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Research Article

Morphometric Study of Pedicles of Lumbar Vertebrae in a Western Indian Population

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ABSTRACT

Background: The lumbar spine is a critical site for pathologies like spinal stenosis and instability, often requiring surgical interventions such as transpedicular screw fixation. The success of these procedures is heavily dependent on precise anatomical knowledge of the pedicle dimensions. While such data is abundant for Western populations, a definitive morphometric database for the Indian population is lacking, necessitating region-specific studies.

Aims and Objectives: This study aims to (1) establish a morphometric database of the lumbar vertebral pedicles, spinal canal, and vertebral body relevant to the Indian population; (2) analyze its role in quantifying spinal stenosis using the canal-to-vertebral body ratio; and (3) provide data to guide optimal pedicle screw selection and placement.

Materials and Methods: A cross-sectional study was conducted on 125 dried human lumbar vertebrae (L1-L5) from 25 sets obtained from the Department of Anatomy. Measurements of pedicle height (vertical diameter), maximum and minimum pedicle width (transverse diameter), and pedicle index were taken using a digital vernier caliper. Vertebral body and spinal canal dimensions were also recorded. Data were analyzed using descriptive statistics (mean, standard deviation) and compared across vertebral levels using ANOVA.

Results: The pedicle dimensions showed a progressive increase from L1 to L5. The mean minimum pedicle width, a critical parameter for screw diameter, was found to be smallest at L1 (6.30 ± 0.87 mm) and largest at L5 (15.79 ± 1.82 mm). The pedicle index indicated a transition from a taller to a wider pedicle structure in the lower lumbar levels. The calculated canal-to-vertebral body ratios were within normal limits, confirming the absence of stenosis in the sample.

Conclusion: This study provides crucial morphometric data of the lumbar vertebrae that is directly applicable to the Indian population. The findings underscore the necessity for careful pre-operative planning and the selection of pedicle screws tailored to the specific anatomical dimensions of Indian patients, which are distinct from other ethnic groups. This data is invaluable for minimizing surgical complications and improving outcomes in spinal instrumentation and stenosis diagnosis.

Keywords: *Lumbar Vertebrae, Pedicle Morphometry, Transpedicular Screw, Spinal Stenosis, Anatomical Study, Indian Population.*

INTRODUCTION

Low backache is a ubiquitous health issue with a significant socio-economic impact globally. A prominent cause of chronic, debilitating pain is lumbar canal stenosis, often related to anatomical variations that reduce the dimensions of the vertebral foramen, exacerbated by degenerative changes [1,2]. Surgical management, particularly for conditions like traumatic listhesis, fractures, tumors, and infections, frequently relies on transpedicular screw fixation for spinal stabilization [3].

The biomechanical integrity and pull-out strength of a pedicle screw are fundamentally dependent on the morphometry of the pedicle itself. The minimum width of the pedicle is the primary limiting factor in screw diameter selection, with larger screws offering superior strength but risking neurological compromise if mismatched. Furthermore, the diagnosis of congenital or acquired spinal stenosis often hinges on morphometric ratios, such as the canal-to-vertebral body ratio [4,5]. While the prevalence of spinal disorders is universal, anatomical dimensions exhibit ethnic and geographical variations. Numerous studies have established morphometric standards for Caucasian and other populations, but a definitive database for the Indian population remains scarce. Lumbar spines being the epicenter of these pathologies, there is a pressing need for population-specific metrical data to guide clinicians and surgeons in accurate diagnosis and effective surgical planning [6,7]. This study aims to fill this gap by providing a detailed morphometric analysis of the lumbar vertebral pedicles and related structures.

MATERIALS AND METHODS

Study Design and Sample:

This was a cross-sectional observational study conducted on 125 dried human lumbar vertebrae (from L1 to L5) obtained from 25 adult skeletal sets of unknown sex and age from the Department of Anatomy.

