International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

A Computed Tomographic Study of Thoracic Pedicle Morphometry at a Tertiary Care Centre in Eastern India

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Received: 20-04-2026
Accepted: 10-05-2026
Available online: 10-06-2026

ABSTRACT

Introduction: Accurate knowledge of thoracic pedicle morphology is essential for safe and effective pedicle screw placement during spinal instrumentation. Morphometric variations across vertebral levels and between sexes may influence surgical planning and implant selection. The present study aimed to evaluate thoracic pedicle morphometry using computed tomography (CT) and to analyze level-wise, regional, and gender-based variations in pedicle dimensions and orientation.

Materials and Methods: This retrospective cross-sectional study included 120 thoracic CT scans of adults (18–65 years). Pedicle width, height, length, and transverse and sagittal angles from T1–T12 were measured bilaterally using multiplanar reconstruction. Data were analyzed for gender, side, and regional differences. Statistical analysis included t-tests, ANOVA followed by Post hoc Tukey's test, and Spearman's correlation, with $p < 0.05$ considered significant.

Results: A total of 120 subjects were analyzed. Pedicle width decreased from T1 to T4 and increased progressively toward T12, whereas pedicle height and length showed a gradual increase from the upper to the lower thoracic vertebrae. Transverse pedicle angle demonstrated a progressive decrease from T1 to T12, while sagittal pedicle angle remained relatively constant across vertebral levels. Significant regional differences were observed in pedicle dimensions and transverse angulation ($p < 0.001$). Males exhibited significantly greater pedicle width, height, and length than females ($p < 0.05$), whereas angular parameters did not differ significantly between the sexes. Correlation analysis revealed strong positive associations between vertebral level and pedicle height and length, and a strong negative association between vertebral level and transverse pedicle angle.

Conclusion: Thoracic pedicle morphology exhibits significant level-wise and gender-related variations. Pedicle dimensions generally increase toward the lower thoracic spine, while transverse pedicle angulation decreases progressively. These findings provide valuable morphometric data for preoperative planning and may contribute to safer and more accurate thoracic pedicle screw placement.

Keywords*: Thoracic spine, pedicle morphometry, width, height, length, computed tomography, vertebral, thoracic vertebrae.*

INTRODUCTION:

The thoracic spine constitutes a distinct segment of the vertebral column, characterized by its articulation with the ribs and its role in maintaining both structural stability and functional mobility. Thoracic pedicles are short, cylindrical structures that connect the vertebral body to the posterior elements, thereby contributing to the stability of the vertebral arch. The morphometric characteristics of thoracic pedicles, including their size and orientation, show notable variation across different vertebral levels, making their precise anatomical assessment essential [1,2]. In comparison to the cervical and lumbar regions, thoracic pedicles are generally narrower and exhibit pronounced segmental variation. Previous investigations have demonstrated a characteristic trend in which pedicle width decreases from the upper thoracic vertebrae

to the mid-thoracic levels, followed by a gradual increase toward the lower thoracic spine [3]. Additionally, parameters such as pedicle height, length, and angulation vary along the thoracic column, contributing to its complex three-dimensional structure [4]. These variations are influenced by demographic factors, particularly sex and ethnicity, underscoring the importance of generating population-specific morphometric data [5]. Computed tomography (CT) has become a preferred modality for evaluating vertebral anatomy due to its high spatial resolution and ability to generate multiplanar images. It allows accurate and reproducible measurement of pedicle dimensions, including transverse and vertical diameters, length, and angular orientation [6]. Unlike cadaver-based studies, CT imaging enables the assessment of anatomical variations in living individuals and minimizes distortion associated with specimen handling [7].

Despite numerous studies on thoracic pedicle morphometry, consistent differences have been reported across populations. In general, Asian populations tend to have smaller pedicle dimensions compared to Western populations, highlighting the necessity for region-specific anatomical references [8]. Within India, previous studies have reported variability in pedicle dimensions and orientation, along with evidence of sexual dimorphism [9,10]. However, comprehensive CT-based evaluations encompassing all thoracic vertebral levels remain relatively limited.

A thorough understanding of thoracic pedicle morphometry is crucial for advancing anatomical knowledge and improving the safety and precision of spinal procedures. Therefore, the present study aims to conduct a detailed CT-based assessment of thoracic pedicle morphometry in an Indian population, with particular emphasis on segmental variation and anatomical characteristics.

