

MORPHOMETRIC PARAMETERS OF THE AXIS RELATED TO INTRALAMINAR FIXATION

PARÂMETROS MORFOMÉTRICOS DO ÁXIS RELACIONADOS COM A FIXAÇÃO INTRALAMINAR

PARÁMETROS MORFOMÉTRICOS DEL ÁXIS RELACIONADOS CON LA FIJACIÓN INTRALAMINAR

VITOR ARAÚJO GONÇALVES¹ , MATHEUS PIPPA DEFINO¹ , GABRIEL MATTOS GOES¹ , THIAGO DE OLIVEIRA DORIGÃO¹ , HELTON LUIZ APARECIDO DEFINO¹ 

1. Universidade de São Paulo (USP), Ribeirão Preto Medical School, Department of Orthopaedia and Anesthesiology, São Paulo, SP, Brazil.

ABSTRACT

Objective: To evaluate the morphometric parameters of the C2 (axis) lamina related to the intralaminar fixation technique and compare the dimensions between sexes. **Methods:** Descriptive anatomical study of 59 C2 vertebrae from cadavers (30 male and 29 female). Seven morphometric parameters were bilaterally measured by four independent examiners using a standard analog caliper. Statistical analysis included normality tests, t-Student, Mann-Whitney, and Kruskal-Wallis. **Results:** Morphometric measurements showed significant differences between sexes, with greater values in males ($p < 0.05$). Lamina thickness was less than 4 mm in 25.20% of cases, more frequently in females. **Conclusions:** Intralaminar fixation of the axis must account for anatomical variations, particularly in females. Lamina thickness below 4 mm limits the safe use of 3.5 mm screws, emphasizing the need for detailed preoperative assessment. **Level of Evidence IV; Descriptive Anatomical Observational Study.**

Keywords: Anatomy; Axis, Cervical Vertebra; Bone Fixation; Spine; Anthropometry.

RESUMO

Objetivo: Avaliar os parâmetros morfométricos da lâmina da vértebra C2 (eixo) relacionados à técnica de fixação intralaminar e comparar as dimensões entre os sexos. **Métodos:** Estudo anatômico descritivo realizado com 59 vértebras C2 provenientes de cadáveres (30 masculinos e 29 femininos). Sete parâmetros morfométricos foram mensurados bilateralmente por quatro avaliadores utilizando paquímetro analógico. **Análises estatísticas** incluíram testes de normalidade, t-Student, Mann-Whitney e Kruskal-Wallis. **Resultados:** As medidas morfométricas apresentaram variações significativas entre os sexos, sendo maiores no sexo masculino ($p < 0,05$). A espessura da lâmina foi inferior a 4 mm em 25,20% dos casos, sendo mais frequente em mulheres. **Conclusões:** A técnica de fixação intralaminar do eixo deve considerar as variações anatômicas, especialmente em mulheres. A espessura inferior a 4 mm limita o uso seguro de parafusos de 3,5 mm, reforçando a necessidade de avaliação pré-operatória detalhada. **Nível de Evidência IV; Estudo Observacional Descritivo Anatômico.**

Descritores: Anatomia; Vértebra Cervical Áxis; Fixação Óssea; Coluna Vertebral; Antropometria.

RESUMEN

Objetivo: Evaluar los parámetros morfométricos de la lámina de la vértebra C2 (eje) relacionados con la técnica de fijación intralaminar y comparar las dimensiones entre sexos. **Métodos:** Estudio anatómico descriptivo con 59 vértebras C2 de cadáveres (30 masculinas y 29 femeninas). Siete parámetros morfométricos fueron medidos bilateralmente por cuatro evaluadores utilizando calibrador analógico. Se aplicaron pruebas de normalidad, t-Student, Mann-Whitney y Kruskal-Wallis. **Resultados:** Las medidas morfométricas mostraron diferencias significativas entre sexos, siendo mayores en los hombres ($p < 0,05$). El grosor de la lámina fue inferior a 4 mm en el 25,20% de los casos, con mayor frecuencia en mujeres. **Conclusiones:** La fijación intralaminar del eje debe considerar variaciones anatómicas, especialmente en mujeres. Un grosor inferior a 4 mm limita el uso seguro de tornillos de 3,5 mm, destacando la importancia de la evaluación preoperatoria. **Nivel de Evidencia IV; Estudio Observacional Anatómico Descriptivo.**

Descritores: Anatomía; Vértebra Cervical Axis; Fijación de Fractura; Columna Vertebral; Antropometría.

