Morphometric analysis of cervical vertebrae morphology and correlation of cervical vertebrae morphometry, cervical spine inclination and cranial base angle to craniofacial morphology and stature in an adult skeletal class I and class II population

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Abstract

Objective: The study was carried out to compare the morphometry of the cervical column between adult Class I and Class II individuals and between gender and to analyze the correlation between the cervical column morphology, the cranial base angle, the craniocervical inclination with craniofacial morphology and stature of Angles Class I and Class II individuals. **Materials and Methods:** The data for this institutional retrospective study were systematically selected according to the specified inclusion and exclusion criteria from the pretreatment cephalometric radiographs of 19 male and 30 female patients visiting the Department of Orthodontics, Manipal College of Dental Sciences, Mangalore, Manipal University, based on their ANB angle. The radiographs were traced and digitized. The reliability of the variables describing the cranial base and vertical and sagittal craniofacial dimensions was assessed. **Conclusions:** Our results showed that there was no statistically significant variation in the cervical vertebrae dimensions between Class I and Class II patients. There was found to be a definite sexual dimorphism, which was not statistically significant. Correlation exists between sagittal skeletal patterns, especially mandibular length and cervicovertebral morphology, but its use to classify the subjects in different sagittal classes is questionable.

Keywords: Angle's classification, cervical inclination, cervical vertebrae, cranial base angle, craniofacial morphology, morphology, orthodontics, stature

Introduction

The skeletal sagittal relations of the maxillary and mandibular bases have been proposed as a valuable factor for diagnosis and treatment planning in orthodontics. Cephalometric analyses of the cervical vertebral column have found that the horizontal and vertical dimensions of the cervical vertebra are associated with head posture, the cranial base angulation, and mandibular shape and growth.[1] Previous research has also focused on associations between the dimensions of atlas and craniocervical posture in adults with neutral occlusion and normal craniofacial morphology. However, no previous studies have described morphology of C1-C5, craniocervical inclination, the cranial base associations with craniofacial morphology in adults with Class I and a Class II craniofacial morphology. Sonnesen *et al*.[2] stated that the cranial base angle was significantly positively correlated with fusion of the cervical column. The cervicohorizontal and cranial base angles were statistically larger in females than in males. Associations were found between fusions of the cervical column and mandibular retrognathia, large cranial base angle, and large horizontal overjet.[3] Hence, the objectives of this study were to assess the morphometric variations of the cervical column between adult Class I and Class II individuals and in different sexes and also to analyze the correlation between the cervical column morphology, the cranial base angle, the craniocervical inclination with craniofacial morphology and stature in Class I and Class II individuals.

Materials and Methods

This retrospective study was carried out at the Department of Orthodontics and Dentofacial Orthopedics, Manipal College of Dental Sciences, Mangalore (Manipal University). Approval for conducting the study was obtained from the Institutional Ethical Committee. The data for the study were systematically selected according to the specified inclusion

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criteria from patients (male - 19 and females - 30) visiting the Department of Orthodontics and Dentofacial Orthopedics, Manipal College of Dental Sciences, Mangalore. The pretreatment cephalometric radiographs of Class I ($n = 18$) and Class II ($n = 31$) were selected based on their ANB angle. For a patient to be included in the Class I skeletal pattern group (normal), two criteria had to be met: ANB angle of $2 \pm 1°$, and a pleasant profile. A patient was classified in the Class II group when the ANB angle was equal to or above 4°.

Inclusion criteria

- Patients between 18 and 30 years of age
- No history of orthodontic treatment during childhood
- Class II group: Patients with Class II skeletal pattern and horizontal maxillary overjet >4 mm (assessed by lateral cephalogram of each patient)
- Class I group: Patients with Class I skeletal pattern and minor dental malocclusion.

Exclusion criteria

- Patients with craniofacial anomalies or systemic muscle or joint disorders
- Nonavailability of a profile radiograph with first five cervical vertebrae visible.

