A study of cervical vertebra anomalies among individuals with different sagittal and vertical facial growth patterns

ABSTRACT

Objective: The objective was to evaluate the prevalence of cervical vertebra anomalies (CVA) in individuals with different sagittal and vertical skeletal growth patterns of jaws and also to establish the associations of anomalies with the type of growth, if any.

Materials and Methods: A total of 293 lateral cephalograms were evaluated for CVA. Based on the Frankfort mandibular plane angle, cephalograms were categorized into three groups: Group I, II, and III. Based on the ANB angle, cephalograms were classified into three classes, Class 1, 2, and 3. Six types of CVA such as partial cleft (PC), block fusion (BF), dehiscence (D), fusion between C2 and C3 (F23), occipitalization (OC), and spina bifida (SB) were identified on lateral cephalograms. Descriptive statistics were applied along with multinomial logistic regression analysis. $P = 0.05$ was considered as the level of statistical significance.

Results: PC was most common in the overall samples (36%). BF was the least common (3.2%) CVA. The frequency of various CVA was comparable between males and females in all the three classes of individuals. The association of vertical growth patterns with CVA was found to be statistically nonsignificant ($P > 0.05$). Class 2 malocclusion was found to be statistically significantly associated with the D ($P = 0.043$).

Conclusions: PC, fusion, and D were the most frequently found CVA, and SB was found only among the hypodivergent growth pattern individuals. The association of CVA with vertical facial growth patterns was not significant, somewhat influenced by age, sex, and sagittal skeletal malocclusions.

Keywords: Cervical vertebral anomalies, lateral cephalograms, sagittal growth pattern, vertical growth pattern

INTRODUCTION

The role of head posture in the craniofacial growth and the influence of craniofacial growth on the cervical vertebra morphology are well correlated in literature.[1-3] Individuals with different vertical facial growth patterns hold their head in different postures,[4] and the functional adaptation leads to altered morphology of the cervical vertebrae.[5] Altered function of the stomatognathic system, such as mouth breathing in children with enlarged adenoids, also changes the head posture, which affects the morphology of the atlas vertebra as an adaptation.[6] Cervical vertebra morphology on lateral cephalograms is frequently analyzed for the evaluation of skeletal maturation.[7] The same lateral cephalograms are also used to analyze the various anomalies of cervical vertebrae.[8] Thus, it serves as a diagnostic tool to rule out any asymptomatic cervical vertebra anomalies (CVA) and to predict the possibilities of future pathology.[9] Researchers have attempted to correlate the head posture and vertebral anomalies among individuals with various malocclusions.[10-16]

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An increased craniocervical angle is common in individuals with hyperdivergent growth pattern.[17] The extended head posture leads to decrease in the height of atlas vertebra as an adaptive compensation.[6] Although there are few studies in the literature mentioning the association between cervical column morphology with the skeletal open bite and deep bite,[18,19] we did not find any study evaluating the association of cervical column morphology and CVA in individuals with different vertical growth pattern of face. Thus, this study was conducted to evaluate the prevalence of CVA in individuals with different vertical growth patterns and among different sagittal skeletal malocclusions and also to establish the associations of anomalies with the type of growth, if any.

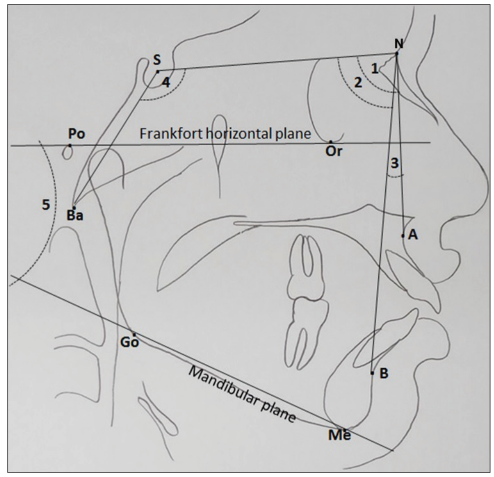

Figure 1: Cephalometric landmarks, reference planes, and various angular parameters used in the study. S – Sella, N – Nasion, Po – Porion, Or – Orbitale, Ba – Basion, A – Point A, B – Point B, Go – Gonion, Me – Menton. Reference planes. Frankfort horizontal plane – the plane between "Porion" and "Orbitale," Mandibular plane – the plane between "Gonion" and "Menton". Angular parameters – 1 – SNA angle, the angle between 'S,' 'N,' and 'A', 2 – SNB angle, the angle between "S," "N," and "B," 3 – ANB angle, the angle between "A," "N," and "B," 4 – Cranial base angle, the angle between "Ba", "S," and "N," 5 – Frankfort mandibular plane angle, the angle between Frankfort horizontal plane and mandibular plane

