Original Article

Quantitative Anatomy of Axis Vertebra in South Indian Population - Implications for Implant Design

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Abstract

Background: Cervical vertebra fractures following road traffic accidents and accidental fall are commonly encountered in Orthopaedic outpatient department and mandate fixation surgeries. The outcome of the surgeries is often compromised by the mismatch between the patient's anatomy and implants designed using western anthropometric data. This study aimed to establish a comprehensive morphometric database for the second cervical vertebra-axis in South Indian population which can be used to design orthopaedic implants. **Material and Methods:** An observational study was conducted on 50 adult dry human Axis vertebra of both sexes from the collection at a tertiary care centre, in Tamil Nadu, India. Five key morphometric parameters were measured using standardized osteometric techniques with a digital vernier caliper. **Results:** The mean pedicle length, width, and height of the axis vertebra were 18.80 ± 1.82 mm, 9.98 ± 2.03 mm, and 8.50 ± 1.69 mm, respectively. The mean superior articular facet length and width were 15.38 ± 1.65 mm and 13.82 ± 1.24 mm, respectively. Compared with previous studies, the South Indian population demonstrated relatively shorter pedicle length and narrower superior articular facet width, while pedicle width and height were comparable to or greater than those reported in other populations. **Conclusion:** The morphometric profile of the South Indian Axis vertebra exhibits smaller dimensions when compared to North Indian and western population. This study emphasizes the necessity for developing population specific Axis implants to enhance geometric compatibility and therefore improve surgical outcomes.

Keywords: Axis vertebra fractures, population specific implants, South Indian population.

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Introduction

The second cervical vertebra acts as an axis for the first cervical vertebra by forming a pivot, allowing the first cervical vertebra to rotate helping the head and neck to achieve a greater range of movement at the atlanto-axial joint earning the name axis vertebra.The axis vertebra is made of vertebral body,dens/odontoid process, pedicle, lamina, spine, superior articular facet, inferior articular facet, vertebral foramen and transverse foramen.The understanding of the morphometry of the axis vertebra is needed for learning the pathology of axis vertebra and for providing a proper surgical intervention whenever it is needed. Several surgical techniques such as inter laminar clamping, plate and screw fixation and inter-spinous wiring are being used for the fixation of atlanto-axial joint in case of fractures occurring at that site. Also, the anatomical knowledge of dens is needed for the diagnosis of basilar invagination.[1-7]

Objectives: To determine the morphometric dimensions of the pedicle and superior articular facet of the axis vertebra in a South Indian population and compare these findings with previously published studies.

Materials and Methods

50 dry second cervical vertebrae were obtained from the Institute of Anatomy, Madras Medical College. Specimens were from mature adult skeletons. Each vertebra was numbered for study. The quantitative measurements were measured at the pedicle & superior articular facet. All symmetrical structures were measured unilaterally. Measurements were made using caliper for linear measurement. Based on the parameters the mean, range and standard deviation were calculated. The statistical analysis of the measurements was done. The following measurement protocol was followed.

1. Pedicle length – measured from anterior most point of pedicle axis to posterior point.
2. Pedicle width - measured from internal surface to external surface at level of transverse foramen.
3. Pedicle height - measured from superior surface to inferior surface within the transverse foramen.
4. Superior articular facet length- maximum antero-posterior diameter of superior facet.
5. Superior articular facet width - maximum transverse diameter of superior facet.

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Results

Table 1: Morphometric Parameters of the Axis Vertebra

Parameter	Mean (mm)	Standard deviation (mm)	Range (mm)
Pedicle Length	18.80	1.82	14-22
Pedicle Width	9.98	2.03	5-15
Pedicle Height	8.50	1.69	6-14
Superior articular facet length	15.38	1.65	12-20
Superior articular facet width	13.82	1.24	11-16

The measurements of the pedicle length, pedicle width, pedicle height, superior articular facet length and superior articular facet width showed uniformity and descriptive statistics including mean, standard deviation and range were calculated.

Discussion

A good anatomical knowledge of the pedicle is necessary for the trans-pedicular screw placement whenever a fracture line through the second cervical vertebra pedicle needs to be stabilized.