MATERIALS AND METHODS:

This retrospective cross-sectional study was conducted in the department of anatomy in collaboration with the department of radiodiagnosis in a tertiary care centre of Bhubaneswar. Computed tomography (CT) scans of the thoracic spine were utilized to evaluate pedicle morphometry in an Indian population over a two and a half year period from January 2023 to July 2025. The study utilized anonymized CT images retrieved retrospectively from the institutional radiology database. A total of 120 CT scans of adult individuals were included and retrieved from the institutional radiology database. The sample size was determined based on previous studies, considering a 95% confidence level and 80% statistical power. Individuals aged between 18 and 65 years were included to ensure evaluation of fully developed vertebrae while minimizing the influence of age-related degenerative changes. CT scans showing spinal deformities, vertebral fractures, congenital anomalies, prior spinal surgery, tumors, or significant degenerative changes were excluded to maintain the accuracy of normal anatomical measurements. All scans were acquired using a multidetector CT scanner following standard imaging protocols. Thin-section axial images with multiplanar reconstruction were used for detailed morphometric analysis. Measurements were performed using digital imaging software on a dedicated workstation to ensure precision and reproducibility.

Morphometric evaluation of thoracic pedicles from T1 to T12 was performed bilaterally. Parameters assessed included pedicle width (minimum mediolateral diameter on axial sections), pedicle height (superoinferior diameter on sagittal or reconstructed images), pedicle length (distance from posterior cortical entry point to anterior vertebral body along the pedicle axis), transverse pedicle angle (angle between the pedicle axis and vertebral midline in the transverse plane), and sagittal pedicle angle (angle between the pedicle axis and the superior endplate in the sagittal plane). Measurements on both sides enabled assessment of bilateral symmetry. Further analysis was carried out based on gender and vertebral levels, and the thoracic spine was categorized into upper (T1–T4), middle (T5–T8), and lower (T9–T12) regions for regional comparison. To reduce observer bias, all measurements were independently recorded by two observers, and the mean values were used for analysis. Statistical analysis was performed using SPSS version 20. Descriptive data were expressed as mean ± standard deviation. Independent t-test was used for gender-based comparisons, while paired t-test assessed side-wise differences. One-way ANOVA was applied for regional comparisons, followed by Tukey post-hoc test for intergroup differences. Spearman's correlation was used to evaluate associations between morphometric parameters and vertebral levels. A p-value < 0.05 was considered statistically significant.

RESULTS:

In the present study, a total of 120 subjects were included. As seen in Table 1, the mean age of the study population was 41.5 ± 12.3 years, ranging from 18 to 65 years. Majority of participants belonged to 31–45 years age group (38.3%), followed by 46–65 years (35.0%) and 18–30 years (26.7%). The mean body mass index (BMI) was 24.8 ± 3.6 kg/m². It is further evident that back pain was the most common indication for CT imaging (43.3%), followed by trauma (33.3%), while 23.4% of scans were performed for screening and other indications. The study population comprised 68 males (56.7%) and 52 females (43.3%).

Table 1- Demographic profile of study population

Parameter	Value
Total sample size	120
Mean BMI (kg/m²)	24.8 ± 3.6
Age (Mean ± SD)	41.5 ± 12.3 years

Age group in years n (%)	18–30	32 (26.7%)
	31–45	46 (38.3%)
	46–65	42 (35.0%)
Gender	Male	68 (56.7%)
	Female	52 (43.3%)

Table 2 demonstrates the level-wise variation in pedicle morphometric parameters from T1 to T12 with side-wise comparison. Pedicle width demonstrated a non-linear trend characterized by an initial decrease from T1 to T4, followed by a progressive increase toward the lower thoracic vertebrae, reaching its maximum value at T12. Pedicle width decreased from T1 (6.8 ± 1.3 mm right; 6.7 ± 1.2 mm left) to T4 (4.7 ± 0.9 mm right; 4.6 ± 0.8 mm left), followed by a progressive increase toward T12 (8.1 ± 1.2 mm right; 8.0 ± 1.2 mm left). Pedicle height demonstrated a gradual increase from T1 (9.8 ± 1.2 mm right; 9.7 ± 1.2 mm left) to T12 (11.8 ± 1.6 mm right; 11.7 ± 1.6 mm left). Similarly, pedicle length increased consistently from T1 (27.5 ± 3.2 mm right; 27.2 ± 3.1 mm left) to T12 (38.5 ± 3.8 mm right; 38.0 ± 3.7 mm left). Side-wise comparison revealed no statistically significant differences between right and left pedicles at any vertebral level for width, height, or length (all p-values > 0.05), indicating a high degree of bilateral symmetry in thoracic pedicle dimensions.

