Original Article

Cervical vertebra morphology in different skeletal classes

A three-dimensional computed tomography evaluation

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ABSTRACT

Objective: To describe cervical vertebra morphology in subjects with different anteroposterior jaw relationships.

Materials and Methods: Cone-beam computed tomography images of 31 female subjects aged 19 to 41 years were evaluated. Subjects constituted two groups according to the ANB angle: group 1, skeletal Class II (ANB angle >5); and group 2, skeletal Class III (ANB angle <1). Nine linear measurements and one angular measurement were used to assess the vertebral morphology. The Mann-Whitney U-test was used for statistical analysis.

Results: The mean atlas dorsal arch height was significantly shorter in Class II subjects compared with those in Class III ($P < .05$). The cervical vertebra morphological analysis by cone-beam computed tomography was of comparable precision to three-dimensional computed tomography evaluations. This study confirmed previous findings that Class II subjects have significantly lower atlas dorsal arch heights.

Conclusion: The height of the atlas dorsal arch of cervical vertebrae is affected by the anteroposterior skeletal pattern. (*Angle Orthod.* 2010;80:719–724.)

KEY WORDS: Cervical vertebrae; Skeletal Class II; Skeletal Class III; Cone-beam computed tomography (CBCT)

INTRODUCTION

The cervical vertebra column supporting the head comprises seven vertebrae. The first vertebra (C1) or atlas and the second vertebra or axis together form the superior or suboccipital segment connecting the spine to the occiput and involving a complex chain of joints. Suboccipital muscles attached to this region determine head posture, controlling fine through complicated movements for compound flexion and extension, as well as lateral flexion with rotation.[1]

Dimensions of C1 as well as head and neck posture are associated with factors such as craniofacial morphology, including the cranial base,[2–4] upper airway space,[5] occlusion,[2–7] and temporomandibular disorders.[8,9] Furthermore, head posture is linked to the development and function of dentofacial structures.[9] The relationship between C1 dimensions and craniocervical posture has also been studied.[2] Cervical posture was linked to mandibular length, with longer mandibles associated with cervical columns more inclined to the true horizontal.[10] Mandibular length was also directly correlated with straightness of the cervical column (ie, a lower cervical lordosis angle).[11] However, no previous studies have described the relationship between cervical vertebra morphology using three-dimensional imaging and maxillofacial morphology.

Computed tomography (CT) was first considered for such a study because of the accurate three-dimensional imaging that is possible with CT. However, limitations such as radiation, machine size, and cost made this approach impractical. The more recently established cone-beam computed tomography (CBCT) presents a more feasible alternative, as these lower-cost and smaller machines still produce high-quality data. With several CBCT scanners now available, involving lower radiation dosages[12–15] and lower costs,[16] three-dimensional (3D) radiography is becoming more commonplace in the dental profession as a valuable diagnostic tool.

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This study investigated the detailed morphology of cervical vertebrae in three dimensions in subjects with different anteroposterior skeletal patterning.

MATERIALS AND METHODS

Subjects

CBCT scan radiographs were obtained from the Department of Orthodontics files at Showa University Dental Hospital for orthognathic surgery. Images were derived from pretreatment CBCT scans of 31 female subjects aged 19 to 41 years, for the following conditions: maxillofacial injury without fracture, diffuse inflammation, soft tissue tumor, neuralgia, and unknown lesion. Subjects were excluded from the study if they had congenital disorders such as cleft palate, general physical problems, or disorders of the pharyngeal soft tissue, including adenoiditis or enlarged tonsils, or if they were not of Japanese racial heritage. Final participants met the following requirements: all permanent teeth erupted, except third molars; no functional mandibular deviations; no evident facial asymmetry; no history of orthodontic treatment during childhood; and no neck pain or medical history of cervical disorders. Only females were included in this study because the number of males with skeletal Class II (ANB angle >5) and/or skeletal Class III (ANB angle <1) established with CBCT images was insufficient for meaningful analysis. This study was approved by the Showa University Dental Hospital Ethics Committee.