MATERIALS AND METHOD

The present cross-sectional study was conducted on lateral cephalograms of the orthodontic patients who reported to the Orthodontic Clinic, Department of Dentistry, for the correction of their malocclusions. The radiographs recorded between February 2017 and January 2019 were examined. Selection criteria included individuals with age ≥10 years, with good-quality lateral cephalograms recorded in natural head position with Frankfort horizontal plane parallel to the floor, with teeth at centric occlusion, and with lips at the relaxed position. All the cephalograms were recorded by a trained technician in the same machine (NewTom GiANO, Italy) with exposure parameters of 80 kVp, 10 mA, and 1.6 s. Patients with various craniofacial anomalies such as cleft lip and palate, syndromes, and history of maxillofacial or cervical spine trauma were excluded.

A total of 313 cephalograms were examined initially for the quality and visibility of cervical vertebrae. After excluding 20 cephalograms, those were having positional errors, 293 cephalograms (male = 121, female = 172) were analyzed for final evaluation. Tracing and analysis of the lateral cephalograms were done in a two-dimensional orthodontic treatment planner (AudaxCeph software, Ljubljana, Slovenia) by two experienced orthodontists (AV and JS) independently. The demographic data such as age and sex were extracted from the patients' record file. Various cephalometric landmarks, reference planers, and angular parameters used in the present study are mentioned in Figure 1. Based on the Frankfort mandibular plane angle (FMA), cephalograms were categorized into three groups, i.e., Group I (hypodivergent, FMA <20°), Group II (normodivergent, FMA = 25° ±5°), and Group III (hyperdivergent, FMA >30°). Similarly, based on the ANB angle, which determines the sagittal maxilla-mandibular growth pattern, cephalograms were categorized into three classes, i.e., Class 1 (ANB 0°–4°), Class 2 (ANB >4°), and Class 3 (ANB <0°). The morphological characteristics of the cervical vertebra were divided into five types as per the classification suggested by Sandham,[20] i.e., partial cleft (PC), block fusion (BF), dehiscence (D), fusion (F23, between C2 and C3), and occipitalization (OC) [Figure 2a-f]. In addition to this, spina bifida (SB) at the atlas vertebra was also included [Figure 2g]. Morphology of each type of anomalies was repeatedly practiced by two examiners independently. Each radiograph was visually examined for the presence of vertebral anomalies and identified separately by two examiners. The inter-observer error was calculated from the original findings. For the evaluation of intra-observer error, examiners randomly selected fifty radiographs after 2 weeks of interval and re-diagnosed the findings of CVA.

Statistical analysis

All statistical analyses were performed in the SPSS software (Statistical Packages for Social Sciences, Chicago, IL; Version 25). The collected data contained both in numerical and nominal scales. The inter-observer and intra-observer errors were calculated by using Cohen's Kappa coefficient. Descriptive statistics were used to find out the frequency of anomalies among the different sagittal and vertical growth patterns. Multinomial logistic regression analysis was done to evaluate the association of various CVA with sagittal skeletal malocclusions and with vertical facial growth patterns. Estimates of the coefficients and odds ratio (OR) were obtained with a 95% confidence interval. Along with it, the effects of sexual dimorphism and age were also evaluated as an additional output. The $P = 0.05$ was considered as the level of statistical significance.

