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RESEARCH ARTICLE

A Morphometric Study of the Adult Human Axis Vertebra and its Clinical Implications

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Abstract

Introduction: The axis (second cervical vertebra) is unique in possessing a dens or odontoid process and a specialised superior articular facet. It acts as an axle for the rotation of the atlas and the head around the strong dens which project cranially from the superior surface of the body. A good understanding of the dimensions of this bone is necessary for the evaluation of many clinical problems. **Objectives:** 1. To measure various parameters of the axis vertebra. 2. To compare the results with the previous studies. **Materials and Methods:** This observational study was carried out on 100 dried human vertebrae of unknown sex used for teaching in the Department of Anatomy at Madras Medical College. The parameters were measured by a digital vernier calliper and an inch tape. **Results:** The mean pedicle length on the right and left sides were 28.7mm and 27.8mm, the mean pedicle width on the right and left sides were 8.1mm and 8.3±1.61mm, and the mean pedicle height on the right and left sides were 9.4±1.54 mm and 9.4±1.34mm. The mean anteroposterior diameter of the superior articular facet on the right and left sides was 16.53±1.44mm and 16.62±1.52mm. The mean transverse diameter of the superior articular facet on the right and left side was 14.42 ±1.48mm and 14.62±1.68mm**.** The mean anteroposterior diameter of the inlet and outlet of the vertebral canal was 20.9±2.09mm and 18.23±2.32mm. The mean transverse diameter of the inlet and outlet of the vertebral canal was 20.4±1.89 and 20.2mm. The mean height and width of the dens are 15.4±1.77 and 10.05±0.91. **Conclusion**: Anatomical knowledge of accurate dimensions of the axis vertebra is required for evaluation of many surgical problems in the craniovertebral junction. Correction of instability of the atlanto–axial complex due to traumatic and pathological conditions requires surgical techniques like anterior or posterior screw fixation, interspinous wiring and interlaminar clamping. It can also be useful to devise a new method of fixation of the fractured odontoid process or axis pedicle. The observations of this will provide wide knowledge about the dimensions of the pedicle, the superior articular facet, dens, body and vertebral canal.

Keywords: Axis, Atlanto Axial Complex, Screw Fixation, Odontoid Process

1. Introduction

The axis vertebra is the second cervical vertebra. It is an atypical vertebra as it possesses a dens or odontoid process and a superior articular facet. It acts as an axle for the rotation of the atlas and the head around the strong dens which project cranially from the superior surface of the body. The axis is a vital component of the cranio-cervical junction and comprises the tip, body, neck and base. The cervical region, which connects the head and body, is the most flexible part of the vertebral column and contains many important structures. Conservative measures, surgery or a combination of both can be used to treat dens axis fracture. Approximately 10-14 % of all cervical region fractures are caused by a dens fracture of the axis.

Because of the unique shape of the superior articular facet, dens and different orientation of *Foramen transversorium* and complex relationship with vertebral artery, a better understanding of the morphometry of the axis vertebra is essential for efficient management of arising surgical problems. Many operative techniques like interspinous wiring, interlaminal clamping, plate and screw fixation pedicle have been employed to correct occipito cervical, atlanto axial complex instability.

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2. Aim and Objectives

To study the morphometric analysis of the axis vertebra.

- To study Pedicle length: Anterior-most point of the pedicle (anterior-most point on the superior articular facet) to the posterior edge of the inferior articular facet on the inferior aspect of the vertebra, measured.
- Pedicle width: Distance from the external surface of the pedicle to its internal surface at the level of the *Foramen transversarium.*
- Pedicle height: Superior surface of the pedicle to its inferior surface.
- Superior articulating facet: Anteroposterior diameter and transverse diameter.
- Vertebral foramen inlet: Anteroposterior diameter at the midline.
- Vertebral foramen inlet: Transverse diameter: Maximum transverse diameter.
- Vertebral foramen outlet: Anteroposterior diameter: At the midline.
- Vertebral foramen outlet: Transverse diameter: Maximum transverse diameter.
- Height and width of the dens.

3. Review of Literature

Sengül *et al.*[1] - The widest diameter of the dens axis on the coronal plane varied from 7.9 to 16.9mm. The mean distance from the tip of the dens axis to the horizontal line which arbitrarily passed superior to the superior articular facets of the axis (height of dens on coronal plane) was 14.5mm. The mean width of the articular surface of the dens axis on the coronal plane was 8.6mm, and its mean height was 11mm. The mean A-P dimension was 11.6mm (8.5-16.2mm) and the mean transverse dimension was 9.5mm (4.9-13.3mm). The maximum A-P diameters of the vertebral canal were 20.8mm on average, and the mean narrowest AP diameter was 17.7mm. The maximum transverse diameter of the vertebral foramen was 24.7mm, and the mean minimum transverse diameter of the vertebral canal was 24.5mm. The mean width of the pedicle on the transverse plane (the distance from the axis's external surface to the internal surface at the level of the transverse foramen) was 9.5mm. The width of the C2 pedicle was less than 5mm in 7.5% of specimens.