INTRODUCTION

The instability of the atlantoaxial complex caused by different etiologies (trauma, tumor, degenerative, infectious, congenital, failed previous surgery) requires the surgical stabilization of this segment of the spine, which can be obtained through arthrodesis.¹ The arthrodesis is performed, associated with the fixation of the atlantoaxial segment for the maintenance of correction and facilitation of the

consolidation of arthrodesis. The fixation of the atlantoaxial segment was initially carried out by circling with metallic wires (technique by Gallie, Brooks).¹ The fixation with metallic wires presents biomechanical limitations, requires external immobilization in the postoperative period, and reduces the index of consolidation of the arthrodesis.^{2,3} Fixation techniques that provide greater biomechanical stability were developed (transarticular fixation C1-C2- lateral mass C1-pars

Study conducted by the Orthopedics and Anesthesiology Department of the Ribeirão Preto Medical School of the Universidade de São Paulo, 3900, Bandeirante Ave., Vila Monte Alegre, Ribeirão Preto, SP, Brazil. 14049-900.

Correspondence: Vitor Araujo Gonçalves. Rua 3, Chacara 87, Setor Habitacional Vicente Pires, Brasília, DF, Brazil. 72005-785. vitor.ag17@gmail.com



articular, pedicle C2, or lamina of C2). The axis (C2) presents different options for the anchoring of the implants (transarticular fixation, pedicular fixation, lateral mass, and lamina), and its intralaminar portion represents one of the options for implant placement.¹⁻³ The intralaminar fixation technique of the axis was described by Wright (2004), and recommended the placement of bilateral screws inside the laminae of the axis (Figure 1). This technique was developed to avoid the risk of injury to the vertebral artery, related to the other techniques of axis fixation.³ Despite the simplicity of the technique described by Wright in relation to the other techniques, the rupture of the inner part of the lamina was observed with the implementation of this technique and motivated some technical modifications of this procedure, but retaining the intra-laminar placement of the implants.⁴ Although the morphometric characteristics of the axis related to the technique of intralaminar fixation have been described in the literature.⁵⁻⁸

The aim of the study was to evaluate the morphometric characteristics of the axis related to the technique of intralaminar fixation and to compare their dimensions in male and female sex.

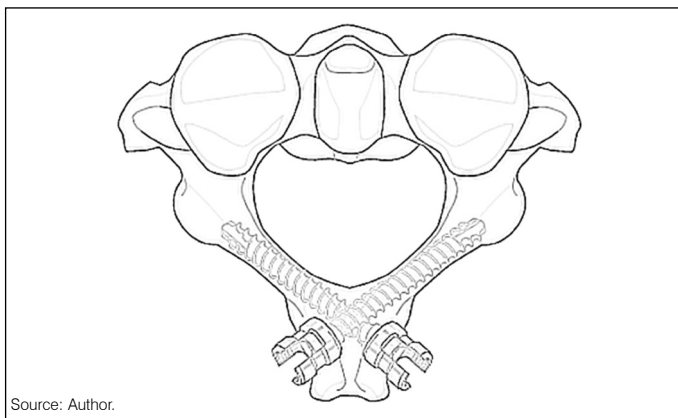


Figure 1. Figure of fixation of C2 lamina.

MATERIALS AND METHODS

59 C2 vertebrae (axis) from the Laboratory of Anatomy of the Faculty of Medicine of Ribeirão Preto - USP were used in the study. Thirty vertebrae were found in male and 29 in female bodies. The Term of Free and Informed Consent was not applied, as the study was conducted on anatomical pieces donated to the Department of Orthopaedia and Anesthesiology of the Faculty of Medicine of Ribeirão Preto - USP. All vertebrae were in a good state of preservation and with their anatomical characteristics preserved. This study was submitted for review and approved by the Ethics Committee (CAAE) number 81159324.7.0000.5440.

