



OPEN Three dimensional morphometric analysis of cervical uncinate process from C3 to C7 with surgical implications

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The uncinate process is a key anatomical structure in the cervical spine, essential for uncovertebral joint formation and spinal biomechanics. Although its linear dimensions have been previously described, the relationship between its vertical height and angular orientation remains underexplored. This study aimed to evaluate the three-dimensional morphometry of the uncinate process from C3 to C7, focusing on correlations between height and angular parameters. Fifty-one dry human cervical vertebrae (C3–C7), obtained from multiple adult donors (donor count unknown; sex unknown), were analyzed using high-resolution CT (0.75-mm slices). Although specimens were unevenly distributed across vertebral levels, measurements included uncinate height, uncinate angle, and endplate angle on coronal reconstructions. Statistical analysis involved Wilcoxon signed-rank, Kruskal–Wallis, and Spearman’s correlation tests. No significant side-to-side differences were found in uncinate height or angle, though the endplate angle was significantly higher on the left. Inter-level comparisons revealed significant differences in left uncinate height and bilateral endplate angles. Importantly, uncinate height showed a strong negative correlation with uncinate angle (Right: $\rho = -0.557$; Left: $\rho = -0.677$; both $p < 0.001$) and a strong positive correlation with endplate angle (Right: $\rho = 0.777$; Left: $\rho = 0.809$; both $p < 0.001$). These findings underscore the anatomical variability and interdependence of vertical and angular features of the uncinate process, with implications for uncovertebral joint mechanics and surgical approach planning. Recognizing such variations may improve safety and accuracy in anterior cervical spine procedures.

Keywords Uncinate process, Cervical spine, Morphometry, Computed tomography, Uncovertebral joint, Anterior cervical surgery

The cervical segment of the vertebral column consists of seven vertebrae, designated C1 to C7. The uncinate process (processus uncinatus) is a bony projection located on the superior aspect of the vertebral bodies from C3 to C7¹. These structures articulate with the inferior surface of the vertebra above to form the uncovertebral joints. Biomechanically, these joints serve to limit lateral flexion of the head^{2,3}. Each uncinate process has anterior and posterior slopes, a distinct apex, and medially oriented articular surfaces⁴. In the coronal plane, they exhibit a concave morphology along the superior endplate of the vertebral body⁵. Notably, the uncinate processes are positioned more anteriorly in the upper cervical spine and shift posteriorly in the lower cervical segments⁶.

The joint capsule of the uncovertebral articulation is thin, rendering it susceptible to degeneration in cases of repetitive stress, overuse, or poor posture. Nevertheless, such degenerative processes tend to progress slowly^{7–9}. Although the classification of uncovertebral joints as synovial remains debated¹⁰, Huang et al.¹¹ demonstrated the presence of cartilage within these joints, suggesting a synovial nature. Similar to other synovial joints, uncovertebral joints are prone to degenerative changes, including osteophyte formation. In the cervical spine, such pathological changes may affect neighboring anatomical structures—most notably, the vertebral artery and cervical spinal nerves—leading to clinical syndromes such as radiculopathy, myelopathy, or vertebrobasilar insufficiency^{7,8,12}.

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From a neurosurgical standpoint, detailed morphometric evaluation of the uncinate process is essential for procedures such as uncinotomy and uncovertebral foraminotomy. Although several studies have examined the morphometry of the uncinate process, most have focused primarily on linear dimensions or isolated level-based differences^{13,14}. However, the relationship between vertical height and spatial orientation (angle) of the uncinate process remains underexplored, particularly in three-dimensional reconstructed imaging datasets. This represents a relevant gap, as both vertical and angular variations may influence surgical access during anterior cervical procedures and alter joint biomechanics^{15,16}. To the best of our knowledge, few studies have addressed the potential correlation between uncinate height and angular parameters such as the endplate angle or uncinate inclination, especially using high-resolution CT imaging in a Turkish population. By investigating this relationship, the present study aims to provide additional insight into level-specific and potentially interdependent anatomical variations of the uncinate process. These data may support improved anatomical understanding and inform future research or surgical planning related to the cervical spine.

