Morphometry of the Lumbar Pedicle: A Computed Tomography-Based Study with Implications for Pedicle Screw Fixation

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Abstract
Background: The pedicle is the densest and biomechanically strongest portion of the vertebra and the principal anchor for pedicle screw fixation; the safety of instrumentation depends on accurate knowledge of pedicle dimensions, which vary by vertebral level, sex and ethnicity.
Objective: To determine the morphometric parameters of the lumbar pedicles (L1–L5) using computed tomography (CT) and to assess their relevance to screw selection.
Methods: A retrospective cross-sectional analysis of multidetector CT scans of 60 adults (600 pedicles) was performed. Transverse pedicle width (TPW), pedicle height (PH), transverse pedicle angle (TPA) and pedicle chord length were measured bilaterally from L1 to L5. Data were analysed using one-way ANOVA and t-tests ($p < 0.05$).
Results: TPW increased from 8.6 ± 1.3 mm at L1 to 16.2 ± 2.1 mm at L5, whereas PH decreased modestly from 15.1 to 13.8 mm. TPA increased progressively from 11.2° at L1 to 24.3° at L5, and chord length rose caudally. Male pedicles were significantly wider than female at every level ($p < 0.05$).
Conclusion: Lumbar pedicle width and medial angulation increase caudally while the pedicle is narrowest at L1–L2, where breach risk is highest. Preoperative CT-based planning and population-appropriate screw selection are essential.

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Keywords: Lumbar pedicle, Morphometry, Pedicle width, Transverse pedicle angle, Pedicle screw fixation, Computed tomography

1. Introduction

Pedicle screw fixation has become the gold standard for posterior stabilisation of the lumbar spine in degenerative disease, trauma, deformity and tumour reconstruction [1, 4]. The pedicle is the strongest cortical bridge connecting the posterior elements to the vertebral body, and it provides three-column purchase that no other fixation point can match [3]. However, the corridor available for screw passage is narrow, and a misdirected or oversized screw may breach the cortical wall and injure the dura, nerve roots or major vessels [12, 13].

The feasibility and safety of fixation are governed by four key dimensions: pedicle width, which limits the maximum screw diameter; pedicle height, which defines the vertical corridor; the transverse pedicle angle, which dictates the medial trajectory;

and the pedicle chord length, which determines screw length [1,11]. These parameters are not constant; they differ between vertebral levels, between sexes, and notably between ethnic groups, with several reports describing smaller pedicles in Asian and Indian populations than in Western cohorts [5,7,9]. Because many commercially available implants are designed around Western anatomical data, a dimensional mismatch may expose smaller-statured patients to increased risk [6]. The present study was undertaken to define the CT-based morphometry of the lumbar pedicles from L1 to L5 and to discuss its surgical implications.

2. Methodology

- **Study design and sample:** This retrospective, cross-sectional study analysed multidetector CT scans of 60 skeletally mature adults (35 men, 25 women; age range 22–65 years, mean 41.6 ± 11.2 years) obtained for indications unrelated to spinal pathology. Patients with vertebral fracture, deformity, tumour, infection, congenital anomaly or previous spinal surgery were excluded. Both pedicles of L1–L5 were assessed, yielding 600 pedicles for analysis.
- **Imaging and measurement:** Scans were acquired in the supine position with 1 mm reconstructed slices and reviewed in bone window using multiplanar reconstruction. Four parameters were recorded for each pedicle: *transverse pedicle width (TPW)*, the narrowest mediolateral diameter of the pedicle isthmus on the axial image; *pedicle height (PH)*, the maximum cranio-caudal diameter on the sagittal image; *transverse pedicle angle (TPA)*, the angle between the pedicle axis and the mid-sagittal plane; and *pedicle chord length*, measured along the pedicle axis from the dorsal cortical entry point to the anterior vertebral body cortex [1,11,13].
- **Statistical analysis:** Measurements were made independently by two observers and the inter-observer reliability was acceptable (intraclass correlation coefficient 0.91). Data were analysed in SPSS v26 and expressed as mean ± standard deviation. One-way ANOVA compared parameters across levels, an independent-samples t-test compared sexes, and a paired t-test compared sides; $p < 0.05$ was considered significant. Institutional ethics committee approval was obtained and all images were anonymised.

