملت هذه الدراسة الرصدية الاسترجاعية أحادية المركز 60 مريضا بالغا تم إدخالهم إلى المستشفى بسبب كسور في الفقرات الصدرية القطنية، وخضعوا لتثبيت خلفي للعمود الفقري بين أكتوبر 2018 ونوفمبر 2023. تم تحليل صور الأشعة المقطعية قبل وبعد العملية. تم قياس عرض العنيقة، وارتفاع العنيقة، وارتفاع الفقرة، وزاوية العنيقة المستعرضة؛ وتم تسجيل قطر البرغي، وطوله، ومساره، ودرجة الاختراق. تم تطبيق الإحصاءات الوصفية، والاختبارات المزدوجة، ومعاملات ارتباط بيرسون/سبيرمان.

النتائج: تم تحليل 177 فقرة (354 عنيقة) لدى 60 مريضا. لوحظ ازدياد ملحوظ في عرض العنيقة ($p < 0.001$) وارتفاعها بعد العملية. لم تُظهر زوايا إدخال البراغي أي ارتباطٍ بزاوية العنيقة المستعرضة. بلغ متوسط حجم البرغي 6.5 مم × 35-40 مم، ومتوسط طول مسار البرغي 2.82 ± 1.26 سم. بلغ معدل الاختراق الإجمالي 23.3% (الدرجة 0: 76.7%، الدرجة 1: 10%، الدرجة 2: 8.3%، الدرجة 3 فأكثر: 5%).

الاستنتاجات: تُظهر القياسات المورفومترية باستخدام التصوير المقطعي المحوسب أن أبعاد العنيقة الفردية يجب أن تُوجّه اختيار البرغي. تزيد عنيقات الفقرات الصدرية الضيقة والبراغي التي تتجاوز 80% من عرض الساق من خطر الاختراق. يُتيح التصوير المقطعي المحوسب الروتيني استخدام أدوات دقيقة وتثبيتًا أكثر أمانًا.

الكلمات المفتاحية: التصوير المقطعي المحوسب؛ عنيقة الفقرة، قياسات عنيقة الفقرة، خطر التمزق، كسور الفقرات الصدرية والقطنية، العمود الفقري الصدري القطني

Abstract

Background: Previous studies have investigated the morphometry of vertebrae and the general concept of pedicle breach. However, direct correlations have not been established between pedicle morphometry and screw dimensions. This study aimed to determine the relationship between the size and direction of pedicle screws and the morphometry of the pedicles of thoracolumbar vertebrae, which were assessed using computed tomography (CT) scans.

Methods: This single-center, retrospective observational study included 60 adult patients admitted with thoracic and lumbar vertebral fractures who underwent posterior spinal stabilization between October 2018 and November 2023. Pre- and post-operative CT scans were analyzed to assess the pedicle and vertebral morphometry, screw dimensions, and breach grade. Paired tests and correlation analyses were performed.

Results: In total, 177 vertebrae (354 pedicles) were analyzed in 60 patients. Most fractures were burst type (85%), mainly at T12–L1. Post-operative pedicle width ($p < 0.001$) and height ($p < 0.001$) significantly increased. The screw insertion angles had no correlation with the transverse pedicle angle. Narrow thoracic pedicles and

* Corresponding address: Department of Orthopaedics, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, Karnataka, India.

E-mail: shyambhat.n@manipal.edu (S.N. Bhat)

Peer review under responsibility of Taibah University.

Production and hosting by Elsevier

1658-3612 © 2026 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/). https://doi.org/10.1016/j.jtumed.2026.05.013

screws exceeding 80% of the pedicle width were associated with a higher breach risk. The overall breach rate was 23.3% (Grade 0: 76.7%, Grade 1: 10%, Grade 2: 8.3%, Grade 3+: 5%; $p < 0.001$).

Conclusions: CT morphometry analysis demonstrates that individual pedicle dimensions should guide screw selection. Narrow thoracic pedicles and screws that exceed 80% of the pedicle width heighten the risk of breach. Routine CT measurement enables accurate instrumentation and safer stabilization.

Keywords: Computed tomography (CT) scan; Pedicle; Pedicle of vertebra; Risk of breach; Thoracolumbar; Thoracolumbar fractures

© 2026 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

Spinal fractures are frequent and most are caused by blunt trauma. Due to the energy needed to disturb or destroy the structural framework of the spinal column and the presence of various vital organs close to the vertebral column, most people with thoracolumbar fractures will also present with associated non-spinal injury.[1] Spinal column injuries are usually involved and can be devastating, and some degree of neurologic deficit occurs in about 10–25% of patients at all levels of injury.[2]

Failure to accurately diagnose or manage spine injuries may result in neurological deficits or their worsening, permanent impairment of a patient's function and quality of life, and can lead to death in some instances.

A computed tomography (CT) scan is the preferred imaging technique because it takes less time overall than magnetic resonance imaging (MRI). MRI is considered the gold standard, but the findings obtained from these scans have limited value for treatment planning for thoracolumbar burst fractures compared with other radiological tools, although MRI is necessary to exclude occult ligamentous injury.[3]

The canal diameter can be measured based on a CT scan, and it is a valuable indicator for predicting neurological damage and determining the treatment modality. CT scans also help to identify posterior segment fractures and predict neurological outcomes.[4]

The thoracolumbar junction is highly vulnerable to injury compared with other spinal regions. Nearly 40% of all spinal cord injuries and around 50% of vertebral body fractures occur at the thoracolumbar junction (T11–L2 levels).[5]

During surgical intervention, the main objectives are to provide spinal stability, avoid further deformity, and prevent progressive neurological compromise. The posterior surgical approach is preferred for better access to pedicles for pedicle screw application and is less invasive than the anterior approach.[6]

During pedicle screw fixation, breach of the pedicle cortex can potentially result in serious complications, such as dural tears, neural damage, and vascular or visceral complications. Pedicle screw misplacement or malposition may also lead to loss of fixation.[7] Hence, the placement of pedicle screws during fixation is extremely important because malalignment can lead to injuries to neural and vascular structures.

Previous studies have investigated the morphometry of the vertebrae and the general concept of pedicle breach. However, these studies were either conducted based on populations from specific nationalities[8] or measured in cadavers.[9,10]

Few studies have analyzed the relationships between vertebral pedicle morphometry and pedicle screw parameters, and direct correlations have not been established between the pedicle morphometry and screw dimensions, or compared these measurements between pre-operative and post-operative assessments.

Therefore, the aims of this study were to determine the relationships between the size and direction of pedicle screws with the pedicle morphometry of thoracic and lumbar vertebrae based on CT scans.

We hypothesized that narrower thoracic pedicles would have higher pedicle cortical breach rates compared with wider lumbar pedicles, screws with a diameter exceeding 80% of the pedicle width would be associated with increased breach risk, screw insertion angles deviating significantly from the anatomical transverse pedicle angle would be correlated with higher breach incidence, and post-operative pedicle dimensions would exhibit significant expansion compared with pre-operative measurements due to screw placement.

The objectives of this study were to measure the pre-operative pedicle morphometry of affected vertebrae, document the actual screw dimensions used during surgery, measure the post-operative pedicle morphometry and actual screw insertion angles, and determine the grade of pedicle cortical breach by using the Gertzbein–Robbins classification system based on post-operative CT scans.

