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Morphometric Analysis of Pedicles in Adult Human Dried Lumbar Vertebrae: A Cross-Sectional Study

Ranu Gupta[1], Dr Prakash K.G[2], Dr Kumar Sambhav[3], Dr Saniya K[4]* & Priyanshi Balot[5]

[1]Department of Anatomy, Geetanjali Medical College & Hospital, Udaipur, Rajasthan, India
[2]Professor & Head Department of Anatomy, Geetanjali Medical College & Hospital, Udaipur, Rajasthan, India
[3]Assistant Professor Geetanjali Medical College & Hospital, Udaipur, Rajasthan, India
[4]Associate Professor Geetanjali Medical College & Hospital, Udaipur, Rajasthan, India
[5]Department of Anatomy Geetanjali Medical College & Hospital, Udaipur, Rajasthan, India
Corresponding author Dr Saniya K
*Associate Professor Department of Anatomy Geetanjali Medical College & Hospital, Udaipur, Rajasthan, India Email: drsaniyakanatomy@gmail.com

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Abstract

Introduction: The human vertebral column is comprised of 33 vertebrae, five of which are lumbar. The first four (L1 to L4) are typical, while the fifth (L5) is atypical.

Aim and Object: This research aims to analyse the morphology of lumbar vertebrae by collecting their various morphometric data which provide pertinent information to orthopaedicians, neurosurgeons, anatomists, and biomechanical engineers working to enhance the health and well-being of people with spinal disorders.

Material and Methods: The research was conducted on a total of 100 dry adult human lumbar vertebra [typical – 50 & atypical - 50] of unknown sex and age, from the Department of Anatomy at Geetanjali Medical College and Hospital, Udaipur. The typical and typical lumbar vertebrae were determined as per the guidelines mentioned in the standard reference book of anatomy. The sample were collected at random and the necessary data was collected over the course of 12-16 months.

Results: in the present study, a comparison within the group showed significant differences in pedicle width ($p= 0.012$) but not in pedicle height or interpedicular distance ($p > 0.05$). When comparing between typical and atypical lumbar vertebrae, significant differences were observed in pedicle width ($p < 0.001$), whereas pedicle height and interpedicular distance did not show significant variation ($p > 0.05$). These findings highlight distinct morphological differences, particularly in pedicle width, between typical and atypical lumbar vertebrae, suggesting structural adaptations in atypical vertebrae.

Conclusion: These findings contribute to a growing body of literature on vertebral anatomy, offering insights that can improve patient care and outcomes in spinal surgery and orthopedic interventions.

Keywords: Human Vertebral, Orthopaedicians, Human lumbar vertebra, Vertebral anatomy.

Introduction

The neuronal arch is formed by the fusion of the pedicles of the vertebrae, which are short, thick, cylindrical bony processes that extend posteriorly from the superior portion of the vertebral body. They are located in the space between the spinous and transverse processes. The spinal canal of the thoracic spine is made up of segmental nerves and the spinal cord. During spinal instrumentation, the contents of the spinal canal could be damaged (Verma et al., 2020). The morphometric information of the lumbar vertebrae is provided by a small number of studies, although the size of the pars interarticularis in the anatomical collections is not well documented (Ashish et al., 2023).

Understanding the intricate morphometry of the vertebral column is made easier by anatomical research (Berry et al., 1987; Panjabi et al., 1992). Degenerative disorders of the vertebral column are thought to be influenced by the morphometry of the vertebrae (Julin et al., 1976). In order to prevent the intervertebral gap from

expanding and causing subsequent blood vessel damage, the measures are crucial for selecting an appropriate implant (Kot et al., 2022). Examining the morphometry of dried lumbar vertebrae from human cadavers in a sample of Indians was the aim of this anatomical study.

The objective of the morphometric study of the pedicles of dried human lumbar vertebrae is to quantify and analyse the anatomical features of the pedicles, which are bony structures that protrude from the rear of vertebrae and are part of the spinal column. This study is significant because the pedicles are vital to the stability and function of the lumbar spine (Ebraheim et al., 1997; Verma and Agrawal, 2023).

These studies can provide valuable information to clinicians, anatomists, and biomechanical engineers working to enhance the health and well-being of people with spinal disorders. In the fields of anatomy, orthopaedics, and neurosurgery, morphometric examinations of the pedicles of dried human lumbar vertebrae are common. These studies seek to provide information regarding the size, shape, and orientation of the pedicles, which are crucial for surgical procedures involving the lumbar spine (Mitra et al., 2002; Abiodun et al., 2020; Lawal et al., 2024).

