EJMI

DOI: 10.14744/ejmi.2023.47873
EJMI 2024;8(1):35–42

Research Article

Evaluation of Craniovertebral Junction Anatomy by Gender and Age in the Anatolian Population

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Abstract

Objectives: The craniovertebral junction is a complex transition area between the skull and the cervical vertebra. This study aimed to evaluate the typical structure of the craniovertebral junction according to gender and age on computerized tomography (CT).

Methods: In the study, 100 (50 female, 50 male) individuals between the ages of 25-45 who applied to Bakırçay University Çiğli Training and Research Hospital between 2018 and 2022 and underwent head and neck CT scans were evaluated. Fourteen craniometric measurements were made on the sagittal plane.

Results: In women, cervical lordosis angle, anterior atlantodental length, posterior atlantodental length, McRae line, dens axis length, Wackenheim clivus canal angle, craniocervical tilt angle, foramen magnum width, clivus length, pB-C2 line length, dens axis width and dens axis length values were found to be statistically significantly lower than men ($p<0.05$). In addition, a statistically significant difference was found between the Powers ratio and age groups.

Conclusion: Craniovertebral junction anatomy and detecting anomalies are essential for radiologists and neurosurgeons, and CT is a suitable method to evaluate this junction. We think these findings obtained from healthy individuals with CT imaging will guide the evaluation of craniovertebral junction anomalies.

Keywords: Craniometry, Cranium, Craniovertebral junction, Cobbs angle, McRae line

Cite This Article: *Nalbant A, Bedre Duygu O, Temelci H, Oner Z, Oner S. Evaluation of Craniovertebral Junction Anatomy by Gender and Age in the Anatolian Population. EJMI 2024;8(1):35–42.*

The craniovertebral junction (CVJ) is the bony transition between the skull and the cervical vertebra. Condylus occipitalis (Co), atlas (C1), axis (C2), is a biomechanical complex joint containing ligaments, spinal cord, cranial nerves, blood vessels, and lymphatic vessels. Each component contributes different mechanical properties. The ligaments in between provide stability and protect the Co-C1 and C2 articulation from neural damage.[1] CVJ is more mobile than other spinal segments. This junction is a structure that contains vital nerves and vessels and protects these structures.[2]

Congenital, hereditary, acquired anomalies, traumatic, neoplastic, and infectious diseases seen in CVJ may cause instability and affect neural structures. As a result of such pathologies, the dens axis may move towards the foramen magnum and press on the brain stem. This is one of the most dangerous pathologies in the cervical vertebrae.[3,4] Pressure can cause arrhythmia, blood pressure changes, respiratory depression, and sudden death by damaging vital centers.[5] When Dens axis pressure anterior spinal artery, vertebrobasilar insufficiency, transient ischemic attack, or neurological deficits may be seen.[6] Their presence

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Submitted Date: August 14, 2023 **Revision Date:** September 15, 2023 **Accepted Date:** September 17, 2023 **Available Online Date:** October 26, 2023

increases mortality, so surgical treatment is recommended before neurological findings appear.[7] For this reason, it is essential to determine the typical morphology of the anatomical structures in the CVJ and the pathologies affecting this region.

Craniometric measurements are performed on direct radiography, magnetic resonance (MR) imaging, and multislice computed tomography (CT). It is difficult to determine the reference points in the CVJ on direct radiographs.[8] MRI is ideal for evaluating soft tissues, nerves, and ligaments. Multislice CT defines the bony anatomy and pathology of CVJ.[9]

This study aims to compare the craniovertebral junction parameters on CT by gender and age in the Anatolian population and to establish standard data for the population.

Methods

Selection of Study Participants

The universe of the research consists of 100 individuals (50 females, 50 males) between the ages of 25 and 45 who applied to Bakırçay University Çiğli Training and Research Hospital due to mild trauma between January 1, 2018, and March 31, 2022 and underwent head and neck CT scan. According to G Power analysis, 95% confidence (1-α), 95% test power (1-β), and d=0.65 effect size one-tailed independent samples t-test (independent samples t-test) analysis, the number of samples to be taken in each group 50 has been determined. Individuals without apparent pathology in the CT report were included in the study. Individuals who underwent surgery in the head and neck region, had rheumatic disease, cervical vertebra fractures, CVS malformation, or congenital anomalies were excluded from the study.

Permission for the study was obtained from the Ethics Committee of Non-Interventional Clinical Researches of Bakırçay University, with decision no. 588, research number of 568/dated 29.04.2022.

Evaluation of Radiological Images

Radiological images were downloaded in DICOM format from the Hospital Information Management System. The images were loaded onto a portable hard disk, and a specialist radiologist evaluated the CT images obtained.