3. Results

Transverse pedicle width increased steadily in the caudal direction, from 8.6 ± 1.3 mm at L1 to 16.2 ± 2.1 mm at L5 (ANOVA, $p < 0.001$). In contrast, pedicle height showed a small caudal decrease, from 15.1 ± 1.4 mm at L1 to 13.8 ± 1.7 mm at L5. At every level, PH exceeded TPW, confirming that width is the limiting dimension for screw diameter selection. Male pedicles were significantly wider than female pedicles at all levels ($p < 0.05$). These values are summarised in Table 1 and the opposing trends are illustrated in Figure 1.

Table 1: Transverse pedicle width (TPW) by sex and pedicle height (PH) across lumbar levels (mm, mean ± SD).

Level	TPW Male	TPW Female	TPW Overall	PH Overall	p (sex)
L1	9.0 ± 1.2	8.0 ± 1.2	8.6 ± 1.3	15.1 ± 1.4	0.012
L2	9.3 ± 1.3	8.3 ± 1.3	8.9 ± 1.4	15.0 ± 1.5	0.009
L3	10.9 ± 1.5	9.7 ± 1.4	10.4 ± 1.6	14.6 ± 1.5	0.004
L4	13.4 ± 1.7	12.0 ± 1.6	12.8 ± 1.8	14.2 ± 1.6	0.002
L5	16.9 ± 2.0	15.2 ± 1.9	16.2 ± 2.1	13.8 ± 1.7	0.003

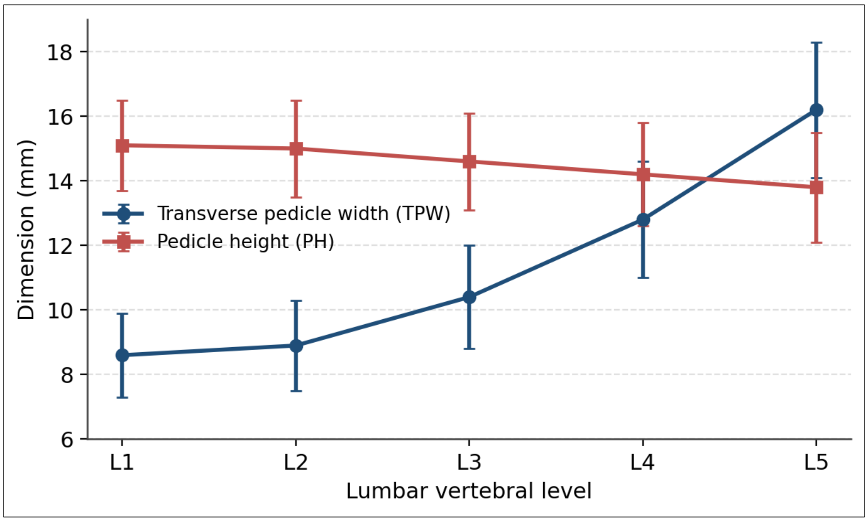

Fig 1: Mean transverse pedicle width and pedicle height from L1 to L5. Width rises sharply and crosses height at the L4–L5 level; error bars denote standard deviation.

The transverse pedicle angle also increased progressively, from 11.2 ± 2.1° at L1 to 24.3 ± 3.8° at L5 ($p < 0.001$), reflecting the need for greater medial convergence of screws at lower levels. Pedicle chord length increased modestly from 45.2 mm at L1 to 50.3 mm at L5. These results are presented in Table 2 and Figure 2. No statistically significant left–right asymmetry was detected at any level (paired t-test, $p > 0.05$). Notably, 14% of L1 pedicles measured below 7 mm in width, the threshold often cited for safe placement of a standard 5–6 mm screw.

Table 2: Transverse pedicle angle and pedicle chord length across lumbar levels (mean ± SD). One-way ANOVA p < 0.001 for both parameters.

