ORIGINAL RESEARCH

Comparison of Association between Cervical Spine and Face in Subjects with Vertical and Horizontal Growth Pattern: An *in vitro* Study using Lateral Cephalogram

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ABSTRACT

Purpose: The purpose of this study was to analyze and compare the association between cervical spine and face in subjects with vertical and horizontal growth pattern using lateral cephalogram.

Materials and methods: Lateral cephalograms of 75 subjects between ages of 18 and 35 years were taken and analyzed. The study sample was divided into three groups of 25 individuals each; i.e., vertical growth pattern (gonial angle > 125°); horizontal growth pattern (gonial angle < 121°); and control group with average growth pattern (gonial angle 123° ± 2.5°). The relation between upper cervical vertebrae and face was compared between three groups by taking linear measurements.

Results: A statistically significant difference was observed in vertical dimensions of second cervical vertebra when it was correlated with anterior cranial base, maxilla and mandible in adults having horizontal and vertical growth pattern as compared to individuals with average growth pattern. Linear vertical measurements between maxilla to cervical spine and mandible to cervical spine were less in horizontal growth pattern as compared to vertical and average growth pattern. The p-value of SCV_2–0.001, $GoCV_2$–0.405, and $PmCV_2$–0.001 showed significant results within intergroups.

Conclusion: It can be concluded that there exists an association between the morphology of the cervical vertebrae and the vertical and horizontal skeletal growth patterns.

Keywords: Cervical vertebrae, Growth pattern, CV_2, CV_3, CV_4.

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INTRODUCTION

The cervical spine has been an area of interest in orthodontics for several reasons. A number of authors have described the association between head posture and craniocervical morphology that may affect the pattern of craniofacial growth. Various studies in the literature have suggested that the morphology of cervical vertebrae seems to be affected by head posture, age, congenital anomalies and skeletal growth pattern. The existence of a relationship between head posture and craniofacial structure was first demonstrated by Solow and Tallgren[1] in 1976 who concluded that a more downward head posture was associated with a more horizontal and an extended head posture was associated with a more vertical growth pattern of the mandible. Kylamarkula and Huggare[2] found that the horizontal and vertical dimensions of first cervical vertebra (CV_1); atlas, related directly with head posture, cranial base angulation, mandibular shape and growth. Watanabe et al[3] in 2010 has described the morphology of cervical vertebra in subjects with different sagittal jaw relationships using cone-beam computed tomography. The cervical vertebral column has also been used as a reference structure for assessing natural head position on lateral cephalograms. In the past three decades, association between the cervical vertebral maturation (CVM) and maxillomandibular growth has received increasing attention. Salagnac et al reported that vertical growth of cervical spine; mandible and upper face were anatomically and physiologically correlated.[5]

Very few studies in the literature have described the existence of relationship between cervical spine and growth pattern. Thus, the purpose of present study was to investigate whether there is a correlation between the morphology of cervical spine and face in individuals with various growth patterns (average, horizontal and vertical) using two-dimensional (2D) imaging technique, i.e., lateral cephalogram. It was hypothesized that there may be correlation between head and spine posture and growth of jaw bases. The head posture alters the muscle function and orientation and so may indirectly contribute to the altered growth of jaw bases.

MATERIALS AND METHODS

The present study was conducted at Sharad Pawar Dental College and Hospital, Wardha, Maharashtra. Lateral cephalograms of 75 subjects between 18 and 35 years age (40 males and 35 females) were taken and analyzed. The cephalometric parameters used for selection of the study sample were enlisted in Table 1.

Based on the parameters, the sample was divided into three groups, i.e., horizontal vertical and average growth pattern (control group) consisting of 25 individuals each. The individuals selected for the study sample had acceptable occlusions, were nonsyndromic with no systemic muscle or joint disorders and had no history of previous orthodontic treatment.

