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ORIGINAL ARTICLE

Pedicle morphometry of the lumbar spine in a sample of the Mexican population, measured by computed tomography

Morfometría pedicular de columna lumbar en una muestra de población mexicana, medida por tomografía computarizada

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Abstract

Background: *The greatest purchase of a screw in the lumbar spine occurs in the pedicle. This makes it important to have the largest diameter possible without damaging its walls.* **Objective:** *The aim of the study was to determine lumbar pedicle parameters in a population sample from Mexico City, to properly select the screw for use in lumbar spine surgery.* **Material and methods:** *Sixty patients, aged 20-70 years, were evaluated. Computed tomography (CT) scans measured the internal and external cortical pedicle height, internal and external cortical pedicle width, and the convergence angle in each lumbar pedicle. Descriptive statistics and the Mann-Whitney U test were used to determine the difference between means by sex and segment.* **Results:** *The mean age was 51.7 and 49.7 years in men and women, respectively. In women, the internal cortical pedicle width was smaller from L1 to L4, and the internal cortical pedicle height was smaller at L5. In men, the inner cortical pedicle width was narrower from L1 to L3, and the inner cortical pedicle height was narrower at L4 and L5. The angle of convergence was narrower at L1 and gradually increased up to L5 in both men and women.* **Conclusions:** *In women, 5.0 mm screws are safe for L4 and L5, and 4.0 mm screws are safe for L1-L3. In men, 5.0 mm screws are safe for L1 and L2, and 5.5 mm screws are safe for L3. At L4 and L5, 5.5 mm screws are safe.*

Keywords: *Pedicle. Screw. Lumbar spine.*

Resumen

Antecedentes: *El mayor agarre del tornillo en columna lumbar se da en el pedículo. De ahí la importancia de que el diámetro de este tornillo sea el mayor posible que pueda soportar sin llegar a dañar sus paredes.* **Objetivo:** *Conocer los parámetros pediculares lumbares en una muestra poblacional de la Ciudad de México, para seleccionar adecuadamente el tornillo a utilizar en cirugía de columna lumbar.* **Material y métodos:** *Se evaluaron 60 pacientes, de 20 a 70 años. En tomografía se midieron en cada pedículo lumbar la altura pedicular cortical interna y externa, anchura pedicular cortical interna y externa, y el ángulo de convergencia. Se utilizó estadística descriptiva y U de Mann-Whitnney para diferencia entre medias por sexo y segmento.* **Resultados:** *La edad media fue 51.7 y 49.7 años en hombres y mujeres, respectivamente.*

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Date of reception: 27-06-2025
Date of acceptance: 01-05-2026
DOI: 10.24875/AMH.M26000158

Available online: 24-07-2026
An Med ABC. 2026;71(3):179-187
www.analesmedicosabc.com

En mujeres, la anchura pedicular cortical interna fue menor de L1 a L4, en L5 fue la altura pedicular cortical interna. En hombres, la anchura pedicular cortical interna fue menor de L1 a L3, en L4 y L5 fue la altura pedicular cortical interna. El ángulo de convergencia fue menor en L1 e incrementó gradualmente hasta L5 en hombres y mujeres. **Conclusiones:** *En mujeres, tornillos de 5.0 mm son seguros para L4 y L5, para L1 a L3 serían los tornillos de 4.0 mm. En hombres, tornillos de 5.0 mm serían seguros para L1 y L2, en L3 los tornillos de diámetro 5.5 mm. En L4 y L5, son seguros tornillos de 5.5.*

Palabras clave: *Pedículo. Tornillo. Columna lumbar.*

Introduction

Transpedicular screws have been widely used in pathologies requiring alignment correction to maintain stability and promote adequate fusion in patients with fractures, spondylolisthesis, tumors, or scoliosis.

The most important factors affecting screw stability are: screw size, insertion depth, orientation, insertion technique, and bone mineral density[1].

With the increased use of these screws, potential complications may increase, including screw malposition, infection, pseudoarthrosis, nerve irritation, and screw or rod breakage[2].The presence of these complications plays an important role since, apart from poor clinical outcomes, they increase the cost related to medical care and the patient's loss of productivity[3].To minimize the risks of complications and costs derived from them, adequate pre-operative planning is essential.

