ORIGINAL ARTICLE

Comparison of cervical vertebral anomalies and sella turcica bridging in different growth stages with various vertical skeletal growth patterns

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Abstract

Purpose To compare cervical vertebral anomalies and sella turcica bridging (STB) in different growth stages in orthodontic patients with different vertical skeletal growth patterns.

Methods Lateral cephalometric radiographs (LCR) of 270 patients in the preadolescent, adolescent, or postadolescent periods and having low angle [LA], normal angle [NA], or high-angle [HA] vertical skeletal growth patterns were evaluated retrospectively. STB was visualized using LCRs while evaluating the deficiency of ponticulus posticus (PP) and atlas posterior arch (PAA) associated with the atlas bone. The Pearson chi-square and Fisher's exact tests were used for categorical data and one-way ANOVA for numerical data.

Results The prevalence of fully calcified PP and STB increased from the preadolescent (PP, 10.0%; STB, 11.1%) to the postadolescent period (PP, 24.4; STB, 21.1%); they did not differ from vertical skeletal growth patterns ($p > 0.05$). The prevalence of PAA deficiency is significantly higher in individuals with LA (46.7%) than with other angles (NA, 27.8%; HA, 26.7%). The vertical skeletal growth pattern was significantly related to STB in the preadolescent period and PAA in the postadolescent period.

Conclusions Different anomalies during different growth periods correlate with the vertical skeletal growth pattern. It will be useful to evaluate a different anomaly according to the relevant growth period.

Keywords Cervical vertebral anomalies · Sella turcica bridging · Vertical skeletal growth pattern · Ponticulus posticus · Lateral cephalometric radiography

Introduction

One of the important stages of dental-orthodontic treatment planning is evaluating lateral cephalometric radiographs (LCRs) [23]. These radiographs can also be used to diagnose different conditions and anomalies related to the craniofacial and cervical vertebral regions and to skeletal maturation [1, 2, 11, 13, 17, 20, 22]. Anatomical variations and morphological abnormalities such as fusion of vertebral bodies, spina bifida, odontoid deformities, elongated styloid process, first cervical vertebrae (CV, atlas) malformations (especially deficiency in the posterior arch and ponticulus posticus [PP] formations), and abnormal ossifications are not common in the cervical vertebrae [6, 7, 28, 30, 34]. The sella turcica, an important anatomical structure for orthodontists, can be easily observed on the intracranial surface of the sphenoid bone anteriorly bordered by the tuberculum sellae and posteriorly by the dorsum sellae with the help of LCRs [18, 20]. Clinoid processes, two in the front and two at the back, surround the upper part of the pituitary gland in the sella turcica [9]. There are certain rates of calcification in the ligament located between the anterior and posterior clinoid processes, which are defined as sella turcica bridging (STB), a sella turcica anomaly [9]. All these anomalies or normal variants of the CV and STB, which can be encountered during a routine orthodontic radiological examination, have been previously shown to be associated with many conditions, such as headache, migraine, cleft lip and palate,

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dental anomalies, dental transposition, temporomandibular disorders (TMDs), and tooth deficiencies [1, 5, 9, 13–18, 20, 21, 24]. They have also been shown to be associated with a variety of dental and craniofacial conditions, although they are not fully known. However, they are highly correlated to the non-syndromic skeletal class II and class III anomalies [1, 5, 20, 21]. In contrast, Sonnesen and Kjaer showed that in a small sample, compared with the control group, they were significantly associated with skeletal open bite and deep bite [29, 30]. Many of these anomalies are asymptomatic until adolescence or young adulthood; hence, orthodontists should consider different perspectives as they can cause degenerative problems and serious complications, especially in adulthood [1, 6].

Therefore, this study aimed to determine and compare the incidence of cervical vertebra anomalies (CVAs) and STB using LCRs of individuals with different vertical growth patterns during different growth periods. Moreover, it aimed to evaluate whether the relationship between CVAs and vertical growth patterns varies during different growth periods.

Materials and methods

In this study performed in the Department of Orthodontics, Erciyes University Faculty of Dentistry, LCRs of 270 individuals (135 girls and 135 boys; mean age, 13.53 ± 2.93 years [range, 8–22.6 years]), including individuals with different vertical skeletal growth patterns and stages, who requested for orthodontic treatments were retrospectively evaluated. This study was approved by the Erciyes University Clinical Research Local Ethics Committee (approval no: 2019/394).