The anatomical parameters selected for the study were the dimensions of the lamina of the second cervical vertebra (axis) related to the technique of intralaminar fixation of this vertebra (Figure 2):

- Height of the pineal process (A.E.) - distance between the most cranial and caudal point of the pineal process.
- Lamina length (C. L) - distance between the base of the axis thinning process and the lamina junction with the lower joint facet.
- Lamina height (A. L.) - vertical distance from the upper and lower edge of the axis lamina.
- Angle between the laminae (\hat{A}) - angle formed by the lines of the superior surfaces of the laminae at the spinolaminar junction.
- Cranial thickness of the lamina (E.L.) - thickness of the lamina in the upper third of its middle part.
- Average lamina thickness - lamina thickness in the middle third of its middle part.
- Flow lamina thickness - lamina thickness in the lower third of the middle part of the lamina.

The measurements were carried out bilaterally by four

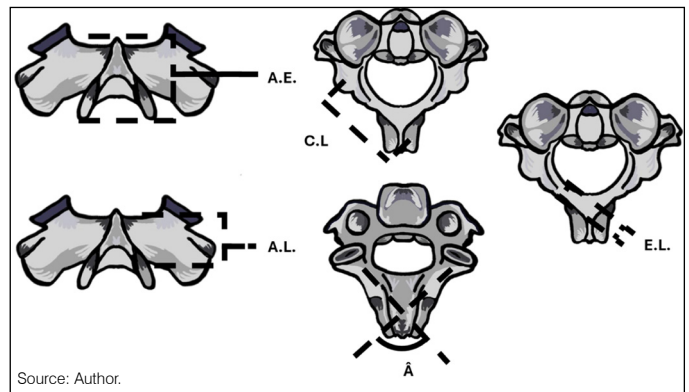


Figure 2. Figure of the study parameters.

independent evaluators using a universal analogue paquimeter 150mm/6" - 0.05mm/6".

The statistical study was conducted using descriptive statistics for continuous variables, the Shapiro-Wilk test to determine sample normality, the t-test, and the Kruskal-Wallis test for comparing parameters. The significance level was established at 5% ($p < 0.05$).

RESULTS

The values of the lamina angle ranged from 34 to 56 degrees (average 43.96 ± 4.54) on the right side and from 34 to 56 degrees (average 44.08 ± 4.78) on the left side. In females, it varied from 34 to 56 degrees (average 43.60 ± 4.70) on the right side, and from 36 to 56 degrees (average 43.67 ± 5.05) on the left side. In the male sex, it varied from 34 to 56 degrees on both sides, with an average of 44.30 ± 4.36 degrees on the right side and 44.48 ± 4.48 degrees on the left side. No statistical difference in lamina angle was observed between males and females. (Figure 3)

The distance from the spine process to half the lateral mass ranged from 20 to 34 mm (average 25.90 ± 2.56) on the right side and from 18-32 mm (average 25.79 ± 2.46) on the left side. In the female sex it varied from 20 to 30 mm (average 24.54 ± 2.09) on the right side and from 18 to 30 mm (average 24.59 ± 2.17) on the left side. In the male sex it varied from 20 to 30 mm (average 24.54 ± 2.09) on the right side, and from 18 to 30 mm (average 24.59 ± 2.17) on the left side. A statistical difference was observed between male and female (Kruskal-Wallis test - $p < 0.05$). (Figure 4)

The height of the pine process ranged from 7 to 21 mm (average 12.73 ± 2.32). In females it varied from 6 to 14 mm (average 10.25 ± 1.37), and from 10 to 21 mm (average 13.78 ± 2.36) in males. Statistical difference was observed between male and female values (Mann-Whitney test- $p < 0.0001$). (Figure 5)