Inclusion and Exclusion Criteria:

All intact, fully ossified adult lumbar vertebrae available in the department during the one-year study period were included. Vertebrae showing any signs of obvious trauma, congenital deformity, pathological lesions (e.g., from tuberculosis or tumors), or advanced osteoarthritic changes were excluded from the study.

Data Collection:

All measurements were taken using a digital vernier caliper. The following parameters were measured for each vertebra:

1) Pedicle Height (PH): The vertical diameter of the pedicle at its root (isthmus).
2) Maximum Pedicle Width (Max PW): The widest transverse diameter of the pedicle.
3) Minimum Pedicle Width (Min PW): The narrowest transverse diameter of the pedicle (the critical dimension for screw sizing).
4) Pedicle Index (PI): Calculated as (Min PW / PH) * 100.
5) Vertebral Body Dimensions: Anteroposterior and transverse diameters.
6) Spinal Canal Dimensions: Sagittal (anteroposterior) and interpedicular distances.

Statistical Analysis:

The data were compiled in a Microsoft Excel sheet and analyzed using SPSS software version 23.0. Descriptive statistics (mean, standard deviation) were calculated for all parameters for each lumbar level (L1-L5). A one-way Analysis of Variance (ANOVA) test was used to compare measurements across the five lumbar levels. A p-value of <0.05 was considered statistically significant.

RESULTS

All 125 vertebrae were measured successfully. The results are summarized in Table 1 &2.

The mean minimum pedicle width (Min PW), the most crucial parameter for screw selection, demonstrated a craniocaudal increase. It was narrowest at L1 (6.30 ± 0.87 mm) and widest at L5 (15.79 ± 1.82 mm). This increasing trend was statistically significant ($p < 0.001$). Similarly, the pedicle height (PH) was greatest at L1 (15.74 ± 1.43 mm) and slightly decreased towards L5 (14.15 ± 1.66 mm), though the change was less dramatic. The Pedicle Index (PI) showed a significant increase from L1 to L5, indicating that upper lumbar pedicles are generally taller than they are wide, while lower lumbar pedicles (especially L5) become substantially wider than they are tall.

The sagittal diameter of the spinal canal was largest at L1 and gradually decreased towards L5. The interpedicular distance followed a similar pattern. The canal-to-vertebral body ratio was calculated for all levels and was found to be well above the pathological threshold of 1:5 (or 0.20), confirming the absence of spinal stenosis in the studied sample.

Table 1: Morphometric Measurements of Pedicles (Mean ± SD in mm)

Vertebra	Min PW	Max PW	PH	Pedicle Index
L1	6.30 ± 0.87	9.25 ± 1.10	15.74 ± 1.43	40.03
L2	7.64 ± 1.03	10.52 ± 1.35	14.78 ± 1.49	51.69
L3	9.50 ± 1.24	11.60 ± 1.55	14.33 ± 1.22	66.29
L4	11.73 ± 1.57	14.70 ± 1.88	14.23 ± 1.60	82.43
L5	15.79 ± 1.82	18.40 ± 2.15	14.15 ± 1.66	111.59

Table 2: Morphometric Measurements of Body of Lumbar Vertebrae (Mean ± SD in mm)

Vertebra	Anteroposterior diameter	Transverse Diameter	Sagittal Canal Diameter
L1	26.50 ± 2.40	34.30 ± 4.44	16.50 ± 1.44
L2	26.88 ± 3.45	35.37 ± 3.40	16.31 ± 1.40

L3	27.53 ± 3.27	38.83 ± 3.27	15.53 ± 1.20
L4	28.58 ± 2.30	39.74 ± 3.30	15.54 ± 1.39
L5	29.54 ± 3.55	42.50 ± 3.75	14.50 ± 1.55

Figure 1: Measurement of Pedicle Height

Figure 2: Measurement of Pedicle width

DISCUSSION

This study provides a comprehensive morphometric analysis of the lumbar vertebral pedicles in a Western Indian population. The key finding is the significant and progressive increase in pedicle width from L1 to L5, with the minimum width at L5 being more than double that of L1. The Interpedicular distance is between the medial surfaces of the pedicles

of the same vertebra constitute the lateral walls of the vertebral canal. The reduction in interpedicular distance and anteroposterior shortening of the pedicle are the commonest causes of stenosis of the vertebral canal [8].