Consequently, morphometric investigations of the pedicles of dried human lumbar vertebrae have yielded important insights into the anatomy of the lumbar spine. The findings of these studies can be utilised to enhance the precision and safety of spinal surgeries and other interventions. It is a well-established fact that morphometric data varies between sexes, races, ethnicities, and geographic regions. Despite the fact that low back pain is equally prevalent throughout the universe, there have been few studies conducted in India. Consequently, there is a need for our own metrical data pertinent to this region, which, if deemed suitable, could fill a significant gap. This information will be useful for clinicians addressing the issue of low back pain, especially when it is caused by skeletal abnormalities or deformities. In relation to back and sciatic pain, the function of a narrow lumbar spinal canal is well-established. This research aims to analyse the morphology of lumbar vertebrae by collecting their various morphometric data which provide pertinent information to orthopaedicians, neurosurgeons, anatomists, and biomechanical engineers working to enhance the health and well-being of people with spinal disorders.

Material and Methods

The research was conducted on a total of 100 dry adult human lumbar vertebra [typical – 50 & atypical - 50] of unknown sex and age, from the Department of Anatomy at Geetanjali Medical College and Hospital, Udaipur. The typical and typical lumbar vertebrae were determined as per the guidelines mentioned in the standard reference book of anatomy (Mitra 2013). The sample were collected at random and the necessary data was collected over the course of 12-16 months (fig 1 & fig 2).

Fig 1: Group photo showing all the samples of Typical lumbar vertebrae

Fig 2: Group photo showing all the samples of Atypical lumbar vertebrae

Study Design: This was a descriptive cross-sectional study included inclusion and exclusion criteria. Inclusion criteria conducted fully ossified lumber vertebrae. Exclusion criteria conducted deformed and broken vertebrae, pathology or an evident abnormality.

Instrument used in the study:

Fig 3: Digital Vernier Calliper

Fig 4: Method showing measurement of pedicle height

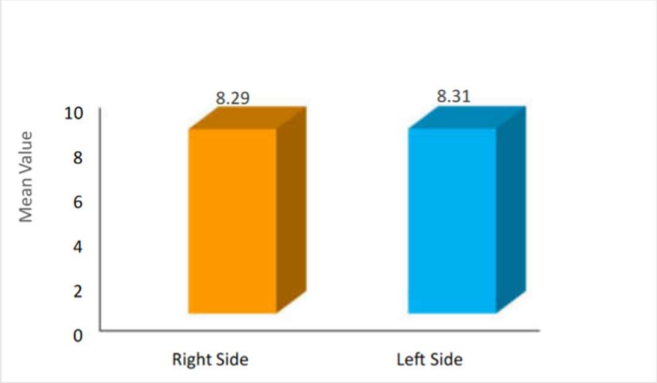
Fig 5: Method showing measurement of pedicle width

Fig 6: Method showing measurement of interpedicular distance

Results:

The findings of this study provide a detailed examination of the measurements of both typical and atypical lumbar vertebrae, with specific focus on pedicle height, pedicle width, and interpedicular distance. These measurements are crucial for understanding vertebral anatomy, which has direct implications for spinal surgery, orthopaedic interventions, and clinical diagnostics.

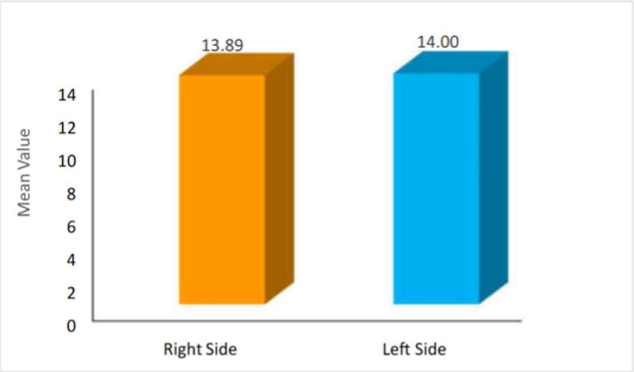
On the right side the mean pedicle width of typical lumbar vertebrae found to be 8.29 mm (±1.76) and hight of typical lumbar vertebrae found to be 13.89 mm (±1.49) while on left side mean pedicle width of typical lumbar vertebrae found to be 8.31 mm (±1.92) and hight of typical lumbar vertebrae found to be 14.00 mm (±1.35) with a p value of 0.96 and 0.70 respectively which was found to be non-significant (Graph 1 and Graph 2) (Table 1 and 2).