Obtaining CBCT Images

Cervical vertebrae were scanned and analyzed using the CB MercuRay (Hitachi Medico Technology, Tokyo, Japan). The scanning conditions were 100 kVp, 10 mA, F-mode 512 slices/scan (slice width of 377 μm), and 9.6 seconds. Data obtained were reconstructed using the CBworks 2.0 three-dimensional reconstruction software (Hitachi Medico Technology).

For CT imaging, patients were positioned in centric occlusion (maximum dental intercuspation), and their heads were positioned such that the Frankfort and midsagittal planes were perpendicular to the floor. Subjects were seated in the CB MercuRay system, with their facial median line vertical to the floor and Frankfort plane parallel to the floor. This position was controlled by a guideline directed from the front and sides.

Measurements

CBCT images were used to assess the maxillofacial characteristics of Class II and Class III subjects, SNA, SNB, ANB, and mandibular plane (linear measurements detailed in Tables 1 and 2). Figure 4 demonstrates both the angular and linear measurements obtained by CBCT. Of those obtained, eight linear measurements and one angular measurement were used to assess cervical vertebra morphology with different sagittal skeletal patterns.

Table 1. The Maxillofacial Characteristics of Class II and Class III Groups

	Class II Group		Class III Group		
	Ave	SD	Ave	SD	*P* Value
SNA, degrees	80.0	5.0	80.8	3.9	NS
SNB, degrees	74.7	3.8	81.7	5.2	.00**
ANB, degrees	5.4	2.3	-0.9	2.5	.00**
Mandibular plane, degrees	32.2	6.2	30.8	5.2	NS

Ave indicates average; SD, standard deviation; and NS, not significant.

** Significant difference, $P < .01$

1. Horizontal outer anteroposterior (AP) diameter of the first cervical vertebra (C1)[17] (mm) (HOAPC1; Figure 1)
2. Horizontal inner AP diameter of C1[17] (mm) (HIAPC1; Figure 1)
3. Horizontal outer transverse diameter of C1[17] (mm) (HOTDC1; Figure 1)
4. Distance between outer margin of transverse foramen and outer margin of lateral mass[17] (mm) (outer margin; Figure 1)
5. AP diameter of superior surface of C1 anterior arch[17] (mm) (superior surface; Figure 1)
6. Lateral outer AP diameter of C1[18] (mm) (LOAPC1; Figure 2)
7. Height of the atlas dorsal arch[18] (mm) (dorsal arch; Figure 2)
8. Frontal outer transverse diameter of C1 (mm) (FOTDC1[17]; Figure 3)
9. Angle along axis line of the dens to occlusal plane (dens angle[19] [degrees]; Figure 4)

Reliability

Measurement error was determined by the random selection of four CBCT images on two separate occasions. One-way analysis of variance, used to test the quality of means for the three measurements, suggested that this sampling was consistent. Mean scores for the three measurements did not differ significantly; the measurement error was thus considered to be negligible.

Statistical Analysis

The statistical significance of differences between the Class II and Class III groups was determined using the Mann-Whitney *U*-test. Analyses were performed

Table 2. Mean Value of Cervical Vertebra Measurements

	Class II Group		Class III Group		
	Ave	SD	Ave	SD	*P* Value
(1) HOAPC1, mm	72.1	3.2	71.5	3.1	.62
(2) HIAPC1, mm	42.1	3.0	42.8	2.2	.47
(3) HOTDC1, mm	72.1	3.2	71.5	3.1	.62
(4) Outer margin, mm	8.2	1.1	8.7	1.4	.26
(5) Superior surface, mm	6.5	1.1	6.5	1.6	.97
(6) LOAPC1, mm	43.0	1.8	42.8	2.5	.81
(7) Dorsal arch, mm	8.3	1.1	9.9	2.6	.03*
(8) FOTDC1, mm	72.3	3.1	71.4	3.1	.43
(9) Dens angle, degrees	79.7	8.2	76.7	8.6	.33

Ave indicates average; SD, standard deviation.
* Significant difference, $P < .05$

using Statcel 2 (four-step Excel statistics, version 2, OMS Publishing, Saitama, Japan). *P* values less than .05 were considered statistically significant.

RESULTS

Table 1 details the mean value of maxillofacial dimensions in the Class II and Class III groups. No statistically significant difference in SNA and mandibular plane angle was noted between Class II and Class III subjects.

