International Journal of Research in Medical Sciences
Hiwarkar M et al. Int J Res Med Sci. 2025 Oct;13(10):4022-4028
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20252885

Original Research Article

A morphometric study of variation in dens of second cervical vertebrae: corona dentis and its clinical implication

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Received: 29 July 2025
Revised: 27 August 2025
Accepted: 28 August 2025

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ABSTRACT

Background: Type-II odontoid fractures are often managed by anterior screw fixation, a technique that requires precise morphometric knowledge of the dens. The corona dentis, a bony spur at the odontoid apex, may artificially elongate measurements, leading to potential surgical complications if unrecognized.
Methods: Thirty dry human C2 vertebrae were studied using a digital vernier caliper. Morphometric parameters of the dens and vertebral body were recorded, including height, anteroposterior (AP) and mediolateral (ML) diameters, and dimensions of the corona dentis. Non-metric features such as dens tip shape, orientation, and transverse ligament groove morphology were assessed independently by two observers. Measurements were repeated to minimize intra-observer variability.
Results: Corona dentis was observed in 8 of 30 specimens (26.7%). The mean height of the dens without corona was 15.35±1.84 mm anteriorly and 15.65±1.70 mm posteriorly, whereas combined heights with corona averaged 18.95 mm and 19.25 mm, respectively. The corona itself measured 3.60±0.79 mm in height and 9.80±0.99 mm in width. The dens averaged 10.1±0.91 mm (AP) and 9.8±0.99 mm (ML). Non-metric analysis showed tapering tips in 40%, retroverted axes in 56.7%, and transverse-type ligament grooves in 60% of specimens.
Conclusions: The corona dentis is a relatively common anatomical variation that significantly increases apparent dens height. Failure to recognize this structure may result in overestimation of screw length during anterior odontoid fixation. Preoperative CT evaluation and careful apex identification are essential for safe surgical planning.

Keywords: Corona dentis, Odontoid process, Axis vertebra, Morphometry, Anterior odontoid screw, Craniovertebral junction

INTRODUCTION

Fractures of the odontoid process (dens) are among the most common cervical spine injuries, accounting for approximately 12-15% of all cervical vertebral fractures and nearly 20% of all spinal injuries in older adults.[1,2] These fractures predominantly affect two demographic extremes: the elderly, due to low-energy falls, and younger individuals subjected to high-velocity trauma such as road traffic accidents.[3] The second cervical vertebra (C2), or axis, plays a pivotal role in the rotational movement of the head, and injury to its odontoid process can compromise spinal stability and neurological integrity.

The classification of odontoid fractures most commonly referenced in clinical settings is the Anderson and D'Alonzo system, which divides them into three types: Type I involves the tip of the odontoid process; Type II occurs at the base and is the most unstable and frequently encountered variant; and type III extends into the body of the axis.[4] Type II fractures, due to their precarious location and tenuous vascular supply, are particularly notorious for non-union and complications, making their diagnosis and management critically important.[5]

Because the odontoid process sits immediately next to the medulla oblongata and within the highly mobile cranio-vertebral junction, even subtle shifts can lead to catastrophic events such as spinal-cord compression or vertebrobasilar insufficiency.[6] Precise diagnosis and meticulous surgical planning are therefore indispensable.

The initial work-up for an odontoid fracture generally starts with standard radiographs, most commonly the lateral and open-mouth (odontoid) views. When plain films are inconclusive or the injury pattern appears complex, computed tomography (CT) remains the gold standard for evaluating bony detail owing to its superior spatial resolution. Magnetic resonance imaging (MRI) is often added when ligamentous injury or spinal-cord involvement is suspected.[7]

Management is guided by fracture type, patient age, degree of displacement, and the presence of neurological deficits. Conservative treatment, such as cervical collars or halo vests is typically reserved for minimally displaced, stable fractures, particularly in younger patients. Unstable or displaced fractures, by contrast, usually require surgery to restore atlanto-axial stability and to avert neurological decline.[8]

Among operative strategies, anterior odontoid screw fixation has gained popularity for Type II fractures. This method secures internal fixation while preserving cervical rotation, giving it a functional edge over posterior fusion, especially for younger, more active patients.[9] Success, however, hinges on precise morphometric knowledge of the dens, including its height, width, inclination, and any anatomical variants.