RESULTS

The inter-observer agreement of Kappa was found as 0.871. The intra-observer measure of agreement Kappa for examiner AV was 0.923, and JS was 0.954. Age and cephalometric characteristics of the individuals in Group I, II, and III and in Class 1, 2, and 3 are outlined in Tables 1 and 2, respectively. The frequency of different CVA and their gender-wise distribution in the three groups are described in Table 3. Among the six types of CVA, PC was most common in the overall samples (36%) and also in all the three vertical growth patterns. The BF was the least common (3.2%) CVA. The SB was found only in Group I individuals (hypodivergent). OC and PC were highest in the Group III individuals. A significant increase in the vertebral anomalies was found in females of Group III (hyperdivergent), and the difference between males and females was statistically significant ($P = 0.025$). Table 4 outlines the distribution and comparison of anomalies among patients with various sagittal skeletal malocclusions (Class 1, 2, and 3). The frequency of various CVA was comparable between males and females in all the three classes of individuals.

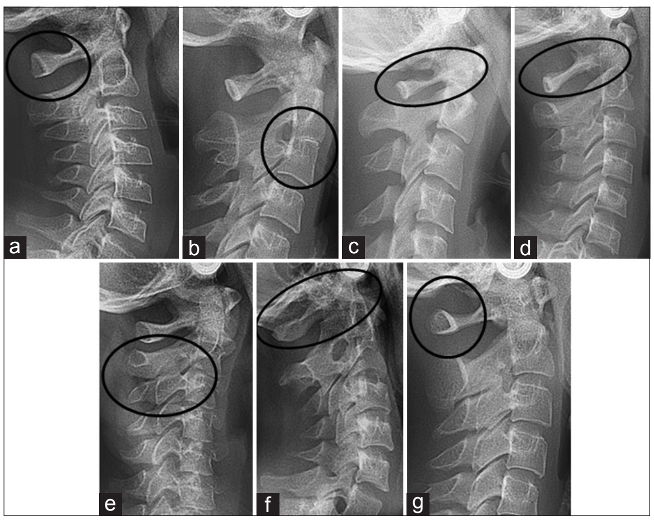

Figure 2: Various cervical vertebral anomalies according to Sandham.[20] (a) Partial cleft, (b) Block fusion, (c and d) Dehiscence, (e) F23 (Fusion between C2 and C3), (f) Occipitalization, and (g) Spina bifida

Table 5 outlines the factors influencing the occurrence of the anomalies via the results of multinomial logistic regression analysis. Model fitting information for the final model revealed a statistically significant ($P = 0.013$) association of the CVA with the factors analyzed, and the Pearson's correlation value was 1.00. However, the individual effect of group ($P = 0.147$) and age ($P = 0.100$) was not that discriminative as the final model, whereas the impact of sex was statistically significant ($P = 0.047$) in the reduced model. The Nagelkerke pseudo R^2 value was 0.144. The PC was chosen as the reference category. The association of vertical growth patterns with anomalies was found to be statistically nonsignificant ($P > 0.05$). Compared to skeletal Class 3, Class 2 malocclusion was found to be significantly associated with the D ($P = 0.043$). Skeletal Class 2 malocclusion patients had 9.692 times more D than PC. Table 5 explains the effect of age on the likelihood of other anomalies relative to the incomplete cleft. A significant difference was found between the PC, normal vertebrae, and fusion anomalies. For each unit increase in the age, it was less likely to have normal vertebrae (0.943 = OR) and fusion anomalies (0.837 = OR) relative to the PC.

DISCUSSION

The study analyzed six different types of CVA, i.e., PC, D, SB, vertebrae fusion, BF, and OC among subjects with different sagittal and vertical jaw relationship. Among

Table 1: Age, sex, and cephalometric characteristics of Group I, Group II, and Group III individuals

Parameters	Mean±SD		
	Group I (*n*=89; male=46, female=43)	Group II (*n*=148; male=56, female=92)	Group III (*n*=56; male=20, female=36)
Age (years)	21.34±6.15	20.41±6.32	20.47±5.77
FMA (°)	17.64±2.29	24.66±2.13	32.18±2.67
ANB (°)	3.14±3.56	3.41±2.90	5.71±3.15
CBA (°)	125.91±5.46	128.31±5.93	128.22±4.79

FMA - Frankfort mandibular plane angle, ANB - Angle formed between the point A, B and N, CBA - Cranial base angle. Angle formed between N, S, and Ba, SD- Standard deviation

Table 2: Age, sex, and cephalometric characteristics of Class 1, Class 2, and Class 3 individuals