All measurements of CT images included in the study were performed using the RadiAnt DICOM Viewer Program on a Dell computer with an Intel Core i5 processor.

Measurements to evaluate the craniocervical junction on sagittal section CT images (Fig. 1):

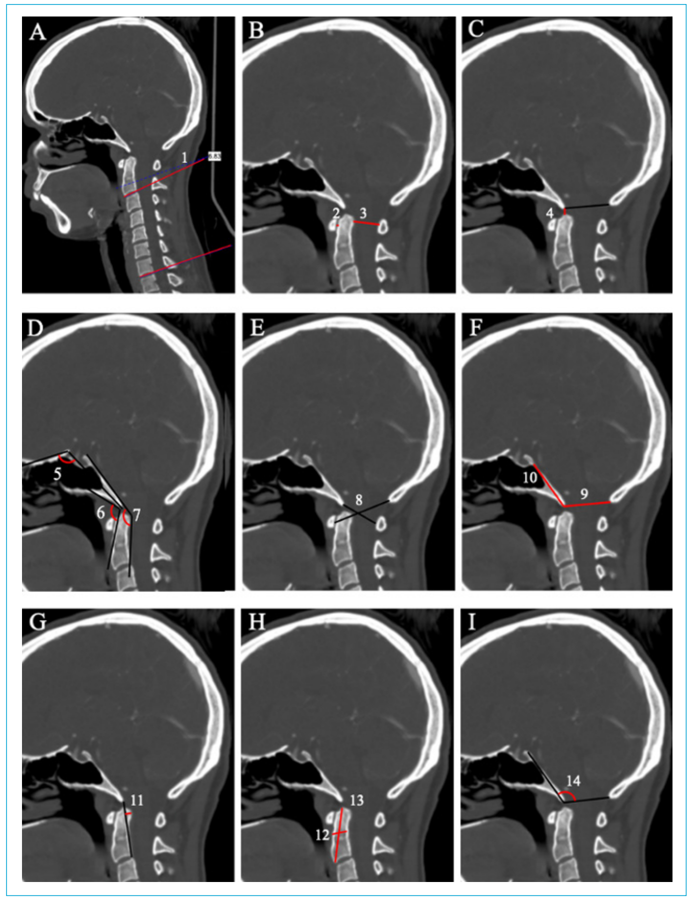

Figure 1. Measurements of the craniovertebral junction.

A 1: Cervical lordosis angle. B 2: Anterior atlantodental length. 3: Posterior atlantodental length. C 4: Length from McRae line to dens axis. D 5: Welcher basal angle. 6: Craniocervical tilt angle. 7: Wackenheim clivus canal angle E 8: Powers ratio. F 9: Foramen magnum width. 10: Clivus length. G 11: pB-C2 line length. H 12: Dens axis width. 13: Dens axis length. I 14: Dorsum sellae, basion, ophisthion angle.

- Cervical lordosis angle (CLA): It is the angle between the C2 vertebra inferior plateau and the C7 vertebra inferior plateau.
- Anterior atlantodental length (AADL): It is the length between the anterior border of the dens axis and the closest point of the arcus anterior of the atlas in the lateral cervical vertebra graph.
- Posterior atlantodental length (PADL): The length between the posterior border of the dens axis and the closest point of the arcus posterior of the atlas on the lateral cervical vertebra graph.
- Length between McRae line and dens axis (MDAL): McRae line is the line drawn from the lower end of the clivus (basion) to the posterosuperior of the foramen magnum (opisthion). The length between the McRae line and the upper border of the dens axis was evaluated.

- Wackenheim clivus canal angle (WCKA): The angle between the line passing through the clivus and the line extending from the back of the dens axis to the canalis vertebralis.
- Welcher basal angle (WBA): The angle formed by the line extending from the nasal tubercle to the tuberculum sellae and the line passing parallel to the clivus from the basion.
- Craniocervical tilt angle (CTA): The craniocervical tilt angle is the angle between the line drawn upward from the anterior face of the dens axis and the line drawn from the anterior border of the clivus.
- Powers ratio (PR): It is the ratio of the distance between the basion and the arcus posterior of the atlas to the distance between the opisthion and the arcus anterior of the atlas.
- Foramen magnum width (FMW): The length between the anterior and posterior border of the foramen magnum.
- Clivus length: It is the length between the upper and lower border of the clivus.
- The length of the pB - C2 line is the length between the line extending from the lower surface of the basion to the posteroinferior of the axis and the perpendicular line drawn from the posterosuperior of the dens axis.
- Dens axis width: It is the length between the anterior and posterior borders of the central part of the dens axis.
- Dens axis length: The anteroinferior length of the dens axis.
- Dorsum sellae, basion, opisthion angle: The upper border of the dorsum sellae is the angle between the basion and the opisthion.