The height of the lamina on the right side ranged from 7 to 26 mm

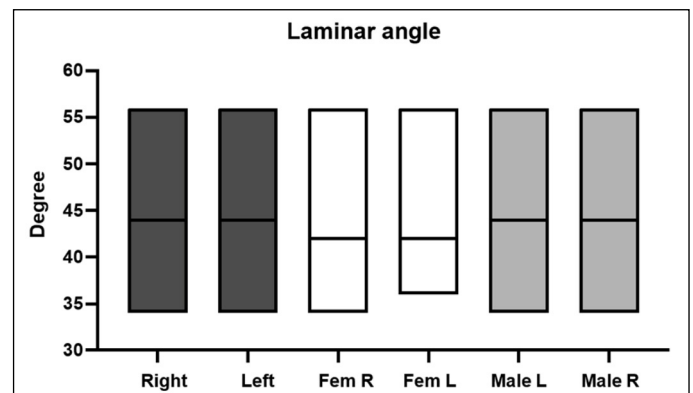


Figure 3. Graph illustrating the variation and average of the values of the lamina angle across the group, in both female and male sides.

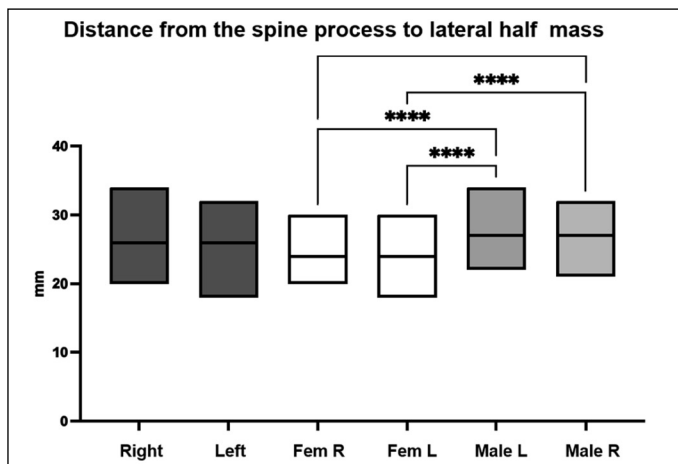


Figure 4. Graph illustrating the distance from the spinal process to the center of the lateral mass in the entire group, in male and female. The asterisk (*) indicates Mann-Whitney test statistical difference – $p < 0.0001$.

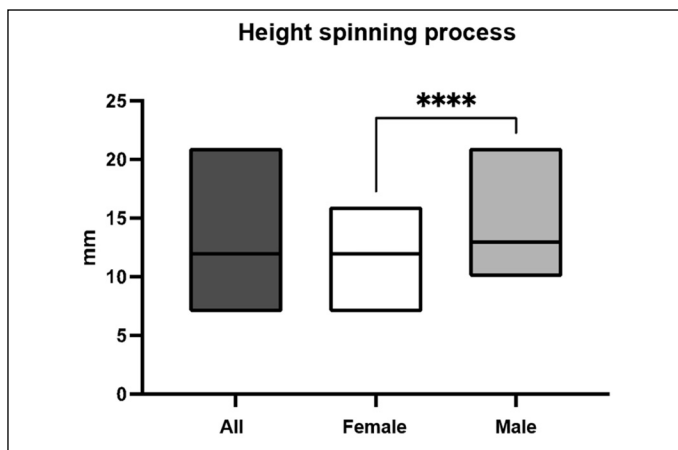


Figure 5. Graph illustrating the height of the spinal process in the entire group, in male and female sex. The asterisk (*) indicates Mann-Whitney test statistical difference – $p < 0.0001$.

(average 11.09 ± 1.83), and from 6 to 26 mm (average 11.11 ± 1.85) on the left side. In females it varied from 7 to 13 mm (average 10.29 ± 1.12) on the right side, and from 6 to 14 mm (average 10.25 ± 1.37) on the left side. In the male sex it varied from 8 to 26 mm (average 11.86 ± 2.05) on the right side, and from 8 to 26 mm (average 11.95 ± 1.87) on the left side. A statistical difference was observed between male and female values. (Kruskal-Wallis- $p < 0.0001$). (Figure 6)