The pedicle is a cylinder of bone located between the lamina and the vertebral body and has an outstanding function in the stability of these screws.

Biomechanical studies recommend that a screw should be chosen that has a diameter close to the internal pedicle diameter to achieve a good interface, a recommendation valid for vertebrae with normal bone quality[4].

In studies of screw pullout resistance, the pedicle provides 60% axial resistance and 80% stiffness, which suggests that the pedicle plays an important role in vertebral biomechanics and postoperative recovery. Many academics agree that pedicle width and height are the most important anatomical parameters of this structure[5].

The inner pedicle diameter is very important in screw placement to achieve safe placement and strong stabilization[6]. It has been observed that screw pullout forces are greater when the screw diameter fills more than 80% of the pedicle and lower when this percentage is < 80%[7].

Cadaver studies have reported that plastic deformity occurs in the pedicle, and this precedes fracture when the threads are larger than the endosteal diameter or when the screw diameter is > 80% of the external cortical diameter[8].

The importance of the pedicle for lumbar fixations is such that multiple studies of pedicle morphometry have been conducted in various populations to determine the appropriate diameter and angulation of screws in the lumbar region. In our country, there is only one registered study conducted on cadavers regarding pedicle morphometry.

The objective of this study is to create a database focused on the Mexican population regarding pedicle morphometry and to determine if there are differences between males and females.

Materials and methods

Retrospective study of pedicle morphometry of 60 patients, performing measurements on computed tomography (CT) scans taken between January and December 2022 were done. CT scans taken of the lumbar spine with 3 mm cuts were reviewed, using a Siemens Somatom Perspective scanner at a tertiary care hospital.

Study population

The CT scans of 60 patients were evaluated, 30 men and 30 women, aged between 20 and 70 years, who attended the outpatient clinic for lumbar pain and to whom non-surgical treatment was provided.

Patients younger than 20 years and older than 70 years, patients presenting fractures of the lumbar spine, tumors, spondylolisthesis, previous lumbar spine surgery, and vertebral deformities were excluded from this study.

Measurements

The internal and external cortical pedicle width was measured; these measurements were performed on an axial projection for both the left and right pedicles at the level of the pedicle isthmus, and the values were recorded in millimeters (Fig. 1).

The pedicle convergence angle was measured in degrees for each pedicle from L1 to L5 (Fig. 2).

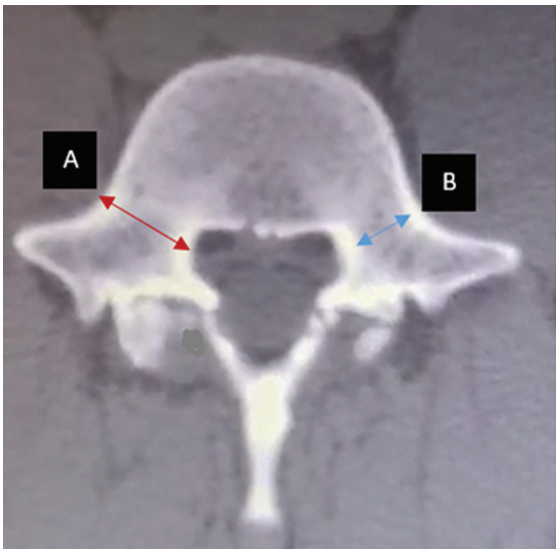

Figure 1. Simple computed tomography scan showing an axial cut of L5. **A:** external cortical width and **B:** internal cortical width.

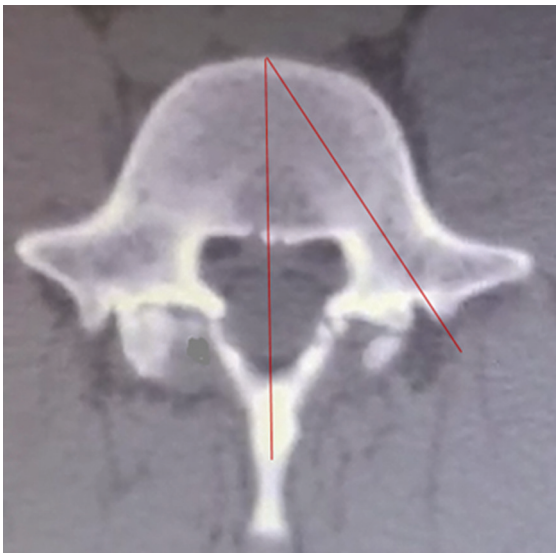

Figure 2. Simple computed tomography scan showing an axial cut of L5. The pedicle convergence angle is shown.

