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Original Article

Morphometric analysis of the lateral mass of atlas and its clinical significance in craniovertebral junction surgeries

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ABSTRACT

Background: The surgery at the craniovertebral junction (CVJ) area needs meticulous knowledge of the atlas vertebra which forms the CVJ. The screws need to be placed in the lateral mass of the atlas to stabilize the C1 and C2 joints in case of CVJ anomalies. Our study aimed to determine the dimensions of the lateral mass in dry bones for the accurate placement of screws.

Methods: We have analyzed 82 dried atlas vertebrae and measurements of inferior articular facet (IAF) in terms of length, breadth, height, and angles were done.

Results: The length of IAF was 17.93 ± 0.76 mm and 18.01 ± 0.75 mm on the right and left side, respectively ($P = 0.0038$). The mean width was 14.88 ± 0.85 mm on the right and 14.86 ± 0.79 mm on the left side. The mean distance measured between the posterior arch of the atlas to the anterior margin of IAF was 22.87 ± 0.60 mm on the right side and 22.79 ± 0.61 mm on the left side ($P = 0.0247$). The horizontal thickness of lateral mass on the right and left sides were 15.91 ± 1.73 mm and 15.83 ± 1.56 mm, respectively, with a P-value of 0.3771. The angle measured for the screw trajectory in lateral mass of the atlas was 16.61 ± 1.49 on the right side of vertebrae and 16.53 ± 1.43 on the left side.

Conclusion: The study provided comprehensive data on the approximate screw length needed for the lateral mass of atlas in an adult patient. The detailed morphometric measurements provided in this study offer valuable insights that can help surgeons optimize surgical planning, potentially reducing complications and enhancing patient outcomes in craniovertebral junction procedures.

Keywords: Atlas vertebrae, Craniovertebral junction, Lateral mass, Morphometric analysis, Screw fixation

INTRODUCTION

The craniovertebral junction (CVJ), consisting of the occiput, the atlas, and the axis, plays a pivotal role in head movement. Surgical procedures in this region demand precise anatomical knowledge to deal with conditions of instability on CVJ, including some congenital disorders such as Chiari malformation, basilar invagination (BI), and atlantoaxial dislocation.[10,16] CVJ instability poses complex diagnostic and management difficulties due to its complex anatomy and biomechanics, potentially resulting in sudden death or gradual neurological deterioration.[16] Advanced imaging techniques, including dynamic magnetic resonance imaging and computed tomography scans, have enhanced the ability to visualize bony deformities and associated neural and vascular distortions, aiding in the evaluation of BI, joint biomechanics, and the development of surgical strategies. Significant advancements have been made in the management of CVJ disorders, evolving from early ventral decompression approaches to contemporary CVJ realignment techniques.[8]

The atlas vertebra (C1) in the CVJ features paired lateral masses connected anteriorly by the anterior arch and posteriorly by the posterior arch. The anterior arch includes an anterior tubercle, while the posterior arch contains a groove for the third part of the vertebral artery along its superior border. The lateral mass comprises superior and inferior articular facets (IAFs), along with the foramen transversarium, which transmits the second part of the vertebral artery. Recent advances in posterior screw fixation of the C1–C2 lateral mass have improved postoperative outcomes, and the morphometric analysis of the atlas's lateral masses offers valuable insight into the proper screw size, screw trajectory for joint stabilization in CVJ conditions.[1,5,7]

The present study aimed to measure and analyze the dimensions and angles of the lateral mass of the atlas vertebrae bilaterally. It will help the surgeons to evaluate the ideal key points for posterior screw fixation of C1 lateral mass. Moreover, the correct entry point, angle of screw projection, and optimal screw length will be elucidated by the study.

MATERIALS AND METHODS

Observation of 82 atlas vertebrae was done in the Department of Anatomy, King George's Medical University, Lucknow, India. The Institutional Ethical Clearance was obtained for this study bearing reference code 131 ECM IIA/P17, dated 23/09/24. All vertebrae were meticulously measured on their lateral masses bilaterally with a total of 164 lateral masses.