Variables	Mean±SD		
	Class 1 (*n*=128; male=57, female=71)	Class 2 (*n*=93; male=30, female=63)	Class 3 (*n*=72; male=37, female=35)
Age (years)	22.22±6.41	19.81±5.51	20.31±6.06
FMA (°)	22.80±4.84	25.21±5.65	23.00±4.57
ANB (°)	2.49±1.24	6.57±0.82	−2.21±2.11
CBA (°)	128.52±5.23	128.63±4.63	128.26±6.58

FMA - Frankfort mandibular plane angle, ANB - Angle formed between point A, B, and N, CBA - Cranial base angle. Angle formed between N, S, and Ba, SD- Standard deviation

Table 3: Gender-wise frequency of various cervical vertebra anomalies among the Group I, II, and III individuals

Groups	Gender	Anomalies (%)						Significance(*P*)
		PC	D	F23	BF	OC	SB	
Group I (hypodivergent)	Female	47.4	10.5	21.1	-	10.5	10.5	0.151 (NS)
	Male	30.0	15.0	25.0	10.0	0.0	20.0	
	Total	38.5	12.8	23.1	5.1	5.1	15.4	
Group II (normodivergent)	Female	31.7	34.1	26.8	-	7.3	0.0	0.086 (NS)
	Male	38.1	14.3	38.1	4.8	4.8	0.0	
	Total	33.9	27.4	30.6	1.6	6.5	0.0	
Group III (hyperdivergent)	Female	38.9	27.8	33.3	-	0.0	0.0	0.025*
	Male	33.3	0.0	16.7	16.7	33.3	0.0	
	Total	37.5	20.8	29.2	4.2	8.3	0.0	
Overall total=100%		36.0%	21.6	28.0	3.2	6.4	4.8	

$^*P<0.05$, overall likelihood ratio is 13.006, df=5 with $P=0.023$. PC - Partial cleft, BF - Block fusion, D - Dehiscence, F23 - Fusion between C2 and C3, OC - Occipitalization, SB - Spina bifida, NS - Nonsignificant

Table 4: Distribution and comparison of various cervical vertebra anomalies among the sagittal skeletal classes of malocclusion

Classes	Gender	Various vertebra anomalies (%)						Significance (*P*)
		PC	D	F23	BF	OC	SB	
Class 1	Female	41.2	20.6	29.4	0.0	8.8	0.0	0.722 (NS)
	Male	32.0	8.0	32.0	4.0	8.0	16.0	
	Total	37.3	15.3	30.5	1.7	8.5	6.8	
Class 2	Female	30.6	33.3	25.0	0.0	5.6	5.6	0.603 (NS)
	Male	41.7	16.7	16.7	16.7	8.3	0.0	
	Total	33.3	29.2	22.9	4.2	6.3	4.2	
Class 3	Female	50.0	25.0	25.0	0.0	0.0	0.0	0.716 (NS)
	Male	30.0	20.0	40.0	10.0	0.0	0.0	
	Total	38.9	22.2	33.3	5.6	0.0	0.0	
Overall total=100%		36.0	21.6	28.0	3.2	6.4	4.8	

$^*P<0.05$. PC - Partial cleft, BF - Block fusion, D - Dehiscence, F23 - Fusion between C2 and C3, OC - Occipitalization, SB - Spina bifida, NS - Nonsignificant

Table 5: Factors influencing the occurrence of the anomalies

Anomalies	Factor	*B*	Significant	Exp (*B*)
N	Age	−0.059	0.027*	0.943
F23	Age	−0.102	0.009**	0.837
D	Skeletal Class 2	2.271	0.043*	9.692

$^*P<0.05$, $^{**}P<0.01$. Reference category is PC, df=1, Sex male and skeletal Class 3 was set to zero as they are redundant. N - Normal, D - Dehiscence, F23 - Fusion between C2 and C3, PC - Partial cleft

them, PC, fusion, and D were very common. PC, SB, and D are the anomalies at the posterior arch of the atlas. PC and D are due to the posterior arch deficiency. SB results from the failure of fusion at the posterior arch. Whereas, fusion anomalies are fusion and BF where joining between two vertebrae occurs at different levels, and OC is the fusion of atlas with the occipital bone. The findings of our study deviate from the previous study concerning the order of CVA prevalence, where the most common anomalies were in the descending order of D, fusion, and PC.[12] In our total sample, 42.6% deviated from the normal cervical vertebra morphology, and the fusion was commonly found between C2 and C3 vertebrae. These findings were inconsistent with those of the previous study.[12] Furthermore, the present study analyzed the anomalies among the three different vertical growth patterns that were not studied before.