The internal and external cortical pedicle height was measured in a parasagittal projection for both the left and right pedicle at the level of the pedicle isthmus, and the values were recorded in millimeters (Figs. 3 and 4).

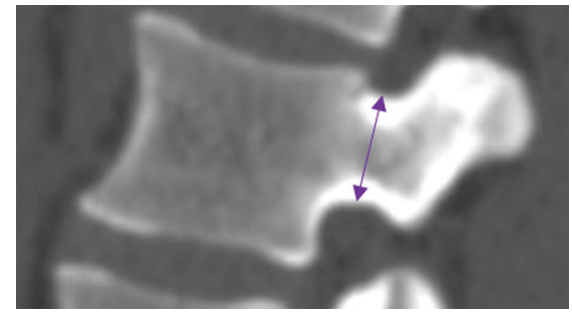

Figure 3. Simple computed tomography scan showing a parasagittal cut of L2. The arrow schematizes the external cortical height.

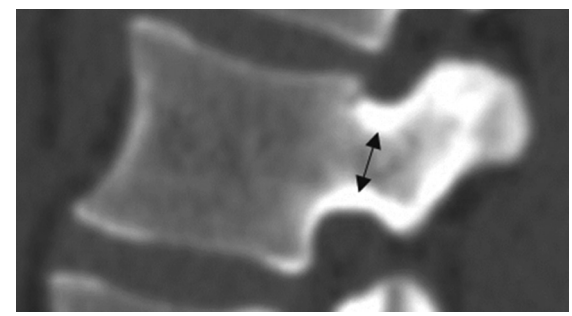

Figure 4. Simple computed tomography scan showing a parasagittal cut of L2. The arrow schematizes the internal cortical pedicle height.

Statistical analysis

The differences in these parameters in women and men were evaluated using the Mann-Whitney U statistical test, and $p < 0.05$ was accepted as an indication of statistical significance.

This research work complies with the ethical aspects in research matters, respects the principles of privacy, dignity, and well-being of the participants, and the anonymity of the participants was maintained at all times.

Results

The mean age was 51.7 ± 13 and 49.7 ± 12.6 years, for men and women, respectively.

At L1, the smallest parameter found in men was the internal cortical pedicle width, and the mean was 4.8 ± 2.7 and 3.67 ± 2.87 mm for right and left pedicles, respectively. The right and left pedicle convergence

Table 1. Pedicle parameters of L1 vertebra

Variables	Sex	Mean	SD	Mean difference	p
Internal cortical pedicle height_r	Men	7.83	4.28	1.05	0.328
	Women	6.77	3.27		
Internal cortical pedicle height_l	Men	5.78	4.99	0.31	0.882
	Women	5.47	3.79		
External cortical pedicle height_r	Men	12.61	5.52	3.04	0.219
	Women	9.56	5.93		
External cortical pedicle height_l	Men	8.81	7.52	–0.31	0.175
	Women	9.12	5.58		
Internal cortical pedicle width_r	Men	4.8	2.69	1.49	0.946
	Women	3.31	1.86		
Internal cortical pedicle width_l	Men	3.67	2.87	0.29	0.894
	Women	3.38	1.8		
External cortical pedicle width_r	Men	6.95	3.92	1.89	0.629
	Women	5.05	2.73		
External cortical pedicle width_l	Men	5.36	4.01	–0.035	0.152
	Women	5.4	2.65		
Convergence angle_r	Men	14.1	10.1	2.6	0.488
	Women	11.5	10.1		
Convergence angle_l	Men	17.4	8.7	–5.3	0.111
	Women	12.7	40.1		

A $p < 0.05$ was considered statistically significant.
r: right; l: left; SD: standard deviation; p: probability.

angles were 14.1 ± 1 and 17.4 ± 0.9°, respectively. In women, the internal cortical pedicle width was the smallest parameter found; the mean was 3.3 ± 1.8 mm for both pedicles, with a convergence angle of 11.5 ± 1 and 12.7 ± 4° for right and left pedicles, respectively. In all parameters evaluated for L1, there were no statistically significant differences (Table 1).