Materials and Methods

This single-center, retrospective observational study was conducted at a tertiary care hospital, and was initiated after obtaining institutional ethical clearance.

Patients aged 18 years or older with thoracic and lumbar vertebral fractures admitted to the Department of Orthopedics at Kasturba Medical College, Manipal Academy of Higher Education, Manipal, Karnataka, India, from October 2018 to November 2023, and fixed with a pedicle screw construct were analyzed retrospectively and included in the study.

We excluded pathological fractures and translational injuries, as well as cases where CT scans were not available in the hospital's Picture Archiving and Communication System (PACS) (Figure 1).

The proposed sample size was 385. The total number of spinal injuries recorded during this period was about 600. After excluding patients with translational injuries (n = 188) and pathological fractures (n = 255), the number of patients who underwent surgery was 157. Among these patients, 97 lacked CT scans that could be retrieved from PACS, resulting in a final sample size of 60. The missing CT scans were random. No data were missing from the final sample.

The pre-operative and post-operative CT scans for the included patients were retrieved from PACS. Post-operative CT scans were obtained within 48–72 h of surgery (mean: 5.2 days, range: 3–14 days) to assess screw placement and pedicle breach. The selection process for the study cohort is summarized in Figure 1 in accordance with CONSORT guidelines.

All measurements were acquired using tools available in PACS. Case records for patients were analyzed retrospectively from electronic medical records using ICD-10 codes for thoracic (S.22) and lumbar (S.32) vertebral fractures. Descriptive data were also collected with requisite administrative permissions. All measurements were performed by a single observer, and repeat measurements were conducted by two independent observers, yielding intra-class correlation coefficients ranging from 0.83 to 0.95, indicating excellent reliability.

For the pre-operative CT scan, we measured the pedicle height, pedicle width, kyphotic angle, vertebral height, transverse pedicle angle, and screw path length using radiological tools in PACS (Figures 2 and 3).[11] In the post-operative CT scan (Figure 4), the pedicle height, pedicle width, kyphotic angle, vertebral height, and screw insertion angle were measured. The screw dimensions for the upper,

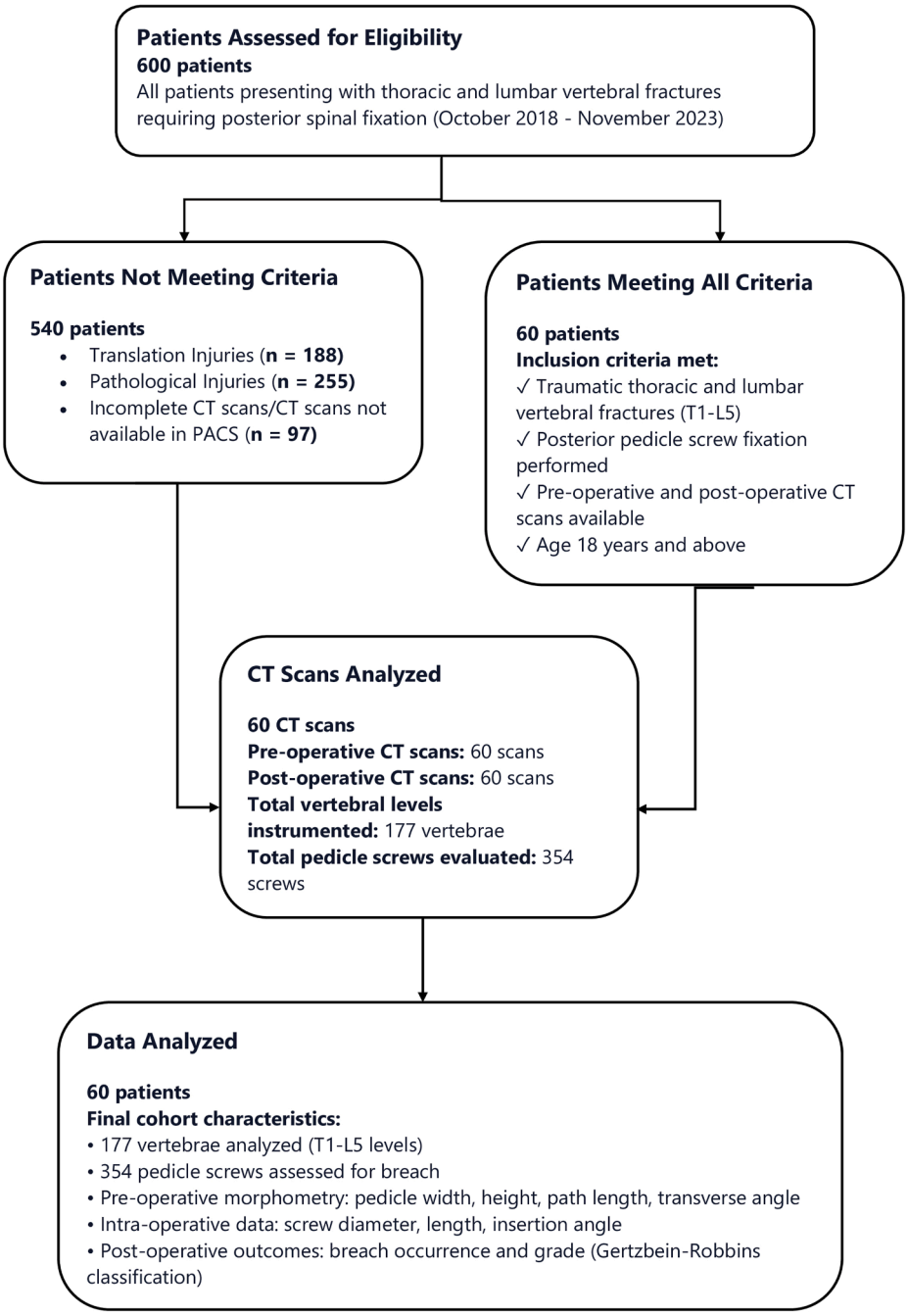


Figure 1: CONSORT flowchart illustrating patient selection process.

middle, and lower screws were obtained from the operative notes.

All CT measurements were performed by the primary observer, with repeat measurements by the same observer after an interval of 1 month (intra-observer reliability) and by two independent observers (inter-observer reliability). The intra-class correlation coefficients ranged from 0.83 to 0.95 (intra-observer: 0.89 to 0.95, and inter-observer: 0.83 to 0.91), indicating good to excellent reliability (Table 1).

Data analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 23 (IBM Corp.). In this retrospective observational study, we used descriptive statistics to summarize variables. Continuous data were reported as the mean ± standard deviation (SD) for normal distributions or medians for skewed distributions, and categorical variables were expressed as frequencies and percentages. The primary outcomes involved comparing the pre-operative and post-operative pedicle morphometry, specifically the pedicle width and height, using the Wilcoxon signed-rank test. Secondary outcomes, including vertebral height restoration, were analyzed using paired *t*-tests. The distribution of pedicle breach grades was evaluated using analysis of variance (ANOVA) to detect significant deviations from expected frequencies. In addition, the relationships between screw dimensions, screw path lengths, screw insertion angles, and transverse pedicle angles were assessed using Pearson's and Spearman's correlation coefficients. For all analyses, a p-value <0.05 was considered to indicate a statistically significant difference.