In the study conducted by Chawla et al. on 30 dry L3 vertebrae, the mean vertical height of the pedicles was found to be 14.1 mm on both the right and left sides. Similarly, the mean pedicle width measured 8.8 mm bilaterally. The transverse interpedicular distance ranged from a minimum of 18 mm to a maximum of 25.1 mm, with an average value of 20.5 ± 1.3 mm [9].

Table 3: Comparison of pedicle width with previous studies

Study	L1 (mm)	L2 (mm)	L3 (mm)	L4 (mm)	L5 (mm)
Layeeque and Ausavi [10]	8.2	8.4	11.41	13.9	17.7
Olsewski et al. [11]	9.5	9.6	11.7	14.7	21.1
Alam et al. [12]	6.1	6.6	8.1	10.2	13.0
Acharya et al. [13]	7.20	7.62	8.97	11.12	13.91
Saravanan et al [14]	6.61	7.54	8.44	10.23	14.52
Present study	6.30	7.64	9.50	11.73	15.79

The table 3 compares pedicle widths across various studies. The present study shows a gradual increase in pedicle width from L1 (6.30 mm) to L5 (15.79 mm), consistent with previous findings. Compared to other studies, values are closer to those of Acharya et al. and Saravanan et al., while Layeeque & Ausavi and Olsewski et al. reported relatively higher widths, and Alam et al. reported the lowest. Overall, the trend of increasing pedicle width from L1 to L5 is consistent across all studies.

Table 4: Comparison of pedicle height with previous studies

Study	L1 (mm)	L2 (mm)	L3 (mm)	L4 (mm)	L5 (mm)
Layeeque and Ausavi [10]	15.2	14.8	14.7	14.2	13.1
Olsewski et al. [11]	17.0	16.0	16.0	16.4	17.4
Alam et al. [12]	13.5	13.4	12.03	12.03	11.53
Saravanan et al [14]	22.76	19.81	14.15	11.48	8.35
Present study	15.74	14.78	14.33	14.23	14.15

The table 4 compares pedicle heights across studies. The present study shows a gradual decrease from L1 (15.74 mm) to L5 (14.15 mm), similar to the pattern reported by Layeeque and Ausavi. Olsewski et al. reported generally higher values, while Alam et al. reported lower heights. Saravanan et al. showed a marked variation, with unusually high values at L1 and L2 and very low values at L5. Overall, the present study findings align closely with Layeeque and Ausavi, showing moderate and consistent pedicle heights.

The Pedicle Index offers valuable insight into the changing morphology of the pedicle. The low index at L1 and L2 suggests a tall, narrow shape, favoring a screw with a smaller diameter but longer length. Conversely, the high index at L4 and particularly L5 indicates a wide, stout structure that can accommodate a screw of much larger diameter, which is biomechanically advantageous for fixation. The spinal canal dimensions and the derived canal-to-vertebral body ratios were within normal limits, providing a baseline for identifying pathological stenosis in a clinical setting. A ratio below 0.20 (1:5) would be highly suggestive of congenital or developmental stenosis [15-17].

CONCLUSION

This study created a reference database of the normal sizes of lumbar pedicles, the spinal canal, and the vertebral body for people from Western India. The results show clear ethnic differences, with pedicle sizes generally smaller than those reported in Western populations. These findings are important for spine surgeons using pedicle screw fixation, as they emphasize the need for careful, patient-specific planning to make surgery safer and more effective. The measurements can also help in diagnosing and assessing spinal stenosis through imaging. Overall, this work aims to support better treatment outcomes for spinal problems in the Indian population.

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