In our study, we included patients having (a) no craniofacial syndrome or systemic disease and no long-term drug use affecting the bone development, (b) no history of prior orthodontic or orthognathic surgical treatment, (c) high-quality radiographs made using a standardized method and by the same technician, (d) ANB angle, representing maxillomandibular relationship, between 0 and 4°, and (e) individuals belonging to the same ethnic group. Patients with (a) insufficient treatment records and radiographs, (b) a history of trauma and treatment affecting the craniofacial region, and (c) individuals whose cervical vertebrae were not sufficiently visualized in radiographic evaluation, were excluded.

Because of the power analysis (G*Power version 3.1.9.4; Franz Faul, Universität Kiel, Kiel, Germany) performed on the data of a previous study to deduce a sample size to be used in this study, it was found that a statistically significant difference could be obtained when 30 patients were included in each group according to the 0.74 effect value, 95% power, and $\alpha = 0.05$ [27].

LCRs used for determining the vertical skeletal growth patterns and growth development phases of all individuals included in the study were performed by the same technician using the same device (Orthoceph OP300, Instrumentarium, Tuusula, Finland). The patients were divided into three groups (preadolescent [PrAD], adolescent [AD], and postadolescent [PsAD]) according to growth stages and three subgroups (low angle [LA], normal angle [NA], and high angle [HA]) according to vertical skeletal growth patterns; hence, a total of nine groups were included in this study (Table 1).

The individuals belonging to the same ethnic group (Turkish) were divided into three groups (PrAD, AD, and PsAD) according to the growth and development periods. The cervical vertebral maturation stage (CVMS) method recommended by Franchi et al. [11] was used while evaluating LCRs to divide individuals into groups. Accordingly, those with CVMS I and II were PrADs, CVMS III and IV were AD, and CVMS V and VI were PsADs [4]. Ninety patients were included in each of the main groups. Each of the three main groups was divided into three subgroups according to the vertical skeletal growth pattern ($LA \leq 26°$; $26° < NA < 38°$; $HA \geq 38°$) determined using the SN-MP (Sella Nasion-Mandibular Plane) angle [8]. All patients in the PrAD, AD, and PtAD groups had skeletal class I relationships (ANB; PrAD-LA = $1.63 \pm 2.15°$, PrAD-NA = $2.55 \pm 2.45°$, PrAD-HA = $2.87 \pm 3.19°$, AD-LA = $2.58 \pm 2.90°$, AD-NA = $3.32 \pm 2.17°$, AD-HA = $2.96 \pm 2.68°$, PsAD-LA = $1.45 \pm 3.15°$, PsAD-NA = $2.54 \pm 2.09°$, and PsAD-HA = $3.36 \pm 2.71°$), and the SN-MP angles were PrAD-LA = $24.65 \pm 1.97°$, PrAD-NA = $33.08 \pm 2.67°$, PrAD-HA = $40.08 \pm 2.44°$, AD-LA = $24.32 \pm 1.78°$, AD-NA = $32.97 \pm 2.24°$, AD-HA = $41.24 \pm 2.74°$, PsAD-LA = $23.21 \pm 2.66°$, PsAD-NA = $32.77 \pm 2.60°$, and PsAD-HA = $41.63 \pm 3.60°$ (Table 1). The cephalometric analyses required to determine the vertical skeletal growth pattern and skeletal class of individuals were performed using the Dolphin Imaging software (version 11.0; Dolphin Imaging and Management Solutions, Chatsworth, CA).

The LCRs with visual evaluation of the first cervical vertebra (posterior arch of the atlas bone [PAA] and arcuate foramen of the atlas [PP]) and the first four CV to determine the cervical maturation stage of individuals and sella turcica (for the calcification of the interclinoid ligament [ICL]) were clearly visualized [13, 21]. The arcuate foramen assessment, known as PP, which can be seen on the first vertebral bone, the atlas, was performed similar to the method used by Giudice et al. [14]. Accordingly, the calcification of the atlanto-occipital ligament, which forms the arcuate foramen, was evaluated, and individuals with no PP were defined as "absent" (Fig. 1a), those whose arcuate foramen was not fully calcified and had a visible PP as "incomplete"

Table 1 Growth maturation level, vertical facial growth patterns, and sex distribution of patient samples