Statistical Analysis

Data analysis was performed using the SPSS 27.0 program at a significance level of $p<0.05$, with a confidence interval of 95%. Mean, standard deviation, minimum, and maximum values were calculated in the measurements, and the study used Mann-Whitney U and independent groups t-tests to compare the measurements according to the groups.All parameters were compared by gender with appropriate tests. In addition, age groups were divided into three groups: 2nd, 3rd, and 4th decade and a comparison was made.

Results

The study group of the research consists of 100 participants, 50 women and 50 men. The mean age of the female patients participating in our study was 37.24±6.52, and the mean age of the male patients was 35.04±5.87. Of the patients, 22% are under 30, 41% are in the 30-40 age range, and 37% are over 40.

According to the results, the length between the McRae line and the dens axis, Wackenheim clivus canal angle, Welcher basal angle, Craniocervical tilt angle, Powers ratio, foramen magnum width, clivus length, pB-C2 line length, dens axis width, dens axis length, dorsum sellae, basion, opisthion angle values show normal distribution; Cervical lordosis angle, anterior atlantodental length, and posterior atlantodental length values were not found to show normal distribution (Table 1).

In women, cervical lordosis angle, anterior atlantodental length, posterior atlantodental length, McRae line, dens axis length, Wackenheim clivus canal angle, craniocervical tilt angle, foramen magnum width, clivus length, pB-C2 line length, dens axis width and dens axis length values were found to be statistically significantly lower than men. Welcher basal angle, Powers ratio, length of pB-C2 line and dorsum sellae, basion, opisthion angle values; No statistically significant difference was found in gender (Table 2).

Cervical lordosis angle, anterior atlantodental length, posterior atlantodental length, McRae line and dens axis length, Wackenheim clivus canal angle, Welcher basal

Table 1. Findings related to craniovertebral junction measurement values

Parameters (Median)	Mean±SD	Min-Max.
Cervical lordosis angle (°)	10.71±9.45	1.77–56.45 (37)
Anterior atlantodental lenght (mm)	1.58±0.53	0.6–5 (1)
Posterior atlantodental lenght (mm)	19.33±2.87	13.4–30.9 (19)
Length from McRae line to dens axis (mm)	4.89±1.54	1.4–8.3 (5)
Wackenheim clivus canal angle (°)	155.57±8.09	134.4–179 (155)
Welcher basal angle (°)	129.19±6.13	113.8–144.7 (129)
Craniocervikal tilt angle (°)	125.53±10.89	101.9–156.6 (126)
Powers ratio	0.75±0.07	0.61–0.95 (1)
Foramen magnum width (mm)	35.63±2.93	29.2–44.1 (35)
Clivus lenght (mm)	36.76±5.39	21.2–48.2 (37)
pB-C2 line lenght (mm)	5.28±1.44	0.81–8.8 (5)
Dens axis width (mm)	12.23±1.46	9.6–15.9 (12)
Dens axis lenght (mm)	34.74±3.42	27.6–46.2 (35)
Dorsum sellae, basion, opisthion angle (°)	120.31±6.33	104.7–137.6 (120)

Table 2. Evaluation of craniovertebral junction measurements by gender

Parameters	Women (Mean±SD) (Median)	Men (Mean±SD) (Median)	p
Cervical lordosis angle[MW] (°)	7.85±5.6 (6)	13.56±11.5 (10)	0.014
Anterior atlantodental lenght[MW] (mm)	1.43±0.27 (1)	1.72±0.67 (2)	0.011
Posterior atlantodental lenght[MW] (mm)	17.84±1.57 (17)	20.82±3.1 (20)	<0.001
Length from McRae line to dens axis [T] (mm)	4.06±1.3 (4)	5.72±1.3 (6)	<0.001
Wackenheim clivus canal angle [T] (°)	153.57±7.48 (53)	157.58±8.26 (156)	0.012
Welcher basal angle [T] (°)	129.67±5.06 (29)	128.7±7.05 (129)	0.433
Craniocervikal tilt angle [T] (°)	122.26±11.91 (120)	128.8±8.73 (129)	0.002
Powers ratio [T]	0.75±0.08 (1)	0.75±0.07 (1)	0.892
Foramen magnum width [T] (mm)	34.38±2.64 (34)	36.88±2.69 (37)	<0.001
Clivus lenght [T] (mm)	33.55±3.85 (34)	39.98±4.77 (41)	<0.001
pB-C2 line lenght [T] (mm)	5.26±1.02 (5)	5.3±1.77 (5)	0.868
Dens axis width [T] (mm)	11.46±1 (11)	12.99±1.45 (13)	<0.001
Dens axis lenght [T] (mm)	33.03±3.18 (33)	36.44±2.76 (36)	<0.001
Dorsum sellae, basion, opisthion angle [T] (°)	120.82±6.15 (120)	119.79±6.53 (119)	0.419