The cranial thickness of the lamina ranged from 1 to 5 mm (average 2.66 ± 1.02) on the left side, and from 1 to 6 mm (average 2.73 ± 1.03) on the right side. In the female sex it varied from 1 to 4 mm (average 2.38 ± 0.99) on the right side, and from 1 to 4 mm (average 2.48 ± 0.99) on the left side. In the male sex it varied from 1 to 5 mm (average 2.98 ± 0.94) on the right side, on the left side it varied from 1 to 6 mm (average 2.98 ± 1.02). A statistical difference was observed between male and female. (Kruskal-Wallis test – $p < 0.0001$). (Figure 7)

The middle thickness of the lamina ranged from 1 to 8 mm (average 4.36 ± 1.37) on the right side, and from 2 to 9 mm (average 4.46 ± 1.34) on the left side. In females it varied from 1 to 6 mm (average 3.81 ± 1.19) on the right side, and from 2 to 8 mm (average 4.08 ± 1.26) on the left side. In the male sex it varied from 2 to 8 mm (4.90 ± 1.33) on the right side, and from 2 to 9 mm (average 4.83 ± 1.32) on the left side. Statistical difference between the sexes was observed (Kruskal-Wallis- $p < 0.0001$). (Figure 8)

The thickness of the flow lamina ranged from 2 to 9 mm (average 4.48 ± 1.34) on the right side, and from 1 to 8 mm (average 4.60 ± 1.43)

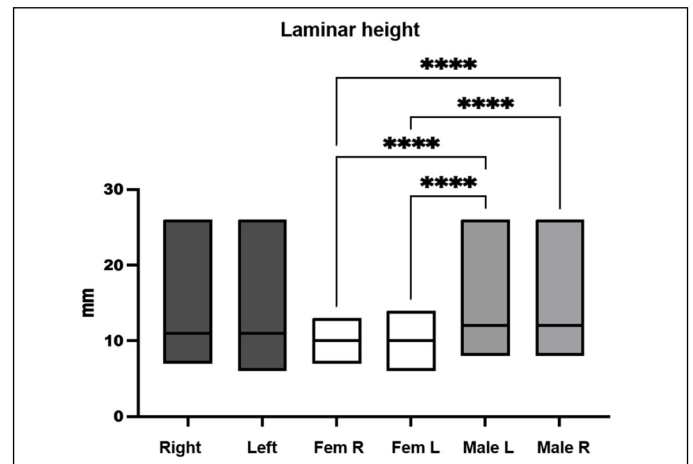


Figure 6. Graph illustrating the height of the lamina in the entire group, male and female. The asterisk (*) indicates statistical difference-(Kruskal-Wallis test- $p < 0.0001$).

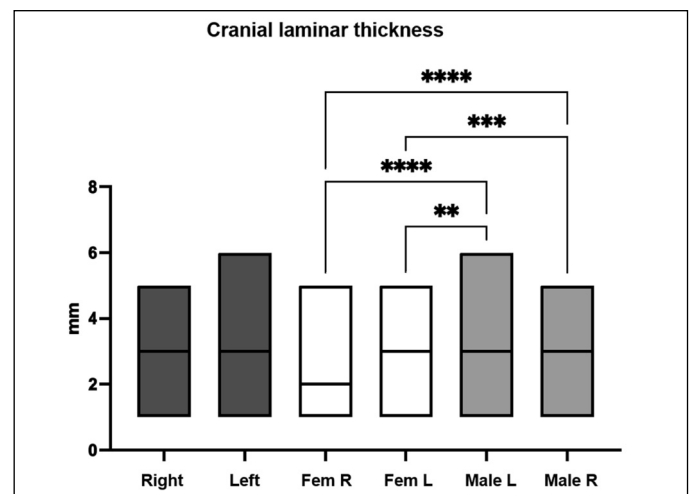


Figure 7. Graph illustrating the thickness of the cranial lamina (Kruskal-Wallis test- $p < 0.0001$).