Methods

This study included 51 dry human cervical vertebrae (C3–C7) from adult Turkish donors (estimated age 65–75 years). Specimens were sourced from an anonymized osteological collection; the exact number of donors was not recorded, and donor sex was unavailable. Only intact specimens exhibiting typical cervical vertebral features were included. Vertebrae with fractures or structural damage were excluded from the study. Measurements were obtained from vertebrae ranging from C3 to C7. Among the specimens, 14 were C3, 17 were C4, 9 were C5, 4 were C6, and 7 were C7 vertebrae. We volumetrically scanned 51 vertebrae at a slice thickness of 0.75 mm via a “Siemens Somatom Scope 16-slice CT” scanner. We then reconstructed the images on a workstation to create MPR (multiplanar reconstruction) and 3D reformatted views, and we performed all the measurements using these reconstructed images. To minimize measurement error, the same researcher conducted all measurements.

All procedures in the study were performed in accordance with national research committee standards and ethical guidelines for the 1964 Helsinki Declaration and later amendments. Ethical approval was obtained from the local non-invasive ethics committee (date: 2025/02, number: 2025-97).

Technique

For accurate morphometric analysis, all vertebrae were aligned using standard anatomical planes:

- In the horizontal plane, the central midpoint of the vertebral body was used as a reference, and the axes were aligned according to vertebral anatomy.
- In the sagittal plane, the center of the vertebral body was marked, and axes were adjusted based on the shape of the corpus.
- In the coronal plane, measurements were made based on alignment from the basal surface (basis) of the vertebral body.
- Angle Measurements:
 - Endplate Angle (coronal plane): The angle between (a) a line connecting the midpoint of the superior endplate to the apex of the uncinate process and (b) a horizontal reference line coincident with the superior endplate (Fig. 1).
 - Uncinate Angle (coronal plane): The medial inclination of the uncinate process, measured as the angle between (a) a line tangent to the posterior slope of the uncinate process and (b) the same horizontal reference line aligned with the superior endplate (Fig. 1).

Statistical analysis

To summarize the study's findings, descriptive statistics for numerical variables were presented in tables based on their distribution, including both mean and median values. Categorical variables were reported as counts and percentages. Distribution was evaluated with the Shapiro–Wilk test and Q–Q plots, supporting the use of non-parametric procedures. The Wilcoxon signed-rank test was used for all paired comparisons and the Kruskal–Wallis test was used for all non-parametric group comparisons. Spearman's correlation test was applied to examine the relationships between uncinate process height and angular parameters.

All statistical analyses were performed in jamovi (Version 2.6; The jamovi project, Sydney, Australia; 2025; <https://www.jamovi.org>). A *p* value of <0.05 was considered to indicate statistical significance.

Results:

Descriptive and comparative analyses of the uncinate process measurements between the right and left sides are presented in Table 1. The mean uncinate height was 5.2 ± 1.6 mm on the right and 5.3 ± 1.5 mm on the left, with no statistically significant difference between sides (*p* = 0.204). The mean endplate angle was significantly greater on the left ($28.47 \pm 6.63^\circ$) compared to the right side ($26.34 \pm 5.97^\circ$), and this difference was statistically significant (*p* = 0.002). In contrast, no significant difference was observed in the uncinate angle between the right ($121.87 \pm 14.34^\circ$) and left ($119.64 \pm 14.17^\circ$) sides (*p* = 0.283).

Further comparisons across cervical levels (C3–C7) revealed statistically significant differences in specific uncinate process parameters (Table 2). The left uncinate process height varied significantly among vertebral levels (*p* = 0.031), as did both right and left endplate angles (*p* = 0.048 and *p* = 0.010, respectively). In contrast, no significant differences were found in right uncinate height (*p* = 0.301), right uncinate angle (*p* = 0.169), or left uncinate angle (*p* = 0.056). These results indicate that the geometry of the uncinate process and its angulation relative to the vertebral endplate may differ depending on cervical level (Table 2).

Correlation analysis between uncinate process height and angular parameters is presented in Table 3. A statistically significant negative correlation was observed between uncinate height and uncinate angle on both the