One such variant drawing increasing surgical interest is the corona dentis, a superior cortical bony projection extending from the tip of the dens. First noted in cadaveric and imaging studies, this morphology can meaningfully influence surgical corridors and fixation techniques, underscoring the need for thorough pre-operative assessment. Initially described in cadaveric and radiological studies, this anatomical variant may significantly alter the morphology of the odontoid process and, if unrecognized, may lead to overestimation of the screw length during anterior fixation procedures.[10] Failure to account for this variation can result in inadequate screw purchase, risk of screw protrusion, injury to the vertebral artery, or compromise of the spinal cord.[11]

Cadaveric investigations indicate that a corona dentis, a superior cortical spur on the tip of the dens appears in roughly 20-30% of specimens.[12] Yet detailed morphometric data on this projection (e.g., its height, basal breadth, and spatial relationship to surrounding structures) remain scarce in Indian cohorts. Because radiologists rarely flag the variant during pre-operative work-ups, surgeons may enter high-precision procedures such as anterior odontoid screw placement without crucial information, thereby increasing the risk of intra-operative complications.[13]

Corona dentis is only one of several anatomical nuances that can shape surgical strategy. Core dimensions of the dens, anterior and posterior height, transverse width, and the inclination or contour of its apex directly influence screw trajectory and purchase. A retroverted or anteverted tip changes the ideal angle of insertion, whereas a truncated or bulbous summit heightens the chance of screw skidding or cortical breach.[14] Qualitative features such as the configuration of the groove for the transverse ligament also matter biomechanically, modulating ligamentous restraint and potentially predisposing patients to chronic atlanto-axial instability after trauma or degeneration.[15]

With C2 fractures rising, especially among older adults and the odontoid process playing a pivotal role in cervical stability, region-specific reference data are urgently needed. The present investigation therefore examined a series of dry axis vertebrae, recording both metric and non-metric characteristics of the dens, with special emphasis on the presence, frequency, and dimensions of corona dentis. In doing so, this study seeks to improve pre-operative planning and reduce iatrogenic risk during anterior cervical instrumentation.

Our primary objective was to identify and characterise corona dentis in the second cervical vertebra (C2), documenting its prevalence and measuring its length. A secondary aim involved a comprehensive morphometric survey of the dens, capturing parameters such as overall length, transverse width, and the anterior and posterior body heights of vertebra while also cataloguing non-metric traits like tip slope and morphology of transverse-ligament groove. Collectively, these data deepen anatomical insight and provide surgeons with clinically actionable guidance for anterior odontoid screw fixation.

METHODS

Study type

This study was designed as a descriptive, cross-sectional morphometric analysis. The objective was to evaluate the prevalence of corona dentis and its impact on dens measurements of the second cervical vertebra (axis, C2).

Study place and period

The work was conducted in the Department of Anatomy, utilizing specimens from the Departmental Osteology collection in one year.

Selection criteria

A total of 30 dry human C2 vertebrae were included. The inclusion criteria were intact, fully ossified vertebrae with preserved odontoid process and vertebral body.

Exclusion criteria were vertebrae with gross damage, fractures, erosion, congenital malformations, or degenerative changes that could compromise morphometric measurements. All specimens were carefully examined prior to inclusion, and those failing to meet the criteria were excluded from analysis.

Procedure

Each vertebra was examined systematically for the presence of corona dentis, defined as a distinct bony spur arising from the apex of the odontoid process. Morphometric measurements were obtained using a high-precision digital vernier calliper (Mitutoyo, accuracy 0.01 mm) under standardized laboratory conditions with adequate ambient lighting. Each measurement was taken with the specimen placed on a flat surface to minimize error.

The following parameters were measured:Dens height (anterior and posterior), both with and without corona dentis. Anteroposterior (AP) and mediolateral (ML) diameters of the dens at its base. Height and width of the corona dentis in specimens where it was present. Anterior and posterior vertebral body height.

Each parameter was measured twice by the same observer at an interval of one week, and the mean of the two readings was taken for analysis. This approach was employed to reduce intra-observer variability. Additionally, a subset of 10 specimens was re-measured by a second observer to assess reproducibility.

For non-metric analysis, the following traits were recorded: Dens tip morphology (tapering, bulbar, or truncated). Dens orientation (anteverted, retroverted, or straight) assessed relative to the vertical axis. Transverse ligament groove morphology (transverse, oblique, or absent).

These features were assessed independently by two observers, and disagreements were resolved by the consensus.

Ethical approval

As the study utilized dry osteological specimens available in the departmental teaching collection, no living human participants were involved. The research was granted an ethical exemption by the institutional ethics committee.