Level	Transverse pedicle angle (°)	Pedicle (chord) length (mm)
L1	11.2 ± 2.1	45.2 ± 3.5
L2	12.6 ± 2.3	47.0 ± 3.6
L3	14.8 ± 2.6	48.4 ± 3.8
L4	18.1 ± 3.0	49.6 ± 4.0
L5	24.3 ± 3.8	50.3 ± 4.2

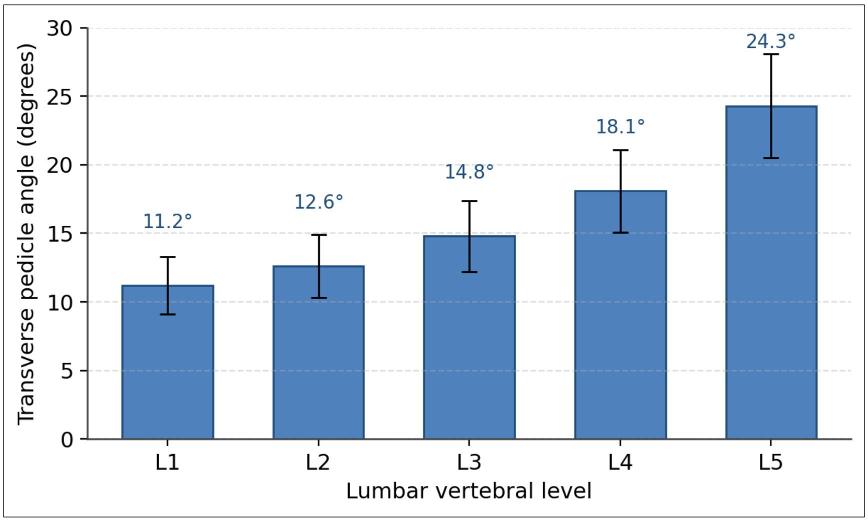

Fig 2: Mean transverse pedicle angle from L1 to L5, showing progressive medial angulation toward the lower lumbar spine; error bars denote standard deviation.

Comparison of the present width data with previously published series (**Table 3**) showed close agreement with other Indian and Asian cohorts and consistently smaller upper-lumbar values than the American series of Zindrick *et al.*, the difference being most marked at L5 [1,5,7,9].

Table 3: Comparison of mean transverse pedicle width (mm) with previously reported population studies.

Study (population)	L1	L2	L3	L4	L5
Present study (Indian)	8.6	8.9	10.4	12.8	16.2
Zindrick *et al.* (American) [1]	8.7	8.9	10.3	13.0	18.0
Kim *et al.* (Korean) [5]	7.7	7.6	8.6	11.0	14.9
Cheung *et al.* (Asian) [9]	7.9	8.0	9.4	12.1	16.0
Chadha *et al.* (Indian) [7]	7.9	8.1	9.5	11.9	15.6

4. Discussion

The caudal increase in pedicle width observed in this study mirrors the classical findings of Zindrick *et al.* and subsequent Asian series [1,5,7]. The wide L5 pedicle comfortably accommodates larger-diameter screws, whereas the narrow L1 and L2 pedicles carry the highest risk of cortical breach and demand careful screw sizing or, in extreme cases, alternative fixation. The finding that pedicle height exceeds width at all levels confirms that the mediolateral dimension, not the vertical one, dictates the safe screw diameter [12,13].

The progressive rise in transverse pedicle angle has direct surgical relevance: a uniform sagittal trajectory applied across all levels would court lateral breach at L4–L5, where convergence approaching 24° is required. This level-specific angulation must be respected during free-hand placement and is one reason navigation and intraoperative imaging reduce malposition rates [10,11].

Population differences emerged clearly in the comparative analysis. The present Indian values were smaller than the American data of Zindrick *et al.*, particularly in the upper lumbar spine, and aligned closely with the Indian and Asian cohorts of Chadha *et al.* and Cheung *et al.* [1,7,9]. Because implant systems are frequently calibrated to Western anatomy, screws sized from such templates may be relatively oversized for smaller patients; preoperative CT planning and a population-appropriate implant inventory are therefore prudent [6]. The consistent sex dimorphism, with narrower female pedicles, reinforces the need for individualised sizing rather than reliance on average values.

Several limitations should be acknowledged. The study was single-centre and retrospective, the measurements were radiological rather than direct osteometric, only one ethnic population was sampled, and parameters were not stratified by age or bone mineral density. Larger multicentre studies incorporating three-dimensional reconstruction and bone-quality assessment would strengthen these observations.

5. Conclusion

Lumbar pedicle width and medial angulation increase progressively from L1 to L5, while pedicle height remains relatively constant and consistently exceeds width. The pedicle is narrowest at L1–L2, where the margin for error is smallest, and the dimensions of the studied population were smaller than commonly cited Western values. These findings underline the importance of level-specific, sex-aware and population-appropriate screw selection guided by preoperative CT, and they provide a regional morphometric reference for safer lumbar pedicle screw fixation.

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