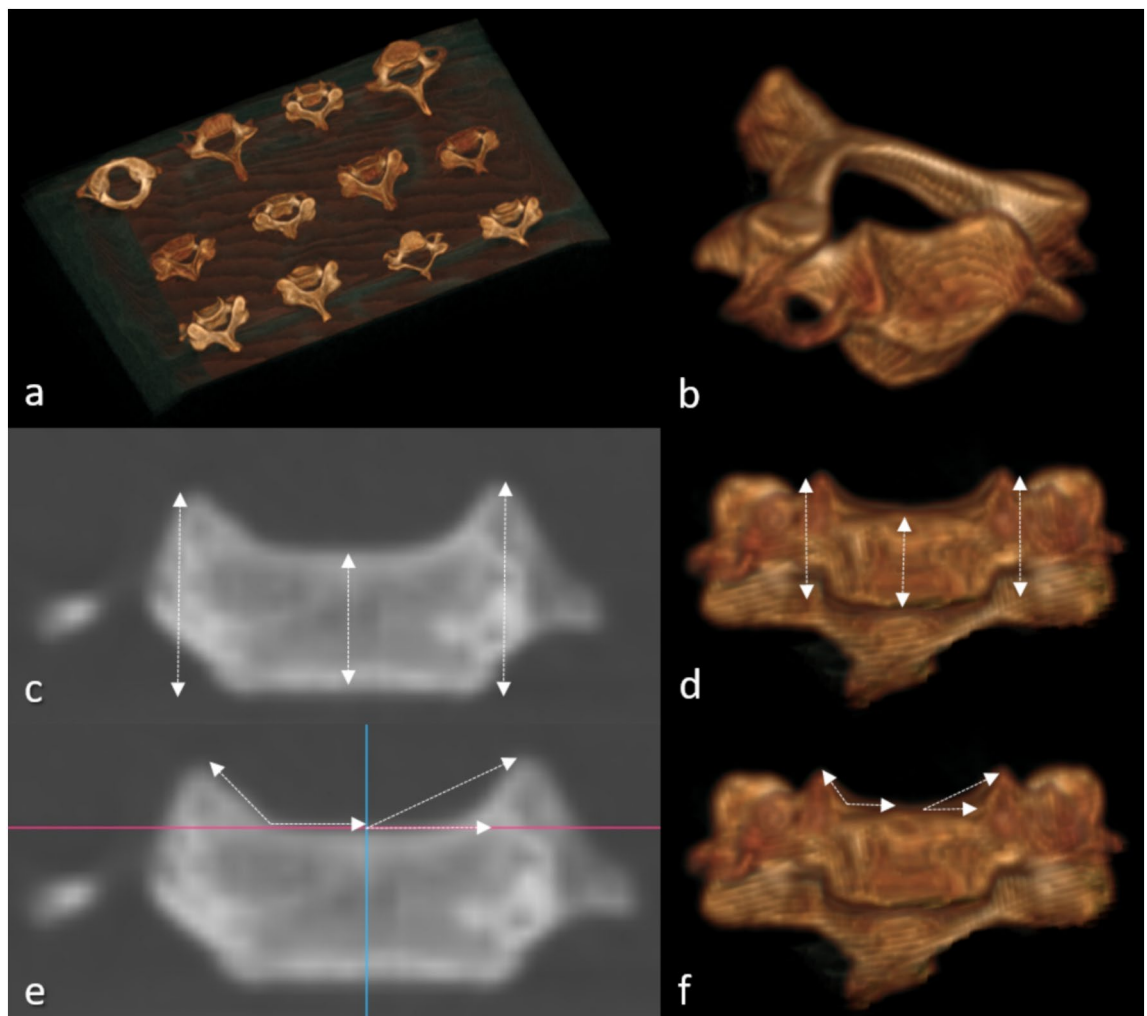


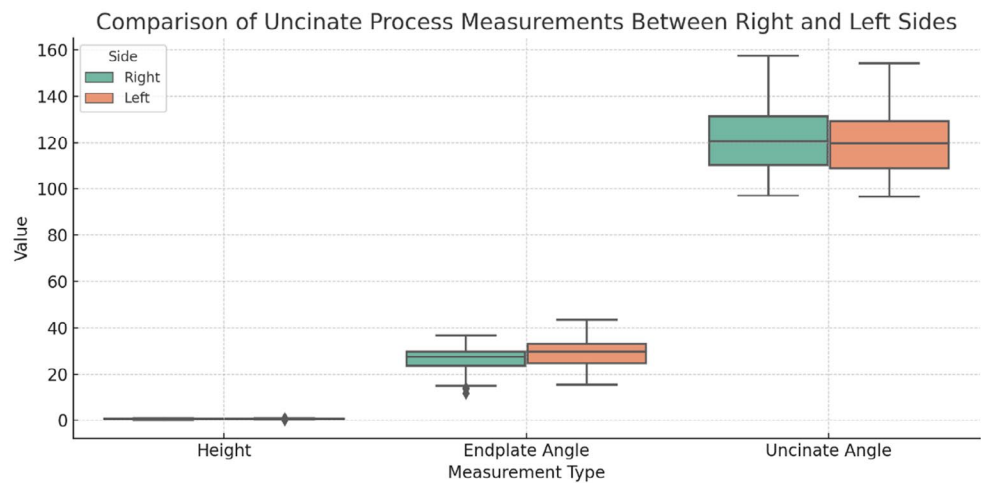
Fig. 1. Measurement workflow and angle definitions for the uncinate process on CT. **(a)** Volume-rendered 3D reconstruction of multiple dry cervical vertebrae (C3–C7) used in the study. **(b)** Close-up 3D view of a representative vertebra demonstrating the uncinate processes (UP) and superior endplate. **(c)** Coronal MPR showing uncinat height on the right and left, measured from the apex of the UP to the inferior endplate at each side. After excluding the vertebral body height in the measurement plane, the height of the left and right uncinate processes were noted individually. **(d)** Corresponding anterior 3D view illustrating the same height landmarks for visual reference. **(e)** Coronal MPR depicting both angular measurements. The vertical reference line (blue) is drawn parallel to the midsagittal plane; the horizontal magenta line indicates the superior endplate level. Endplate angle: the angle between a line from the midpoint of the superior endplate to the apex of the UP and the horizontal magenta line (dotted white vectors). Uncinat angle: the angle between a line tangent to the posterior slope of the UP and the horizontal magenta line (dotted white vectors). **(f)** Anterior 3D view replicating both angle constructs using the same landmarks.