The detailed measurement protocol is provided in the supplementary material (Appendix 1).

This manuscript adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational cohort studies. A completed STROBE checklist is provided as a supplementary file (Appendix 2).

Results

Sixty patients with thoracolumbar vertebral fractures had undergone posterior spinal stabilization. Thus, 177 vertebrae (354 pedicles) were analyzed. All 60 patients had complete pre- and post-operative CT morphometry and screw data, and no measurements were missing from the final analytic data set. The demographic data are presented in Table 2. The fractures evaluated in this study were divided into three fracture patterns: burst fractures, chance fractures, and compression fractures. Translational injuries were excluded from the study. Most fractures (n = 51, 85%) were burst fractures, followed by chance fractures (n = 7, 11.7%), and

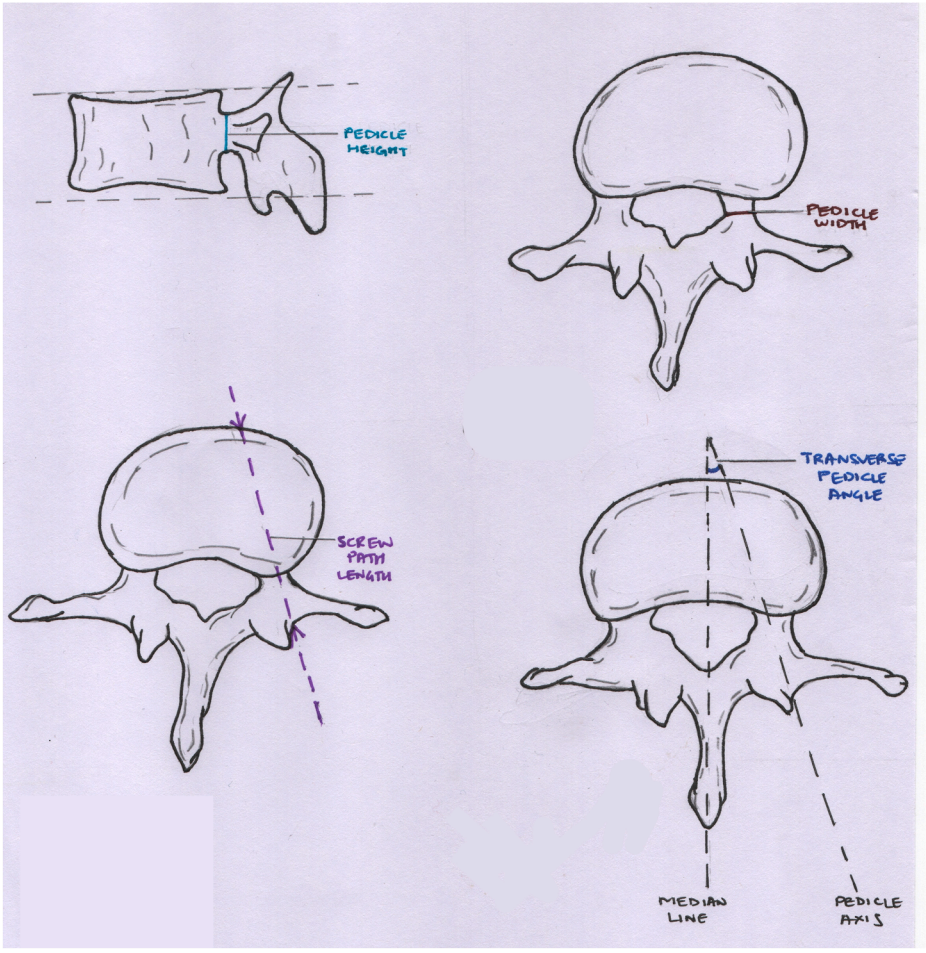


Figure 2: Various measurements.

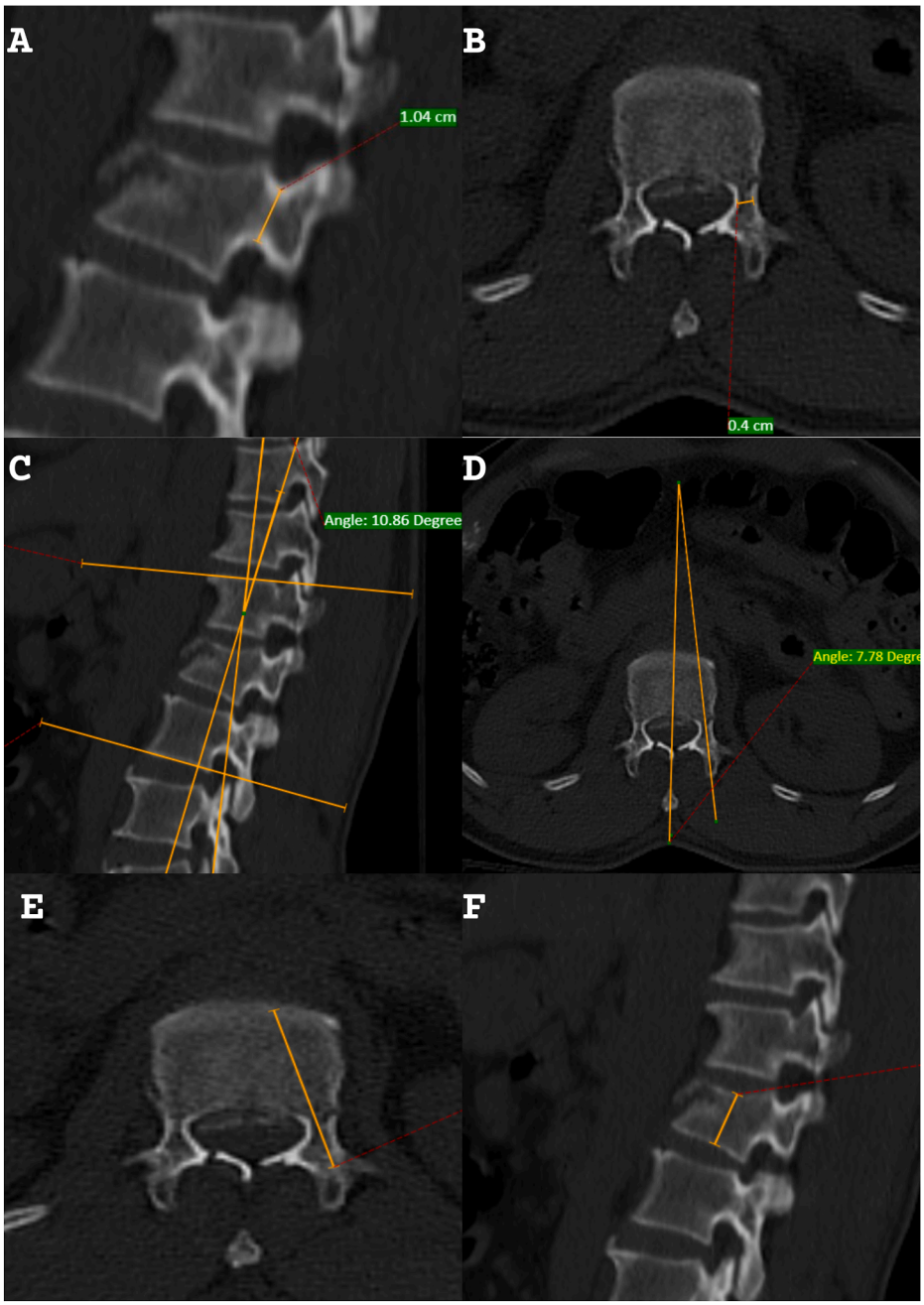


Figure 3: Pre-operative measurements. (A) Pedicle height, (B) pedicle width, (C) kyphotic angle, (D) transverse pedicle angle, (E) screw path length, (F) pre-operative vertebral height.

compression fractures (n = 6, 10%) (Table 3). The fractures (n = 31, 51.7%) were primarily located at the T12 and L1 vertebral levels.