At L2, the smallest parameter found in men was the internal cortical pedicle width, and the mean was 4.9 ± 2.2 and 3.8 ± 2.7 mm in right and left pedicles, respectively. The right and left pedicle convergence angles were 15 ± 1 and 18.4 ± 0.8°, respectively. In women, the internal cortical pedicle width was the smallest parameter found; the mean was 3.1 ± 1.9 and 3.4 ± 1.8 mm in right and left pedicles, respectively, with a convergence angle of 16.9 ± 0.9 and 18.4 ± 0.8° for right and left pedicles, respectively. In all parameters evaluated for L2, there were no statistically significant differences (Table 2).

At L3, the smallest parameter found in men was the internal cortical pedicle width, and the mean was 5.47 ± 2.98 and 5.5 ± 3.06 mm in right and left pedicles, respectively. The right and left pedicle convergence angles were 16.5 ± 1.09 and 19.5 ± 0.97°, respectively. In women, the internal cortical pedicle width was the smallest parameter found, the mean was 4.1 ± 2 and 4.03 ± 2.38 mm in right and left pedicles, respectively, with a convergence angle of 16.5 ± 1 and 19.5 ± 0.9° for right and left pedicles, respectively. In all parameters evaluated for L3, there were no statistically significant differences (Table 3).

At L4, the smallest parameter found in men was the internal cortical pedicle height, and the mean was 7.11 ± 3.77 and 3.66 ± 4.07 mm in right and left pedicles,

Table 2. Pedicle parameters of L2 vertebra

Variables	Sex	Mean	SD	Mean difference	p
Internal cortical pedicle height_r	Men	7.29	3.52	2.36	0.372
	Women	4.93	3.42		
Internal cortical pedicle height_l	Men	5.04	4.15	0.69	0.174
	Women	4.34	3.73		
External cortical pedicle height_r	Men	11.58	5.99	2.07	0.25
	Women	9.5	4.92		
External cortical pedicle height_l	Men	11.61	6.18	3.45	0.96
	Women	8.15	5.69		
Internal cortical pedicle width_r	Men	4.92	2.19	1.82	0.249
	Women	3.09	1.98		
Internal cortical pedicle width_l	Men	3.78	2.69	0.4	0.735
	Women	3.38	1.77		
External cortical pedicle width_r	Men	7.77	2.66	2.66	0.166
	Women	5.11	2.74		
External cortical pedicle width_l	Men	6.78	3.29	1.71	0.213
	Women	5.07	2.76		
Convergence angle_r	Men	15	1	–1.9	0.274
	Women	16.9	9.1		
Convergence angle_l	Men	18.8	7.7	0.43	0.788
	Women	18.4	8.2		

A $p < 0.05$ was considered statistically significant.
r: right; l: left; SD: standard deviation; p: probability.

respectively. The right and left pedicle convergence angles were 17.5 ± 1.25 and 20.8 ± 1.12°, respectively. In women, the internal cortical pedicle width was the smallest parameter found; the mean was 4.59 ± 2.52 and 4.55 ± 2.84 mm in right and left pedicles, respectively, with a convergence angle of 21.4 ± 1.15 and 16.2 ± 1.28° for right and left pedicles, respectively. There were statistically significant differences for the internal cortical pedicle height; in the rest of the evaluated parameters, there were no significant differences (Table 4).