Shilpa Gosavi *et al.*[2] – In a hundred dried intact human axis vertebrae, the width of the pedicle was less on the right side and greater on the left, and this difference was statistically significant. However, the difference in the length of the pedicles was not significant. There was no difference in the diameters of the superior and inferior articular facets on the two sides.

Mukesh Singla *et al.*[3] – In thirty intact human axis vertebrae, the mean A-P and transverse diameter of the inferior surface of the axis was 15.42mm and 17.7mm. Mean transverse diameter and mean A-P diameter of the odontoid process were 9.32mm and 10.1mm. Mean anterior and posterior height of the odontoid process was 14.66 mm and 13.89mm. Mean pedicle width was 10.07mm on the right side and 10.52mm on the left side. Mean transverse diameter of vertebral canal was 22.37±1.73mm. Mean of A-P diameter of vertebral canal at inlet was 18.31±2.05mm, and mean of A-P diameter of vertebral canal at outlet was 14.84±1.63mm.

Monika Lalit *et al.*[4] – In 60 dry axis vertebrae, the mean length, width, and height of the pedicle were 21.61±2.37mm, 8.82±2.43mm, and 5.63±2.06mm.

Dr P. Kanagavalli *et al.*[5] - In 100 dried adult human axes, the mean pedicle length on the right and left sides were 29.2±2.09mm and 28.4±2.29mm, the mean pedicle width on the right and left sides were 7.9±1.84mm and 8.2±1.61mm, mean pedicle height on the right and left sides were 9.1±1.54mm and 9.1±1.34mm. The mean anteroposterior diameter of the inferior articular face on the right and left sides was 9.8±1.54mm and 9.7±1.25mm. The mean transverse diameter on the right and left sides was 9.8±1.44mm and 9.4±1.26mm.

The mean anteroposterior diameter of the inlet and outlet of the vertebral canal was 19.9± 2.09mm and 17.41±2.32mm. The mean transverse diameter of the inlet and outlet of the vertebral canal was 23.7±1.89 mm2 and 3.5±1.81mm.

Raghavi N *et al.*[6]– In 50 dry axis vertebrae of Indian origin, the mean odontoid process height was 19.63±2.01 mm, the mean odontoid process diameter was 10.77±2.07 mm, the mean anterior odontoid facet height and the mean anterior odontoid facet width were found to be 11.70±1.70 mm and 8.01±0.76 mm, respectively. The maximum and minimum mean widths

of the odontoid process ranged from 9.60±1.00mm and 8.03±0.84mm.

Javed Alam *et al.*[7]– A 50-human-axis axis study, found that the average height of the odontoid process of the axis vertebra was 14.55±1.07mm, while the Anteroposterior (AP) diameter was 9.98±0.85mm. The maximum width of the odontoid process was 10.10±0.82 mm, and the average width was 9.16±1.00mm. Additionally, the dens axis sagittal angle was found to be 13.18±4.80 degrees.

Jija E. Varghese *et al.*[8] – Out of Sixty-three second cervical vertebrae, there was no statistical difference between the right and left sides of the dimensions of superior articular facets, foramen transversarium, and the transverse diameter of inferior articular facet. The anteroposterior diameter of the inferior articular facets was more on the right side ($P = 0.009$). The width of the pediculoisthmic component in both the superior and inferior aspects was found to be less on the right side than that of the left ($P = 0.006$ and $P = 0.031$, respectively).

4. Materials and Methods

One hundred adult human axis vertebrae of unknown age and gender were examined in a cross-sectional fashion in the Institute of Anatomy. The parameters of the study are measured using an inch tape and a vernier calliper.

5. Results (Including Observation)

The mean pedicle length on the right and left sides was 28.7mm and 27.8mm (Figure 5), the mean pedicle width on the right and left sides was 8.1mm and 8.3±1.61 mm (Figure 3), the mean pedicle height on the right and left sides was 9.4±1.54 mm and 9.4±1.34mm (Figure 4). The mean anteroposterior diameter of the superior articular facet on the right and left sides was 16.53±1.44mm and 16.62±1.52mm (Figure 1). The mean transverse diameter of the superior articular facet on the right and left sides was 14.42±1.48mm and 14.62±1.68mm

The mean anteroposterior diameter of the inlet and outlet of the vertebral canal was 20.9±2.09 mm and 18.23±2.32mm (Figure 2). The mean transverse diameter of the inlet and outlet of the vertebral canal

Figure 1. Superior articulating facet: Anteroposterior diameter and transverse diameter.