Growth maturation level	Vertical growth pattern	N	ANB° (mean ± SD)	SN/GoGn° (mean ± SD)	Age (year) (mean ± SD)	Female			Male			P value*
						N	%	Age (year) (mean ± SD)	N	%	Age (year) (mean ± SD)	
Preadolescent	Low angle	30	1.63 ± 2.16	24.65 ± 1.97	10.36 ± 1.60	15	5.55	9.57 ± 0.67	15	5.55	11.15 ± 1.88	0.005
	Norm angle	30	2.55 ± 2.45	33.08 ± 2.67	11.20 ± 1.24	15	5.55	10.44 ± 1.14	15	5.55	11.96 ± 0.82	0.000
	High angle	30	2.87 ± 3.19	40.08 ± 2.44	10.48 ± 1.62	15	5.55	9.93 ± 11.06	15	5.55	11.06 ± 1.92	0.058
Adolescent	Low angle	30	2.58 ± 2.90	24.32 ± 1.78	13.45 ± 1.04	15	5.55	13.19 ± 1.04	15	5.55	13.71 ± 1.01	0.182
	Norm angle	30	3.32 ± 2.17	32.97 ± 2.24	13.24 ± 1.78	15	5.55	12.66 ± 0.82	15	5.55	13.81 ± 1.22	0.005
	High angle	30	2.96 ± 2.68	41.24 ± 2.74	12.75 ± 0.98	15	5.55	12.22 ± 0.88	15	5.55	13.29 ± 0.77	0.001
Postadolescent	Low angle	30	1.45 ± 3.15	23.21 ± 2.66	16.95 ± 1.86	15	5.55	16.77 ± 1.88	15	5.55	17.11 ± 1.88	0.625
	Norm angle	30	2.54 ± 2.09	32.77 ± 2.60	16.31 ± 1.51	15	5.55	15.66 ± 1.65	15	5.55	16.95 ± 1.05	0.017
	High angle	30	3.36 ± 2.71	41.63 ± 3.60	16.90 ± 2.42	15	5.55	16.68 ± 3.29	15	5.55	17.13 ± 1.07	0.625
Total		270		32.66 ± 7.39	13.53 ± 2.94	135	50.00	13.01 ± 3.07	135	50.00	14.04 ± 2.70	0.004

N number of subjects, *SD* standard deviation, ° Degree for angle. % Percentage

*Independent samples *t* test and one-way ANOVA test. Statistical significance degree: *p* < 0.05

(Fig. 1b), and those with posterior arc ring-like structures as "complete" (Fig. 1c). Evaluation of the PAA was performed by the presence (Fig. 2a) or absence (Fig. 2b) of the posterior arch, as suggested by Leonardi et al. [17]. Evaluation of STB was performed according to the degree of calcification of the ICL in the sella turcica on the LCR using the method proposed by Leonardi et al. [18]. In this evaluation, ICL that was not calcified was defined as "initial form" (Fig. 3a), that was incomplete between the dorsum sella and tuberculum sella as "incomplete form" (Fig. 3b), and that was fully calcified as "complete form" (Fig. 3c).

To evaluate the method error that may occur in the study, half the sample size was randomly re-evaluated by the same researcher (T.O.), and intraclass correlation coefficients (ICC) were calculated for the analysis of intraobserver reliability in the identification of STB and CVMS.

Statistical analyses

One-way ANOVA and the independent t tests were used to evaluate the differences between ages, ANB, and SN/MP angles of individuals. Pearson chi-square and Fisher's exact tests were used in the intra- and intergroup evaluation of PP, PAA, and STB in both growth period groups and vertical skeletal growth pattern subgroups. Interpretation was based on the prevalence and percentage values for each group, and a *P* value < *0.05* was considered significant. Statistical Package for the Social Sciences (version 24.0 Inc, Chicago, IL) software was used for all statistical analyses.

Results

The ICC evaluation determined the intraobserver reliability value to be between 0.88 and 0.92 for STB and between 0.90 and 0.94 for CVMS. Moreover, analyses performed using LCR were highly reliable [14].

In all growth and development periods, the mean age of NA male individuals was higher than that of NA female individuals, whereas in the PrAD period, the mean age of LA male individuals was higher than that of LA female individuals; a similar situation was found in all HA individuals in the AD period (Table 1).