The mean pedicle width (±SD) increased from 6.2 (±1.7) mm pre-operative to 7.9 (±1.2) mm post-operative. This change was statistically significant ($p < 0.001$) (Table 4). The mean pedicle height (±SD) increased from 10.1 (±1.3) mm pre-operative to 11.7 (±1.7) mm post-operative. This change was found to be statistically significant ($p < 0.001$) (Table 4).

Significant restoration of vertebral height was achieved post-operatively ($p < 0.001$) (Table 5). The mean (±SD), median, and range of the screw dimensions are shown in Table 6. The mean screw path length was 28.2 (±12.6) mm, ranging from 7.6 to 54.7 mm. The mean transverse pedicle angle was 12.92° (±4.98°), ranging from 4.18° to 23.42°.

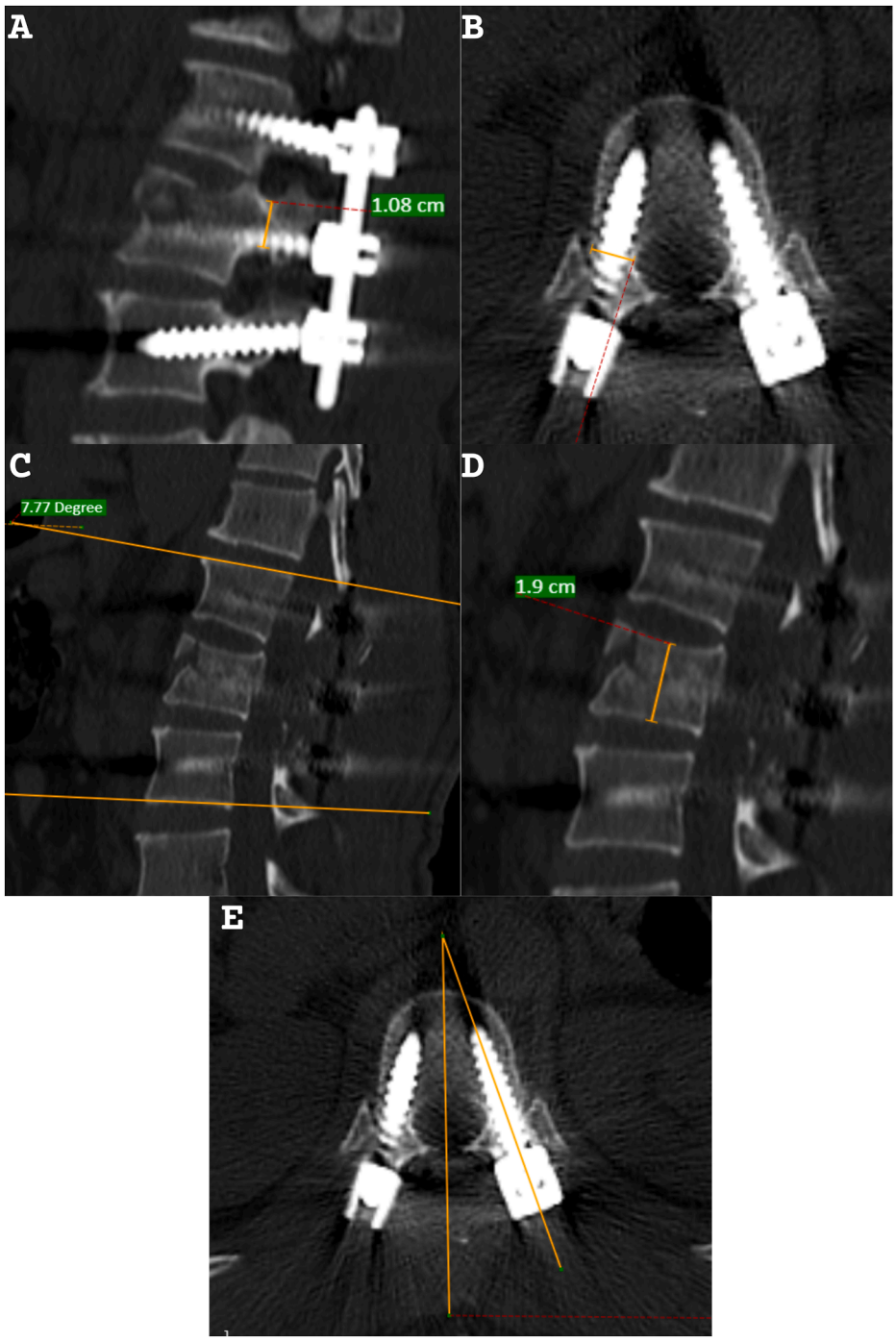


Figure 4: Post-operative measurements. (A) Pedicle height, (B) pedicle width, (C) kyphotic angle, (D) post-operative vertebral height, (E) screw insertion angle.

Table 1: Intraobserver and Interobserver Reliability.

Radiological Parameter	Intraobserver Correlation Coefficient	Interobserver Correlation Coefficient
Pedicle width	0.93	0.88
Pedicle height	0.91	0.86
Vertebral height	0.94	0.89
Transverse pedicle angle	0.90	0.85
Screw path length	0.92	0.88
Screw insertion angle	0.91	0.86
Screw width	0.95	0.91
Kyphotic angle	0.89	0.83
Breach grading (Gertzbein)	0.90	0.86

Table 2: Demographic Data (n = 60).

Demography	Mean ± SD	Min-Max
Age (Years)	46.88 ± 14.04	18–76
Age distribution	n (%)	
18–30 Years	11 (18.3%)	
31–40 Years	9 (15.0%)	
41–50 Years	14 (23.3%)	
51–60 Years	14 (23.3%)	
61–70 Years	11 (18.3%)	
71–80 Years	1 (1.7%)	
Gender		
Male	48 (80.0%)	
Female	12 (20.0%)	
Mechanism of injury		
Fall from height	38 (63.3%)	
Road traffic accident	15 (25.0%)	
Slip and fall	6 (10.0%)	
Assault	1 (1.7%)	
Associated non-spinal injuries	26 (43.3%)	

Table 3: Distribution of fracture patterns (n = 60).

Radiology Type (Pre-Operative)	Number (Per Cent)
Burst fractures	51 (85.0%)
Chance fractures	7 (11.7%)
Compression fractures	6 (10.0%)
Other spinal fractures[a]	3 (5.0%)

[a] Other spinal fractures mentioned here include spinal process fractures, transverse process fractures etc.