SD: Standart deviation; [MW]: Mann Whitney U test; [T]: T test. P<0.05 considered significant.

angle, craniocervical tilt angle, foramen magnum width, clivus length, pB-C2 line length, dens axis width, dens axis length values and dorsum sellae, basion, opisthion angle values; No statistically significant difference was found when compared in terms of age groups. A statistically significant difference was found between the Powers ratio and age groups. Powers ratio was lower in individuals younger than 30 compared to other age groups (Table 3).

Conclusion

Gender is essential in the evaluation of the craniovertebral junction. In this study, all measurements were lower in females than males except Welcher basal angle, Powers ratio, the length of the pB-C2 line, and dorsum sellae, basion, and opisthion angles. The fact that this angle is lower in women may cause an increased risk of neurological symptoms related to craniocervical instability in women. Again, in this

Table 3. Evaluation of craniovertebral junction measurements according to age

Parameters	25-29 Age (Mean±SD) (Median)	30-40 Age (Mean±SD) (Median)	41-48 Age (Mean±SD) (Median)	p
Cervical lordosis angle (°)	10.51±8.68 (6)	12.46±11.83 (9)	8.88±6.24 (8)	0.658
Anterior atlantodental lenght (mm)	1.57±0.38 (1)	1.62±0.46 (2)	1.54±0.67 (1)	0.419
Posterior atlantodental lenght (mm)	19.27±2.11 (19)	19.19±2.05 (19)	19.52±3.91 (19)	0.837
Length from McRae line to dens axis (mm)	4.98±1.31 (5)	4.83±1.74 (5)	4.9±1.46 (5)	0.940
Wackenheim clivus canal angle (°)	155.67±9.65 (154)	155.01±7.59 (155)	156.14±7.82 (158)	0.829
Welcher basal angle (°)	129.26±6.24- (131)	129.43±7.06 (130)	128.87±5 (128)	0.921
Craniocervikal tilt angle (°)	123.17±10.66 (124)	124.01±10.22 (125)	128.62±11.33 (127)	0.089
Powers ratio	0.71±0.06 (1)	0.75±0.08 (1)	0.77±0.07 (1)	0.009
Foramen magnum width (mm)	36.62±2.67 (36)	35.6±3.01 (35)	35.07±2.93 (35)	0.146
Clivus lenght (mm)	37.37±5.2 (38)	36.47±5.93 (37)	36.73±4.97 (36)	0.821
pB-C2 line lenght (mm)	5.29±1.47 (5)	5.24±1.58 (5)	5.32±1.29 (5)	0.967
Dens axis width (mm)	12.17±1.52 (12)	12.41±1.49 (12)	12.06±1.41 (12)	0.548
Dens axis lenght (mm)	35.15±3.66 (36)	35.34±3.53 (35)	33.82±3.03 (33)	0.118
Dorsum sellae, basion, opisthion angle (°)	118.63±7.48- (118)	121.08±6.79 (120)	120.44±4.91 (122)	0.342

SD: Standart deviation; Kruskal Wallis/One way ANOVA test. P<0.05 considered significant.

study, the Powers ratio was higher in older individuals than in other groups. The clivus canal angle value was less than 150°in some healthy individuals included in our research.

In the study of Zhu et al., the cervical lordosis angle was found to be average in Chinese adults. It was found to be 17.1°±6.31°, 17.97°±6.30° in men, and 16.35°±6.23° in women.[10] In the study of Been et al., the cervical lordosis angle was found to be average in Israeli individuals between the ages of 20-50. It was found to be 11.8°±10.40°, 14.6°±10.1° in men, and 9.0°±10.2° in women.[11] Similarly, in this study, the mean cervical lordosis angle values of healthy individuals aged between 30 and 40 years. While 12.46°±11.83° was higher than other age groups, it was found to be 13.56°±11.5° in males and 7.85°±5.6° in females. These angle values appear in the literature in a wide variational range originating from the population.