Table 2 details the mean value of cervical vertebra measurements in Class II and Class III groups. Only the height of the atlas dorsal arch showed a significant difference between Class II and Class III ($P = .029$), with the other measurements not significantly different among subjects regardless of skeletal class.

DISCUSSION

Skeletal class and cervico-vertebral anatomy both are associated with craniofacial structure. CT imaging has proved remarkably accurate in these association studies for linear,[20–23] geometric,[24] and volumetric[25,26] measurements within the maxillofacial complex. Further to this, we now reveal differences in cervical vertebra morphology in subjects with different anteroposterior jaw relationships.

This study demonstrated significant differences between Class II and Class III subjects in height of the atlas dorsal arch. A pattern of positive correlation between mandibular length (Ar-Me) and the anteroposterior length of the atlas was previously shown to

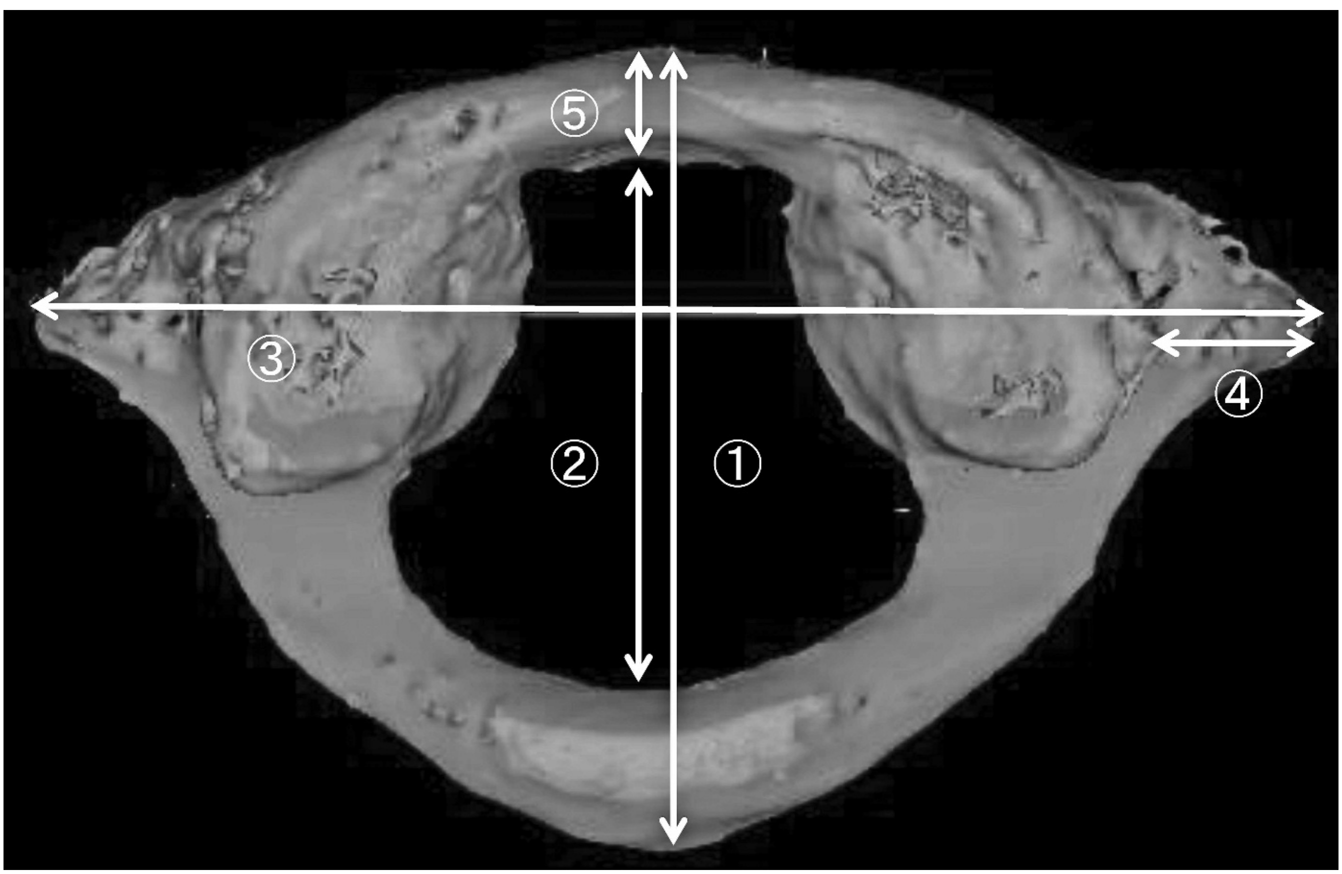

Figure 1. ① Horizontal outer anteroposterior (AP) diameter of the first cervical vertebra (C1) (mm); HOAPC1. ② Horizontal inner AP diameter of C1 (mm); HIAPC1. ③ Horizontal outer transverse diameter of C1 (mm); HOTDC1. ④ Distance between outer margin of transverse foramen and outer margin of lateral mass (mm); outer margin. ⑤ AP diameter of the superior surface of C1 anterior arch (mm); superior surface.

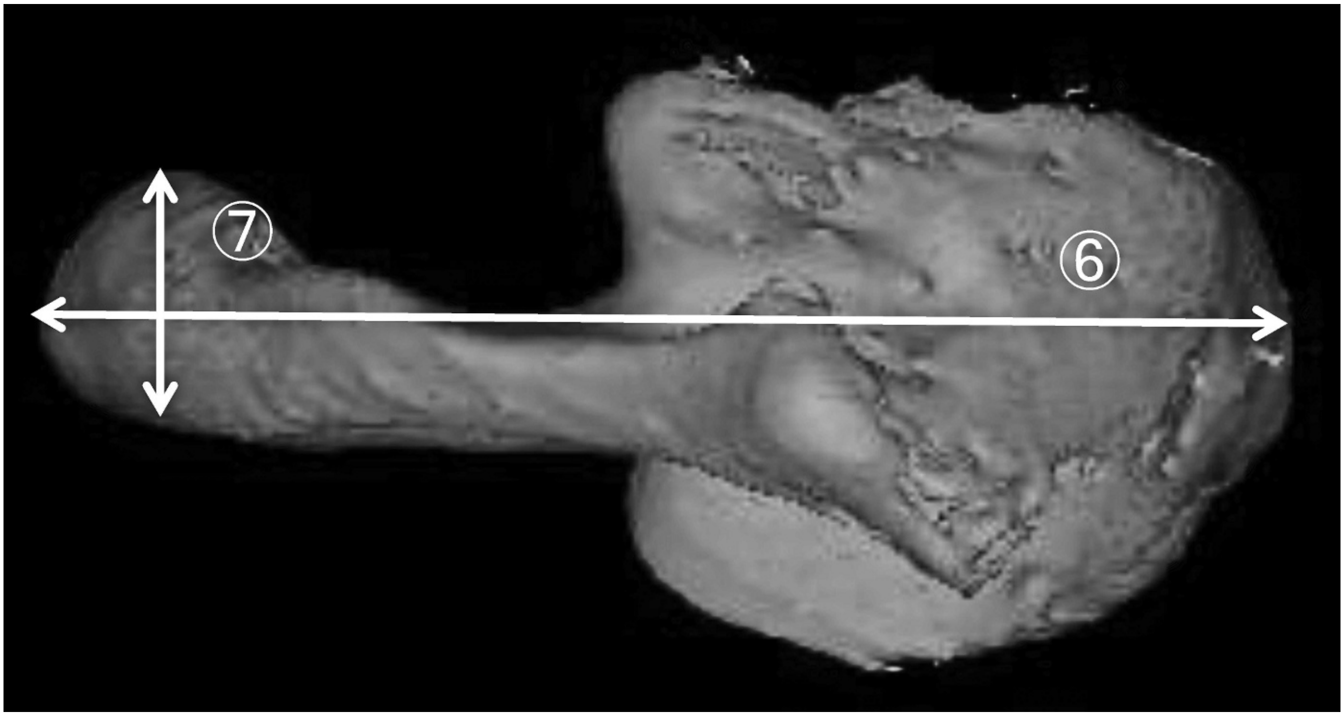

Figure 2. ⑥ Lateral outer AP diameter of C1 (mm); LOAPC1. ⑦ Height of the atlas dorsal arch (mm); dorsal arch.