Table 4: Pedicle Width and Height Changes.

Timepoint	Pedicle Width (mm)		Wilcoxon Test	
	Mean (±SD)	Range	V	*p*-value
Pre-operative	6.2 (±1.7)	3.8–10.0	67.0	<0.001[a]
Post-operative	7.9 (±1.2)	5.1–10.1		
Absolute change	1.7 (±1.3)	−2.2–5.4		
Per cent change	32.9% (±29.3)	−24% to 135%		
Timepoint	**Pedicle height (mm)**		**Wilcoxon test**	
	Mean (±SD)	Range	V	*p*-value
Pre-operative	10.1 (±1.3)	7.8–13.4	88.5	<0.001[a]
Post-operative	11.7 (±1.7)	8.7–17.8		
Absolute change	1.6 (±1.5)	−2.5–5.8		
Percent change	16.4% (±15.0)	−19% to 58%		

[a] Statistically significant.

The mean (±SD) and range of the screw insertion angles for each fixation level are shown in Table 7A.

A weak negative correlation was found between the upper screw insertion angle and transverse pedicle angle. In addition, weak positive correlations were observed between the insertion angles of the middle and lower screws and the transverse pedicle angle. These correlations were not statistically significant (Table 7B).

A statistically significant moderate negative correlation was found ($p < 0.001$) after comparing the pedicle screw lengths and screw path lengths at the upper, middle, and lower screw levels (Table 8).

Fourteen patients (23.3%) had a pedicle breach in the post-operative CT scan. Based on the Gertzbein–Robbins classification system, the following breach grades were observed: Grade 0 (no breach): 46 cases (76.7%); Grade 1 (breach <2 mm): six cases (10%); Grade 2 (breach of 2–4 mm): five cases (8.3%); and Grade 3 or above (breach >4 mm): three cases (5%). A statistically significant difference ($p < 0.001$) was found according to ANOVA, where Grade 0 (no breach) was significantly more common than the other grades. Breaches were significantly more common in the thoracic spine (9/36, 27.4%) compared with the lumbar spine (5/24, 20.8%) ($p < 0.001$). The overall risk ratio was 1.3-fold higher in the thoracic spine (Table 9).

A weak negative correlation ($r = -0.077$) was found between the restoration of vertebral height and pedicle screw breach. Cases with a pedicle breach had an average height of 13.3 mm post-restoration, whereas cases without a pedicle breach had an average height of 13.8 mm post-restoration.

We acknowledge that the cohort of 60 patients (177 vertebrae) represents a modest sample size. The study was primarily designed to evaluate overall pedicle breach rates and their relationship with pedicle morphometry rather than to be powered for multiple subgroup comparisons. Based on the observed breach rates and effect sizes, the study had adequate power to detect clinically meaningful differences in overall breach incidence; however, we recognize that analyses across subgroups (e.g., thoracic vs lumbar levels, and upper vs lower screws) may have lacked sufficient power to detect smaller differences. Therefore, these subgroup findings should be interpreted as exploratory and hypothesis generating.

A formal prior power calculation was limited by the retrospective design, but post-hoc considerations suggest that larger, multi-center cohorts would be required to robustly assess level-specific associations. Selection bias was mitigated by the predefined inclusion criteria, inclusion of consecutive case over a fixed period, and objective CT-based measurements with high inter- and intra-observer reliability. Patients without retrievable CT scans were excluded

Table 5: Comparison of height of fractured vertebrae pre- and post-operatively.

Timepoint	Vertebral Height (mm)			Paired *t*-test	
	Mean (±SD)	Median (IQR)	Range	*t*	*p*-value
Pre-operative	13.6 (±2.9)	13.2 (2.7)	8.2–19.8	10.92	<0.001[a]
Post-operative	17.0 (±3.4)	16.5 (14.4–19.2)	11.2–23.0		
Absolute change	3.8 (±2.7)	3.5 (1.8–5.5)	1.0–9.2		
Per cent change	27.9% (±19.8)	25.7% (13.2–40.4)	6.1%–67.6%		

[a] Statistically significant.

Table 6: Screw diameters used at various vertebral levels.

6A: Upper Screw

Upper Screw Diameter (mm)		Mean (SD)	Median (IQR)	Min - Max
X-ray finding level (pre-operative)	**D2**	Nil (N/A)	N/A	N/A
	D4	6.00 (0.71)	6 (5.75–6.25)	5.5–6.5
	D5	Nil (N/A)	N/A	N/A
	D6	4.50 (N/A)	4.5 (4.5–4.5)	4.5–4.5
	D7	6.50 (N/A)	6.5 (6.5–6.5)	6.5–6.5
	D8	5.50 (N/A)	5.5 (5.5–5.5)	5.5–5.5
	D9	6.07 (0.51)	6.2 (5.85–6.35)	5.5–6.5
	D10	6.00 (0.71)	6 (5.75–6.25)	5.5–6.5
	D11	5.50 (N/A)	5.5 (5.5–5.5)	5.5–5.5
	D12	6.27 (0.51)	6.5 (6.35–6.5)	05-Jul
	L1	6.20 (0.44)	6.5 (6.03–6.5)	5.5–6.5
	L2	6.38 (0.16)	6.5 (6.2–6.5)	6.2–6.5
	L3	5.50 (1.41)	5.5 (5–6)	4.5–6.5
	L4	6.35 (0.21)	6.35 (6.28–6.42)	6.2–6.5
	L5	5.83 (0.71)	5.5 (5.5–6.5)	4.5–6.5
	Multiple	Nil (N/A)	N/A	N/A
Kruskal Wallis test	**$\chi 2$**	11.544		
	***p*-value**	0.483		

6B: Middle Screw

Middle Screw Diameter (mm)		Mean (SD)	Median (IQR)	Min - Max
X-ray finding level (pre-operative)	**D2**	Nil (N/A)	N/A	N/A
	D4	5.50 (0.00)	5.5 (5.5–5.5)	5.5–5.5
	D5	Nil (N/A)	N/A	N/A
	D6	5.00 (N/A)	5 (5–5)	05-May
	D7	5.50 (N/A)	5.5 (5.5–5.5)	5.5–5.5
	D8	5.50 (N/A)	5.5 (5.5–5.5)	5.5–5.5
	D9	5.50 (0.00)	5.5 (5.5–5.5)	5.5–5.5
	D10	5.00 (0.71)	5 (4.75–5.25)	4.5–5.5
	D11	5.50 (N/A)	5.5 (5.5–5.5)	5.5–5.5
	D12	5.88 (0.69)	6.2 (5.5–6.5)	4.5–6.5
	L1	6.32 (0.40)	6.5 (6.5–6.5)	5.5–6.5
	L2	5.50 (1.00)	5.5 (4.5–6.5)	4.5–6.5
	L3	4.50 (N/A)	4.5 (4.5–4.5)	4.5–4.5
	L4	6.50 (N/A)	6.5 (6.5–6.5)	6.5–6.5
	L5	5.72 (0.83)	5.5 (5.5–6.5)	4.5–6.5
	Multiple	Nil (N/A)	N/A	N/A
Kruskal Wallis test	**$\chi 2$**	16.37		
	***p*-value**	0.175		

