

Morphometric Study of Paired and Unpaired Parameters of Axis Vertebra: An Observational Study

SYED Mubashir^{ID}, Shahid Kaleem^{ID}, Mohd Saleem Itoo^{ID}, Gh. Mohammad bhat^{ID}, Javed ahmed khan^{*ID}

Government Medical College, Srinagar, Jammu and Kashmir, India

Abstract

Background: The axis is the second cervical vertebra and is special in having the upward bony projection from its body called the dens. It functions as the pivot around which the first cervical vertebra rotates.

Methods: The present study was observational and conducted in the Department of Anatomy, Government Medical College, Srinagar. The linear and angular parameters were recorded using a manual vernier calliper and goniometer. The vernier calliper's depth gauge was used to measure the depth of the foramen transversarium. All the identical structures were measured on both sides. The measurements recorded from each vertebra on each axis were analyzed statistically using SPSS Statistics.

Results: All the linear paired and unpaired parameters have been recorded using a manual vernier calliper and goniometer. The body's mean A-P diameter was 15.3 ± 1.76 mm, and the transverse diameter was 18.56 ± 1.85 mm. The anterior body height was measured at 22.3 ± 1.75 mm, and the posterior body height was 17.2 ± 1.55 mm. Similarly, the mean height of dens was 15.8 ± 1.77 mm, the A-P diameter was 10.7 ± 0.99 mm, the maximum width was 10.3 mm, and the minimum width was 8.51 ± 0.01 mm. The total height of the dens was 38.1 ± 2.57 mm. Similarly, the dimensions of the pedicle, lateral mass, superior articular facet, inferior articular facet, foramen transversarium, and vertebral foramen were also measured and compared with previous studies.

Conclusion: The study will be useful while performing surgical procedures around the axis vertebrae to prevent injury to vital structures.

Keywords: Axis vertebra; Dens, Morphometry; Goniometer; Vernier caliper; Foramen transversarium.

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Introduction

The axis is the second cervical vertebra and is special in having an upward bony projection from its body called the dens. It has very unique superior articular facets. It functions as a pivot around which the first cervical vertebra rotates.¹ Sufficient knowledge about its measurements and its structure is vital for the assessment of numerous clinical conditions.² Among the most prevailing disorders, the cervical and lumbar regions are commonly involved.³ About one third of total cervical vertebrae fractures accounts for the odontoid process alone.^{4,5} Several invasive procedures have been applied, like plate fixation, screw fixation, interspinous wiring, and interlaminar clamping to fix the instability at the atlanto-axial complex articulation due to trauma or non-traumatic situations. Regardless the advantages by the way of transpedicular screw fixation in the vertebrae of cervical region there occurs differences about its possible risk. The wrong pedicle screw fixation may result in injury to the adjoining important structures, such as spinal cord, roots of nerves, cranial nerves, and

vertebra and aid in the development of new

vertebral arteries.⁶ As new internal fixation strategies emerge, the improved shape and structure of the bone in question are clearly visible as a result of the development of new internal fixation techniques.²

Purpose of the study

The rationale for conducting this study is to address the importance of the axis vertebra and its unique features in the assessment of various clinical conditions that affect the cervical region. Understanding the measurements and structure of the axis vertebra is crucial for developing new techniques in internal fixation and for treating injuries and disorders in this region. The purpose of this study is to perform a morphometric analysis of the paired and unpaired parameters of the axis vertebra, including measurements of its unique features such as the dens and superior articular facets. The study aims to determine the clinical significance of these measurements in assessing various conditions affecting the cervical region, particularly the axis vertebra. This may lead to a better understanding of the bone structure of the axis

techniques in internal fixation, ultimately improving the



*Correspondence to: Sumirini Puppala, Email: sumirini@gmail.com

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treatment of injuries and disorders in this region.

Materials and Methods

The present observational study was conducted on 30 human dried axis vertebrae taken from the bone bank by the judgmental sampling method. This study was conducted in the Department of Anatomy, Government Medical College, Srinagar, Jammu and Kashmir, India, over 4 months from August to November 2022.

Linear parameters measured with a manual vernier caliper.

1. Anterior and posterior height, A-P (A-P) diameter, transverse diameter, and end plate height of the body of the axis vertebra were recorded.