In the study by Rojas et al., the normal anatomy of the craniovertebral junction was examined on CT images of 200 patients without bone and soft tissue problems, and the anterior atlantodental length was found to be less than 2 mm in 95% of the patients. This value is lower than the value of 3 mm, which was accepted as the upper limit of normal in studies conducted in the 1960s.[12] In our study, only nine patients had anterior atlantodental space more significant than 2 mm. In the study of Tanrısever et al., the anterior anlantodental space was found to be 1.29±0.40 mm in men and 1.27±0.50 mm in women, and no significant difference was observed. In our study, it was found to be 1.72±0.67 mm in men and 1.43±0.27 mm in women, and a significant difference was observed between the genders. Considering that spine surgery is based on CT and MR images, it can be regarded that the upper standard limit of the anterior dental space in sagittal CT should be 2 mm in the Anatolian population. This change will affect the sensitivity of CT scans in detecting many diseases, such as atlantoaxial instability.

In the study by Boden et al., a posterior atlantodental length of less than 14 mm was associated with neurological deficits in 97% of cases.[13] The posterior atlantodental length of only one individual participating in our study was less than 14 mm. In the study of Kibo Yoon et al., the mean posterior atlantodental length on CT images was 18±2.1 mm.[14] In our study, the mean value of posterior atlantodental length was 19.33±2.87 mm. Tanrısever et al. found the mean length as 19.54±2.24 mm, 20.20±2.20 mm in males and 18.82±2.06 mm in females, and stated that there was a significant difference between the genders. In our study, it was found to be 20.82±3.1 mm in men and 17.84±1.57 mm in women, and there was a very significant difference between the genders. PADL values were found to be lower in women in our study. This suggests that it may cause neurological deficits to be seen earlier in women than in men.

Many studies evaluate the length between the McRae line and the upper point of the dens axis. The dens axis above the McRae line is considered pathological and is indicative of basilar intussusception. Previous studies reported that the mean length value between the McRae line and the dens axis in the control group was between 4.60 mm and 5.80 mm.[15-20] In the images evaluated in these studies, The upper point of the dens axis is located below the McRae line.[19,20] In the study of Mzumara et al., the McRae line was found to be 4.7±1.3 mm, Cronin et al. 4.6±2.6 mm, Kwong et al. 5.8±1.6 mm, while Dash et al. found it to be 5.11±1.65 mm in Indians, 5.09 mm in males, and 5.16 mm in females.[15-20] In the study conducted by Tanrısever et al., the mean length value between the McRae line and the upper point of the dens axis was found to be 5.30±1.59 mm, 5.39±1.63 mm in men and 5.20±1.55 mm in women.[21] In our study, the mean length value between the McRae line and the upper point of the dens axis was found to be 4.89±1.54 mm, 5.72±1.3 mm in men, and 4.06±1.3 mm in women, in line with the literature.

Wackenheim clivus canal angle average value is between 150° and 180° in measurements made on direct radiographs. However, in MR and CT studies, the average value of the angle was different. In the study by Botelho and Ferreira, the tip of the clivus canal of 33 patients was evaluated. The mean value of the clivus canal angle was 148°±9.8° (min 129°-max 179°).[22] In our study, the clivus canal angle's mean value was 155.57°±8.09° (min 134.4°-max 179°). We think the difference in these values is due to the higher number of patients in our study compared to the other research and the use of CT, which evaluates the anatomical structure more precisely. It was determined that the clivus canal angle value of 21 individuals included in our study was below 150°. At the same time, this angle was significantly smaller in women than in men (Table 2).

In the study conducted by Konigsberg et al., the mean value of the basal angle was found to be 129°±6° in the study in which the Welcher basal angle of 200 adults was evaluated on MR images.[23] In the study by Botelho and Ferreira, the mean basal angle value was found to be 119°±7.1°. When the basal angle is above 133°, the diagnosis of platybasis is made.[22] In the study by Smoker et al., it was reported that the basal angle should be less than 140°. In basal angle measurement, angle values were higher when the center of the tuberculum sellae or sella turcica was taken as a reference instead of the dorsum sellae.[24] The mean basal angle value obtained in this study was less than 140° (129.19°±6.13°) and is quite similar to the angle values of the study by Konigsberg et al.

In the study by Chandra et al., The craniocervical tilt angle was 119.8°±9.2° in the control group and 96.0°±15.1° in the group with atlantoaxial dislocation and basilar intussusception.[25] In the study conducted by Tanrısever et al., the mean craniocervical tilt angle was found to be 126.98°±12.24° in healthy individuals, 128.83°±12.41° in men and 125.01°±11.79° in women.[21] In our study, the mean craniocervical tilt angle was found to be 125.53°±10.89°, 128.8°±8.73° in men and 122.26°±11.91° in women. Craniocervical tilt angle differed significantly between men and women.