The following measurements were taken-

1. IAF, [Figure 1] for maximum length (L) and maximum width (W)
2. SL, length from posterior arch to anterior margin of IAF, [Figure 2] to find the suitable length of the screw during lateral mass fixation.
3. The horizontal thickness of lateral mass-posteriorly, H, [Figure 3a] to find the diameter of screw for fixation (H = Length of posterior tubercle to the lateral aspect of inferior articular (IA) process — Length of posterior tubercle to the medial aspect of IA process).
4. The vertical distance between the posterior arch and posterior margin of the IA process, V, [Figure 3b] to estimate the vertical diameter of the screw.
5. Angle of screw trajectory in lateral mass of atlas, α [Figure 4].

All measurements were taken by digital Vernier caliper and by goniometer. Data were statistically analyzed to identify trends and variations in lateral mass of atlas vertebrae. The mean, standard deviation, and p-value of the data were calculated for bilateral observations in C1 vertebrae.

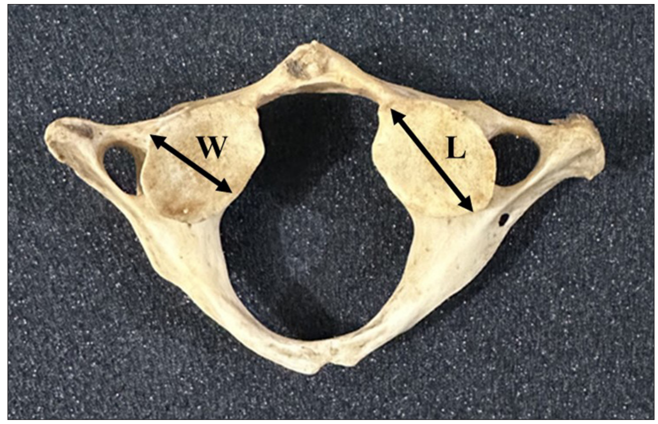

Figure 1: Atlas vertebra (inferior view), maximum length (L), and maximum width (W) of inferior articular facet.

Figure 2: Atlas vertebra (inferior view), SL-length from posterior arch to anterior margin of inferior articular facet. SL: Screw length.

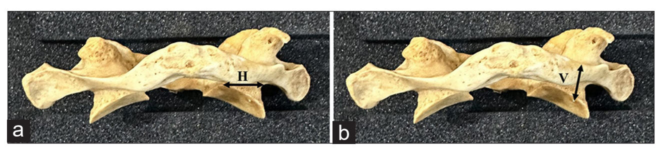

Figure 3: Atlas vertebra (posterior view), (a) H-horizontal thickness of lateral mass posteriorly. (b) Atlas vertebra (posterior view), and (b) V-vertical distance between the posterior arch and posterior margin of inferior articular process.

RESULTS

The study revealed remarkable variations in dimensions and angles of the lateral masses of an atlas.

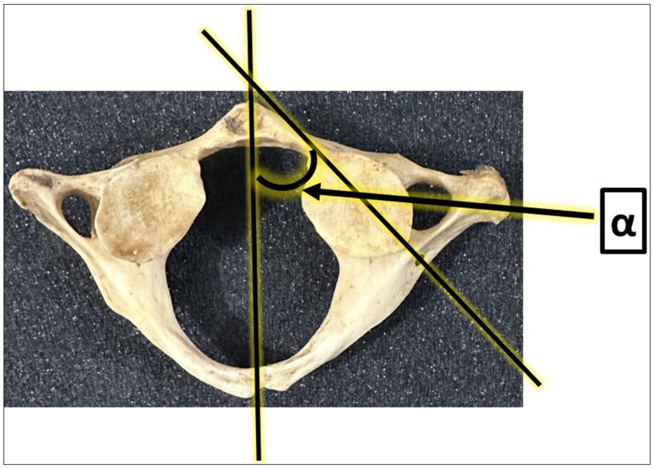

Figure 4: Atlas vertebra (inferior view), alpha is the angle of screw trajectory in lateral mass of atlas.