The prevalence of PP, PAA, and STB significantly varied according to the different growth periods (*p* < 0.05, Table 2). Complete PP prevalence significantly increased (*p* < 0.05, Table 2 from the PrAD period (*n* = 9, 10.0%) to the PsAD period (*n* = 22, 24.4%). The absence of PAA decreased (*p* < 0.05, Table 2) from the PrAD period (*n* = 46, 51.1%) to the PsAD period (*n* = 34, 37.8%). Complete STB prevalence increased (*p* < 0.05, Table 2) from the PrAD period (*n* = 10, 11.1%) to PsAD period (*n* = 19, 21.1%). When the relationship between vertical skeletal
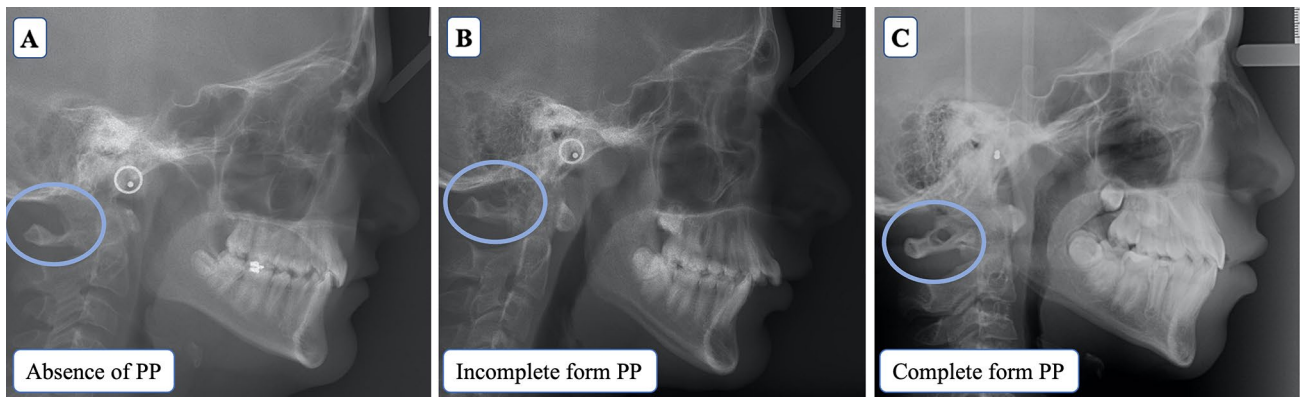
Fig. 1 Sample images for the method used for Ponticulus Posticus (PP) evaluation. **a** Atlanto-occipital ligament (Absence of PP view), which is not calcified. **b** Partially calcified atlanto-occipital ligament (incomplete form of PP view). **c** An atlanto-occipital ligament that has been fully calcified (complete form of PP view)
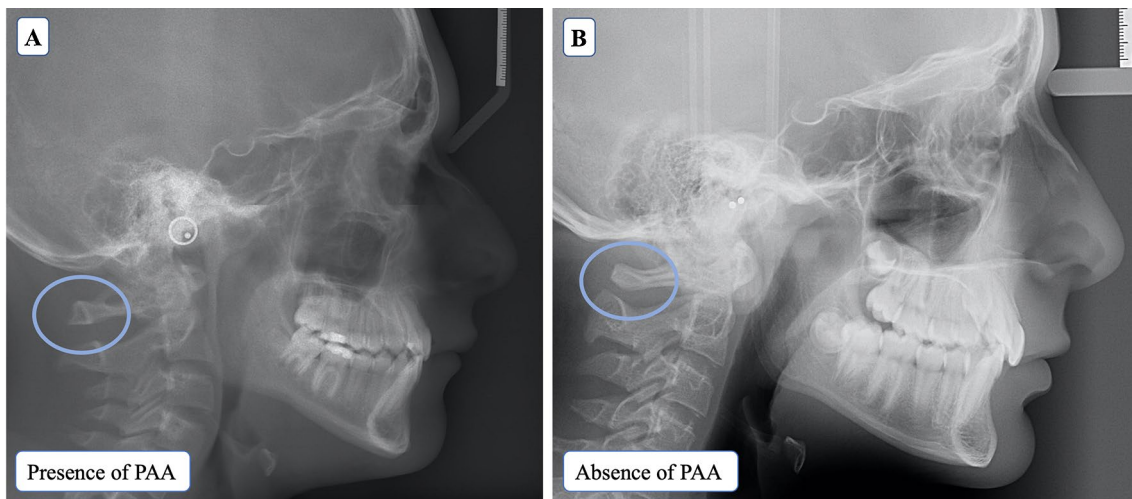