The Powers ratio was defined by Powers in 1979. This ratio is the most commonly used method in diagnosing atlantooccipital instability. A ratio of less than 0.9 is considered normal. Ratios between 0.9 and 1 are considered as an uncertain gray area. A Powers ratio greater than 1 suggests anterior atlantooccipital dislocation. Li et al. reported that the strong relationship between Powers ratio and atlantooccipital dislocation is supported by experimental and clinical studies conducted with different methods, including direct X-ray, CT, and three-dimensional CT (26). Rojas et al. calculated the mean Powers ratio value as 0.8°±0.08° on multislice CT images of 200 individuals.[12] Lee et al. reported the mean Powers ratio value for 100 adults to be 0.74. The Powers ratio cannot be calculated due to difficulties determining opisthion on direct radiographs.[27] In the study conducted by Tanrısever et al., the mean Powers ratio was found to be 0.72°±0.06° on average, 0.72°±0.06° in men and 0.72°±0.06° in women.[21] In this study, where we used CT images, the mean Powers ratio value was found to be 0.75°±0.07°, 0.75°±0.07° for men and 0.75°±0.08° for women, and the results of the study are similar to other studies. While the Powers ratio did not show a significant difference between the sexes, it was the only parameter that showed a significant difference between the ages. We believe the Powers ratio should be considered in the routine control of individuals over 40.

Kanchan et al. measured the mean foramen magnum width as 34.03±2.54 mm, 34.51±2.71 mm in males and 33.60±2.63 mm in females; Batista et al. found 33.9±2.7 mm, while Dash et al. found the width of the foramen magnum as 36.29±2.35 mm, 36.48 mm in men and 35.97 mm in women.[20,28,29] In the study of Bahşi et al., it was found to be 33.39±2.99 mm in men and 31.72±2.62 mm in women.[30] In our research, the foramen magnum width value was average, similar to previous studies. It was found to be 35.63±2.93 mm, 36.88±2.69 mm in men, and 34.38±2.64 mm in women.

In the study of Batista et al., the mean clivus length was found to be 44.7±3.5 mm.[29] In the study by Heiss et al., the mean clivus length of 48 patients with Chiari malformation was 38.6±3.4 mm, and the mean clivus length of 18 patients in the control group was 43.2±3.5 mm.[31] The mean clivus length (36.76±5.38 mm) of the individuals participating in our study was 39.98±4.77 mm in males and 33.55±3.85 mm in females, and there is a significant difference between genders. Compared to other studies, the length of the clivus was lower in our study. We think that the lower clivus length in this study conducted in healthy individuals compared to other studies is due to the population difference. However, we can state that the length of the clivus in women is shorter than in men.

In the study of Batista et al., The mean value of the length (pB-C2 line) between the line extending from the lower surface of the basion to the posteroinferior of the axis and the vertical line drawn from the posterosuperior of the dens axis was found to be 6.7 mm. This value was above 9 mm in only one patient.[29] In our study, the mean length value of the pB-C2 line was 5.28±1.44 mm. In addition, in our study, the maximum length value of this line was determined as 8.8 mm.

In the study of Mukadder et al. on MR images, the mean width of the dens axis was measured as 10.6±1.1 mm in men and 9.8±1.2 mm in women.[32] In the study by Ec et al. on five people on CT, the mean width of the dens axis in the sagittal plane was 12.4±1.5 mm.[33] Similarly, in our study, the mean width of the dens axis was 12.23±1.46 mm, 12.99±1.45 mm in men, and 11.46±1 mm in women. It is thought that the results of this study are because it is more in terms of both imaging technique and number.

In the study conducted by Kosif et al. on the Anatolian population, the mean dens axis length was found to be 2.41±4.9 mm in males and 27.59±4.2 mm in females.[34] In this study, the mean dens axis length in males was 36.44±2.76 in females and 33.03±3.18 in females. It is thought that the difference between the studies is due to the difference in imaging methods, and because CT imaging is more sensitive, the measurements of this study are closer to the truth.

In the study of Naderi et al. on cadavers, the dens axis length was found to be 33.2±2.9 mm, and in the study of Sengul and Kadioglu on cadavers, it was found to be 36.6±2.3 mm.[35,36] In the CT study we conducted on the Anatolian population, the mean dens axis length was 34.74±3.42 mm. There are differences in studies on cadaver and CT images.