Length

The maximum length of IAF was 17.93 ± 0.76 mm on the right side and 18.01 ± 0.75 mm on the left side ($P = 0.0038$), whereas the distance measured from the posterior arch of atlas vertebrae to the anterior margin of IAF was found to be 22.87 ± 0.60 mm and 22.79 ± 0.61 mm on the right and left side, respectively ($P = 0.0247$) [Table 1].

Width

The mean width of IAF was 14.88 ± 0.85 mm and 14.86 ± 0.79 mm on the right and left sides, respectively. No significant differences were noticed in the width of IAF ($P = 0.2335$) on the right and left side [Table 1].

*L of IAF - Maximum length in mm
*W of IAF - Maximum width in mm
*SL - Length from posterior arch to anterior margin of IAF in mm

Horizontal thickness

The horizontal thickness of lateral mass on the right and left side was 15.91 ± 1.73 mm and 15.83 ± 1.56 mm, respectively ($P = 0.3771$) [Table 2].

Vertical thickness

The **v**ertical thickness of lateral mass was measured between the posterior arch and posterior margin of the IA process, having measurements of 5.69 ± 1.23 mm and 5.71 ± 1.24 mm on the right and left sides, respectively ($P = 0.4624$) [Table 2].

H* - Horizontal thickness of lateral mass-posteriorly (mm)
V* - Vertical distance between posterior arch and posterior margin of IA process (mm)

Angle

The angle measured for the screw trajectory in lateral mass of the atlas was 16.61 ± 1.49 on the right side of vertebrae and 16.53 ± 1.43 on the left side with P-value of 0.38 [Table 3].

DISCUSSION

The placement of screws in the C1 lateral mass can be a technically challenging procedure due to the complex anatomy of the CVJ. This surgical approach carries a significant risk of damaging critical neurovascular structures, such as the spinal cord and vertebral artery, which are in close proximity to the lateral mass, requiring precise planning and technique to avoid serious complications.[2] The screw entry point in the lateral mass depends on the surgeon's preference. Some surgeons prefer the midpoint of lateral mass as the entry point, whereas others prefer to have an entry point from the posterior arch. We believe that the former is a better approach as it obviates the need to cut the C2 nerve root, and the SL is also more; therefore, better purchase in lateral mass can be obtained.

In the present study, the length of the screw which can be safely placed from the midpoint of IAF ranges from 15.91 ± 1.73 mm to 15.83 ± 1.56 mm on the right and left sides, respectively. This is the most common entry point used by Neurosurgeons. This finding is consistent with the approach used by Simsek *et al*., who identified the entry point as being located between the posterior arch and the lateral mass of C1.[15] However, Bunmaprasert *et al*. proposed a slightly different entry point, positioning the screw between the lateral mass and the inferomedial edge of the posterior arch.[2] In contrast, Zhang *et al*. recommended a pedicle screw placement, which differs from the posterior arch-based entry points suggested in the present study and other studies.[17] These variations highlight the diversity in surgical approaches to C1 lateral mass fixation, emphasizing the importance of individualized techniques based on anatomical considerations.

In our study, the optimum SL for posterior C1 lateral mass fixation was determined by measuring the distance between the entry point from the posterior arch of the atlas to the anterior margin of the IAF, yielding values of 22.87 ± 0.60 mm on the right side and 22.79 ± 0.61 mm on the left. This measurement aligns closely with the findings of Hong *et al*., who reported an optimum SL of 22 mm[9], while Simsek *et al*. recorded a shorter length of 19.59 ± 2.20 mm.[15] In contrast, Albert suggested an even shorter length of 17.3 mm[1], and Resnick *et al*. indicated a longer SL of 26 ± 2 mm.[13] Notably, Niu *et al*. found a significantly longer SL of 31.05 mm.[12] These discrepancies in SL recommendations reflect variations in anatomical measurements and surgical techniques, highlighting the importance of individualized planning

Table 1: Measurements of maximum length, maximum width of inferior articular facet and distance from posterior arch to anterior margin of inferior articular facet.