The profile radiographs were taken with the teeth in occlusion and standardized head posture which was determined using a fluid level device. The radiographs were taken at the Department of Oral Medicine and Radiology, Manipal College of Dental Sciences, Mangalore, with a film-to-focus distance of 180 cm and a film-to-median plane distance of 10 cm. The radiographs were traced and digitized [Figure 2]. The reliability of the variables describing the cranial base and vertical and sagittal craniofacial dimensions was assessed by re-measurement of 20 lateral radiographs that were selected at random from the previously recorded radiographs. The radiographs were digitized again, and the differences between the two sets of recordings were calculated. The morphometry of the cervical column was assessed from length and width measurements of the first five cervical vertebrae (C1-C5) as they are normally seen on a standardized lateral cephalogram. The cranial base angle, craniocervical inclination and craniofacial morphology was assessed from the linear and angular measurements.

Reference points of the cephalograms

- S: Sella turcica (the midpoint of sella turcica)
- N: Nasion (the intersection of the internasal suture with nasofrontal suture in the mid sagittal plane)
- ANS: Anterior nasal spine (tip of the ANS seen on the X-ray from the normal lateralis)
- PNS: Posterior nasal spine (tip of the posterior spine of the palatine bone in the hard palate)
- Cv2tg: Tangent point of odontoid process tangent (OPT) line on the odontoid process of the second cervical vertebra
- Cv2ip: The most inferior posterior point on the corpus of the second cervical vertebra
- Cv4ip: The most inferior posterior point on the corpus of the fourth cervical vertebra.

Reference lines of the cephalograms Figure 2

- Ver: True vertical line (true vertical line projected on the film)
- Hor: True horizontal line (true horizontal line projected on the film)
- NSL: Cranial base (line extending between sella and nasion)
- CVT: Cervical vertebra tangent (posterior tangent to the odontoid process through Cv4ip to cranial base)
- OPT: Posterior tangent to the odontoid process through Cv2ip to cranial base
- Mandibular plane: Tangent to the lower border of the mandible.

Craniocervical angulations Figure 2

- NSL/OPT: Craniocervical posture (downward opening angle between NSL line and OPT line)

Table 1: Cv measurements used in the study Figure 1

Cv1sl	The distance between the most anterior point on the tubercle of atlas and most posterior point on dorsal arch of atlas
Cv2sl	The maximum antero-posterior length of second cervical vertebra measured from most posterior part on its spine
Cv3sl	The maximum antero-posterior length of third cervical vertebra measured from most posterior part on its spine
Cv4sl	The maximum antero-posterior length of fourth cervical vertebra measured from most posterior part on its spine
Cv5sl	The maximum antero-posterior length of fifth cervical vertebra measured from most posterior part on its spine
Cv1bl	The distance between the midpoint of antero-superior and antero-inferior points and midpoint of the postero-superior and postero-inferior point of the body of first cervical vertebra
Cv2bl	The distance between the midpoint of antero-superior and antero-inferior points and midpoint of the postero-superior and postero-inferior point of the body of second cervical vertebra
Cv3bl	The distance between the midpoint of antero-superior and antero-inferior points and midpoint of the postero-superior and postero-inferior points of the body of third cervical vertebra
Cv4bl	The distance between the midpoint of antero-superior and antero-inferior points and midpoint of the postero-superior and postero-inferior points of the body of fourth cervical vertebra
Cv5bl	The distance between the midpoint of antero-superior and antero-inferior points and midpoint of the postero-superior and postero-inferior points of the body of fifth cervical vertebra
Cv1ht	The distance between antero-superior and antero-inferior points of the body of first cervical vertebra
Cv2ht	The distance between antero-superior and antero-inferior points of the body of second cervical vertebra
Cv3ht	The distance between antero-superior and antero-inferior points of the body of third cervical vertebra
Cv4ht	The distance between antero-superior and antero-inferior points of the body of fourth cervical vertebra
Cv5ht	The distance between antero-superior and antero-inferior points of the body of fifth cervical vertebra

Cv: Cervicovertebral

- NSL/CVT: Craniocervical posture (downward opening angle between NSL line and CVT line).

Madibular incisor inclination

Incisor mandibular plane angle (upward opening angle between mandibular plane and long axis of mandibular incisor).