In the study of Botelho et al. in 33 healthy individuals, The mean value of dorsum sellae, basion, and opisthion angles was 126°, and 136.9° in the study of Alkoç et al. in 33 healthy individuals. In our study, the mean value of this angle (120.31°) in 100 healthy individuals was lower than in other studies.[22,37] This may be due to the larger sample size in our study.

Normal angle and length values of the craniovertebral junction: It is essential for developing diagnostic criteria for congenital diseases and acquired neurological and anatomical problems. We think the normal parameters of the Anatolian population obtained in this study will contribute to the literature in the comparative evaluation of craniovertebral junction anomalies. In reviewing the craniovertebral junction, more accurate results are obtained by making more accurately defined bone markings on CT scans instead of direct radiographs. The data of our study was one of the few studies that gave average values of the craniovertebral junction of the Anatolian population. We think our study will contribute to head and neck CT scans and shed light on the studies to be done in this field.

Disclosures

Ethics Committee Approval: Permission for the study was obtained from the Ethics Committee of Non-Interventional Clinical Researches of Bakırçay University, with decision no. 588, research number of 568/dated 29.04.2022.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – A.N., Z.O., S.O.; Design – A.N., Z.O., S.O.; Supervision – A.N., O.B.D., H.T.; Materials – S.O.; Data Collection – S.O., O.B.D., H.T.; Analysis and/or Interpretation – A.N., O.B.D., S.O., Z.O., H.T.; Literature Search – A.N., O.B.D.; Writing – A.N., O.B.D.; Critical Review – A.N., S.O., Z.O., O.B.D., H.T.

References

1. Gaunt T, Mankad K, Calder A, Tan AP, Talenti G, Watson TA, Thompson D. Abnormalities of the craniovertebral junction in the paediatric population: a novel biomechanical approach. Clin Radiol 2018;73:839-54.
2. Goel A. Craniovertebral junction instability: a review of facts about facets. Asian Spine J 2015;9:636–44.
3. Kwong Y, Rao N, Latief K. Craniometric measurements in the assessment of craniovertebral settling: are they still relevant in the age of cross-sectional imaging? AJR Am J Roentgenol 2011;196:421-5.
4. Goel A, Jankharia B, Shah A, Sathe P. Three-dimensional models: an emerging investigational revolution for craniovertebral junction surgery. J Neurosurg Spine 2016;25:740-4.
5. Riew KD, Hilibrand AS, Palumbo MA, Sethi N, Bohlman HH. Diagnosing basilar invagination in the rheumatoid patient. The reliability of radiographic criteria. J Bone Jt Surg Am 2001;83:194–200.
6. Kim DH, Hilibrand AS. Rheumatoid arthritis in the cervical spine. J Am Acad Orthop Surg 2005;13:463–74.
7. Schweitzer ME, Hodler J, Cervilla V, Resnick D. Craniovertebral junction: normal anatomy with MR correlation. AJR Am J Roentgenol 1992;158:1087–90.
8. Kawaida H, Sakou T, Morizono Y . Vertical settling in rheumatoid arthritis. Diagnostic value of the Ranawat and Redlund-Johnell methods. Clin Orthop Relat Res. 1989;239:128–135.
9. Smoker WRK, Khanna G. Imaging the craniocervical junction. Childs Nerv Syst 2008; 24:1123–45.
10. Zhu Y, An Z, Zhang Y, Wei H, Dong L. Predictive formula of cervical lordosis in asymptomatic young population. Journal of Orthopaedic Surgery and Research 2020;15:2-6.
11. Been E, Shefi S, Soudack M. Cervical lordosis: the effect of age and gender. Spine J 2017;17(6):880-888.
12. Rojas CA, Bertozzi JC, Martinez CR, Whitlow J. Reassessment of the craniocervical junction: Normal values on CT. AJNR Am J Neuroradiol 2007;28:1819-23.
13. Boden SD, Dodge LD, Bohlman HH, Rechtine GR. Rheumatoid arthritis of the cervical spine. A long-term analysis with predictors of paralysis and recovery. J Bone Joint Surg Am 1993;75:1282–97.
14. Yoon K, Cha S, Ryu J, Park D, Lee S, Joo K. Anterior atlantodental and posterior atlantodental intervals on plain radiography, multidetector CT and MRI. J Korean Soc Radiol 2015;72:57–64.
15. Mzumara SS, Kimani NM, Onyambu CK. Evaluating Chamberlain's, McGregor's, and Mcrae's skull-base lines using multi detector computerised tomography. East Afr Med J 2012;89:272–77.
16. Cronin CG, Lohan DG, Mhuircheartigh JN, Meehan CP, Murphy J, Roche C. CT evaluation of Chamberlain's, McGregor's, and McRae's skull-base lines. Clin Radiol 2009;64:64–9.
17. Cronin CG, Lohan DG, Mhuircheartigh JN, Meehan CP, Murphy JM, Roche C. MRI evaluation and measurement of the normal odontoid peg position. Clin Radiol 2007;62:897–903.
18. Kwong Y, Rao N, Latief K. Craniometric measurements in the assessment of craniovertebral settling: are they still relevant in the age of cross-sectional imaging? AJR Am J Roentgenol 2011;196:W421–5.
19. Tassanawipas A, Mokkhavesa S, Chatchavong S, Worawittayawong P. Magnetic resonance imaging study of the craniocervical junction. J Orthop Surg 2005;13:228–31.
20. Dash C, Singla R, Agarwal M, Kumar A, Kumar H, Mishra S, Sharma BS. Craniovertebral junction evaluation by computed tomography in asymptomatic individuals in the Indian population. Neurol India 2018;66:797–803.
21. Tanrisever S, Orhan M, Bahşi İ, Yalçin ED. Anatomical evaluation of the craniovertebral junction on cone-beam computed tomography images. Surgical and Radiologic Anatomy 2020;42:797–815.
22. Botelho RV, Ferreira EDZ. Angular craniometry in craniocervical junction malformation. Neurosurg Rev 2013;36:603–10.
23. Konigsberg RA, Vakil N, Hong TA, Htaik T, Faerber E, Maiorano T et al. Evaluation of platybasia with MR imaging. AJNR Am J Neuroradiol 2005;26:89–92.
24. Smoker WR. Craniovertebral junction: normal anatomy,