At L5, the smallest parameter found in men was the internal cortical pedicle height, and the mean was 6.52 ± 4.21 and 6.65 ± 5.03 mm in right and left pedicles, respectively. The right and left pedicle convergence angles were 17.7 ± 1.49 and 19 ± 1.53°, respectively. In women, the internal cortical pedicle height was the smallest parameter found, the mean was 5.22 ± 3.04 and 4.76 ± 3.27 mm in right and left pedicles, respectively, with a convergence angle of 30.6 ± 5.7 and 28.5 ± 1.31° for right and left pedicles, respectively. There were statistically significant differences for the internal cortical pedicle width; in the rest of the evaluated parameters, there were no significant differences (Table 5).

The mean of the internal and external pedicle width and the convergence angle gradually increased from L1 to L5 in both men and women.

Discussion

In the present study, emphasis was placed on the internal and external cortical diameters of the pedicle isthmus and on the pedicle convergence angle.

Based on the results obtained regarding the internal cortical pedicle width for L1 and L2 in males, it is possible to safely place screws with a diameter of 5.0 mm,

Table 3. Pedicle parameters of L3 vertebra

Variables	Sex	Mean	SD	Mean difference	p
Internal cortical pedicle height_r	Men	7.7	3.47	1.68	0.241
	Women	6.02	3.29		
Internal cortical pedicle height_l	Men	4.94	4.19	0.23	0.785
	Women	4.71	3.57		
External cortical pedicle height_r	Men	9.87	6.41	–0.57	0.257
	Women	10.45	4.33		
External cortical pedicle height_l	Men	7.61	7.07	–3.16	0.517
	Women	10.78	4.11		
Internal cortical pedicle width_r	Men	5.47	2.98	1.36	0.528
	Women	4.1	2		
Internal cortical pedicle width_l	Men	5.5	3.06	1.47	0.668
	Women	4.03	2.38		
External cortical pedicle width_r	Men	7.89	4.14	0.98	0.08
	Women	6.91	1.88		
External cortical pedicle width_l	Men	8.13	4.36	1.21	0.834
	Women	6.92	2.44		
Convergence angle_r	Men	16.5	1.09	0	0.436
	Women	16.5	1.09		
Convergence angle_l	Men	19.5	0.97	0	0.199
	Women	19.5	0.95		

A $p < 0.05$ was considered statistically significant.
r: right; l: left; SD: standard deviation; p: probability.

and in the pedicles of L3, the use of 5.5 mm screws would be allowed; in pedicles of L4 and L5, the placement of screws with a diameter of 5.5 mm would be safe and up to 6.5 mm with a higher risk of plastic deformity of the pedicle.

In women, regarding the internal pedicle width, it is observed that the placement of screws with a diameter of 4.0 mm is safe from L1 to L3, with a risk of presenting plastic deformity in L1 and L2 despite the small diameter of the screw; for vertebrae L4 and L5, the safe screw diameter would be 5.0 mm.

With the safe measurements found for the Mexican population, the recommendation of Acharya et al.[9] is agreed upon, who in their study concluded that the use of 7 mm diameter screws in upper lumbar levels is not justified because it can generate violation of the pedicle isthmus and lead to neurological complications.

Regarding the internal cortical pedicle width, values lower than those reported by Olmos-Alfonso et al.[10] in the Spanish population were found. While the values reported by Li et al. were similar compared to this study, as were those reported by Zhe-Heng et al.[11,12] The results obtained for external pedicle width by Urrutia-Vega et al.[13] in their study conducted on 60 cadavers are similar to the values found in men; the results of this study in women were lower.

The measurements of the internal and external pedicle width showed a gradual increase from L1, with the values obtained at L5 being higher for women and men; this trend was similar to that found by Sugisaki et al[14].

In the results obtained for the internal and external pedicle height, a gradual decrease was found, being higher at L1 and lower at L5, in both men and women. These results contrast with those found by Torun et al.[15], who reported that these values practically