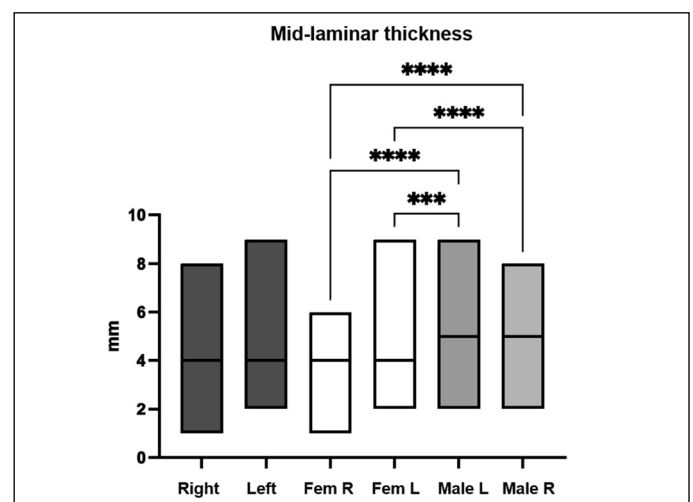


Figure 8. Graph illustrating the middle thickness of the lamina (Kruskal-Wallis test- $p < 0.0001$).

on the left side. In females it varied from 2 to 7 mm (average 4.07 ± 1.05) on the right side, and from 1 to 8 mm (average 4.25 ± 1.28) on the left side. Statistical differences between the sexes were observed (Kruskal-Wallis- $p < 0.0001$). (Figure 9)

The thickness (diameter) of the lamina is of great importance for placing the implants inside it, and the diameter of 4mm has been considered the limit for placing screws of 3.5mm diameter. Among all the measurements performed, the diameter of the axis lamina was less than 4mm in 25.20% of the subjects (3mm-18.43%; 2mm-6.35% and 1mm-6.42%) (Figure 10). On the right side the lamina had a thickness of less than 4mm in 25.41% of the measurements and in 24.90% on the left side. In females the thickness of the lamina was less than 4mm in 39.26% of the measurements and in 12.5% in males.

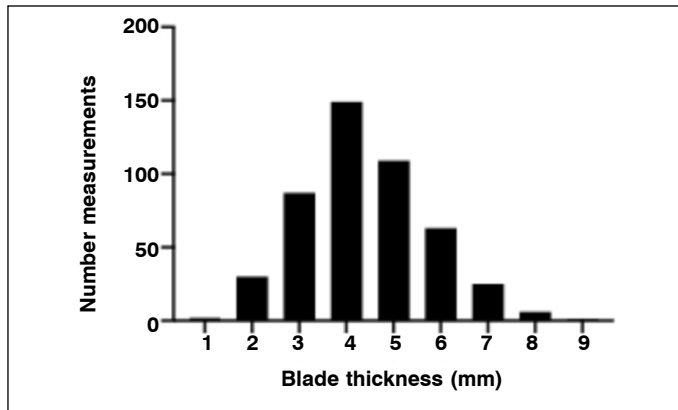


Figure 9. Graph illustrating the flow lamina thickness (Kruskal-Wallis test $p < 0.0001$).

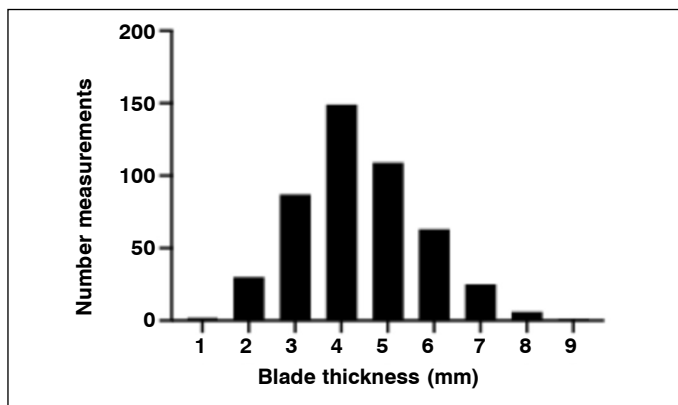


Figure 10. Frequency of axis lamina thickness in all group measurements.