6C: Lower Screw

Lower Screw Diameter (mm)		Mean (SD)	Median (IQR)	Min - Max
X-ray finding level (pre-operative)	**D2**	Nil (N/A)	N/A	N/A
	D4	6.00 (0.71)	6 (5.75–6.25)	5.5–6.5
	D5	Nil (N/A)	N/A	N/A
	D6	4.50 (N/A)	4.5 (4.5–4.5)	4.5–4.5
	D7	6.50 (N/A)	6.5 (6.5–6.5)	6.5–6.5
	D8	5.50 (N/A)	5.5 (5.5–5.5)	5.5–5.5
	D9	6.07 (0.51)	6.2 (5.85–6.35)	5.5–6.5
	D10	6.00 (0.71)	6 (5.75–6.25)	5.5–6.5
	D11	6.50 (N/A)	6.5 (6.5–6.5)	6.5–6.5
	D12	6.33 (0.47)	6.5 (6.5–6.5)	05-Jul
	L1	6.31 (0.39)	6.5 (6.42–6.5)	5.5–6.5
	L2	6.44 (0.13)	6.5 (6.5–6.5)	6.2–6.5
	L3	5.50 (1.41)	5.5 (5–6)	4.5–6.5
	L4	6.35 (0.21)	6.35 (6.28–6.42)	6.2–6.5
	L5	6.00 (0.61)	6.5 (5.5–6.5)	5–6.5
	Multiple	Nil (N/A)	N/A	N/A
Kruskal Wallis test	**$\chi 2$**	12.305		
	***p*-value**	0.422		

Table 7A: Screw Insertion Angles of all Pedicle Screws at different levels.

Upper Screw Insertion Angle (Degrees)	
Mean (±SD)	10.85 (±4.47)
Range	4.5−22.69
Middle screw insertion angle (degrees)	
Mean (±SD)	11.33 (±4.72)
Range	3.39−23.2
Lower screw insertion angle (degrees)	
Mean (±SD)	12.69 (±4.98)
Range	4.53−22.49

Table 7B: Correlation between Screw Insertion Angle and Transverse Pedicle Angle.

Correlation	Spearman Correlation Coefficient	*p*-value
Upper screw insertion angle v/s transverse pedicle angle	−0.15 (95%CI: −0.45 to 0.16)	0.249
Middle screw insertion angle v/s transverse pedicle angle	0.17 (95%CI: −0.1 to 0.41)	0.211
Lower screw insertion angle v/s transverse pedicle angle	0.09 (95%CI: −0.16 to 0.34)	0.480

Table 8: Correlation between Pedicle Screw Lengths and Screw Path Length.

Correlation	Spearman Correlation Coefficient	*p*-value
Upper screw length v/s screw path length	−0.47 (95%CI: −0.66 to −0.22)	<0.001[a]
Middle screw length v/s screw path length	−0.46 (95%CI: −0.67 to −0.18)	<0.001[a]
Lower screw length v/s screw path length	−0.5 (95%CI: −0.68 to −0.28)	<0.001[a]

[a] Statistically significant.

Table 9: No of pedicle breaches per vertebral level.

Vertebral Level	Pedicle Breach		
	Grade 1	Grade 2	Grade 3
T4			1
T6			1
T12	3	3	1
L1	2	1	
L2	1	2	

uniformly, reducing differential misclassification rather than outcome-based selection.

Discussion

Males were predominantly affected (80%) compared with females (20%). Males also sustained more burst fractures (89.6%) than females (66.7%). This gender distribution is less balanced than that in the study by Hu et al.,[1] who reported a more balanced representation of both genders. However, the distribution is comparable to that in the survey conducted by Khurjekar et al.,[12] who reported a sex ratio of 8:1. The mean (±SD) age of admitted patients was 46.88 ± 14.04 years. By contrast, Hu et al.[1] found that younger males and elderly females were affected. However, a similar bimodal pattern was not observed in the age distribution curve for spinal fractures in our study, which had a single peak.

In our study, most of the patients sustained spinal injuries following an alleged fall from height (63.3%). Similarly, Savitsky et al.[2] noted that high-energy trauma was more prevalent in fractures. Moreover, the survey by Parizel et al.[13] reported that spinal fractures, mainly burst fractures, occurred due to vertical loading forces, which are commonly seen in high-energy trauma. The same study found that most burst fractures occurred at the T11−L2 vertebral levels, which aligns with our findings where T12 and L1 were the most commonly affected levels.

Denis et al.[14] and Gertzbein et al.[15] showed that the thoracolumbar region (T11−L2) was the most common site. This region forms a transition zone between the thoracic spine, which is comparatively fixed and kyphotic, and the lumbar spine, which is relatively mobile and lordotic, thereby concentrating stress forces at the thoracolumbar junction.

In our study, approximately 43.3% of cases were associated with other injuries, including long-bone fractures

(23.3%), and this result is comparable with that reported by Niedermeier et al.[16]

Fifty-two patients sustained only one spinal fracture (86.7%), whereas the remaining eight patients sustained more than one fracture (13.3%). Cho and Kim[17] reported that 52.08% of patients had more than one fracture and were continuous.

According to our study, about 85% of patients sustained burst fractures, followed by 11.7% with chance fractures, 10% with compression fractures, and 5% with other spinal fractures. By contrast, Cigerci et al.[18] found that compression fractures were the most commonly detected vertebral fractures (in 52% of patients).

We found a statistically significant increase in pedicle width from the pre-operative time point to the post-operative time point. Grabala et al.[19] also observed that the pedicle expanded in proportion to the diameter of the screw inserted into it.

We found that the thoracic pedicles (T4–T10) were narrow, leading to a breach rate of 37.5%. Cho et al.[20] reported that pedicle breaches were more common with narrower pedicles. We also found that pedicles with a width of less than 0.5 cm had a higher breach risk ($p = 0.003$). Moreover, we found that screw diameters exceeding 80% of the pedicular width increased the risk of pedicle breach.[21]

The statistically significant, moderate inverse correlation between pedicle screw lengths and screw path lengths indicates that surgeons tend to select shorter screws when the measured screw path is longer, probably to avoid anterior or lateral breaches in severely compromised anatomy. This finding aligns with the study by Chua et al.,[22] who observed that longer screws theoretically provide superior fixation and kyphotic correction, but screws must be shorter in fractured segments to mitigate breach risks and accommodate the altered vertebral morphometry. In the present study, a weak negative correlation was found between the upper screw insertion angle and transverse pedicle angle, and a weak positive correlation was found between the middle and lower screw insertion angles and transverse pedicle angle, but these correlations were not statistically significant. However, we found that transverse angle deviations $>5^\circ$ increased the breach risk by 18% ($p = 0.002$). Similarly, Matsukawa et al. showed that deviations of 5° increased the cortical strain by 18%, thereby supporting our breach risk findings.[23]

In the present study, a shorter screw path length was associated with fractured vertebrae, and Chua et al.[22] also recommended screw lengths $\leq$80% of the vertebral body length to avoid anterior breaches, especially in fractured segments with compromised anatomy. However, Matsukawa et al.[23] reported that longer screws provide improved fixation strength in osteoporotic vertebrae, which conflicts with our findings.