Table 4. Pedicle parameters of L4 vertebra

Variables	Sex	Mean	SD	Mean difference	p
Internal cortical pedicle height_r	Men	7.11	3.77	0.91	0.635
	Women	6.19	2.48		
Internal cortical pedicle height_l	Men	3.66	4.07	–1.13	0.018
	Women	4.79	3.28		
External cortical pedicle height_r	Men	9.94	5.48	0.9	0.331
	Women	9.04	4.21		
External cortical pedicle height_l	Men	8.45	6.18	–0.21	0.953
	Women	8.67	4.59		
Internal cortical pedicle width_r	Men	6.39	2.99	1.8	0.141
	Women	4.59	2.52		
Internal cortical pedicle width_l	Men	4.98	3.92	0.42	0.435
	Women	4.55	2.84		
External cortical pedicle width_r	Men	9.22	4.06	2.93	0.084
	Women	6.28	4.01		
External cortical pedicle width_l	Men	9.69	3.67	2.2	0.679
	Women	7.48	3.45		
Convergence angle_r	Men	17.5	1.25	–3.8	0.825
	Women	21.4	1.15		
Convergence angle_l	Men	20.8	1.12	4.5	0.764
	Women	16.2	1.28		

A $p < 0.05$ was considered statistically significant.
r: right; l: left; SD: standard deviation; p: probability.

remain constant in all lumbar vertebrae in men and women. The results in these parameters were similar to those reported by Cook and Baker[16] in a Maori population, where pedicle height values decreased gradually, being higher at L1 and lower at L5.

The measurements obtained for the external cortical pedicle height in males were similar to those reported by Singel et al. in Gujarat, India. The results in women for this same parameter were similar to those reported by Verma and Agrawal in their study on dry lumbar specimens[17].

Regarding the pedicle convergence angle, a gradual increase was found; the angle was smaller at L1 and larger at L5; this was true for both women and men. This trend was similar to that reported by Chen et al.[18] and by Zindrick et al.[19], in Chinese volunteers and in their cadaver study, respectively.

In this population sample, the pedicle convergence angle was greater at L5, but these values were lower than those reported by Grivas et al.[20] in a Greek population.

Conclusion

This study provides a database on pedicle morphometry specific to the Mexican population sample. The mean values obtained will help us to adequately select the diameter of the transpedicular screw required to be applied for each lumbar vertebra. In the population studied, 5.0 mm diameter screws are safe for pedicles of vertebrae L1 and L2, and 5.5 mm screws are safe for placement from L3 to L5 in men. In women, it is safe to use screws with a diameter of 5.0 mm at L4 and L5; while from L1 to L3, the safe diameter is 4.0 mm, with an increase in plastic deformity in these vertebrae.

Table 5. Pedicle parameters of L5 vertebra

Variables	Sex	Mean	SD	Mean difference	p
Internal cortical pedicle height_r	Men	6.52	4.21	1.29	0.361
	Women	5.22	3.04		
Internal cortical pedicle height_l	Men	6.65	5.03	1.89	0.386
	Women	4.76	3.27		
External cortical pedicle height_r	Men	9.65	6.56	1.16	0.153
	Women	8.49	4.31		
External cortical pedicle height_l	Men	8.68	7.05	0.76	0.451
	Women	7.92	4.54		
Internal cortical pedicle width_r	Men	6.77	4.71	0.36	0.453
	Women	6.4	3.45		
Internal cortical pedicle width_l	Men	8.78	2.92	2.4	0.011
	Women	6.38	3.75		
External cortical pedicle width_r	Men	10.06	5.53	0.71	0.861
	Women	9.34	5.09		
External cortical pedicle width_l	Men	10.02	6.01	–0.07	0.524
	Women	10.1	4.38		
Convergence angle_r	Men	17.7	1.49	–12.8	0.431
	Women	30.6	5.7		
Convergence angle_l	Men	19	1.53	–9.5	0.706
	Women	28.5	1.31		

A $p < 0.05$ was considered statistically significant.
r: right; l: left; SD: standard deviation; p: probability.

Funding

The authors declare that they have not received funding.

Conflicts of interest

J. Loría-Castellanos is a member of the editorial committee of the journal *Anales Médicos*. The other authors declare no conflicts of interest.

Ethical considerations

Protection of human subjects and animals. The authors declare that no experiments on humans or animals were performed for this research.

Confidentiality, informed consent, and ethical approval. The authors have obtained approval from the Ethics Committee for the analysis of routinely collected and anonymized clinical data; therefore, individual informed consent was not required. Relevant ethical recommendations have been followed.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing or creation of the content of this manuscript.

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