Statistical analysis

All data were entered into Microsoft excel and analyzed using SPSS version [insert version, e.g., 22.0]. Continuous variables (dens height, body height, diameters, corona dentis dimensions) were expressed as mean±standard deviation (SD) and range. Categorical data (presence of corona dentis, dens morphology, orientation, groove types) were summarized as frequencies and percentages.

Comparative analysis of dens height between vertebrae with and without corona dentis was performed using Student's t test for independent samples. A $p<0.05$ was considered statistically significant. Intra-observer reliability of repeated measurements was assessed using the intraclass correlation coefficient (ICC, two-way mixed model, absolute agreement). Inter-observer agreement for non-metric traits was evaluated using Cohen's kappa statistic.

RESULTS

In this study, thirty dry adult second cervical vertebrae were analyzed for both metric and non-metric parameters, with special attention given to the identification and characterization of corona dentis, a cortical bony projection arising from the apex of the odontoid process.

This anatomical variant was observed in 8 out of 30 specimens, reflecting a prevalence of 27%. The presence of corona dentis was consistently associated with an increase in the total vertical height of the dens. Specifically, the mean anterior height of the dens in vertebrae with this feature was 18.95 mm, while the posterior height reached 19.25 mm. In contrast, specimens without corona dentis showed mean anterior and posterior dens heights of 15.35±1.84 mm and 15.65±1.70 mm, respectively. This difference represents an approximate 23-24% increase in height due to the presence of the corona, a variation that may have significant clinical implications in surgical procedures such as anterior odontoid screw fixation. The mean width of corona dentis was 9.8±0.99 mm, with values ranging from 7.94 mm to 11.67 mm. Its height ranged from 2.9 mm to 5.0 mm, with a mean of 3.6±0.79 mm.

Morphometric evaluation of the dens also included the measurement of transverse and antero-posterior diameters. The average transverse width of the dens was 9.8±0.99 mm, which closely mirrors the basal width of the corona, while the antero-posterior diameter was slightly greater at 10.1±0.91 mm, ranging from 8.7 mm to 12.12 mm. These findings indicate near symmetry in dens width but demonstrate variability in its sagittal depth, which may influence the choice of screw dimensions and trajectory in clinical practice.

The height of the vertebral body was also measured to better understand the structural context of the dens. The mean anterior body height was found to be 19.53±2.65 mm, with a narrow range of 19.39 mm to 24.68 mm, suggesting relatively uniform anterior vertebral structure across the sample. The posterior body height, however, showed a wider range, averaging 14.90±1.80 mm with values between 10.87 mm and 15.84 mm. These measurements are summarized in Table 1.

Table 1: Metric parameters of the second cervical vertebra (C2) and corona dentis (in mm).

Parameters	Mean±SD	Range (mm)
Width of corona dentis	9.8±0.99	7.94-11.67
Height of corona dentis	3.6±0.79	2.9-5.0
Anterior height of normal dens	15.35±1.84	11.86-20.75
Posterior height of normal dens	15.65±1.70	12.46-18.27
Combined height with corona (anterior)	18.95 (no SD given)	14.76-25.75
Combined height with corona (posterior)	19.25 (no SD given)	15.36-23.27
Transverse width of dens	9.8±0.99	7.94-11.67
Antero-posterior diameter of dens	10.1±0.91	8.7-12.12
Anterior height of vertebral body	19.53±2.65	19.39-24.68
Posterior height of vertebral body	14.90±1.80	10.87-15.84

Table 2: Non-metric anatomical variations of the dens and transverse ligament groove (n=30).

Parameters	Type	N	Percent (%)
Shape of tip of dens	Bulbar	9	30
	Tapering	12	40
	Truncated	9	30
Slant of dens	Retroverted	17	57
	Straight	13	43
	Anteverted	0	0
Shape of groove for transverse ligament	Transverse	18	60
	Round	7	24
	Oval	4	13
	Elliptical	1	3

Non-metric anatomical features of the dens were also assessed in each specimen. The shape of the tip of the dens was classified into three categories: tapering, bulbar, and truncated. Tapering tips were the most common, observed in 40% of specimens, while bulbar and truncated types each accounted for 30% of the sample. The slant or inclination of the dens revealed two configurations: retroverted and straight. Retroversion was predominant, present in 57% of the vertebrae, while the remaining 43% exhibited a straight alignment. Interestingly, no anteverted specimens were encountered in the study, reinforcing the dominance of posteriorly inclined dens morphology in this population. The shape of the groove for the transverse ligament on the posterior surface of the dens also showed variation. The most frequent form was the transverse groove, seen in 60% of cases, followed by round (24%), oval (13%), and elliptical (3%) shapes. These non-metric findings, while qualitative, may have functional implications for ligament attachment and joint stability and are presented in Table 2.