Graph 1: Pedicle Width in (mm) of Typical Lumbar Vertebrae of both Right & Left sides

Table 1: Pedicle Width in (mm) of Typical Lumbar Vertebrae of both Right & Left sides

Pedicle Width (mm)	Right Side	Left Side	P value
Mean	8.29	8.31	0.96
Standard Deviation	1.76	1.92	



Graph 2: Pedicle Height in (mm) of Typical Lumbar Vertebrae of both Right & Left sides

Table 2: Pedicle Height in (mm) of Typical Lumbar Vertebrae of both Right & Left sides

Pedicle Height (mm)	Right Side	Left Side	P value
Mean	13.89	14.00	0.70
Standard Deviation	1.49	1.35	

On the other hand, interpedicular distance of typical lumbar vertebrae found to be 17.34mm (+2.07) with a p value of 0.98 which was found to be non-significant (Table 3).

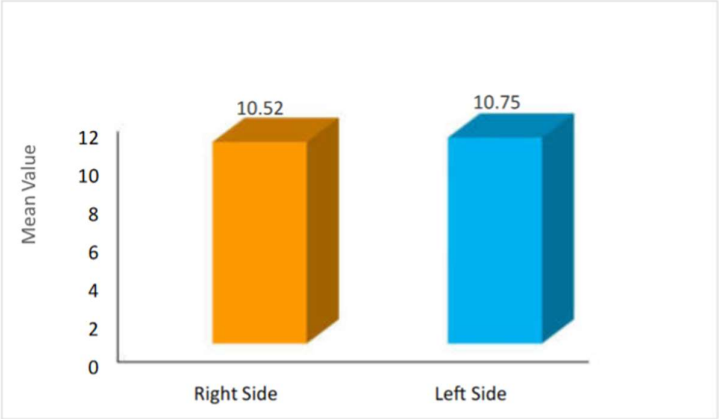
Table 3: Interpedicular Distance (mm) of Typical Lumbar Vertebrae

Pedicle Distance (mm)		P value
Mean	17.34	0.98
Standard Deviation	2.07	

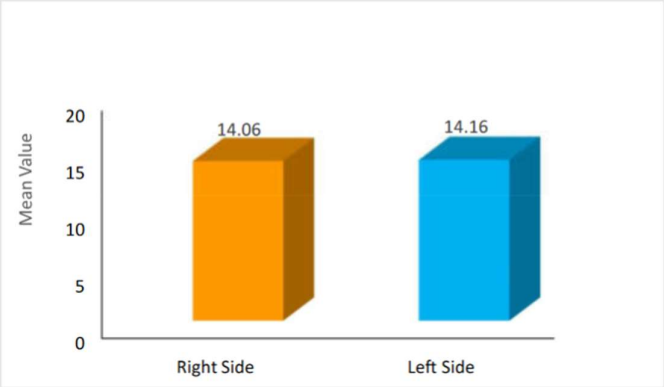
On the right side the mean pedicle width of atypical lumber vertebrae was found to be 10.52 mm (±2.82) and 14.06 mm (±2.23) while on left side mean pedicle width of atypical lumber vertebrae found to be 10.75 mm (±2.77) and 14.16 mm (±2.24) with a p value of 0.68and 0.82 which was found to be non-significant (Graph 3 and Graph 4) (Table 4 and 5).

Table 4- Pedicle Width in (mm) of Atypical Lumbar Vertebrae of both Right & Left sides

Pedicle Width (mm)	Right Side	Left Side	P value
Mean	10.52	10.75	0.68
Standard Deviation	2.82	2.77	



Graph 3: Pedicle Width in (mm) of Atypical Lumbar Vertebrae of both Right & Left sides



Graph 4: Pedicle Height in (mm) of Atypical Lumbar Vertebrae of both Right & Left sides

Table 5: Pedicle Height in (mm) of Atypical Lumbar Vertebrae of both Right & Left sides