The order of anomalies among the three groups was similar to that of total samples, i.e., PC, fusion, and D. Compared to previous studies,[11-14] another morphology found in the present study was SB in the atlas. In total samples, 4.8% was the SB, which was also noticed only in the hypodivergent growth pattern subjects. After the PC and fusion, SB was found more in hypodivergent subjects. Generally, SB occurs often with other syndromes; the defect of the atlas can be at the posterior or anterior arch. The defect in the posterior arch occurs more about 4% of the cases compared to the anterior arch. The specific finding of the bifid spine in the hypodivergent growth pattern may guide us to look for the other associated syndrome or anomalies.

OC was found highest among the hyperdivergent growth pattern individuals. The association of cervical column morphology with the large cranial angle has been observed previously, and the role of embryological development in the early pattern of cranial growth was noted.[21] The OC is congenital synostosis with failure of separation of the most caudal sclerotome between the last occipital and first cervical sclerotome. Generally, it presents with other skeletal malformations, about 70% with the fusion of C2–C3.[22] Clinical manifestations of OC are usually asymptomatic in younger age, but neurological dysfunction tends to occur with the increase of age.[23]

Hyperdivergent growth pattern patients with downward and backward rotation of jaws have a large cranial angle and maintain an extended neck posture. The change of growth pattern in the vertical dimension with adaptation in the cervical vertebrae to maintain the balance in head posture led us to quest the expected association between the two. However, from the multinomial analysis, the association in the prevalence of anomalies with the vertical growth patterns was not statistically significant except for the specific occurrence of SB only in the hypodivergent growth pattern. The D and fusion were more likely to occur in normodivergent growth patterns than hyperdivergent, though the difference was not significant. When the sexual dimorphism was considered, a significant difference was found in the hyperdivergent growth pattern individuals. Females were more prone to have anomalies compared to males. This effect could even be due to the chance that a higher representation of female gender in the hyperdivergent group than other groups.

Among different sagittal skeletal malocclusion individuals, the prevalence of the CVA was in the same order as in overall, i.e., PC, fusion, and D. SB and OC were not present in the Class 3 individuals, whereas they were found maximum in the Class 1 individuals. This was in contrast to the previous study, where Class 3 individuals were having the highest occurrence of D and fusion.[12,15] In addition, OC was seen only in Class 3 individuals.[12] It could be due to the difference in the population chosen in both the studies and the influence of their genetic and ethnic components over the vertebral morphology. When sexual dimorphism was concerned, there was no significant sexual dimorphism found in any of the anomalies. Logistic regression analysis revealed a significant influence of age, sex, and growth patterns. Although multifactorial, the effect of age on the fusion of vertebral units was significantly associated with each other, i.e., with the increase in age, the occurrence of fusion was less. This explained the role of early embryological changes with the fusion anomalies. In addition, a significant relation was found between the D and skeletal Class 2 malocclusions when comparing with Class 3 malocclusions. A similar finding was also noted in the previous study, but the reason remains inexplicable.[12]

The only limitation of the present study was the use of lateral cephalograms, as two-dimensional images may influence the representation of actual anomalies. However, all the radiographs were recorded by an experienced technician in the standard position. Hence, it will possibly eliminate the effect of change in the head posture and the appearance of vertebrae in the lateral cephalogram. As the growth pattern was the primary concern, the remaining dental and soft tissue cephalometric parameters were not analyzed.

CONCLUSIONS

The following conclusions were drawn from the present study:

- PC, fusion, and D were the most frequently found CVA, and SB was found only among the hypodivergent growth pattern
- The association of CVA with vertical facial growth patterns was not significant, somewhat influenced by age, sex, and sagittal skeletal malocclusions
- PC and fusion anomalies were associated with age
- D was associated with skeletal Class 2 malocclusion.

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Conflicts of interest

There are no conflicts of interest.

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