2. The dimensions of the odontoid process, including the length, maximum and minimum transverse diameter, and A-P diameter.

3. The A-P and transverse diameter of the vertebral foramen were recorded at the inlet and outlet of the foramen, and dimensions of the lamina, including length, height, and width, were measured

4. The pedicle parameters, including the distance between the anterior and posterior aspects of the superior and inferior articular facets, the width and height of the pedicle at the foramen transversarium.

5. The depth and width of the foramen transversarium and dimensions of the lamina, including length, height, and width, were measured. Additionally, the A-P and transverse diameter of the superior articular facet (SAF) and inferior articular facet (IAF), and the superior facet angle were measured bilaterally.

Angular parameters were measured with a standard goniometer.

1. Vertical angle of dens and median angle of the pedicle

The collected data were entered into a Microsoft Excel spreadsheet and analyzed using SPSS version 20.0. Descriptive statistics, such as means, standard deviations, and frequencies, were used to summarize the sample's characteristics. The exclusion criteria for the study included axis vertebrae with osteophytes, congenital abnormalities, and fractured vertebrae.

Unpaired parameters

Body measurements: A-P diameter, transverse diameter, anterior and posterior height, and end plate height were recorded.

Dimensions of the odontoid process —length, maximum and minimum transverse diameters, A-P (A-P) diameter, and vertical angle — were measured.

Vertebral foramen dimensions: A-P and transverse diameter were measured at the inlet and outlet of the foramen.

Paired parameters

Pedicle parameters: Distance between anterior and

posterior aspects of superior and inferior articular facets, width and height of pedicle at the foramen transversarium, and median angle of pedicle were recorded.

Foramen transversarium: The depth and width of the foramen transversarium were measured.

Lamina dimensions: Length, height, and width of the lamina were recorded.

Superior and inferior articular facet dimensions: A-P and transverse diameter were measured bilaterally, as well as the superior facet angle.

The median angle, dens, and width of the pedicle are shown.

Results

The mean A-P diameter of the body was found to be 15.3mm, and the transverse diameter 18.56mm. The anterior body height was measured at 22.3mm, and the posterior body height was 17.2mm. Similarly, the mean height of dens was 15.8mm, the A-P diameter was 10.7mm, the maximum width was 10.3mm, the minimum width was 8.5mm, and the total height of dens was 38.1 mm. Shown in Fig. 1/ 1/ Table 1.

The external height of the lateral mass was measured at 9.1 mm on the right side and 9.1 mm on the left, as shown in Fig. 1 and Table 2.

The mean height of the foramen transversarium was recorded as 5.6 mm and 5.9 mm on the right and left sides, and the mean width as 6.0 mm and 5.9mm, respectively, as shown in Fig. 1 and Table 2.

The dimensions of the lamina were also noted on the right and left sides, respectively. The mean height of the lamina was found to be 10.63mm on the right side and 10.7mm on the left side, and the mean length was noted to be 15.7mm and 15.5mm. The mean thickness of the right side and left side was recorded as 6.5mm and 6.4mm, respectively, as shown in Fig. 1 and Table 2.

It was determined that the A-P diameter of SAF on the right and left sides was 18.56 mm and 18.16 mm, respectively, and its transverse diameter was found to be 15.1 mm and 15.1 mm on both sides, as shown in Fig. 1 and Table 2.

The A-P diameters of the IAF were measured to be 11.73 mm on the right side and 11.2 mm on the left side, respectively, and the transverse diameters were recorded to be 9.83 mm and 9.7 mm on the right and left sides, respectively, as shown in Fig. 1 and Table 2.

The width of the pedicle was measured as 8.5 mm on the right and 8.26 mm on the left, respectively, and the median angles were 34.7 and 34.6 degrees, as shown in Fig. 2 and Table 2.