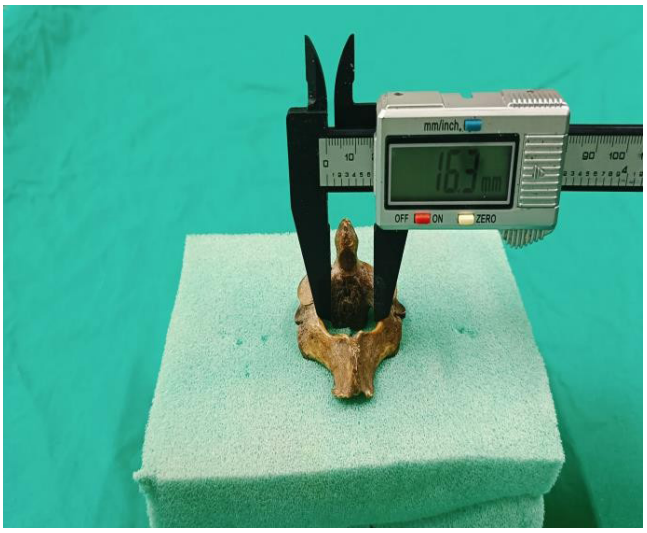

Figure 2. Vertebral foramen inlet: Transverse diameter: Maximum transverse diameter.

Figure 3. Pedicle width: distance from the external surface of the pedicle to its internal surface at the level of the foramen transversarium.

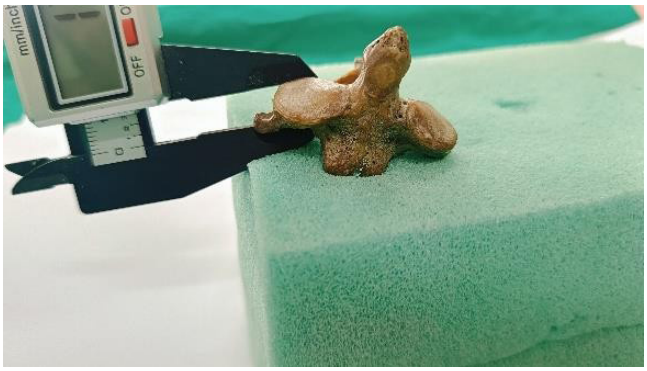

Figure 4. Pedicle height: the superior surface of the pedicle to its inferior surface

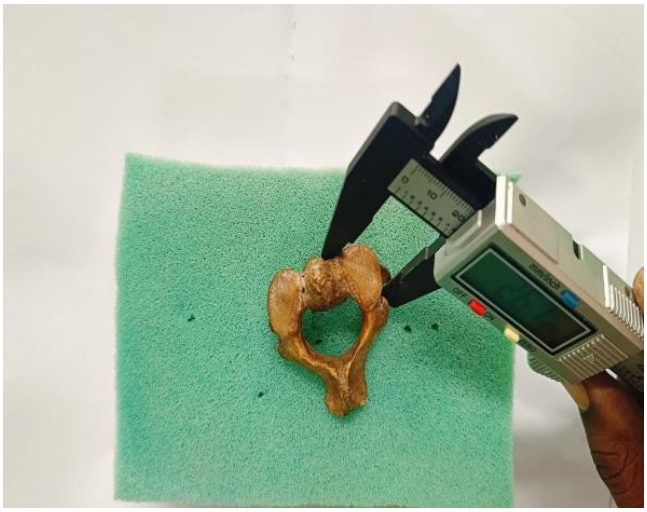

Figure 5. To study the pedicle length.

Figure 6. To study the dense width.

was 20.4±1.89 and 20.2mm. The mean height and width of the dens are 15.4±1.77 and 10.5±0.91(Figures 6 and 7).

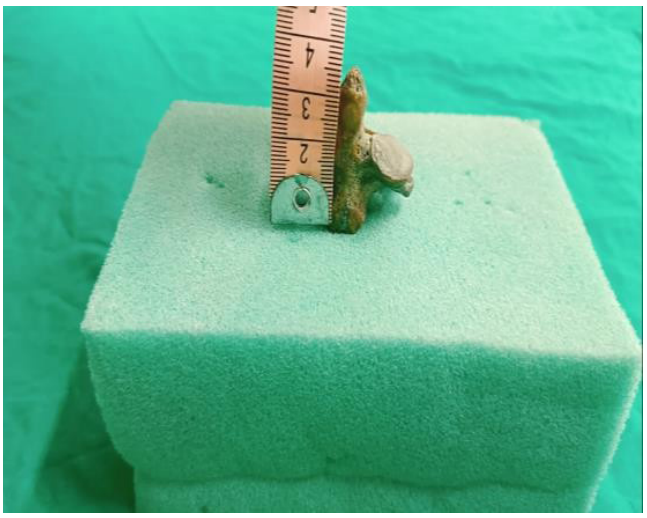

Figure 7. To study dense length.