The stature was assessed from the height, and weight measurements recorded. The methodological error within the cephalometric analysis was determined by having the measurement values analyzed on randomly chosen cephalograms after a week interval by the same examiner. SPSS 17.0 (SPSS Inc.) was used to statistically analyze the measured values. Descriptive statistics was used to assess the correlation between the craniofacial dimensions, cranial base angle, craniocervical inclination and cervical vertebrae morphology in Class I and Class II patients.

Results and Observations

Our results showed that there was no statistically significant variation in the cervical vertebrae dimensions between Class I and Class II patients. There was found to be a definite sexual dimorphism, which was not statistically significant [Table 2]. The observations were as depicted in [Tables 2-4 and Figure 1].

Table 2: Descriptive mean statistics based on gender and malocclusion

Measurement	Male	Female	Class I	Class II
Cv1sl	44.6	41.91	41.17	43.65
Cv1bl	17.87	17	17.78	16.97
Cv1ht	15.3	15.74	14.36	16.32
Cv2sl	49	47.15	47.11	48.06
Cv2bl	16.8	16.6	16.17	16.97
Cv2ht	41.8	39.35	40.7	39.74
Cv3sl	41.4	40.38	40.3	40.8
Cv3bl	16.1	15.26	15.6	15.45
Cv3ht	15.13	14.65	14.28	15.1
Cv4sl	40.36	39.01	39.38	39.45
Cv4bl	16.16	15.17	15.3	15.54
Cv4ht	14.3	14.21	13.8	14.48
Cv5sl	39.3	38.5	39.4	38.3
Cv5bl	15.6	14.82	14.9	15.11
Cv5ht	14.27	13.8	13.5	14.23

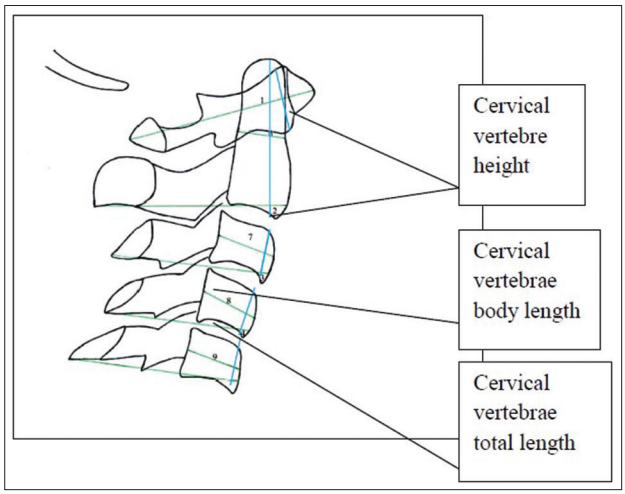

Figure 1: Pictorial depiction of the cervicovertebral measurement

Discussion

In orthodontics, the skeletal sagittal relations of the maxillary and mandibular bases have been proposed as a valuable factor for diagnosis and treatment planning. Facial profile of the patients may be well explained by the antero-posterior relations of the jaws regarding the cranial base.[4] Using a parameter of the relative relation of the jaws will be valuable while considering correlation of both jaws simultaneously with another factor such as the cervical column curvature. This would enhance the treatment prognosis. To make these assessments possible, in several studies lateral cephalometric radiography has been used for analysis of the head and neck posture.[5,6,7-9] Inclination of the cervical column in several studies has been measured as an angle like OPT/Hor and CVT/Hor.[4,7,10,11] This study was done on a group of adults belonging to Angles Class I and Class II groups in order to find a relationship if any, between sagittal skeletal pattern of the jaws and cervicovertebral morphology, cranial base angle, craniocervical inclination. The common origin of the spine and posterior part of the cranial base is the background for the hypothesis of associations between craniofacial morphology and the cervical spine, head posture and cranial base. In this study a strong correlation was shown by total body length of first cervical vertebrae (Cv1SL), height of atlas (Cv1HT), axis (Cv2HT) with age in both Angles Class I and Class II patients. Furthermore, a negative correlation was observed between atlas height and SNA and SNB angles in normal skeletal pattern (Class I) and with base plane angle in Angles Class II patients. Apart from this a good correlation was seen between axial height and mandibular length, as well as with the lower facial height (not significant) of Angles Class II patients. Mandibular length and stature also showed a good correlation with a total length of third and fourth cervical vertebrae and height of fourth and fifth cervical vertebrae. There was no correlation between atlas length and length of mandible in this study that is not in accordance with the findings of Huggare and Houghton,[11] whereas a very good correlation exists between the axial height and total skull width. Gonial angle showed a negative correlation with atlas and axial height though not significant, which was in accordance with the findings of Huggare and Houghton.[11] There was also a good correlation though not significant, between gonial angle and the cervical inclination as shown by the angle OPT-Hor, which related more to the inclination