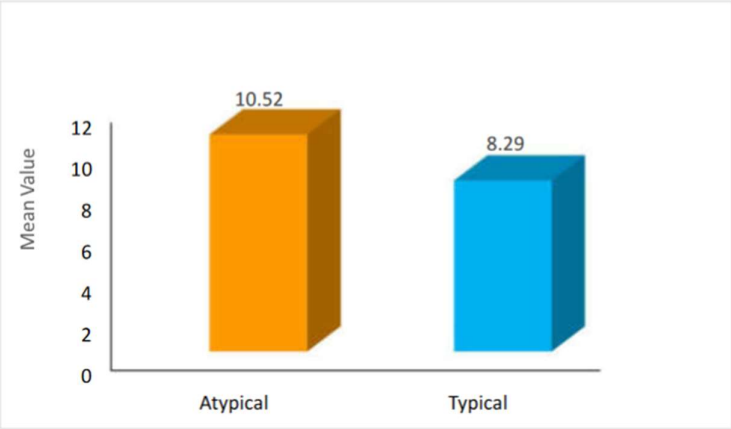
Pedicle Height (mm)	Right Side	Left Side	P value
Mean	14.06	14.16	0.82
Standard Deviation	2.23	2.24	

On the typical lumbar vertebrae Interpedicular Distance found to be 18.71mm (+3.99) with a p value of 1.00 which was found to be non-significant (Table 6).

Table 6: Interpedicular Distance in (mm) of Atypical Lumbar Vertebrae

Pedicular Distance (mm)		P value
Mean	18.71	1.00
Standard Deviation	3.99	

On the atypical lumbar vertebrae, the mean pedicle width of left side found to be 10.52mm (±2.82) while on typical lumbar vertebrae the mean pedicle width found to be 8.29 mm (±1.76) with a p value of <0.001 which was found to be highly significant (Graph 5) (Table 7).

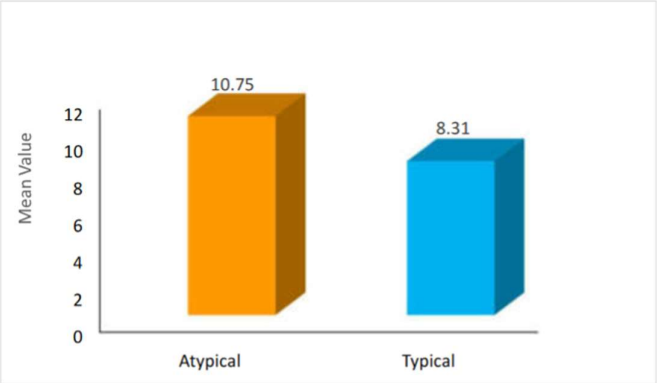


Graph 5: Comparison of Pedicle Width in (mm) on the right side between Atypical & Typical Lumbar Vertebrae

Table 7: Comparison of Pedicle Width in (mm) on the right side between Atypical & Typical Lumbar Vertebrae

Pedicle Width (mm)	Atypical	Typical	P value
Mean	10.52	8.29	<0.001
Standard Deviation	2.82	1.76	

On atypical lumbar vertebrae, the mean pedicle width found to be 10.75 mm (±2.77) while on typical lumbar vertebrae mean pedicle width found to be 8.31 mm (±1.92) with a p value of <0.001 which was found to be highly significant (Graph 6) (Table 8).

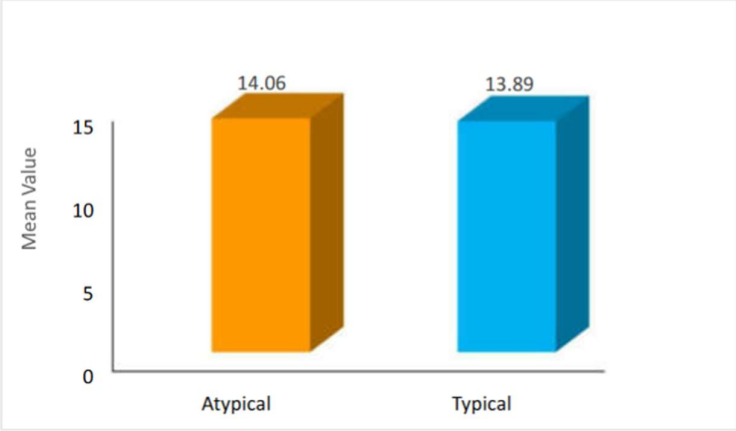


Graph 6: Comparison of Pedicle Width in (mm) on the left side between Atypical & Typical Lumbar Vertebrae

Table 8: Comparison of Pedicle Width in (mm) on the left side between Atypical & Typical Lumbar Vertebrae (SD = standard deviation)

Pedicle Width (mm)	Atypical	Typical	P value
Mean	10.75	8.31	<0.001
Standard Deviation	2.77	1.92	

On the atypical lumbar vertebrae, the mean pedicle height of right side found to be 14.06mm (±2.23) while on typical lumbar vertebrae the mean pedicle height found to be 13.89 mm (±1.49) with a p value of 0.65 which was found to be non-significant (Graph 7) (Table9).