Discussion

In our Study, the anteroposterior (A-P) and transverse diameters of the C2 body were found to be 15.42±1.78mm and 17.7±2.22mm, respectively. This is in line with the results reported by Naderi et al.9, who reported these parameters as 15.8mm and 18.1mm, respectively. They

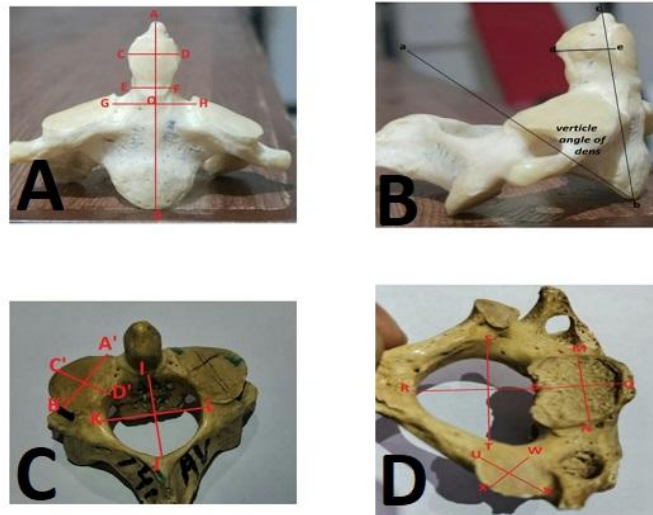


Figure 1. (A) line GH is the arbitrary line joining bilateral superior articular facets, AB shows total anterior height of axis, OA shows height of odontoid process, OB shows height of body of axis, CD shows the maximum transverse diameter of dens, EF shows minimum transverse diameter of dens. Image (B) Line joining the ab and bc shows the vertical angle of dens and de shows the A-P diameter of dens. Image (C) Line KL shows the transverse diameter and line IJ shows a-p diameter of vertebral foramen at inlet, line A'B' and C'D' show the A-P diameter and transverse diameter of superior articular facet. Image (D) Line MN and line PQ Shows transverse and a-p diameter of the body of axis on inferior surface respectively, line RP and line ST shows the measurement of a-p and transverse diameter of vertebral foramen respectively, line UV and WX shows a-p and transverse diameter of inferior articular facet respectively.

Table 1. It showing measurements of body and odontoid process of axis vertebra.

	Parameters measured	Range (mm)	Mean (mm)	S D (mm)
Body of axis	A-P diameter	12-19	15.63	1.76
	Transverse diameter	14-22	18.56	1.85
	Anterior height of body	19-25	22.3	1.75
	Posterior height of body	14-20	17.2	1.55
	End plate lip height	2-9	5.2	1.37
Odontoid process	Height	13.0-19.0	15.8	1.77
	A-P Diameter	9.0-12.0	10.7	0.99
	Maximum Width	9.0-12.0	10.3	0.91
	Minimum Width	6.0-10.0	8.5	1.01
	Vertical Angle of Dens	35.0-65.0	52.2	8.51
	Total Height	33.0-43.0	38.1	2.57
	Transverse Diameter.	19-25	21.93	1.38
	A-P Diameter At Inlet.	14-24	18.96	2.08
A-P Diameter At Outlet.	12-18	15.06	1.45	

stated that these parameters can be considered during anterior plating of the C2 body using screws to determine screw length.

The present study was carried out on 30 dry human adult axis vertebrae obtained from the Department of Anatomy, Government Medical College, Srinagar.

The axis is characterized by a unique feature: superior articular facets and a bony projection

extending upward from its body, called the odontoid process.¹ For the assessment of numerous clinical conditions, sufficient knowledge about their parameters and their structure is important.²

The results obtained in the present study have been compared with those of different researchers, as shown in Table A. Mukesh Singla et al.¹⁰ reported a mean anterior height of the body of the axis vertebra of 19.67mm. While

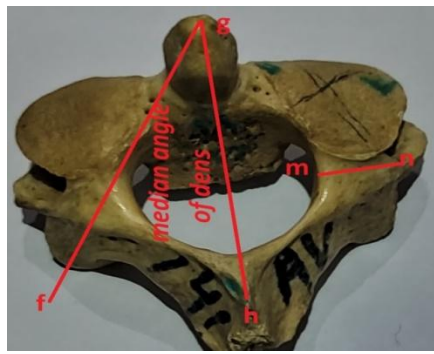


Figure 1. line "fgh" shows the median angle of dens and line "mr" shows the measurement of width of pedicle.