6. Discussion

The pedicle dimensions of the present study closely correspond to the previous author's findings. The mean pedicle length on the right side is 28.7mm, and on the left side is 27.8mm, which closely resembles the findings of Gosavi *et al*[2]. The mean pedicle width measured on the right side was 8.1±1.84mm and on the left side 8.3±1.61mm, which is similar to the findings of Gosavi *et al*[2] and less than the findings of Kaur *et al*[9]. The mean height of the pedicle on the right side is 9.4±1.54mm and on the left side 9.4±1.34mm, which is slightly higher than the observations of Gosavi *et al*[2] (Table 1).

The mean anteroposterior diameter of the superior articular facet on the right and left sides was

16.53±1.44mm and 16.62±1.52mm. The mean transverse diameter of the superior articular facet on the right and left sides was 14.42±1.48mm and 14.62±1.68mm. These findings are equivalent to the findings of Mukesh *et al*[3] and Gosavi *et al*[2] (Table 2).

The mean anteroposterior diameter of the inlet and outlet of the vertebral canal was 20.9±2.09mm and 18.23±2.32mm. The mean transverse diameter of the vertebral canal was 20.4±1.89. The findings are equivalent to the findings of Xu *et al.*[10] and Mukesh *et al.*[3], and less than the findings of Seng *et al*[1]. (Table 3).

Dens length and width were 15.4±1.77mm and 10.5±0.91mm findings were similar to Xu *et al.*[10] and higher when compared to Sengal and Kadioglu *et al*[1] and Gosavai *et al*[2] (Table 4).

Table 1. Comparison of dimensions of the pedicle

Study	Pedicle length		pedicle Width		Pedicle height	
	Mean (n=100) ± SD (mm)		Mean (n=100) ± SD (mm)		Mean (n=100) ± SD (mm)	
	Right	Left	Right	Left	Right	Left
Sengal & kadioglu *et al.*[1]			9.6 ±2.4	9.6± 2.4		
Gosavai *et al.*[2]	28.71±3.25	28.29±3.25	7.19±1.31	7.73±1.63	8.20±1.48	8.32±7.67
Kaur *et al.*[9]			10.52±1.99	10.61±1.67		
present study	28.7 ±2.09	27.8 ±2.29	8.1 ±1.84	8.3±1.61	9.4 ±1.54	9.4 ±1.34

Table 2. Mean of SAF (AP and transverse diameter)

Study	SAF-AP Diameter		SAF-Transverse Diameter	
	Mean (n=100) ±SD (mm)		Mean (n=100) ± SD (mm)	
	Right	Left	Right	Left
Sengal & kadioglu *et al.*[1]	17.5		14	
Gosavai *et al.*[2]	16.64	16.66	14.44	14.64
Mukesh *et al.*[3]	16.61±1.33	16.7±1.49	14.92±1.76	14.79±1.48
present study	16.53 ±1.44	16.62 ±1.52	14.42 ±1.48	14.62 ±1.68

Table 3. Mean of inlet and outlet (AP and transverse diameter)

Study	AP Inlet	AP outLet	Traaansverse Diameter
	Mean (n=100) ±SD (mm)	Mean (n=100) ±SD (mm)	Mean (n=100) ± SD (mm)
Xu *et al.*[10]	18	15.3	21.9
Sengal & kadioglu *et al.*[1]	20.8		24.7
Mukesh *et al.*[3]	18.31± 2.05	14.84 ± 1.63	22.37 ± 1.73
present study	20.9 ± 2.09	18.23 ±2.32	20.4 ± 1.89

Table 4. Dense length and width

Parameter	Xu *et al.*[10]	Sengal & kadioglu *et al.*[1]	Gosavai *et al.*[2]	Present Study
Dens Length	15.5 mm	14.5mm	14.86mm	15.4 ± 1.77mm
Dens Width	10mm	11.2mm	9.28mm	10.5 ± 0.91mm

7. Summary and Conclusion

Anatomical knowledge of accurate dimensions of the axis vertebra is required for evaluation of many surgical problems in the craniovertebral junction[11]. Correction of instability of the atlanto–axial complex due to traumatic and pathological conditions requires surgical techniques like anterior or posterior screw fixation, interspinous wiring and interlaminar clamping[1,10,12,13]. It can also be useful to devise a new method of fixation of fractured odontoid process or axis pedicle[6,14,15,16]. The observations of this will provide wide knowledge about the dimensions of pedicle, Superior articular facet, dens, body and vertebral canal[1,5,9,4].

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