Overall, the results underscore the presence of significant morphometric variability in the second cervical vertebra. The identification of corona dentis in over one-fourth of the specimens, along with measurable differences in dens height and shape, highlights the clinical importance of preoperative morphological evaluation. Such anatomical nuances should be carefully considered in radiological interpretation and surgical planning to reduce the risk of intraoperative complications, particularly during instrumentation procedures involving craniovertebral junction.

DISCUSSION

The morphometric and morphological assessment of the second cervical vertebra is of considerable importance in both clinical anatomy and spinal surgery. Among various anatomical variants associated with the odontoid process, corona dentis, a bony cortical protrusion from the apex of dens has emerged as a variant with potential implications in diagnostic imaging, biomechanical function, and surgical intervention. In the present study, corona dentis was identified in 27% of dry axis vertebrae, a prevalence that is notably higher than previously reported in literature.

The identification of corona dentis is essential due to its potential to increase the effective height of the dens by as much as 23-24%. This increase can mislead the estimation of screw length during anterior odontoid screw fixation, potentially resulting in surgical complications. Alonso et al were among the first to describe the variant in a detailed anatomical study, reporting an incidence of 20% in their series of 20 dry cervical vertebrae.[16] They emphasized the risk of vertebral artery injury and breach of the spinal canal if the length of the corona dentis is not accounted for during anterior instrumentation. Their reported average dimensions of the corona, 4.5 mm in height and 9 mm in width are consistent with the current study, which found mean values of 3.6±0.79 mm and 9.8±0.99 mm, respectively in Table 3.

Other authors have proposed differing etiologies for the formation of corona dentis. Padmalatha et al in a large-scale analysis of 210 dried cervical vertebrae, found a much lower incidence of 0.48%, attributing the formation of the projection to calcification of ligaments attached to the apex of the dens, likely associated with chronic inflammatory conditions or degenerative changes.[19] Similarly, Kumar et al described an incidence of 3.33% in their sample of 30 vertebrae and suggested that ossification of ligaments in conditions such as diffuse idiopathic skeletal hyperostosis (DISH) or ankylosing spondylitis may be responsible.[17] Their reported height of 24.28 mm for the elongated odontoid process highlights the considerable anatomical variability that exists across populations.

Table 3: Comparative studies on incidence and morphometry of corona dentis/elongated odontoid process.

Author (years)	Sample Size	Incidence and metric parameters	Conclusion
Alonso et al[16] (2017)	20 dry cervical vertebrae	Incidence: 20% Avg width: 9 mm Avg height: 4.5 mm	Corona dentis develops due to degenerative arthritic changes, similar to pannus formation.
Padmalatha et al[19] (2019)	210 dried cervical vertebrae	Incidence: 0.48% (1 case) of elongated dens	Elongation due to calcification of ligaments; commonly seen in elderly with inflammatory conditions.
Prathap Kumar et al[17] (2014)	30 dried cervical vertebrae	Incidence: 3.33% (1 case) Length: 24.28 mm Base: 11.08 mm Apex: 12.5 mm	Associated with ligament ossification in degenerative diseases such as DISH, AS, CPPD, and SpA.
Suby et al[18] (2018)	14 dried cervical vertebrae	Incidence: 14.3% (2 out of 14) A: 5.55 mm (H), 1.77 mm (W) B: 4.4 mm (H), 2.95 mm (W)	Likely post-traumatic ossification; no evidence of neoplastic or arthritic changes.

A paleopathological perspective on corona dentis was offered by Suby et al who identified elongated odontoid processes in 2 of 14 late Holocene skeletal remains.[18] The dimensions in their findings, 5.55 mm and 4.4 mm in height are comparable to those of Alonso and our present study. Importantly, Suby and colleagues found no signs of osteoarthritic or neoplastic changes, suggesting that traumatic soft tissue injury without bone fracture may also contribute to the development of corona dentis as a post-traumatic ossification phenomenon.