Table 2: Pedicle Length

Parameter	Nagaarjun et al (mm)	Lalit et al (mm)	Xu et al (mm)	Madawi et al (mm)
Mean Pedicle Length	18.8	21.6	25.6	28.7
Range	14-22	16-25.5	23-29	22-36

Pedicle Length: In the present study, the mean pedicle length was 18.8 ± 1.82 mm, with a range of 14–22 mm. This value was lower than those reported by Lalit et al. (21.6 mm), Xu et al. (25.6 mm), and Madawi et al. (28.7 mm). The observed difference reflects the fact that the length is significantly less in South Indian population compared to North Indian population and western population. Since pedicle length determines the maximum safe screw length during transpedicular fixation, preoperative morphometric evaluation before surgical intervention is mandatory. Failure to consider these variations may increase the risk of injury to adjacent structures.

Pedicle width:

Table 3: Pedicle Width

Parameter	Nagaarjun et al (mm)	Lalit et al(mm)	Xu et al(mm)	Madawi et al(mm)
Mean Pedicle width	9.98	8.8	7.7	7.9
Range	5-15	4-12	5-10	5-12.4

The mean pedicle width recorded in this study was 9.98 ± 2.03 mm (range 5–15 mm). These findings are comparable with those reported by Lalit et al. (8.8 mm), Xu et al. (7.7 mm), and Madawi et al. (7.9 mm). Pedicle width is one of the most critical parameters in determining the feasibility of transpedicular screw placement. The relatively larger mean width observed in the present study suggests that adequate bone stock is available in most specimens for safe screw insertion. Nevertheless, the wide range observed emphasizes the need for individual assessment, as narrower pedicles may increase the risk of vertebral artery injury.

Pedicle height:

Table 4: Pedicle Height

Parameter	Nagaarjun(mm)	Lalit et al(mm)	Xu et al(mm)	Madawi et al(mm)
Mean Pedicle Height	8.5	5.6	8.6	7.8
Range	6-14	2-13	6-12	3.4-12.2

The mean pedicle height in the present study was 8.5 ± 1.69 mm, with values ranging from 6–14 mm. These findings closely resemble those reported by Xu et al. (8.6 mm) and Madawi et al. (7.8 mm), although they are greater than the values reported by Lalit et al. (5.6 mm). Pedicle height is another important determinant of screw trajectory and fixation stability. Adequate pedicle height provides sufficient vertical clearance for screw placement.

Table 5: Superior articular facet (SAF) length:

Parameter	Nagaarjun et al (mm)	Lalit et al(mm)	Xu et al(mm)	Gupta & Goel (mm)
Mean SAF Length	15.38	18.2	16.49	16.5
Range	12-20	16-23	13.90-20.50	13.5-20

The mean superior articular facet length was 15.38 ± 1.65 mm, with a range of 12–20 mm. These measurements are consistent with previous studies by Xu et al. (16.49 mm) and Gupta and Goel (16.5 mm), although slightly lower than the values reported by Lalit et al. (18.2 mm). The superior articular facet forms the articulating surface with the atlas and plays a crucial role in atlantoaxial stability. Knowledge of its dimensions is important during placement of fixation devices and in surgical procedures involving the craniovertebral junction.

Table 6: Superior Articular Facet (SAF) Width

Parameter	Nagaarjun et al (mm)	Xu et al (mm)	Gupta & Goel (mm)	Lalit et al(mm)
Mean SAF Width	13.82	17.6	15.9	14.35
Range	11-16	16-21	12-19.5	11-17

The mean superior articular facet width observed in this study was 13.82 ± 1.24 mm (range 11–16 mm). This value was comparable to that reported by Lalit et al. (14.35 mm) but lower than those reported by Xu et al. (17.6 mm) and Gupta and Goel (15.9 mm). Since the vertebral artery courses in close proximity to the superior articular facet, accurate knowledge of these dimensions is essential to minimize vascular complications during screw fixation procedures.[8-11]

Conclusion

The present study demonstrates that certain dimensions of axis vertebra like pedicle length and superior articular facet width are relatively smaller in the South Indian population. These findings reinforce the importance of knowledge of population-specific morphometric data in preoperative planning. Such information can assist orthopaedic surgeons in selecting appropriate implant sizes, determining safe screw trajectories, and reducing the risk of complications during atlantoaxial fixation procedures.

The results of the present study contribute valuable baseline anatomical data for the South Indian population and may serve as a useful reference for orthopaedic surgeons, neurosurgeons, radiologists, and anatomists involved in the management of craniovertebral junction pathologies. The superior articular facet of axis vertebra has an anatomical significance to the course of vertebral artery and that makes the vertebral artery more vulnerable to injury.

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Conflicts of interest

There are no conflicts of interest.

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