right and left sides (Right: $\rho = -0.557$; Left: $\rho = -0.677$; both $p < 0.001$), indicating that taller uncinate processes tend to exhibit a more vertical orientation. Conversely, a strong positive correlation was found between uncinat height and endplate angle on both sides (right: $\rho = 0.777$; left: $\rho = 0.809$; both $p < 0.001$), suggesting that as the uncinate process height increases, the angle between its tip and the vertebral endplate becomes steeper. These results highlight a complex morphological relationship between vertical and angular parameters of the uncinate process.

Discussion

Our principal finding is that uncinate process height is strongly and directionally coupled with angular morphology: taller processes are associated with steeper endplate angles and narrower medial inclination, whereas shorter processes show wider uncinate angles. These correlations, demonstrated bilaterally, suggest that vertical and angular dimensions of the uncinate process co-vary in a manner that likely influences uncovertebral joint mechanics and surgical corridors during anterior cervical procedures.

In 1834, Rathke described the uncinate process as a projection located at the posterocranialateral margin of the vertebral body¹⁷. In 1858, von Luschka defined the articulation formed between the uncinate process

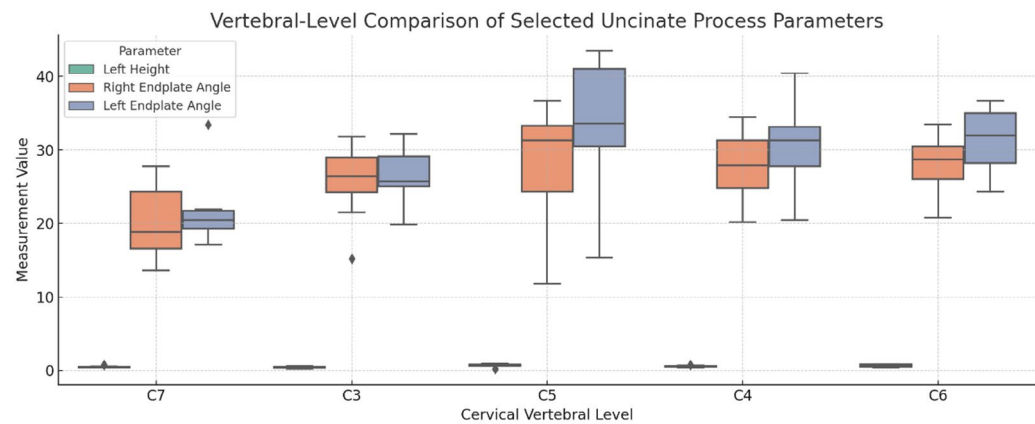


Parameter	Number of vertebrae (R/L)	Right (Mean ± SD)	Left (Mean ± SD)	Median (R / L)	Min–Max (R / L)	p-value
C3 Uncinate Height (mm)	14/14	4.6 ± 1.0	4.6 ± 1.0	4.5 / 4.8	2.8–6.6 / 2.6–6.0	0.826
C3 Endplate Angle (°)		25.87 ± 4.2	26.28 ± 3.78	26.40 / 25.70	15.20–31.80 / 19.80–32.20	0.683
C3 Uncinate Angle (°)		120.19 ± 12.33	122.51 ± 11.53	120.80 / 122.10	102.60–144.10 / 99.70–140.40	0.300
C4 Uncinate Height (mm)	17/17	5.3 ± 1.2	5.5 ± 0.9	5.5 / 5.5	2.4–7.3 / 4.0–8.0	0.218
C4 Endplate Angle (°)		28.24 ± 4.37	30.51 ± 4.48	27.90 / 31.30	20.20–34.40 / 20.50–40.40	0.031
C4 Uncinate Angle (°)		119.13 ± 12.12	113.65 ± 11.88	116.80 / 110.80	97.00–141.90 / 96.90–141.10	0.084
C5 Uncinate Height (mm)	9/9	5.9 ± 2.6	6.2 ± 2.4	7.4 / 7.2	1.3–8.8 / 2.0–8.7	0.593
C5 Endplate Angle (°)		27.51 ± 9.02	31.93 ± 10.27	31.30 / 33.60	11.80–36.70 / 15.30–43.50	0.086