increase in growing subjects.[18] In addition, morphological analysis of the atlas dorsal arch revealed a clear association with the growth direction of the mandible, whereby a lower atlas dorsal arch indicated less horizontal growth of the mandible.[27] This is probably due to the fact that subjects with a low dorsal arch had a relatively elevated head position and thus altered suprahyoidal muscular activity, which would permanently affect the position of the mandible.[27] Therefore, it was proposed that understanding the form of the cervical vertebra and the orthodontic treatment would enhance the treatment plan for subsequent growth.[2]

This study found no difference in mandibular plane angle between Class II and Class III groups (Table 1). Therefore, the variation demonstrated here in height of the atlas dorsal arch seems independent of craniofacial vertical differences. Several studies have suggested that craniofacial vertical differences are related to differences in cervical morphology.[6,7] The present findings showed no difference in outer margin values between groups, although the vertical differences in craniofacial morphology were related to the outer margin measurements.[28]

The anatomy and position of the cervical curvature in space depend on various body factors, including ethnicity,[29–31] gender,[29,30,32–34] age,[3,32,33] stature,[35] and craniofacial morphology.[4,10,11,36–39] Differences in these correlations might be attributed to factors such as racial difference,[39] although the association between craniofacial measurements and atlas morphology

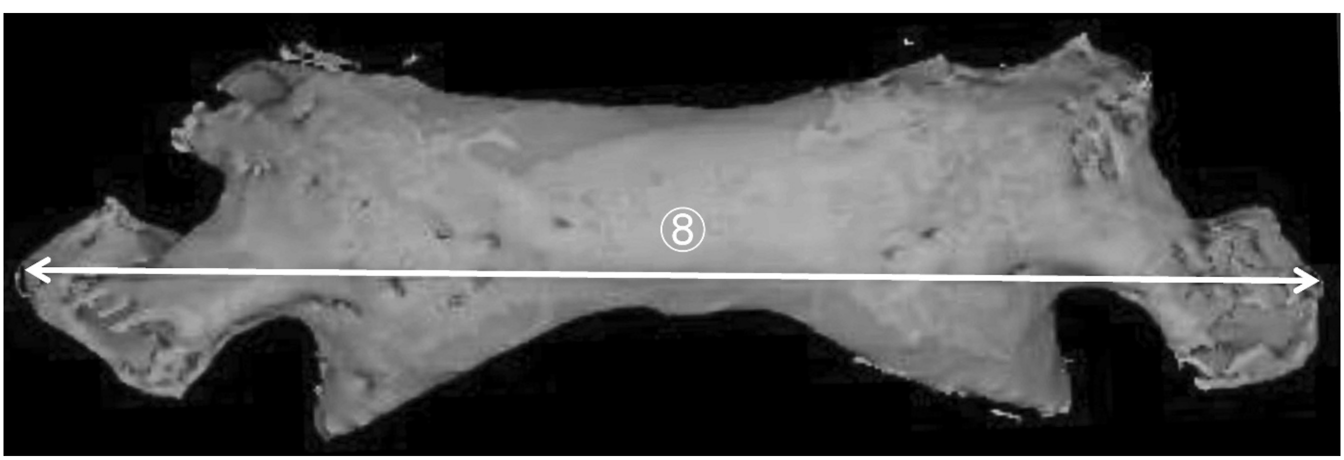

Figure 3. ⑧ Frontal outer transverse diameter of C1 (mm); FOTDC1.