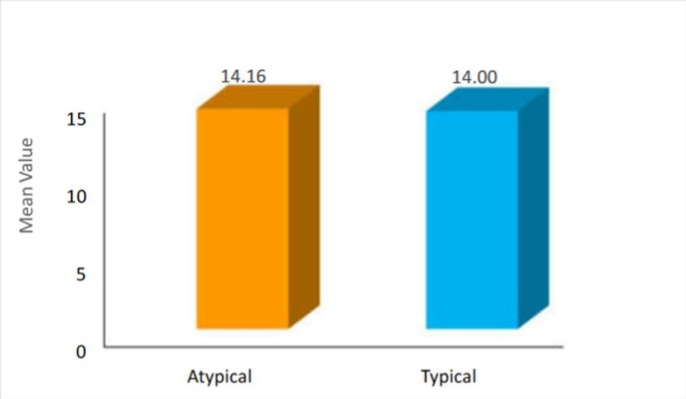


Graph 7: Comparison of Pedicle Height in (mm) on the right side between Atypical & Typical Lumbar Vertebrae

Table 9: Comparison of Pedicle Height in (mm) on the right side between Atypical & Typical Lumbar Vertebrae

Pedicle Height (mm)	Atypical	Typical	P value
Mean	14.06	13.89	0.65
Standard Deviation	2.23	1.49	

On the atypical lumbar vertebrae, the mean pedicle height of left side found to be 14.16mm (±2.24) while on typical lumbar vertebrae the mean pedicle height found to be 14.00 mm (±1.35) with a p value of 0.66 which was found to be non-significant (Graph 8) (Table 10).

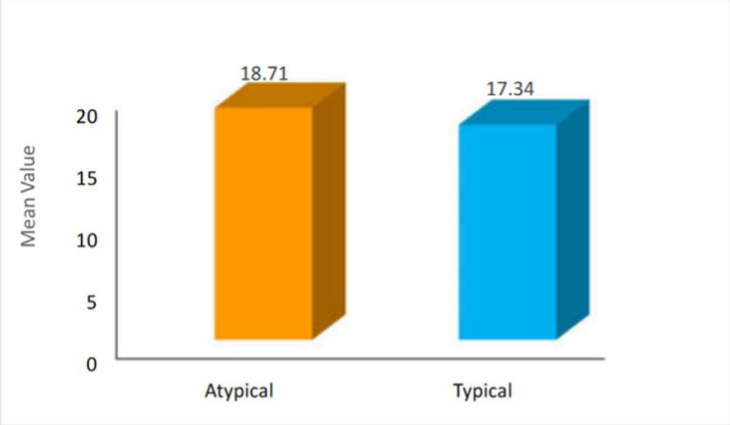


Graph 8: Comparison of Pedicle Height in (mm) on the left side between Atypical & Typical Lumbar Vertebrae

Table 10: Comparison of Pedicle Height in (mm) on the left side between Atypical & Typical Lumbar Vertebrae

Pedicle Height (mm)	Atypical	Typical	P value
Mean	14.16	14.00	0.66
Standard Deviation	2.24	1.35	

On the atypical lumbar vertebrae, the Interpedicular Distance found to be 18.71mm (±3.99) while on typical lumbar vertebrae the Interpedicular Distance found to be 17.34 mm (±2.07) with a p value of 0.003 which was found to be significant (Graph 9) (Table 11).



Graph 9: Comparison of Interpedicular Distance (mm) between Atypical & Typical Lumbar Vertebrae

Table 11: Comparison of Interpedicular Distance (mm) between Atypical & Typical Lumbar Vertebrae

Pedicle Distance (mm)	Atypical	Typical	P value
Mean	18.71	17.34	0.003 (S)
Standard Deviation	3.99	2.07	

In the present study, the measurements of both typical and atypical lumbar vertebrae were analysed, focusing on pedicle height, pedicle width, and interpedicular distance. On the right side of the typical vertebrae, the mean pedicle height was found to be 13.89 mm (±1.49) and pedicle width was 8.29 mm (±1.76). For the left side, similar measurements were observed with a mean pedicle height of 14 mm (±1.35) and pedicle width of 8.31 mm (±1.92), and with interpedicular distance of 17.33 mm (±2.07) of both sides. The comparison within the group showed no significant differences between the right and left sides for any of the variables, as indicated by the p-values (all > 0.05).