ANALYSIS OF MORPHOLOGY AND GROWTH

The first to fifth cervical vertebrae which are normally seen in the lateral skull radiograph were assessed. The following reference points and lines were identified: nasion (N), orbitale (Or), spinal-point (Sp), gnathion (Gn), sella (S), basion (Ba), condylion (Cd), porion (Po), pterygomaxillary (Pm), gonion (Go), SN-line (SN), Frankfort horizontal plane (FH), mandibular plane (MP), tangential mandibular line (ML_1), second cervical vertebra (CV_2), third cervical vertebra (CV_3), and fourth cervical vertebra (CV_4). Most points and lines are well known; only a few need explanation:

Second cervical vertebra was defined as the lower and anterior most point on inferior border of the body of the second cervical vertebra, CV_3 as the lower and anterior most point on inferior border of the third cervical vertebra, and CV_4 as the lower and anterior most point on inferior border of the body of the fourth cervical vertebra. Each cephalogram was manually traced and measured twice. Tolerance limits of 1 mm and 1° were set for the difference between the first and second observations of linear and angular measurements.

On cephalogram, angle FH-SN was measured and designated angle alpha (α) (Fig. 1). On subsequent cephalograms, line was constructed through S at angle to SN equivalent to angle α which was designated as FH estimated (FHe). Points within upper cervical spine (CV_2, CV_3, CV_4), maxilla (Pm) and mandible (Go) were projected on line perpendicular to FHe and extended inferiorly from S. Vertical dimension of upper cervical spine (variable 1 Table 2), vertical positions of cervical vertebrae (variables 2–4 of Table 2) were measured along line extended inferiorly from S. Linear dimensions were measured to evaluate the variations in vertical dimension of the cervical vertebrae relative to cranial base, maxilla and mandible in adults with vertical and horizontal growth pattern. These values were then compared with average growth pattern.

STATISTICAL METHOD

Descriptive and analytical statistics were done. The Kolmogorov-Smirnov test was used to check normality of data and one-way ANOVA with Scheffe's *post hoc* test was used to check the mean differences between groups.
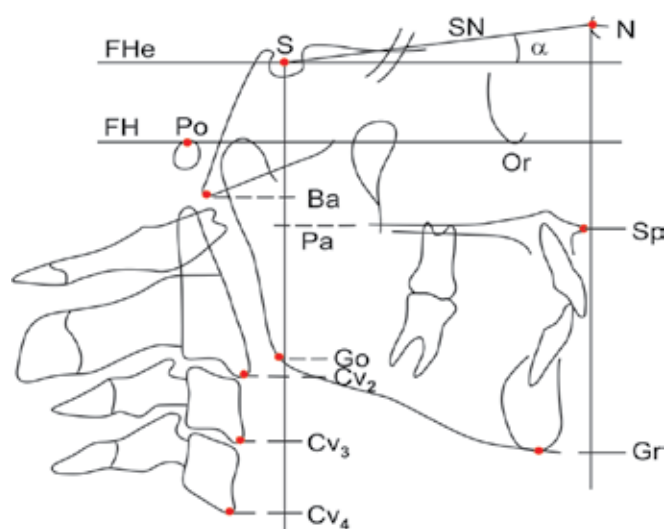

Fig. 1: Reference points and lines [Angle FH-SN was measured and designated angle alpha (α). On subsequent cephalograms, line was constructed through S at angle to SN equivalent to angle α which was designated as FH estimated (FHe). Points within upper cervical spine (CV2, CV_3, CV_4), maxilla (Pm) and mandible (Go) were projected on line perpendicular to FHe and extended inferiorly from S]

Table 1: Cephalometric parameters used for selection of the study sample

Sl. no.	Cephalometric parameter	Subjects with horizontal growth pattern	Subjects with vertical growth pattern
1	Gonial angle	<121°	>135°
2	Mandibular plane angle (FH-Me)	<17°	>28°
3	Basal plane angle	<15°	>30°
4	Jaraback ratio	<65%	>75%
5	Lower anterior facial height	<58 mm	>72 mm

Table 2: Definitions of variable

Sl. no.	Cephalometric parameter	Subjects with horizontal growth pattern	Subjects with vertical growth pattern
1	Gonial angle	<121°	>135°
2	Mandibular plane angle (FH-Me)	<17°	>28°
3	Basal plane angle	<15°	>30°
4	Jaraback ratio	<65%	>75%
5	Lower anterior facial height	<58 mm	>72 mm