S.No.	Measurement	Length of IAF		Width of IAF		Screw length	
		Right side	Left side	Right side	Left side	Right side	Left side
1	Mean	17.93	18.01	14.88	14.86	22.87	22.79
2	Standard deviation	0.76	0.75	0.85	0.79	0.60	0.61
3	P value	**0.0038**		0.2335		**0.0247**	

IAF: Inferior articular facet. Bold: The difference between the length of inferior articular facet and screw length of right and left side respectively were statistically significant.

Table 2: Measurements of horizontal and vertical thickness of lateral mass posteriorly.

S. No.	Measurement	Horizontal thickness		Vertical thickness	
		Right side	Left Side	Right side	Left Side
1.	Mean	15.91	15.83	5.69	5.71
2.	Standard deviation	1.73	1.56	1.23	1.24
3.	P value	0.3771		0.4624	

Table 3: Angle of screw trajectory in lateral mass of atlas [α]

S. No.	Measurement	Angle (Right side)	Angle (Left side)
1	Mean	16.61	16.53
2	Standard deviation	1.49	1.43
3	*P*-value	0.38	

to optimize screw placement and minimize the risk of complications during fixation procedures.

The present study showed the suitable screw width for posterior C1 lateral mass fixation as 5.69 ± 1.23 mm on the right and 5.71 ± 1.24 mm on the left side. This measurement contrasts with the findings of Resnick *et al.*, who recommended a wider screw with a mean width of 7 ± 1.6 mm.[13] On the other hand, Buteera and Lukhele and Hong *et al.* reported a narrower screw width of 3.5 mm [3,9], while Albert suggested widths of 3.7 ± 0.8 mm on the right side and 3.5 ± 0.9 mm on the left side.[1] A radiological study by Lin *et al.* indicated a much larger screw width of 12.6 ± 1.7 mm.[11] These variations in screw width underscore the diversity in anatomical measurements and the need for tailored approaches to ensure optimal screw fit and minimize the risk of complications during C1 lateral mass fixation.

In the present study, the suitable angle for the screw trajectory from the midline was measured at 16.61° ± 1.49° on the right and 16.53° ± 1.43° on the left side. This finding is in line with the recommendations of Hong *et al.*, who suggested a screw trajectory angle ranging from 15° to 20°,[9] and Simsek *et al.*, who reported angles of 13.5° ± 1.9° on the right and 15.2° ± 2.6° on the left.[15] However, Albert proposed a narrower range of 11–14° [1], while Butt *et al.*, in a radiological study, found significantly wider angles of 23° ± 3.8° and 32° ± 5°.[4] Seal *et al.* documented a broader range of 10–22° [14], and Gebauer *et al.* observed a considerably smaller angle range of 7.3–7.9°.[6] These variations highlight the differences in anatomical considerations and surgical techniques, emphasizing the need for personalized screw trajectory planning to ensure optimal fixation while minimizing the risk of neurovascular injury.

These findings provide crucial insights for surgeons, aiding in the selection of appropriate surgical techniques and implant sizes for CVJ procedures. The primary goals of surgical intervention are decompression of neural structures, spinal realignment, and stabilization of the CVJ. Morphometry of lateral masses of atlas vertebrae enhances the insight of possible trajectory for screw fixation during surgeries for joint stabilization.

CONCLUSION

The study provides a comprehensive idea of the approximate SL needed for the lateral mass of the atlas in an adult patient. The screw trajectory positioned on the posterior arch, just behind the inferior articular process, offers a more reproducible technique compared to attempts at targeting the center of the lateral mass. This approach minimizes the risk of injury to the venous plexus and the C2 nerve root, as the surrounding bony landmarks provide clear guidance for screw placement. The detailed morphometric measurements provided in this study offer valuable insights that can help surgeons optimize surgical planning, potentially reducing complications and enhancing patient outcomes in CVJ procedures.

Ethical approval: The research/study was approved by the Institutional Review Board at King George's Medical University, number 131-ECMIIA/P17, dated 09/07/2024.

Declaration of patient consent: Patient's consent was not required as there are no patients in this study.

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