Analysis of screw size selection showed that larger screws were selected for larger pedicles, such as lumbar vertebrae pedicles, which is consistent with the findings reported by Misenhimer et al.[24] who also demonstrated that screws exceeding 80% of the pedicle width caused plastic deformation, increasing the risk of fractured pedicles.

We found that a screw path length <3 cm correlated with an 18% increase in kyphotic angle correction ($p = 0.008$), which is consistent with the findings reported by Perna et al.[25]

Vertebral height restoration was 18% less in older patients than younger patients ($p = 0.021$). Similarly, Shi et al.[26] showed that older age correlated with post-operative vertebral height loss, particularly in patients with osteoporosis. However, it did not influence or lead to higher breach rates, indicating a higher impact on height recovery.

These individuals may benefit from adjunctive therapies such as cement augmentation to bridge the gap between surgical technique and biological constraints.

Age did not have a significant correlation with breach incidence ($p = 0.32$). By contrast, New and Epi[27] found that older patients had higher complication rates, including infections, which could indirectly increase the risk of pedicle breach.

Thoracic pedicles had a breach rate of 37.5% compared with 18.9% for lumbar vertebrae, which are comparable to the findings reported by Gertzbein and Robbins[28] who showed that narrower pedicles correlated with Grade C–E breaches as there is a limited margin for error.

However, Öztürk et al.[29] demonstrated that vertebral pedicles (especially osteoporotic pedicles) would benefit from larger screws for stability, despite an increased breach risk, which contrasts with our findings. The reasons for pedicle breach appear to be a mismatch between the screw diameter and pedicle width, or a mismatch in the screw insertion angles.

CT-based morphometric analysis is essential, especially for upper thoracic levels, where 47.8% of pedicles measure $\leq$5 mm. The study by Gierse et al.[30] strongly validated the fundamental finding that the breach rate is significantly higher for the thoracic spine than the lumbar spine, and their study and ours demonstrated that the breach risk is 2–3 times higher in the thoracic region. The mid-thoracic region (T6–T10) appears to be the most challenging according to our analysis, as also shown by Gierse et al.[30]

Based on the observed breach patterns and morphometric thresholds, we propose a stepwise clinical decision framework for pre-operative planning and intra-operative screw selection, which is provided as a supplementary file (Appendix 3).

The present study focused on free-hand and fluoroscopy-guided techniques, but other intra-operative adjuncts can further mitigate breach risk, including advanced navigation systems, robotic-assisted pedicle screw placement, and intra-operative neuromonitoring, which have all been shown to improve the trajectory accuracy and reduce the likelihood of critical cortical violations, particularly in narrower pedicles. Increasing surgeon experience and familiarity with CT-based morphometric planning combined with the use of high-quality image intensifiers that provide clear visualization can also play crucial roles in minimizing breach rates. However, in centers where navigation or robotics are unavailable, meticulous pre-operative CT assessment, strict adherence to pedicle width-based screw selection, and optimizing fluoroscopic imaging remain essential strategies, and have also been consistently highlighted in previous studies as key determinants of safe screw placement.[31]

This study had several limitations, including its retrospective design. In addition, our findings may have limited

generalizability given that the data were acquired from a single center and due to the specific surgical practices at this center, and thus they might not apply to other populations, healthcare systems, or surgical techniques and instrumentation. The relatively small sample size (n = 60 patients, 177 vertebrae, 354 pedicles) means that the power was limited for multivariable modeling and subgroup analyses, particularly for breach grades. The absence of long-term clinical outcomes or screw loosening and failure data is a significant limitation. In this study, we focused on radiographic breach occurrence and severity rather than clinical consequences, such as functional outcomes, pain, neurological complications, or hardware-related complications over time. Finally, our findings may not be applicable to pathological fractures, translational injuries, spinal deformity correction, revision surgeries, or pediatric populations. Metal artifact reduction software for CT scans is valuable because it can facilitate the production of images with less distortion due to the presence of screws. However, this method was not used in the present study. Statistically significant correlations were found but they do not imply causation because anatomical measurement variability and surgical decision making influence the risk of pedicle breach.

Conclusion

The unique contribution of the present study was the detection of pre-to post-operative correlations between pedicle morphometry and screw dimensions in a single cohort.

This CT-based morphometric study demonstrated that pedicle screw dimensions and thoracolumbar pedicle anatomy were closely linked, where narrower thoracic pedicles and higher screw diameter-to-pedicle width ratios were associated with an increased risk of pedicle breach. Pre-operative CT measurements indicated substantial variability in pedicle widths and transverse pedicle angles across levels. In addition, post-operative scans confirmed significant pedicle expansion and vertebral height restoration after screw insertion. Breaches occurred in 23.3% of patients and were more frequent in the thoracic spine, supporting the hypothesis that thoracic pedicles are inherently at higher risk. Maintaining screw diameters at or below 80% of the pedicle width, particularly using 5.5−6.0 mm screws in pedicles $\geq$5.5 mm, appears to minimize breach rates and offers a pragmatic safety threshold for thoracolumbar posterior spinal stabilization.

Therefore, routine, patient-specific CT morphometric planning should be incorporated into pre-operative workflows to optimize screw selection and trajectory, and reduce complications.

Pre-operative CT morphometry can identify high-risk pedicles, enabling surgeons to tailor screw selection and selectively apply navigation or fluoroscopic guidance where needed/anatomically constrained. This evidence-based risk stratification from reactive intraoperative adjustments to strategic pre-operative planning can help prevent breaches.

Future studies should focus on larger study populations to further confirm the results obtained in the present study, as well as correlating radiographic breach patterns with clinical neurological outcomes, evaluating the cost-effectiveness of routine CT morphometric planning, and assessing whether integrating pre-operative morphometric data with navigation technology can further optimize screw placement in high-risk anatomical scenarios.

Source of funding

No funding was received for this study.

Conflict of interest

The authors have no conflicts of interest to declare.

Ethics approval and consent to participate

The protocol was approved by the Kasturba Medical College and Kasturba Hospital Ethics Committee-2 (IEC2: 534/2023). The images were anonymized to maintain the confidentiality of each patient. Due to the retrospective nature of the study, the requirement for informed consent was waived by the ethics committee.

Authors contributions

AS contributed to data acquisition, analysis, and drafting the manuscript. SNB was involved in conception, design, and critical revision of the manuscript for important intellectual content. RSK and MPK contributed to revision of the manuscript and interpretation. All authors read and approved the final version of the manuscript.

Availability of data and materials

The data used to support the findings obtained in this study have been uploaded as supplementary material (also available as text from the corresponding author upon request).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jtumed.2026.05.013.

References

1. Hu R, Mustard CA, Burns C. Epidemiology of incident spinal fracture in a complete population. **Spine 1996**; 21(4): 492−499.
2. Savitsky E, Votey S. Emergency department approach to acute thoracolumbar spine injury. **J Emerg Med 1997**; 15(1): 49−60.
3. Dai LY, Ding WG, Wang XY, Jiang LS, Jiang SD, Xu HZ. Assessment of ligamentous injury in patients with thoracolumbar burst fractures using MRI. **J Trauma Inj Infect Crit Care 2009**; 66(6): 1610−1615.
4. McAfee PC, Yuan HA, Fredrickson BE, Lubicky JP. The value of computed tomography in thoracolumbar fractures. An analysis of one hundred consecutive cases and a new classification. **J Bone Joint Surg Am 1983**; 65(4): 461−473.
5. Prévost MA, McGuire RA, Garfin SR, Eismont FJ. Thoracic and upper lumbar spine injuries. In: *Skeletal trauma: Basic science, management, and reconstruction*. 3rd ed. Elsevier Health Sciences; 2003. pp. 875−943.