Doherty & Heggeness² and Lue et al.¹¹ reported the same dimension at 23.3mm and 20.4 mm, respectively. Similarly, Senoglu & Kodiglu⁶ and Lang¹² in their studies recorded the height of the axis vertebra on its anterior aspect at 22.1mm each, which is almost similar to our present study, where the anterior body height was found to be 22.3mm. In the same manner, the height of the body of the axis was recorded on the posterior aspect by Naderi et al.⁸ and was found to be 19.7mm. This parameter was found to be 17.8mm by Mukesh Singla et al.⁹ and 16.07mm by Gosavi S and Swamy¹³. In our present study, the posterior height of the body of the axis was noted as 17.2mm, which is similar to the value reported by Schaffer et al.¹⁴, namely 17.2mm.

Xu et al.¹⁴ measured the A-P and transverse diameters of the body of the axis as 16.1mm and 19mm, respectively. Similarly, Doherty and Highness² reported the A-P and transverse diameters to be 16.2mm and 18.7mm, respectively, and in our present study, the A-P and transverse diameters were 15.63mm and 18.56mm, respectively, and were almost concordant with the findings of Doherty and highness.²

In the present study, the end plate lip height was found to be 5.2mm, which differs from the values reported by Doherty and Heggeness² and Gosavis and Swamy¹³, who found endplate lip heights of 4.1mm and 4.42mm, respectively.

Xu et al.¹⁵ noted that the height of the odontoid process was 15.5mm, A-P diameter 10.3mm, and max width 10mm, and another similar study by Naderi et al.⁸ noted the height of the odontoid process was 15.5mm, A-P diameter 11.3mm, and transverse diameter 10.5mm. In our present study, the height of dens was found to be 15.8mm, the A-P diameter 10.7mm, and the transverse diameter 10.3mm. Hence, the values found in our study almost correspond to those found by Xu et al.¹⁵ Similarly, Xu et al.¹⁵ in the same study observed the vertical angle of the odontoid process as 53.6 ± 6.55 degrees, and in our present study, the vertical angle was found to be 52.2 ± 8.51 degrees.

In our study, we recorded the mean transverse diameter of the vertebral foramen as 21.93mm, the A-P diameter at the inlet of the vertebral foramen as 18.96mm, and the A-P diameter at the outlet of the vertebral foramen as

Table 2. It showing measurements of pedicle/lateral mass/foramen transversarium/lamina/superior articular facet (SAF) and inferior articular facet (IAF) of axis vertebra.

	Parameters Measured	Range (mm)		Mean (mm) and S.D	
		Right	Left	Right	Left
Pedicle	Length	25-38	28-39	32.1±2.98	32.1 ± 2.48
	Width	6-12	6-11	8.5 ± 1.82	8.26 ± 1.61
	Height	4-11	3-11	8.03±1.62	7.63 ± 1.70
	Median Angle	30-40	30-41	34.7±2.91	34.6 ± 2.80
Lateral Mass	External Height	5-13	6-13	9.1 ±1.97	9±1.78
Foramen Tansversarium	Height	4-7	4-7	5.6 ±0.98	5.4±0.98
	Width	4-8	4-8	6.0 ±0.93	5.9±1.22
Lamina	Length	10-20	10-20	15.7 ± 2.66	15.5±2.74
	Height	8-13	8-15	10.63± 1.32	10.7±1.55
	Thickness	5-10	4-9	6.5 ± 1.31	6.4±1.35
SAF	A-P Diameter	15-22	15-21	18.56±2.06	18.16±1.76
	Transverse Diameter	11-18	13-18	15.1±2.23	15.6±2.72
IAF	A-P Diameter	8-17	6-15	11.73±2.23	11.2±2.72
	Transverse Diameter	6-16	6-14	9.83±1.35	9.7 ±1.35

Table 3. It showing comparison parameters of body/ dens/ vertebral foramen/ superior articular facet (SAF) and inferior articular facet (IAF) of axis with the previous studies. All parameters have been measured in millimeters (mm).