C5 Uncinate Angle (°)		122.43 ± 16.98	118.9 ± 16.62	114.30 / 116.30	108.90–157.40 / 97.20–154.20	0.374
C6 Uncinate Height (mm)	4/4	5.9 ± 1.9	6.4 ± 2.1	5.9 / 6.6	4.2–7.6 / 4.0–8.3	0.144
C6 Endplate Angle (°)		27.90 ± 5.3	31.25 ± 5.53	28.65 / 32.00	20.80–33.50 / 24.30–36.70	0.273
C6 Uncinate Angle (°)		115.38 ± 18.71	114.22 ± 12.79	110.65 / 114.30	99.60–140.60 / 100.80–127.50	>0.999
C7 Uncinate Height (mm)	7/7	5.0 ± 1.3	4.8 ± 1.3	4.5 / 4.6	3.6–7.1 / 3.9–7.5	0.933
C7 Endplate Angle (°)		20.29 ± 5.31	21.86 ± 5.37	18.90 / 20.50	13.60–27.80 / 17.10–33.40	0.398
C7 Uncinate Angle (°)		134.87 ± 13.42	132.47 ± 15.04	135.90 / 131.50	111.30–151.30 / 108.20–153.20	0.735
Overall Uncinate Height (mm)	51/51	5.2 ± 1.6	5.3 ± 1.5	5.1 / 5.0	1.3–8.8 / 2.0–8.7	0.204
Overall Endplate Angle (°)		26.34 ± 5.97	28.47 ± 6.63	27.40 / 29.50	11.80–36.70 / 15.30–43.50	0.002
Overall Uncinate Angle (°)		121.87 ± 14.34	119.64 ± 14.17	120.60 / 119.70	97.00–157.40 / 96.60–154.20	0.283

Table 1. Descriptive statistics and side-to-side comparison of uncinate process measurements in Turkish Population. Wilcoxon signed-rank test was used for paired comparisons between right and left sides.

and the vertebral body of the superior segment as the uncovertebral joint¹⁸. The uncovertebral joint forms the medial boundary of the foramen transversarium and lies in close proximity to the vertebral artery. It is believed to contribute to the stability and mobility of the cervical spine by limiting lateral flexion between adjacent vertebrae¹⁹. Additionally, it has been proposed that the uncovertebral joint facilitates axial rotation of the cervical vertebrae²⁰.

In our study, we did not evaluate the morphometry of the T1 vertebra. However, Tubbs et al.¹ reported in their study that they did not observe any specimens with an uncinate projection on the T1 vertebra. Tubbs et



Parameter	Statistical Test	p-value
Right Height	Kruskal-Wallis	0.301
Left Height	Kruskal-Wallis	0.031
Right Endplate Angle	Kruskal-Wallis	0.048
Left Endplate Angle	Kruskal-Wallis	0.010
Right Uncinate Angle	Kruskal-Wallis	0.169
Left Uncinate Angle	Kruskal-Wallis	0.056

Table 2. Statistical comparison of uncinate process measurements among cervical vertebral levels (C3–C7). Kruskal–Wallis test was used for non-parametric group comparisons.