DISCUSSION

The values of the parameters evaluated for the second cervical vertebra (axis) and related to the technique of intralaminar fixation showed variation of their values in the studied sample. No difference was observed in the values of the parameters studied between the right and left side in the total sample and considering gender. However, statistical differences were observed between male and female values in all evaluated parameters. The values of all parameters were statistically higher in males.

The technique of intralaminar axis fixation has been useful in patients who present smaller dimensions or morphological anomalies of the pedicle, axis joint pars and trajectory of the vertebral artery.⁹⁻¹¹ However, the poor positioning of the screw in the axis lamina can break the internal cortical and cause injury of the dura mater or spinal cord.⁹ The evaluation of the dimensions of the axis related to intralaminar fixation should be performed more frequently during the planning of the surgical procedure considering the variation in the dimensions of the parameters related to this fixation modality.¹² In patients with basilar invagination the reduced dimensions of the pedicles and isthmus and their association with changes in the trajectory of the vertebral artery have contributed to the more secure achievement of the axis. However, in patients with basilar invagination, the dimensions of the lamina allow the technique to be performed in a smaller percentage of patients.⁶ Patients with basilar invagination have the narrower and smaller axis lamina, and the possibility of intralaminar fixation is less than in the general population.⁶

The morphology of the axis lamina presents variations as observed in our series and described in the literature.¹³ A small percentage of individuals have a small blade diameter for screw placement of 3.5mm.^{14,15} The diameter of the axis blade is a critical parameter for the implementation of the intralaminar fixation technique due to the diameter of the implant placed inside it. The axis morphometric studies have shown that 5% of the subjects presented a bilateral axis lamina thickness of less than 4 mm and 9.2% unilateral.^{6,9} The placement of intralaminar screws of 3.5mm would be possible in 80.3% of the subjects according to the Chan morphometric study.⁶ We observed a certain percentage of laminae with a thickness of less than 4mm in the tested vertebra sample, mainly in females. This observation reinforces the need for the preoperative evaluation of the thickness of the axis lamina, as in some patients its thickness does not allow the placement of implants with 3.5mm diameter in its interior.

Criteria have been developed for the safety and accuracy of translaminar axle fixation.^{6,8,13} In unilateral fixation 4,5mm is minimum lamina thickness and axle height for the placement of screws of 3.5mm diameter with the error margin of 0.5mm.⁹

Although the intralaminar axis fixation is a safe technique and of great use in patients with small axis pedicles or alteration of the trajectory of the vertebral artery, some disadvantages have been reported. In thin patients, the protrusion of the screw head dorsally to the spinal process can make it prominent and palpable on the skin.¹⁶ The placement of the implants provides less bed for the placement of the bone graft, and the higher rate of pseudoarthrosis in patients over 65 years old and with odontoid fracture.^{15,17}

The anatomical axis parameters related to the intralaminar technique presented differences in the study sample, and were smaller in the female sex. The thickness of the lamina below 4mm was observed in part of the study sample, and this parameter should be considered in the preoperative evaluation for the safe implementation of the technique.

All authors declare no potential conflict of interest related to this article.

CONTRIBUTIONS OF THE AUTHORS: All authors have contributed individually and significantly to the development of this article. VAG: substantial contributions to the design of the study; acquisition and interpretation of the data. Final approval of the manuscript to be published. GMG and MPD and TOD: support in the scientific writing of the study and the review of the manuscript. HLAD: substantial contributions to the study design; data acquisition and interpretation. Guidance and final approval of the manuscript to be published.

REFERENCES

- Magerl F, Seemann PS. Stable posterior fusion of the atlas and axis by transarticular screw fixation. In: Kehr P, Weidner A. Cervical spine I. Wien: Springer; 1987.p.322-327.
- Harms J, Melcher RP. Posterior C1-C2 fusion with polyaxial screw and rod fixation. Spine (Phila Pa 1976). 2001;26(22):2467-71. doi: 10.1097/00007632-200111150-00014.
- Wright NM. Posterior C2 fixation using bilateral, crossing C2 laminar screws: case series and technical note. J Spinal Disord Tech. 2004;17(2):158-62. doi: 10.1097/00024720-200404000-00014