Table 3: Correlation between Cv and CF dimensions in Class I patients

Correlation between Cv and CF dimensions in Class I patients

Measurements	Class I								
	MXL	MNL	LAFH	GON ANG	HT	SNA	SNB	IMPA	BA PL ANG
Cv1sl	NS	NS	NS	NS	NS	−NS	−NS	−NS	−NS
Cv1bl	0.558*	NS	NS	−NS	NS	NS	NS	NS	−NS
Cv1ht	NS	−NS	NS	−NS	NS	−0.619**	−0.547*	NS	NS
Cv2sl	NS	−NS	NS	−NS	NS	NS	NS	NS	−NS
Cv2bl	NS	NS	NS	−NS	NS	NS	NS	NS	−NS
Cv2ht	NS	NS	NS	−NS	−NS	NS	NS	NS	NS
Cv3sl	−NS	NS	NS	NS	−NS	−NS	−NS	NS	NS
Cv3bl	NS	NS	NS	NS	NS	−NS	NS	NS	−NS
Cv3ht	NS	NS	NS	NS	0.481*	−NS	−NS	NS	NS
Cv4sl	−NS	NS	NS	0.615**	−NS	NS	−NS	−NS	0.750**
Cv4bl	NS	NS	NS	NS	−NS	−NS	−NS	−NS	NS
Cv4ht	0.541*	NS	NS	NS	NS	−NS	−NS	NS	−NS
Cv5sl	−NS	NS	NS	NS	NS	−NS	−0.612**	−NS	NS
Cv5bl	NS	NS	NS	NS	NS	−NS	−NS	−0.471*	NS
Cv5ht	0.627**	0.523*	NS	NS	0.472*	−NS	−NS	−NS	−NS
SAD ANG	NS	NS	−NS	−NS	NS	−0.582*	−NS	NS	NS
OPT-Hor	−NS	−NS	−NS	NS	−NS	NS	NS	−NS	−NS
CVT-Hor	−NS	−NS	−NS	NS	NS	NS	NS	−NS	−NS

*Correlation is significant at the 0.05 level (two-tailed); **Correlation is significant at the 0.01 level (two-tailed). Cv: Cervicovertebral; CF: Craniofacial; IMPA: Incisor mandibular plane angle; NS: Not significant; OPT: Odontoid process tangent; Hor: Horizontal; CVT: Cervical vertebra tangent, SNA: SNA angle, SNB: SNB angle, ANB: ANB angle, MNL: Mandibular plane angle, LAFH: Lower facial height, SAD ANG: Saddle angle, GON: Gonial angle, HT: Stature