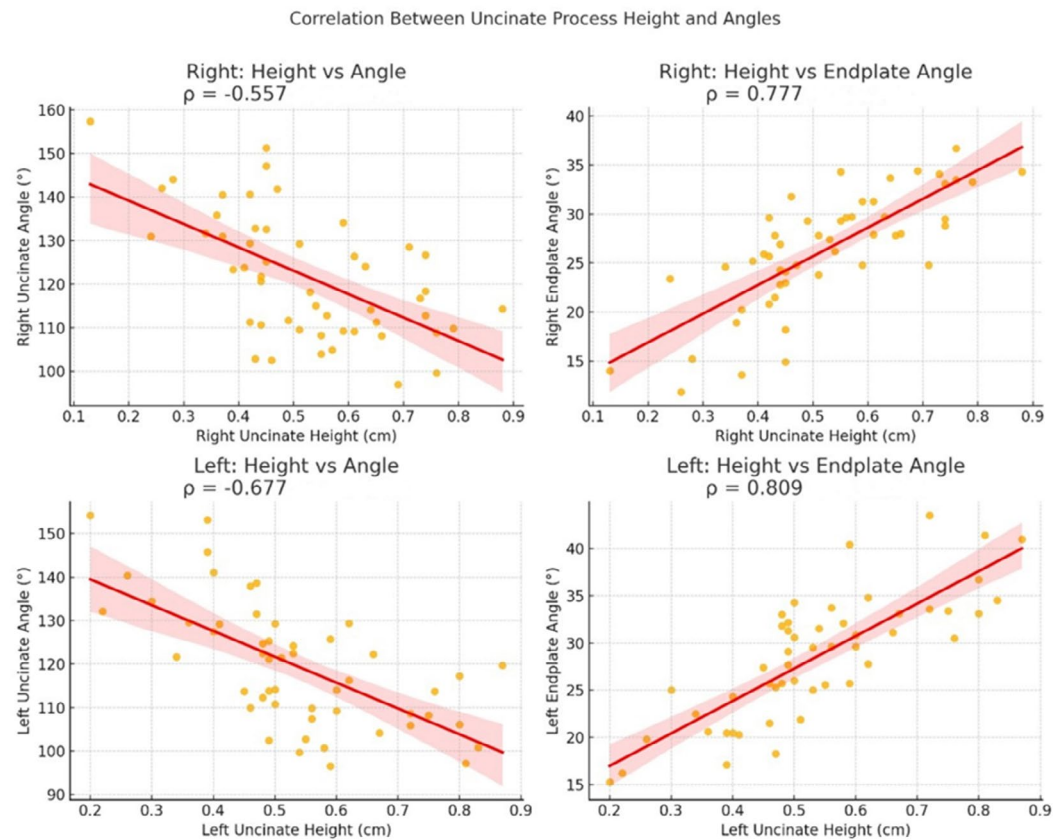
al.¹ reported that the height of the uncinate process ranges from 2 to 6.1 mm, with a mean of 4.8 mm. They also noted that taller uncinate processes were generally located below the C3 vertebral level. In a morphometric study, Civelek et al.²¹ reported that the uncinate process height at the C5 vertebra was shorter than those at the adjacent C4 and C6 levels. Additionally, the uncinate height at C7 was reported to be shorter than at C6. Raveendranath et al.¹⁴ observed that uncinate height gradually increased from C3 to C6, followed by a decrease at C7. Similarly, Yilmazlar et al.²² also reported a progressive increase in uncinate process height from C3 to C7. According to findings from previous literature (Table 4), the lowest recorded uncinate height was 2 mm at C7, and the highest was 10.5 mm at C6^{1,23}. These morphometric discrepancies may be attributed to variations in sample types, including the use of both dry bones and fresh cadaveric specimens. In our study, the mean uncinate process height was found to be 5.2 ± 1.6 mm on the right side and 5.3 ± 1.5 mm on the left side. We found that the uncinate processes at the C7 vertebra exhibited the lowest height measurements in our sample.

Tubbs et al.¹ reported that the angle of the uncinate process from the midline ranged between 10° and 15°, with an average of 13°. Panjabi et al.²⁴ measured the inclination of the uncinate processes relative to the sagittal plane and found a relatively constant angle, peaking at the C7 level, with a mean value of 40.3°. Necdet et al.¹³ reported this angle as $46.13 \pm 15.6^\circ$ on the right side and $47.25 \pm 15.64^\circ$ on the left side in their study.

Saringer et al.²⁵ measured the angle between the long axis of the uncinate processes and the sagittal plane and reported that this angle increases toward the lower cervical levels. The mean value of this angle was reported as 5.06°. Ugur et al.²⁶ assessed the angle between the medial surface of the uncinate process and the superior surface of the vertebral body, reporting a highly variable range between 90° and 162°.