4. Jea A, Sheth RN, Vanni S, Green BA, Levi AD. Modification of Wright's technique for placement of bilateral crossing C2 translaminar screws: technical note. *Spine J*. 2008;8(4):656-60. doi: 10.1016/j.spinee.2007.06.008.
5. Singh DK, Shankar D, Singh N, Singh RK, Chand VK. C2 Screw fixation techniques in atlantoaxial instability: A technical review. *J Craniovertebr Junction Spine*. 2022;13(4):368-377. doi: 10.4103/jcvjs.jcvjs_128_22.
6. Chan AKH, Yusof MI, Abdullah MS. Computed Tomographic Morphometric Analysis of C1 and C2 for Lamina Cross Screw Placement in Malay Ethnicity. *Asian Spine J*. 2021;15(1):1-8. doi: 10.31616/asj.2019.0242.
7. Joaquim AF, Tan L, Riew KD. Posterior screw fixation in the subaxial cervical spine: a technique and literature review. *J Spine Surg*. 2020;6(1):252-261. doi: 10.21037/jss.2019.09.28.
8. Sharma RM, Pruthi N, Pandey P, Dawn R, Ravindranath Y, Ravindranath R. Morphometric and radiological assessments of dimensions of Axis in dry vertebrae: A study in Indian population. *Indian J Orthop*. 2015;49(6):583-8. doi: 10.4103/0019-5413.168758.
9. Zhou LP, Shang J, Zhang ZG, Jiang ZF, Zhang HQ, Jia CY, et al. Characteristics and Comparisons of Morphometric Measurements and Computed Tomography Hounsfield Unit Values of C2 Laminae for Translaminar Screw Placement Between Patients With and Without Basilar Invagination. *Neurospine*. 2022;19(4):899-911. doi: 10.14245/ns.2244730.365.
10. Nassos JT, Ghanayem AJ, Sasso RC, Tzermiadianos MN, Voronov LI, Havey RM, et al. Biomechanical evaluation of segmental occipitoatlantoaxial stabilization techniques. *Spine (Phila Pa 1976)*. 2009;34(25):2740-4. doi: 10.1097/BRS.0b013e3181b61185.
11. Moon BJ, Choi KH, Shin DA, Yi S, Kim KN, Yoon DH, et al. Anatomical variations of vertebral artery and C2 isthmus in atlanto-axial fusion: Consecutive surgical 100 cases. *J Clin Neurosci*. 2018;53:147-152. doi: 10.1016/j.jocn.2018.04.058.
12. Lin S, Bao M, Wang Z, Zou X, Ge S, Ma X, et al. Morphological Evaluation of the Subaxial Cervical Spine in Patients with Basilar Invagination: A CT-based Study. *Spine (Phila Pa 1976)*. 2021;46(20):1387-1393. doi: 10.1097/BRS.0000000000004040.
13. Ma XY, Yin QS, Wu ZH, Xia H, Riew KD, Liu JF. C2 anatomy and dimensions relative to translaminar screw placement in an Asian population. *Spine (Phila Pa 1976)*. 2010;35(6):704-8. doi: 10.1097/BRS.0b013e3181bb8831.
14. Chan AKH, Yusof MI, Abdullah MS. Computed Tomographic Morphometric Analysis of C1 and C2 for Lamina Cross Screw Placement in Malay Ethnicity. *Asian Spine J*. 2021;15(1):1-8. doi: 10.31616/asj.2019.0242.
15. Vaccaro A, Baron EM. *Operative techniques in spine surgery*. 4th edition. Philadelphia: Elsevier;2025.p.72.
16. Cassinelli EH, Lee M, Skalak A, Ahn NU, Wright NM. Anatomic considerations for the placement of C2 laminar screws. *Spine (Phila Pa 1976)*. 2006;31(24):2767-71. doi: 10.1097/01.brs.0000245869.85276.f4.
17. Dorward IG, Wright NM. Seven years of experience with C2 translaminar screw fixation: clinical series and review of the literature. *Neurosurgery*. 2011;68(6):1491-9; discussion 1499. doi: 10.1227/NEU.0b013e318212a4d7.