6. Vaccaro AR, Lim MR, Hurlbert RJ, Lehman RA, Harrop J, Fisher DC, et al. Surgical decision making for unstable thoracolumbar spine injuries: results of a consensus panel review by the spine trauma study group. **J Spinal Disord Tech 2006**; 19(1): 1−10.
7. Mesare V, Kulkarni R, Gursale A, Tiwari A, Kaware R. Accuracy of pedicle screw fixation in lumbar spine by free-hand technique studied post-operatively by computed tomography. **J Orthop Spine 2021**; 9(2): 73.
8. Liau KM, Yusof MI, Abdullah MS, Abdullah S, Yusof AH. Computed tomographic morphometry of thoracic pedicles: safety margin of transpedicular screw fixation in Malaysian Malay population. **Spine 2006**; 31(16): E545−E550.
9. Cinotti G, Gumina S, Ripani M, Postacchini F. Pedicle instrumentation in the thoracic spine: a morphometric and cadaveric study for placement of screws. **Spine 1999**; 24(2): 114−119.
10. Singh R, Srivastava SK, Prasath CSV, Rohilla RK, Siwach R, Magu NK. Morphometric measurements of cadaveric thoracic spine in Indian population and its clinical applications. **Asian Spine J 2011**; 5(1): 20.
11. Morita K, Ohashi H, Kawamura D, Tani S, Karagiozov K, Murayama Y. Thoracic and lumbar spine pedicle morphology in Japanese patients. **Surg Radiol Anat 2021**; 43: 1−10.
12. Khurjekar K, Hadgaonkar S, Kothari A, Raut R, Krishnan V, Shyam A, et al. Demographics of thoracolumbar fracture in Indian population presenting to a tertiary level trauma centre. **Asian Spine J 2015**; 9(3): 344.
13. Parizel PM, Van Der Zijden T, Gaudino S, Spaepen M, Voormolen MHJ, Venstermans C, et al. Trauma of the spine and spinal cord: imaging strategies. **Eur Spine J 2010**; 19(S1): 8−17.
14. Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries: spine **1983**; 8(8): 817−831.
15. Gertzbein SD. Multicenter spine fracture study: spine **1992**; 17(5): 528−540.
16. Niedermeier SR, Khan SN. Polytrauma patients with associated spine fractures: an assessment of surgical intervention on patient outcome. **Clin Spine Surg Spine Publ 2017**; 30(1): E38−E43.
17. Cho Y, Kim YG. Clinical features and treatment outcomes of acute multiple thoracic and lumbar spinal fractures : a comparison of continuous and noncontinuous fractures. **J Korean Neurosurg Soc 2019**; 62(6): 700−711.
18. CïGerci Ç, Saşmaz Mİ, Cigerci NE. Evaluation of vertebral fractures and associated injuries in multiple trauma patients. **E J Med 2024**; 29(2): 186−192.
19. Grabala P, Helenius IJ, Grabala M, Shah SA. Influences of increasing pedicle screw diameter on widening vertebral pedicle size during surgery in spinal deformities in children and adolescents without higher risk of pedicle and vertebral breaches. **J Clin Med 2023**; 12(16): 5368.
20. Cho SK, Skovrlj B, Lu Y, Caridi JM, Lenke LG. The effect of increasing pedicle screw size on thoracic spinal canal dimensions: an anatomic study. **Spine 2014**; 39(20): E1195−E1200.
21. Solitro GF, Whitlock K, Amirouche F, Mehta AI, McDonnell A. Currently adopted criteria for pedicle screw diameter selection. **Int J Spine Surg 2019**; 13(2): 132−145.
22. Chua MJ, Siddiqui S, Yu CS, Nolan CP, Oh JYL. The optimal screw length of lumbar pedicle screws during minimally invasive surgery fixation: a computed tomography-guided evaluation of 771 screws. **Asian Spine J 2019**; 13(6): 936−941.
23. Matsukawa K, Yato Y, Imabayashi H. Impact of screw diameter and length on pedicle screw fixation strength in osteoporotic vertebrae: a finite element analysis. **Asian Spine J 2021**; 15(5): 566−574.
24. Misenhimer GR, Peek RD, Wiltse LL, Rothman SLG, Widell EH. Anatomic analysis of pedicle cortical and cancellous diameter as related to screw size. **Spine (Phila Pa 1976) 1989**; 14(4): 367−372. Available from: https://www.researchgate.net/publication/20438274_Misenhimer_GR_Peek_RD_Wiltse_LL_Rothman_SLG_Widell_EH_Anatomic_analysis_of_pedicle_cortical_and_cancellous_diameter_as_related_to_screw_size.
25. Perna A, Santagada DA, Bocchi MB, Zirio G, Proietti L, Tamburrelli FC, et al. Early loss of angular kyphosis correction in patients with thoracolumbar vertebral burst (A3-A4) fractures who underwent percutaneous pedicle screws fixation. **J Orthop 2021**; 24: 77−81.
26. Shi Z, Zhang C, Wang B, Nicolas YSM, Chen J, Yang G. Analysis of influencing factors of vertebral height loss after pedicle screw fixation of thoracolumbar fracture. **Clin Spine Surg. 2023**; 36(8): E362−E368.
27. New PW, Epi MC. The influence of age and gender on rehabilitation outcomes in nontraumatic spinal cord injury. **J Spinal Cord Med 2007**; 30(3): 225−237.
28. Gertzbein SD, Robbins SE. Accuracy of pedicular screw placement in vivo. **Spine 1990**; 15(1): 11−14.
29. Öztürk AM, Süer O, Aydemir S, Kılıçlı B, Akçalı Ö. The effect of the size of pedicle screw on the long-term radiological and clinical results of short-segment posterior instrumentation in the management of thoracolumbar vertebral fractures. **Acta Orthop Traumatol Turc 2024**; 58(1): 20−26.
30. Gierse J, Zimmermann F, Grützner PA, Stallkamp J, Vetter SY, Mandelka E. Analysis of Screw/pedicle-width ratio and accuracy in navigated versus 3D-Controlled fluoroscopy-guided pedicle screw placement. **Glob Spine J 2025**; 19:21925682251343523.
31. Papalia GF, Vadalà G, Russo F, Marcello G, Nardi N, Papalia R, et al. Higher accuracy and better clinical outcomes in navigated thoraco-lumbar pedicle screw fixation versus conventional techniques. **Spine [Internet] 2024**; 49(19): 1370−1380 [cited 2026 Feb 16], https://pmc.ncbi.nlm.nih.gov/articles/PMC11386964/.

How to cite this article: Shetty A, Bhat SN, Kundangar RS, K MP. Association between pedicle screw dimensions and pedicle morphometry in computed tomography scans. J Taibah Univ Med Sc 2026;21(4):651−662.