Because our angular measurements are based on anatomical landmarks that differ from those in prior studies, direct comparisons are necessarily limited. Variations in angle definitions, reference planes, and tangent selection may alter absolute values, even when overall trends are similar. The measurement method applied here may offer a more consistent and practical reference framework for evaluating uncinate morphology in three-dimensional reconstructions. These findings may broaden the understanding of geometric relationships within uncinate anatomy—an aspect that appears underrepresented in current anatomical and surgical literature. In our cohort, the mean endplate angle measured $26.34^\circ \pm 5.97^\circ$ on the right and $28.47^\circ \pm 6.63^\circ$ on the left, whereas the uncinate angle measured $121.87^\circ \pm 14.34^\circ$ on the right and $119.64^\circ \pm 14.17^\circ$ on the left.

Additionally, we conducted a comparison not previously addressed in the literature: the correlation between uncinate process height and angular parameters (Table 3). A statistically significant negative correlation was



Correlation	Spearman ρ	p-value	95% CI
Right: Height vs Angle	-0.557	< 0.001	[-0.716, -0.339]
Right: Height vs Endplate Angle	0.777	< 0.001	[0.635, 0.864]
Left: Height vs Angle	-0.677	< 0.001	[-0.808, -0.476]
Left: Height vs Endplate Angle	0.809	< 0.001	[0.664, 0.888]

Table 3. Correlation between uncinate process height and angular parameters. Spearman’s rank correlation was used to evaluate the association between uncinate process height and two angular parameters: uncinate angle and endplate angle.

Study	Materials	Mean height (mm)				
		C3	C4	C5	C6	C7
Lu et al. ¹⁹	Dry bone	5.05	5.55	5.57	6.35	5.16
Uğur et al. ²⁶	Dry bone	4.94	5.62	5.70	6.30	6.60
Yilmazlar et al. ²²	Cadaveric	4.83	5.56	5.66	6.39	6.63
Tubbs et al. ¹	Dry bone	4.80	5.00	4.90	5.10	4.90
Kocabiyik et al. ¹³	Dry bone	6.40	7.44	6.50	7.23	6.25
Raveendranath et al. ¹⁴	Dry bone	4.08	4.37	4.60	5.35	5.27

Table 4. Comparison of the mean height of uncinate process reported in the literature.

found between uncinat height and the uncinat angle, indicating that shorter uncinat processes tend to exhibit wider medial inclination. Conversely, a statistically significant positive correlation was observed between uncinat height and the endplate angle, suggesting that taller processes are associated with steeper endplate trajectories.

These findings suggest that the morphology of the uncinat process is not an isolated feature but part of a complex anatomical configuration that may influence joint biomechanics, osteophyte formation, and the safety margins for anterior cervical surgical approaches. Recognizing these correlated variations may improve both preoperative radiological assessments and intraoperative navigation accuracy. From a radiological and surgical perspective, these results highlight that shorter uncinat processes with wider inclination may alter the uncovertebral joint space, potentially affecting patterns of degeneration and modifying access angles during anterior cervical procedures. Overall, these correlations underscore the importance of accounting for individual morphometric variability when planning surgical strategies and interpreting cervical spine imaging.

Tubbs et al.¹ noted that the general morphological characteristics of the uncinat processes—such as thickness and height—were approximately similar in both young and elderly skeletal specimens. Although the exact age of the dry bones used in our study was not known, the estimated age range of our specimens was between 65 and 75 years.

Tubbs et al.¹ also reported that there were no statistically significant differences in uncinat process measurements based on sex or laterality. Since the sex of the vertebrae in our study was unknown, a sex-based comparison could not be performed. Consistent with their findings, we observed no significant differences in uncinat height or angle between sides. However, a statistically significant difference was found in the endplate angle ($p < 0.01$), with higher values on the left side (Table 1). Although this difference reached statistical significance, the absolute magnitude was relatively small. Therefore, its clinical relevance may be limited. Nonetheless, the finding underscores the importance of recognizing subtle anatomical variations between sides during preoperative planning—particularly in procedures involving anterior cervical approaches or uncovertebral joint decompression.

Previous studies examining differences across cervical levels have shown that uncovertebral joints tend to be located more posterolaterally in the lower cervical spine, and that the basal width of the uncinat process gradually increases at these levels. Uncovertebral joints situated closer to the superior vertebral body are exposed to greater mechanical stress compared to other regions of the vertebral body, which may contribute to delayed degenerative changes^{2,3}.