craniometry, and congenital anomalies. Radiographics 1994;14:255–77.

25. Chandra PS, Goyal N, Chauhan A, Ansari A, Sharma BS, Garg A. The severity of basilar invagination and atlantoaxial dislocation correlates with sagittal joint inclination, coronal joint inclination, and craniocervical tilt: a description of new indexes for the craniovertebral junction. Neurosurgery 2014;10:621–30.
26. Li G, Passias P, Kozanek M, Shannon BD, Li G, Villamil F, Bono CM, Harris M, Wood KB. Interobserver reliability and intraobserver reproducibility of powers ratio for assessment of atlantooccipital junction: comparison of plain radiography and computed tomography. Eur Spine J 2009;18:577–82.
27. Lee C, Woodring JH, Goldstein SJ, Daniel TL, Young AB, Tibbs PA. Evaluation of traumatic atlantooccipital dislocations. AJNR Am J Neuroradiol 1987;8:19–26.
28. Kanchan T, Gupta A, Krishan K. Estimation of sex from mastoid triangle- a craniometric analysis. J Forensic Leg Med 2013 Cot;20(7):855-60.
29. Batista UC, Joaquim AF, Fernandes YB, Mathias RN, Ghizoni E, Tedeschi H. Computed tomography evaluation of the normal craniocervical junction craniometry in 100 asymptomatic patients. Neurosurg Focus 2015;38:5.
30. Bahşi İ, Adanır S, Orhan M, et al. (November 08, 2021) Anatomical Evaluation of the Foramen Magnum on Cone-Beam Computed Tomography Images and Review of Literature. Cureus 13(11): e19385.
31. Heiss JD, Suffredini G, Bakhtian KD, Sarntinoranont M, Oldfield EH. Normalization of hindbrain morphology after decompression of Chiari malformation Type I. J Neurosurg 2012;117:942–6.
32. Sunar M. Manyetik Rezonans Görüntüleme Yöntemi ile Craniocervical Bileşkenin Morfometrik Değerlendirilmesi. Doktora Tezi. 2013.
33. Ec T, Haiblikova S, Winkelstein B, Welch W, Holsgrove T, Cazzola D. Morphometric Analysis of Human Second Cervical Vertebrae (Axis). J Spine 2017;6:6.
34. Kosif R, Huvaj S, Abanonu HE. Morphometric analysis of Occipitocervical region and cervical height in the female and male. Gulhane Med J 2007;49:173-7.
35. Naderi S, Arman C, Güvencer M, Korman E, Senoğlu M, Tetik S, et al. Morphometric analysis of the C2 body and the odontoid process. Turk Neurosurg 2006;16:14-8.
36. Sengul G, Kadioglu HH. Morphometric anatomy of atlas and axis vertebra. Turk Neurosurg 2006;16:69-76.
37. Alkoç OA, Songur A, Eser O, et al. Stereological and morphometric analysis of MRI Chiari malformation type-1. J Korean Neurosurg Soc 2015;5:454–61.