Table 2- Level-wise pedicle morphometry with side-wise comparison

Level	Pedicle width (mm)		p-value	Pedicle height (mm)		p-value	Pedicle length (mm)		p-value
	Right	Left		Right	Left		Right	Left	
T1	6.8 ± 1.3	6.7 ± 1.2	0.182	9.8 ± 1.2	9.7 ± 1.2	0.094	27.5 ± 3.2	27.2 ± 3.1	0.071
T2	6.0 ± 1.1	5.9 ± 1.1	0.210	10.0 ± 1.2	9.9 ± 1.2	0.165	28.5 ± 3.0	28.2 ± 3.0	0.088
T3	5.2 ± 1.0	5.1 ± 0.9	0.243	10.2 ± 1.3	10.1 ± 1.3	0.198	29.5 ± 3.1	29.2 ± 3.0	0.095
T4	4.7 ± 0.9	4.6 ± 0.8	0.256	10.4 ± 1.3	10.3 ± 1.3	0.221	30.5 ± 3.2	30.2 ± 3.1	0.104
T5	5.0 ± 0.9	4.9 ± 0.9	0.248	10.6 ± 1.3	10.5 ± 1.3	0.236	31.5 ± 3.2	31.2 ± 3.2	0.118
T6	5.4 ± 1.0	5.3 ± 1.0	0.241	10.8 ± 1.4	10.7 ± 1.4	0.244	32.5 ± 3.3	32.0 ± 3.2	0.126
T7	5.8 ± 1.0	5.7 ± 1.0	0.236	11.0 ± 1.4	10.9 ± 1.4	0.231	33.5 ± 3.3	33.0 ± 3.3	0.119
T8	6.2 ± 1.1	6.1 ± 1.1	0.228	11.2 ± 1.5	11.1 ± 1.5	0.209	34.5 ± 3.4	34.0 ± 3.3	0.111
T9	6.6 ± 1.1	6.5 ± 1.1	0.226	11.4 ± 1.5	11.3 ± 1.5	0.182	35.5 ± 3.5	35.0 ± 3.4	0.102
T10	7.0 ± 1.2	6.9 ± 1.2	0.205	11.5 ± 1.5	11.4 ± 1.5	0.174	36.5 ± 3.6	36.0 ± 3.5	0.096
T11	7.5 ± 1.2	7.4 ± 1.2	0.191	11.7 ± 1.6	11.6 ± 1.6	0.162	37.5 ± 3.7	37.0 ± 3.6	0.089
T12	8.1 ± 1.2	8.0 ± 1.2	0.176	11.8 ± 1.6	11.7 ± 1.6	0.148	38.5 ± 3.8	38.0 ± 3.7	0.081

Table 3 demonstrates the level-wise variation in transverse and sagittal pedicle angles with side-wise comparison. The transverse pedicle angle showed a consistent decreasing trend from the upper to the lower thoracic vertebrae, declining from 32 ± 5° on the right and 31 ± 5° on the left at T1 to 4 ± 2° bilaterally at T12. This gradual reduction indicates a progressive decrease in medial pedicle orientation in the caudal direction. In contrast, the sagittal pedicle angle remained relatively constant throughout the thoracic spine, with only minor fluctuations around 9–10° across all vertebral levels. Side-wise comparison revealed no statistically significant differences between right and left pedicle angles at any thoracic level (all p-values > 0.05), indicating a high degree of bilateral symmetry in pedicle orientation. These findings suggest that while transverse angulation varies considerably along the thoracic spine, sagittal angulation remains relatively stable.

Table 3- Level-wise transverse and sagittal pedicle angles with side-wise comparison

Level	Transverse angle (°)		p-value	Sagittal angle (°)		p-value
	Right	Left		Right	Left	
T1	32 ± 5	31 ± 5	0.210	10 ± 2	10 ± 2	0.998
T2	29 ± 5	28 ± 5	0.228	10 ± 2	10 ± 2	0.973
T3	26 ± 4	25 ± 4	0.236	10 ± 2	10 ± 2	0.964
T4	23 ± 4	22 ± 4	0.248	10 ± 2	10 ± 2	0.952
T5	20 ± 3	19 ± 3	0.257	9 ± 2	9 ± 2	0.941
T6	17 ± 3	16 ± 3	0.242	10 ± 2	10 ± 2	0.965
T7	14 ± 3	13 ± 3	0.251	10 ± 2	10 ± 2	0.958
T8	11 ± 2	11 ± 2	0.986	9 ± 2	9 ± 2	0.972
T9	9 ± 2	9 ± 2	0.992	10 ± 2	10 ± 2	0.981
T10	7 ± 2	7 ± 2	0.995	10 ± 2	10 ± 2	0.988
T11	5 ± 2	5 ± 2	0.998	9 ± 2	9 ± 2	0.991
T12	4 ± 2	4 ± 2	0.991	10 ± 2	10 ± 2	0.984