Table 4: Correlation between Cv and CF dimensions in Class II patients

Correlation between Cv and CF dimensions in Class II patients

Measurements	Class II (*n*=31)								
	MXL	MNL	LAFH	GON ANG	HT	SNA	SNB	IMPA	BA PL ANG
Cv1sl	0.389*	0.466**	NS	NS	0.404*	NS	−NS	−NS	−NS
Cv1bl	−NS	−NS	NS	−NS	NS	NS	−NS	NS	−NS
Cv1ht	NS	NS	−NS	−NS	NS	NS	NS	NS	−0.450*
Cv2sl	NS	−NS	NS	−NS	−NS	NS	−NS	−NS	−NS
Cv2bl	NS	NS	NS	−NS	NS	NS	NS	−NS	−NS
Cv2ht	NS	0.492**	0.349 (NS)	−NS	−NS	NS	NS	−NS	−NS
Cv3sl	0.467**	0.560**	NS	NS	0.607**	NS	NS	−NS	−NS
Cv3bl	0.456**	0.452*	NS	NS	NS	NS	NS	−NS	−NS
Cv3ht	NS	NS	NS	NS	NS	NS	−NS	−NS	NS
Cv4sl	0.536**	0.688**	NS	0.615**	0.648**	NS	−NS	−NS	−NS
Cv4bl	NS	NS	NS	NS	−NS	NS	NS	−NS	NS
Cv4ht	−NS	NS	0.473**	NS	NS	NS	NS	−NS	0.361*
Cv5sl	−NS	0.451*	NS	NS	0.526**	NS	NS	NS	−NS
Cv5bl	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cv5ht	NS	0.627*	NS	NS	NS	NS	NS	NS	NS
SAD ANG	0.451*	NS	−NS	−NS	0.402*	−NS	−0.423*	NS	−NS
OPT-Hor	−NS	−NS	NS	NS	−NS	−NS	NS	NS	NS
CVT-Hor	−NS	−NS	NS	NS	NS	−NS	NS	NS	NS

*Correlation is significant at the 0.05 level (two-tailed); **Correlation is significant at the 0.01 level (two-tailed). Cv: Cervicovertebral; CF: Craniofacial; IMPA: Incisor mandibular plane angle; OPT: Odontoid process tangent; HOR: Horizontal; CVT: Cervical vertebra tangent; NS: Not significant, SNA: SNA angle, SNB: SNB angle, ANB: ANB angle, MNL: Mandibular plane angle, LAFH: Lower facial height, SAD ANG: Saddle angle, GON: Gonial angle, HT: Stature

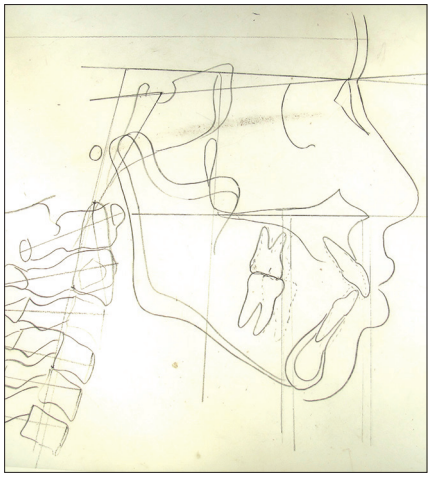

Figure 2: Descriptive mean statistics based on gender and malocclusion

of first and second cervical vertebrae to the cranium, whereas there was no correlation between the inclination of the lower vertebrae with the gonial angle. It was also found that a very good correlation exists between the saddle angle and ANB angle which corroborates the fact that the mandible is retrusive in Angle's Class II individuals and also with maxillary length and stature and was negatively correlated with SNB angle.

Conclusion

In this study, there was no statistically significant variation in the cervical vertebrae dimensions between Class I and Class II patients. There was found to be a definite sexual dimorphism, which was not statistically significant. Showed that a correlation exists between sagittal skeletal patterns especially mandibular length and cervicovertebral morphology but its use to classify the subjects in different sagittal classes is questionable. However, the height of the dens of the axis vertebrae and height of the fifth vertebrae showed a good association with the facial height and mandibular length in Angles Class II individuals and stature, maxillary and mandibular length in Class I individuals. Further longitudinal studies in this regard are required to confirm these findings.

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Clinical relevance

The skeletal sagittal relations of the maxillary and mandibular bases have been proposed as a valuable factor for diagnosis and treatment planning in orthodontics. Cephalometric analyses of the cervical vertebral column have found that the horizontal and vertical dimensions of the cervical vertebra are associated with head posture, the cranial base angulation, and mandibular shape and growth. Earlier attempts were carried out to study the association of morphological anomalies of cervical vertebrae with the craniofacial morphology. No previous studies have described morphology of C1-C5, craniocervical inclination, the cranial base associations with craniofacial morphology in adults with Class I and a Class II craniofacial morphology and this study has attempted to provide insight into the sexual dimorphism and correlation between cervical vertebral morphology, cranial base and craniocervical inclination with craniofacial morphology and stature.

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