For atypical lumbar vertebrae, the right side displayed a mean pedicle height of 14.06 mm (±2.23), and pedicle width of 10.52 mm (±2.82). Similarly, the left side had a mean pedicle height of 14.16 mm (±2.24), and pedicle width of 10.75 mm (±2.77), with interpedicular distance of 18.71 mm (±3.98) of both sides. A comparison within the group showed significant differences in pedicle width ($p = 0.012$) but not in pedicle height or interpedicular distance ($p > 0.05$). When comparing between typical and atypical lumbar vertebrae, significant differences were observed in pedicle width ($p < 0.001$), whereas pedicle height and interpedicular distance did not show significant variation ($p > 0.05$). These findings highlight distinct morphological differences, particularly in pedicle width, between typical and atypical lumbar vertebrae, suggesting structural adaptations in atypical vertebrae.

Discussion:

The findings of this study provide a detailed examination of the measurements of both typical and atypical lumbar vertebrae, with specific focus on pedicle height, pedicle width, and interpedicular distance. These measurements are crucial for understanding vertebral anatomy, which has direct implications for spinal surgery, orthopaedic interventions, and clinical diagnostics. The study revealed that the mean pedicle height and pedicle width were consistent across both the left and right sides of typical lumbar vertebrae with interpedicular distance with no significant difference observed ($p > 0.05$). This symmetry is clinically important, as it suggests that interventions or assessments based on these parameters can be reliably generalized across both sides of the spine.

For example, during procedures such as pedicle screw placement in spinal fusion surgeries, symmetrical measurements provide a solid basis for planning, ensuring that one side does not require special consideration over the other. In contrast, the measurements of atypical lumbar vertebrae presented distinct characteristics. The pedicle width was notably larger in atypical vertebrae (mean of 10.52 mm on the right and 10.7 mm on the left) compared to the typical vertebrae (mean of 8.29 mm on the right and 8.31 mm on the left). This difference was statistically significant ($p < 0.001$), underscoring the structural deviations in atypical lumbar vertebrae. The larger pedicle width in atypical vertebrae may reflect adaptations to support greater biomechanical loads or variations in anatomical development. This finding is of particular relevance for orthopaedic surgeons, as atypical vertebrae may require different surgical approaches or hardware dimensions to ensure optimal patient outcomes.

Previous studies have also demonstrated that the lumbar vertebrae exhibit significant variation in their anatomy, especially when comparing typical to atypical vertebrae. The consistency in pedicle height and width measurements observed in this study aligns with earlier research on vertebral symmetry, reinforcing the understanding that these dimensions are critical for spinal stability and function. However, the significant difference in pedicle width between typical and atypical vertebrae offers a new perspective, indicating that surgeons and clinicians should be mindful of these variations when planning interventions (Choubisa and Babel, 2018; Londhe et al., 2022; Ashish, 2023).

Additionally, the interpedicular distance did not show significant variation between typical and atypical vertebrae ($p > 0.05$). This suggests that while pedicle width may vary, the space between the pedicles remains consistent, which is an important consideration for spinal canal assessments and ensuring sufficient space for nerve roots in surgical planning. The findings from this study have practical implications for both surgical planning and clinical diagnostics. The wider pedicles in atypical lumbar vertebrae could present both advantages and challenges in spinal surgeries. Surgeons could take advantage of the larger pedicle width for more secure pedicle screw placement, reducing the risk of misplacement or hardware failure (Ashish et al., 2022; Priya et al., 2023).

However, this also requires careful preoperative imaging and planning, particularly in patients with atypical vertebral anatomy, to avoid complications. Moreover, understanding these anatomical differences is also crucial for developing personalized treatment plans. In patients with atypical lumbar vertebrae, individualized approaches may be necessary to accommodate the wider pedicle dimensions, ensuring that treatment is both safe and effective. This study highlights the need for thorough pre-surgical evaluation and customized surgical techniques, especially in cases involving vertebral anomalies.

Conclusion

This study highlights significant differences in pedicle width between typical and atypical lumbar vertebrae, with important implications for surgical planning and clinical practice. The symmetry in pedicle height across both sides and interpedicular distance reinforces the reliability of these measurements for clinical applications. However, the greater width of pedicles in atypical vertebrae emphasizes the need for personalized surgical approaches. These findings contribute to a growing body of literature on vertebral anatomy, offering insights that can improve patient care and outcomes in spinal surgery and orthopedic interventions.

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