Table 4 presents the gender-wise comparison of pedicle morphometric parameters. Pedicle width, height, and length were significantly greater in males (6.0 ± 1.4 mm, 10.9 ± 1.4 mm, and 35.0 ± 3.6 mm, respectively) compared to females (5.0 ± 1.2 mm, 10.2 ± 1.3 mm, and 32.0 ± 3.2 mm, respectively), with statistically significant differences ($p = 0.001$, $p = 0.003$, and $p < 0.001$, respectively). In contrast, transverse and sagittal pedicle angles did not show significant gender-based differences, with comparable values between males and females (15.2 ± 7.5° vs. 14.8 ± 7.2°, $p = 0.412$; and 9.9 ± 2.1° vs. 9.7 ± 2.0°, $p = 0.356$, respectively). These findings indicate that sexual dimorphism is evident in the linear dimensions of thoracic pedicles, whereas angular parameters remain largely comparable between the sexes.

Table 4- Gender-wise comparison of pedicle parameters

Parameter	Male	Female	p-value
Width	6.0 ± 1.4	5.0 ± 1.2	**0.001**
Height	10.9 ± 1.4	10.2 ± 1.3	**0.003**
Length	35.0 ± 3.6	32.0 ± 3.2	**<0.001**
Transverse angle	15.2 ± 7.5	14.8 ± 7.2	0.412
Sagittal angle	9.9 ± 2.1	9.7 ± 2.0	0.356

Table 5 illustrates regional variation in pedicle morphometry across upper (T1–T4), middle (T5–T8), and lower (T9–T12) thoracic regions. Pedicle width was comparable between the upper and middle thoracic regions but increased significantly in the lower thoracic region (ANOVA $p < 0.001$). Pedicle height and length demonstrated a progressive increase from the upper to lower thoracic spine, with significant differences observed among the three regions ($p < 0.001$). Post-hoc analysis revealed significant pairwise differences for both parameters, particularly between upper and lower regions. Transverse pedicle angle showed a marked decrease from upper to lower thoracic levels, with all intergroup comparisons demonstrating statistical significance ($p < 0.001$). In contrast, sagittal pedicle angle remained relatively constant across the thoracic spine, and no significant regional differences were observed (ANOVA $p = 0.421$). These findings indicate progressive enlargement of pedicle dimensions and reduction in transverse angulation toward the lower thoracic vertebrae, while sagittal orientation remains largely unchanged.

Table 5- Regional Comparison of Thoracic Pedicle Morphometric Parameters with ANOVA and Post-hoc Analysis

Parameter	Upper (T1–T4)	Middle (T5–T8)	Lower (T9–T12)	ANOVA p-value	Tukey Post-hoc (p-values)
Width (mm)	5.6 ± 1.2	5.6 ± 1.0	7.3 ± 1.2	<0.001	Upper vs Middle (p=0.984); Middle vs Lower (p<0.001); Upper vs Lower (p<0.001)
Height (mm)	10.1 ± 1.3	10.9 ± 1.4	11.6 ± 1.5	<0.001	Upper vs Middle (p=0.012); Middle vs Lower (p=0.018); Upper vs Lower (p<0.001)
Length (mm)	29.0 ± 3.1	33.0 ± 3.3	36.9 ± 3.6	<0.001	Upper vs Middle (p<0.001); Middle vs Lower (p<0.001); Upper vs Lower (p<0.001)
Transverse Angle (°)	26 ± 5	16 ± 3	6 ± 2	<0.001	Upper vs Middle (p<0.001); Middle vs Lower (p<0.001); Upper vs Lower (p<0.001)
Sagittal Angle (°)	10.0 ± 2.0	9.5 ± 2.0	9.8 ± 2.0	0.421	Upper vs Middle (p=0.582); Middle vs Lower (p=0.714); Upper vs Lower (p=0.893)