In our morphometric analysis of measurements among cervical vertebral levels (C3–C7), statistically significant differences were observed in the left uncinat process length ($p = 0.031$) and both right and left endplate angles ($p = 0.048$ and $p = 0.010$, respectively) (Table 2). These findings suggest that the geometry of the uncinat process and its spatial relationship to the vertebral endplate may vary depending on the vertebral level.

From a clinical standpoint, these anatomical differences are particularly important in procedures involving the uncovertebral joint or the anterior approach to the cervical spine (e.g., anterior cervical discectomy and fusion—ACDF). Pre-operative CT can be used to extract the same height and angle metrics we report. Higher uncinat height with steeper endplate angle implies a narrower, more cranially inclined corridor over the uncovertebral joint. In such cases, surgeons may select a slightly more medial starting point for osteophyte removal to avoid skiving laterally toward the vertebral artery, orient the burr trajectory more cranio-medially to respect the endplate slope, and anticipate reduced working room between the apex and superior endplate—favoring thinner instruments and incremental bony resection. Conversely, shorter uncinat height with wider medial inclination suggests a broader lateral working angle, but may increase the tendency to over-resect laterally; frequent fluoroscopic checks and attention to the medial border of the foramen are advisable. These morphology-guided adjustments can refine safety margins and help tailor decompression to level-specific anatomy^{2,19,23,25,26}. Therefore, understanding vertebral level-specific morphologic characteristics can enhance surgical precision, reduce complications, and potentially guide the design of level-specific implants or surgical navigation protocols^{2,3,25}.

This study has several limitations. First, the number of vertebrae analyzed was limited, which may affect the generalizability of the findings. Second, due to the retrospective design and the use of dry vertebrae, information regarding the sex and exact age of the specimens was unavailable, and the exact number of donors was not recorded; together, these constraints prevented subgroup analyses based on sex, age, or donor-related factors and may have introduced sampling imbalance. Third, dry bone specimens may exhibit anatomical alterations due to postmortem changes or long-term storage conditions, which could influence the accuracy of certain measurements. Additionally, artificial intelligence (AI) use. No generative AI was used for writing, interpretation, or decision-making. Earlier drafts leveraged AI tools only to orchestrate standard statistical routines; however, all analyses were re-run and cross-checked in jamovi (Version 2.6). This is acknowledged as a limitation. Despite these limitations, the study provides valuable insights into the morphometric characteristics of the uncinat process and their potential clinical relevance.

Conclusion

This 3D morphometric analysis of the uncinat process between C3 and C7 offers new quantitative insights into its vertical and angular anatomy. The findings indicate that uncinat process height and its spatial orientation not only vary across cervical levels but also show significant correlations with angular parameters. Specifically, taller uncinat processes tended to be associated with steeper endplate angles and narrower medial inclinations, while shorter processes exhibited wider uncinat angles.

Although side-to-side comparisons revealed a statistically significant difference in endplate angles, the clinical significance of this asymmetry may be limited. Nevertheless, these subtle anatomical variations highlight the

importance of accounting for individual morphometric differences, particularly in the context of preoperative imaging evaluation and surgical planning.

From a radiological and anatomical perspective, a more detailed understanding of uncinate morphology may improve the interpretation of cervical spine imaging, assist in identifying uncovertebral joint degeneration, and support safer, more customized anterior surgical interventions.

In summary, this study provides correlation-based morphometric data that may help refine preoperative planning and inform future anatomical or surgical research. The observed interdependence between vertical and angular dimensions adds to the anatomical literature by offering a potentially useful framework for understanding uncinate process variation.

Data availability

This study used dry human vertebrae from an anonymized osteological collection; no living human participants or identifiable data were involved. CT datasets of the dry vertebrae (0.75-mm) were acquired and reconstructed on a workstation; datasets and measurement sheets are available from the corresponding author on reasonable request.

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Author contributions

Asoc. Prof. Nurcan ERCIKTI contributed to the conceptualization of the study. Asst. Prof. Şeref Barbaros Arık

evaluated the imaging, and statistical analyses, and prepared the final draft of the manuscript. Ahmet Metehan ÖCAL, MD collected patient data, conducted all measurements. All authors reviewed the manuscript critically for important intellectual content and approved the final version for publication. All authors agree to be accountable for all aspects of the work.

Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

The Health Science University, Turkey, Ankara Non-invasive Investigation Ethics Committee approved this study. Diagnosis methods were performed according to the approved guidelines. All procedures in the study were performed in accordance with national research committee standards and ethical guidelines for the 1964 Helsinki Declaration and later amendments.

Additional information

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