Table 3: Mean, standard error and standard deviations for the variables in the horizontal, vertical, and average growth pattern groups

Sl. no.	Cephalometric parameter	Subjects with horizontal growth pattern	Subjects with vertical growth pattern
1	Gonial angle	<121°	>135°
2	Mandibular plane angle (FH-Me)	<17°	>28°
3	Basal plane angle	<15°	>30°
4	Jaraback ratio	<65%	>75%
5	Lower anterior facial height	<58 mm	>72 mm

Table 4: Intergroup correlation between variables

Sl. no.	Cephalometric parameter	Subjects with horizontal growth pattern	Subjects with vertical growth pattern
1	Gonial angle	<121°	>135°
2	Mandibular plane angle (FH-Me)	<17°	>28°
3	Basal plane angle	<15°	>30°
4	Jaraback ratio	<65%	>75%
5	Lower anterior facial height	<58 mm	>72 mm

Table 5: Correlation of variables between intergroups

Sl. no.	Item	Groups		Mean difference	Std. error	Sig.	95% CI Lower	95% CI Upper
1	$BaCV_4$	Vertical	Horizontal	10.60	2.23	0.000*	5.02	16.17
		Vertical	Average	3.32	2.23	0.336	− 2.25	8.89
		Horizontal	Average	− 7.28	2.23	0.007*	− 12.85	− 1.70
2	SCV_2	Vertical	Horizontal	8.28	1.63	0.000*	4.18	12.37
		Vertical	Average	− 0.68	1.63	0.917	− 4.77	3.41
		Horizontal	Average	− 8.96	1.63	0.001*	− 13.05	− 4.86
3	SCV_3	Vertical	Horizontal	9.84	1.83	0.001*	5.25	14.42
		Vertical	Average	− 1.20	1.83	0.808	− 5.78	3.38
		Horizontal	Average	−11.04	1.83	0.001*	− 15.62	− 6.45
4	SCV_4	Vertical	Horizontal	10.28	2.09	0.001*	5.04	15.51
		Vertical	Average	−10.28	2.09	0.001*	− 15.51	− 5.04
		Horizontal	Average	−11.64	2.09	0.001*	− 16.87	− 6.40
5	$GoCV_2$	Vertical	Horizontal	3.64	3.67	0.615	− 5.55	12.83
		Vertical	Average	4.76	3.67	0.437	− 4.43	13.95
		Horizontal	Average	1.12	3.67	0.955	− 8.07	10.31
6	$PmCV_2$	Vertical	Horizontal	5.60	2.23	0.050*	0.03	11.19
		Vertical	Average	− 5.48	2.23	0.056*	− 11.07	0.11
		Horizontal	Average	− 11.08	2.23	0.001*	− 16.67	− 5.48

OBSERVATIONS AND RESULTS

The mean linear measurement of SCV_2, $GoCV_2$ and $PmCV_2$ showed significant difference between the three groups. It was 76.08 mm (± 1.27), 8.28 mm (± 2.41), and 59.40 mm (± 2.03) respectively in vertical. It was 67.80 mm (± 1.10), 4.64 mm (± 0.76) and 53.80 mm (± 1.33) respectively in horizontal and 76.76 mm (± 1.04), 3.52 mm (± 0.44) and 64.88 mm (± 0.94) in control or average subjects (Table 3).

The mean linear measurement of SCV_3 showed significant difference. It was 93.36 mm (± 1.25) in vertical and 83.52 (± 1.28) in horizontal group. The skeletal horizontal pattern and skeletal vertical pattern subjects showed a significant increase in the height of the vertebrae body of C3.

The mean linear measurement of $BaCV_4$ and SCV_4 showed significant difference between three groups. It was 71.48 (± 1.10) and 108.92 (± 1.41) in vertical group; 60.88 (± 2.08) and 98.64 (± 1.45) in horizontal group and 68.16 (± 1.33) and 110.28 (± 1.58) in average group respectively (Tables 4 and 5).