The clinical importance of a corona dentis becomes most evident during anterior odontoid screw fixation for type II fractures. This technique preserves atlanto-axial motion while providing stable fixation, yet its success hinges on selecting the correct screw length and trajectory. Surgeons usually calculate length by drawing a straight line from the anterior-inferior corner of the C2 body to the dens apex.[5] If a corona dentis goes unrecognised, that measurement can be artificially lengthened, increasing the risk that the screw will pierce the apical cortex. Jain et al contend that computed tomography is the best modality for detecting such anatomical variants, although subtle cortical spurs like the corona may still escape notice without meticulous multiplanar reconstruction.[20]

Short screws, on the other hand, may fail to cross the fracture site adequately, resulting in poor purchase in the apical segment of the dens and incomplete fracture reduction. This is particularly relevant in elderly individuals, where bone density is reduced and the margin for error is narrower. Thus, knowledge of corona dentis becomes critical not only to avoid complications but also to ensure optimal biomechanical performance of the fixation construct.

The current study also investigated non-metric variations of the dens, including tip morphology, slant, and the shape of the groove for the transverse ligament. Tapering of the dens tip was the most common form, consistent with the findings of Singla et al who similarly noted tapering to be predominant in their morphometric study of Indian axis vertebrae.[21] The slant of the dens was retroverted in 57% of our specimens, a finding with direct surgical relevance as posterior inclination necessitates steeper screw trajectory and increases the risk of posterior cortical breach.

The shape of the groove for the transverse ligament showed considerable variability, with transverse grooves being the most frequent (60%). These anatomical details have important implications for the biomechanical stability of the atlantoaxial joint, particularly in the presence of ligamentous laxity or instability. Additionally, such non-metric variations may affect imaging interpretation and should be considered when evaluating pathology involving the craniovertebral junction.

It is also essential to differentiate corona dentis from other known variants of the odontoid process, such as os odontoideum and persistent ossiculum terminale. Os odontoideum represents a well-corticated, separate ossicle at the location of the dens, often due to failed fusion or remote trauma. It may be orthotopic or dystopic, with the latter often fused to the occipital bone (basion).[22] Persistent ossiculum terminale, by contrast, involves failure of fusion of the secondary ossification center at the tip of the dens and is usually asymptomatic, although it can mimic a type II fracture on radiographs.[23] Differentiating these from corona dentis is crucial, as their management strategies differ substantially.

The variability in incidence of corona dentis across different populations, as evidenced in studies by Alonso, Padmalatha, and Suby, underscores the need for region-specific anatomical databases.[16,18,19] The present study, conducted on an Indian population, suggests a higher prevalence than previously reported, possibly due to unrecognized degenerative or traumatic etiologies. Given its frequency and the risk, it poses during anterior odontoid instrumentation, radiologists and spine surgeons should be vigilant in assessing its presence during preoperative planning.

Limitations

The present study has certain limitations that should be acknowledged. First, the sample size was relatively small (30 vertebrae) and derived from a single institutional collection, which may not fully represent population-based variability. Second, as the specimens were dry bones of unknown age and sex, the influence of demographic and physiological factors such as sexual dimorphism, bone density, or age-related changes could not be evaluated. Third, the absence of radiological correlation (CT or MRI) limited the ability to validate morphometric findings in living patients where soft tissue relationships and surgical positioning may alter operative perspectives. Finally, only gross morphometry was assessed; microstructural and biomechanical characteristics that could impact screw purchase and stability were not explored. Future multicentric studies with larger, demographically stratified samples and radiological correlation are warranted to strengthen the clinical applicability of these findings.

CONCLUSION

The present morphometric study emphasizes the anatomical and clinical importance of corona dentis, a superior cortical bony protrusion arising from the apex of the dens. With a notable prevalence of 27% in our sample, this variant must be recognized as a potential contributor to cervical pathology and a critical consideration during anterior odontoid screw placement. Its presence significantly increases the vertical height of the dens, which, if unaccounted for, may result in incorrect screw length estimation, potentially leading to cortical breach, neurovascular injury, or surgical failure. Etiologically, corona dentis may develop from a range of pathological processes, including post-traumatic ossification, degenerative arthritis, chronic inflammation, or less commonly, neoplastic changes. Given this variability, preoperative imaging and surgical planning should include meticulous assessment for this variant, particularly in elderly patients or those with suspected chronic cervical pathology. Importantly, during anterior screw fixation for type II odontoid fractures, the height of corona dentis should be excluded from total screw trajectory to avoid over-penetration and neurological complications. Awareness of such anatomical nuances can significantly enhance surgical precision and patient safety. Future studies with radiological correlation are warranted to better define its etiology and prevalence across populations.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Hiwarkar M, Sharma S, Krishna PA, Agarwal J, Singh HJ, Ramkumar M. A morphometric study of variation in dens of second cervical vertebrae: corona dentis and its clinical implication. Int J Res Med Sci 2025;13:4022-8.