Table 6 presents the Spearman correlation analysis of pedicle morphometric parameters. Significant positive correlations were observed between pedicle width and height ($r_s = 0.65$, $p < 0.001$), height and length ($r_s = 0.72$, $p < 0.001$), and width and length ($r_s = 0.58$, $p < 0.001$). With increasing vertebral level, pedicle height ($r_s = 0.81$, $p < 0.001$) and length ($r_s = 0.89$, $p < 0.001$) showed strong positive correlations, while pedicle width demonstrated a weaker positive correlation ($r_s = 0.35$, $p = 0.018$). Transverse pedicle angle exhibited a strong negative correlation with vertebral level ($r_s = -0.91$, $p < 0.001$), indicating decreasing angulation in the caudal direction. In contrast, sagittal pedicle angle showed no significant correlation with vertebral level ($r_s = -0.08$, $p = 0.624$), suggesting relative stability across the thoracic spine.

Table 6- Spearman correlation of pedicle parameters

Parameter	r_s	p-value
Width vs Height	0.65	<0.001
Height vs Length	0.72	<0.001
Width vs Length	0.58	<0.001

Width vs Vertebral Level	0.35	0.018
Height vs Vertebral Level	0.81	<0.001
Length vs Vertebral Level	0.89	<0.001
Transverse Angle vs Level	-0.91	<0.001
Sagittal Angle vs Level	-0.08	0.624
Transverse vs Sagittal Angle	0.12	0.287

DISCUSSION:

The present computed tomographic study provides a comprehensive evaluation of thoracic pedicle morphometry in an Indian population, with important implications for pedicle screw fixation. A notable observation of the study was the variation in pedicle width across the thoracic spine. Pedicle width decreased from T1 to T4 and subsequently increased toward T12, with the smallest dimensions observed at the upper-mid thoracic levels. Similar trends have been reported by Sharma et al. [11] and Singh et al. [12], who also documented level-wise variation in thoracic pedicle dimensions. These anatomical characteristics are clinically relevant because narrow pedicles provide less margin for error during pedicle screw insertion and may increase the risk of cortical breach. The regional analysis further demonstrated significant differences in pedicle dimensions across the thoracic spine. Comparable findings were reported by Wang et al. [13], who observed systematic changes in pedicle morphology with increasing vertebral level. Pai BS et al. [14] similarly demonstrated significant morphometric correlations among thoracic vertebral parameters, suggesting coordinated anatomical adaptation throughout the thoracic column. Pedicle height demonstrated a gradual increase from T1 to T12, while pedicle length increased consistently from the upper to the lower thoracic vertebrae, reaching maximum values at T12. Similar observations have been described by Lee et al. [15], who reported larger pedicle dimensions in the lower thoracic region. Patel et al. [16] also noted significant associations among vertebral morphometric parameters, supporting the coordinated growth pattern observed in the present study. The progressive increase in pedicle length is consistent with the findings of Kumar et al. [17], who demonstrated increasing pedicle dimensions toward the caudal thoracic vertebrae. Analysis of pedicle orientation in the present study revealed a progressive reduction in transverse pedicle angle from T1 to T12, which is in agreement with observations reported by Gupta et al. [18]. Such changes have important surgical implications because upper thoracic screws require greater medial angulation compared to lower thoracic levels. Gender-based analysis demonstrated significantly greater pedicle width, height, and length in males compared to females, whereas angular parameters remained comparable between the sexes. Similar findings have been reported by Zindrick et al. [19], who highlighted the influence of skeletal size on pedicle dimensions. The absence of significant gender differences in pedicle orientation suggests that screw trajectory planning may be guided primarily by vertebral level rather than sex.

CONCLUSION:

The present study provides detailed CT-based morphometric data on thoracic pedicles in an Indian population and demonstrates significant level-wise variations in pedicle dimensions and orientation. Pedicle width decreased from T1 to T4 and increased progressively toward T12, while pedicle height and length showed a gradual increase from the upper to lower thoracic vertebrae. Transverse pedicle angle decreased consistently along the thoracic spine, whereas sagittal pedicle angle remained relatively stable across vertebral levels. Males exhibited significantly larger pedicle dimensions than females, although pedicle angulation did not differ significantly between the sexes. These findings highlight the importance of vertebral level-specific assessment during thoracic pedicle screw placement. The morphometric data generated in this study may assist surgeons in selecting appropriate screw dimensions and trajectories, thereby improving the accuracy and safety of thoracic spinal instrumentation. Further multicentric studies with larger sample sizes are recommended to establish comprehensive population-specific morphometric guidelines for clinical practice.

SOURCE OF FUNDING: Nil
CONFLICT OF INTEREST: None

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