DISCUSSION

An improved understanding of the association between head posture and craniocervical morphology is essential for diagnosis and treatment of morphological and functional disturbances in the craniofacial region. In the present study, an attempt was made to find a correlation between the morphology of cervical spine and face in individuals with different growth patterns using lateral cephalogram.

When the vertical dimensions between CV_2 with cranial base, maxilla and mandible was compared in all the three different growth pattern, it was found that these linear measurements were less statistically significant in horizontal and more in vertical growth pattern when compared with average growth pattern. There are no studies in the literature correlating the third cervical vertebra with facial variables. When linear measurements between CV_3 and CV_4 with cranial base were made it was found that this distance was more in vertical and

less in horizontal growth pattern. This finding was also statistically significant. These findings are in accordance with the study by Karlsen AT who concluded that a mutual relationship exists between vertical growth of the upper cervical spine and the face, especially the lower face. An explanation for this association was given by Huggare J.[6]

The effects of muscle thickness on bone morphology can be explained Wolff's law (Dibbets, 1992). Which states that the internal structure and shape of bone is closely related to muscle function (Wolff, 1870).[7] Based on the results of EMG and bite-force studies, it has been suggested that long-face individuals have weaker muscles (Moller, 1966; Ringqvist, 1973a; Ingervall and Thilander, 1974; Ingervall, 1976; Sassouni, 1969; Finn, 1978; Proffit et al, 1983). Thus, it can be correlated that weaker muscular pattern have less pull effect of these ligaments which are connecting the face with cervical vertebrae.

The CV_2 is the highest and largest of the cervical vertebra. The odontoid process, or dens of the CV_2 runs approximately parallel to the mandibular ramus. The vertical position of Go might hold the key to the vertical development of the face – particularly in the development of the lower face. In high-angle subjects, a long $GoCV_2$ may give rise to a short-lower posterior facial height.[9,10]

Houston proposed growth of the cervical vertebrae as main determinant of increase in anterior facial height and developed a model in which vertical increase of the cervical spine elevated the cranium in relation to the shoulder girdle (clavicle, sternum, scapula). The growth and stretch of the muscles and fascia passing between the cranium, mandible, hyoid bone, and shoulder girdle were associated with the descent of the symphysis and hyoid bone relative to the cranial base.[11]

Dimensions of C_1 as well as head and neck posture are interrelated with craniofacial morphology, including the cranial[9-11] upper airway space,[12] occlusion,[13] and temporomandibular disorders.[13]

Several 2D studies have evaluated variations in the dimensions of cervical vertebrae as related with skeletal malocclusions.[14]

In an earlier cross-sectional study – a remarkable similarity in facial form was found between subjects with a large craniocervical angle and subjects with a large mandibular plane inclination, and also between subjects with a small craniocervical angle and subjects with a small mandibular plane angle. This suggested that craniocervical angulation might be particularly related to mandibular development, however, cross-sectional correlation studies do not permit inferences regarding cause-and-effect relationships.[15]

An explanation for the associations between the morphologic deviations in the cervical vertebral column and the craniofacial morphology including could be found in the early embryogenesis. Because the notochord determines the development of the body of the cervical vertebra and also of the basilar part of the occipital bone, which is the posterior part of the cranial base angle. Since the cranial base is connected to the cervical vertebral column by the notochord in early embryogenesis, and the jaws are attached to the cranial base, the cranial base could be the developing link between the cervical vertebral column and the jaws.[16]

This suggests that severe vertical skeletal malocclusions are associated with an increase in the vertical dimension of the axis or second cervical vertebrae.

In the present study, an association was seen between morphological deviations of the upper cervical vertebrae (C_2–C_4) and the skeletal growth pattern (vertical and horizontal growth pattern). This indicates that the morphological deviations of the upper cervical vertebrae are associated with malformation of the jaws and also have an association with the craniofacial morphology.

However, the results should be interpreted with caution due to the cross-sectional nature of the study which do not permit inferences regarding cause and effect relationship.

CONCLUSION

It can be concluded that there is an association between the morphology of the cervical vertebrae and the vertical and horizontal skeletal growth patterns. The results of our study indicate that there is a significant association between the morphology of the cervical vertebrae and the growth pattern of the mandible.

ACKNOWLEDGMENTS

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