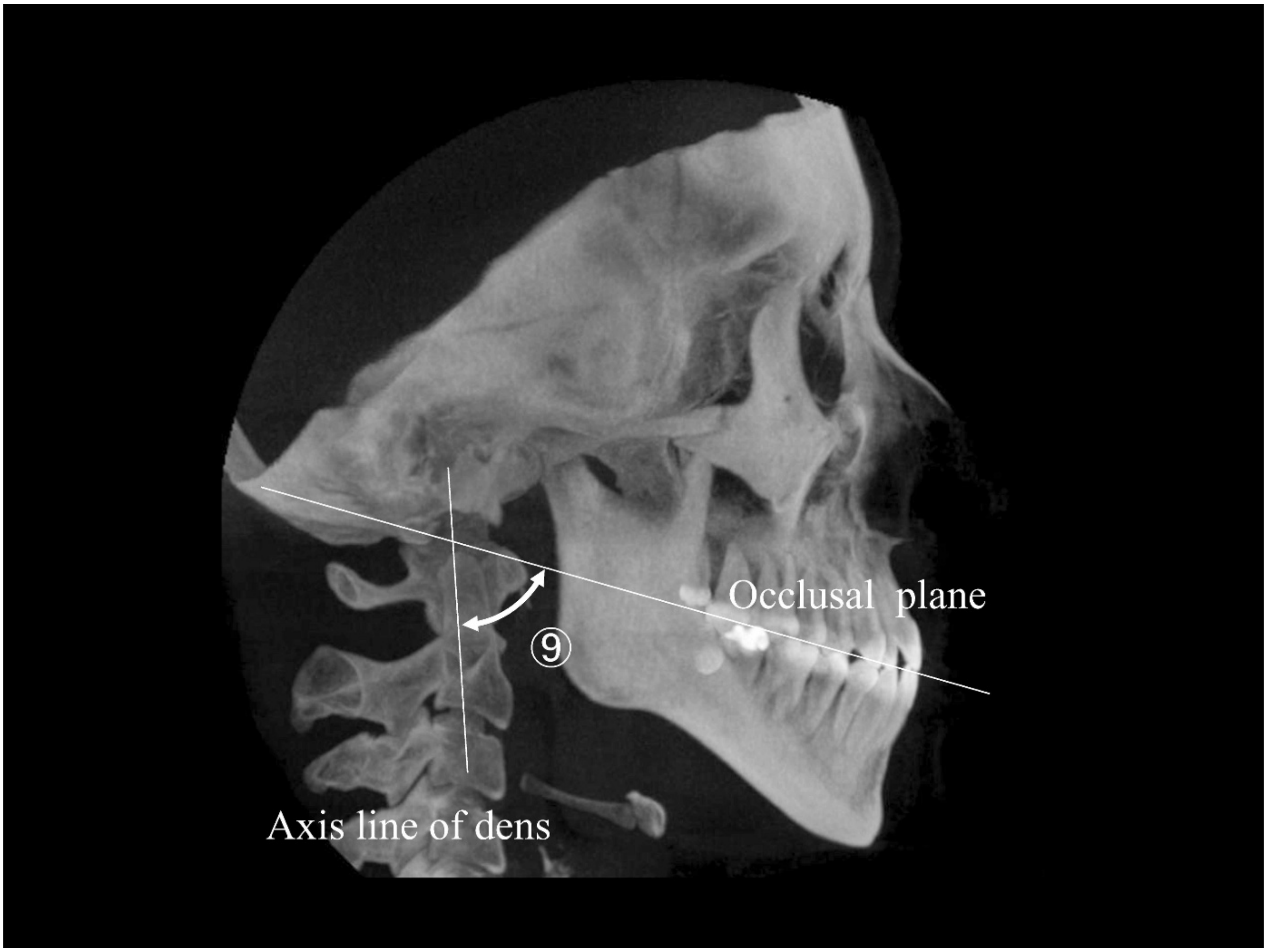

Figure 4. ⑨ Angle along axis line of the dens to occlusal plane; dens angle.

varied with sex and age. The growth directions in cervical vertebrae and mandible growth are certainly associated, although influences here of gender and racial differences are possible.[18] Moreover, this study suggested that Japanese female Class II subjects had lower dorsal arch heights than Class III subjects.

CONCLUSIONS

- This study confirmed past findings that Class II subjects are significantly shorter in terms of atlas dorsal arch height. Our findings on the relationship of anteroposterior skeletal pattern to the transverse diameter of C1 parallel the results of previous studies.[17,40–43]
- The atlas dorsal arch height of cervical vertebrae is affected by the anteroposterior skeletal pattern.

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