Parameters	Mukesh Singla et al	Naderi et al	Doherty & Heggenes	Schaffer et al	xu et al	Gosavi and Swamy	S	Present study
Body	A-P diameter	15.42	15.8	16.2	-----	16.1	14.77	15.63
	Transverse diameter	17.7	18.1	18.7	-----	19	15.99	18.56
	Ant.Body height	19.67	23.2	23.3	-----	21	20.9	22.3
	Post.Body height	17.8	19.7		17.2	16.5	16.07	17.2
	End plate lip height			4.1			4.42	5.2
Dens	Height of dens	15.5	15.5	-----	-----	15.5	14.86	15.8
	A-P diameter	11.3	11.3	11.2	-----	10.3	9.92	10.7
	Transverse diameter	10.5	10.5	10.8	-----	10	9.28	10.3
Vertebral Foramen	Vertical angle of dens					53.6°		52.2°
	A-P Inlet	18.31	18	-----	-----	18	18.47	18.47
	A-P Outlet	14.84	15.3	16.5	-----	15.3	15.11	15.1
	Transverse diameter on right side	22.37	21.93	23.6	-----	21.9	21.59	15.1
	A-P diameter on right side	16.61	-----	-----	-----	-----	16.64	18.56
SAF	A-P diameter on left Side	16.66	-----	-----	-----	-----	16.66	18.16
	Transverse diameter On Left Side	14.64	-----	-----	-----	-----	14.64	15.6
	A-P diameter on right. side	11.75	-----	-----	-----	-----	9.74	11.7
IAF	Transverse diameter On right Side	11.40	-----	-----	-----	-----	9.93	9.83
	A-P diameter on left side	12.02	-----	-----	-----	-----	9.61	11.2
	Transverse diameter On rightSide	11.42	-----	-----	-----	-----	9.92	9.7

15.06mm. Similarly, Gosavi S and Swamy¹³ in their study noted the transverse diameter as 21.59mm, and the A-P diameter at the inlet and outlet as 18.47mm and 15.11mm, respectively.

Gosavi S¹² recorded the A-P diameter and transverse diameter of the superior articulating facet on the right side as 16.64mm and 14.92mm, respectively. They also noted the A-P and transverse diameters on the left side as 14.44mm and 14.64mm, respectively. The values found in their study do not correspond to those in our present study, as we measured the A-P diameter of the superior

articulating, which was 18.56mm, and the transverse diameter, which was 15.1mm.

In another study, Xu et al.¹⁴ found that the angle subtended by the long axis of the superior articular facet with the sagittal plane, known as the superior angle of the superior articular facet, was 66.3° and 68.4° in males and females, respectively. In our present study, it was found to be 67.46 degrees on the right side and 67.36 degrees on the left side of the axis vertebra.

Similarly, Gosavi S and Swamy¹² measured the A-P and transverse diameters of the inferior articular facet in the same study on the right and left sides of the axis vertebra.

Table 4. It showing comparison of various parameters of pedicle with previous studies and are measured in millimeters (mm).

		Madawi study et al.	Xu et al.	Gosawys and Swamy	Present Study
Pedicle	Length	28.7	25.6	28.5	32.1
	Width	7.8	8.6	7.46	8.5
	Height	7.9	7.7	8.26	8.03

They noted 9.74mm and 9.61mm, respectively, which is not in line with our present study, where we recorded the A-P diameter and transverse diameter of the inferior articular facet as 11.73mm and 9.83mm on the right and left sides, respectively.

Madawi et al.⁷ in their study observed the length, width, and height of the pedicle as 28.7mm, 7.8mm, and 7.9mm, respectively, which do not correspond to the values observed in our present study. In our present study, we recorded the parameters of the pedicle on both sides of the axis: length, width, and height. The length, width, and height of the pedicle on the right side were noted as 32.1mm, 8.5mm, and 8.03mm, respectively, and on the left side, the length, width, and height were observed as 32.1mm, 8.26mm, and 7.63mm, respectively.

The median angle between the axis of the pedicle and the median sagittal line of the bone was observed to be 34.7 degrees.

The results obtained in various studies by different researchers have been compared with those of the present study and are presented in Tables 3 and 4.

Conclusion

The results obtained in the present study will be useful when performing surgical procedures around the axis vertebra to prevent injury to vital structures.

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Ethical consideration

This observational study used departmental dry bones from the anatomy department. Prior to the study's start, ethical approval was obtained from the institutional ethics committee in accordance with ethical code 147/eth/2022. For instructional and research purposes, the anatomy department provided all of the bones used in this study. All measurements were carried out in accordance with ethical norms, and the bones were treated with care and dignity. The Declaration of Helsinki and all national and institutional research policies were followed throughout the study.

Competing Interests

The authors declare no conflict of interest.

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