Fig. 2 Sample images for the method used for Posterior Arc of the Atlas (PAA) evaluation. **a** Image in the presence of a posterior arch in the Atlas (presence of PAA view). **b** Image of the absence of the posterior arch in the Atlas (absence of PAA view)
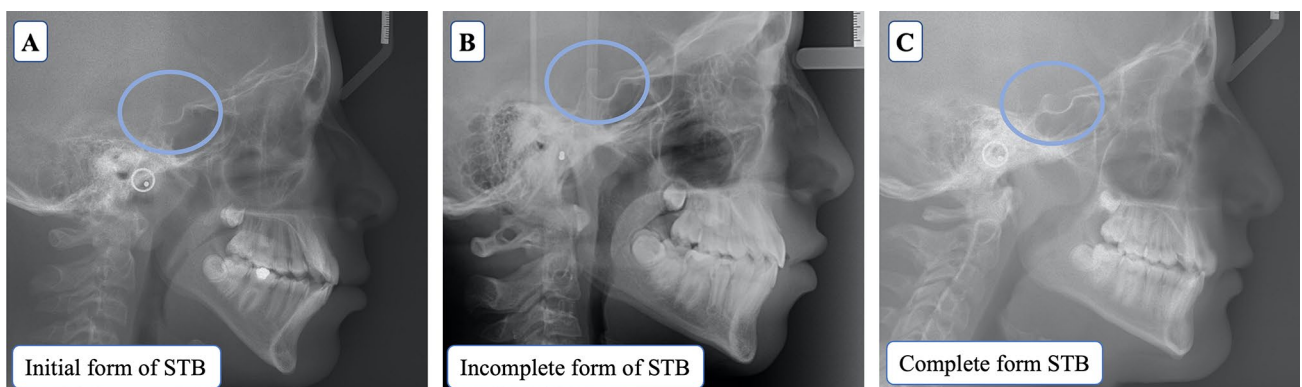

Fig. 3 Sample images for the method used for Sella Turcica Bridging (STB) evaluation. **a** Non-calcified interclinoid ligament (Absence of STB view). **b** Interclinoid ligament partially calcified (Incomplete form of STB view). **c** Interclinoid ligament that has been fully calcified (Complete form of STB view)

Table 2 Ponticulus posticus, posterior ach of the atlas bone, and sella turcica bridging among growth periods and vertical growth patterns

Growth groups		Preadolescent		Adolescent		Postadolescent		Statistics	
		n	%	n	%	n	%	value	p
PP	No calcification (absent)	49	54.4	57	63.3	46	51.1	14.858	0.005^{PC}
	Incomplete	32	35.6	27	30.0	22	24.4		
	Complete	9	10.0	6	6.7	22	24.4		
PAA	Absent	46	51.1	11	12.2	34	37.8	31.460	<0.001^{PC}
	Present	44	48.9	79	87.8	56	62.6		
STB	Initial form	35	38.9	20	22.2	25	27.8	12.336	0.015^{PC}
	Incomplete form	45	50.0	61	67.8	46	51.1		
	Complete form	10	11.1	9	10.0	19	21.1		
Facial-type groups		Low angle		Norm angle		High angle			
		n	%	n	%	n	%	value	P
PP	No calcification (absent)	53	58.9	47	52.2	52	57.8	1.509	0.825^{PC}
	Incomplete	27	30.0	28	31.1	26	28.9		
	Complete	10	11.1	15	16.7	12	13.3		
PAA	Absent	42	46.7	25	27.8	24	26.7	10.177	0.006^{PC}
	Present	48	53.3	65	72.2	66	73.3		
STB	Initial form	22	24.4	25	27.8	33	36.7	5.649	0.229^{PC}
	Incomplete form	55	61.1	55	61.1	42	46.7		
	Complete form	13	14.4	10	11.1	15	16.7		

PP ponticulus posticus, *PAA* posterior arch of the atlas, *STB* sella turcica bridging, ^{PC}Pearson's chi-square test, ^{FE}Fisher's exact test

Statistical significance is $p<0.05$

growth patterns of the face and CVAs were evaluated, PAA was significant ($p < 0.05$, Table 2), whereas there was no significant relationship between the PP and STB anomalies ($p > 0.05$, Table 2). The prevalence of PAA-absent in LA individuals ($n = 42$, 46.7%) was significantly higher than that in HA individuals ($n = 24$, 26.7%).

There was no significant relationship between vertical skeletal growth patterns and the PP anomaly when separated by growth periods ($p < 0.05$, Table 3). Similarly, there was no significant relationship between vertical skeletal growth patterns and the PAA anomaly in the PrAD and AD periods ($p > 0.05$, Table 4), whereas a significant relationship was found in the PsAD period ($p < 0.05$, Table 4). PAA-present prevalence was found to be higher ($p < 0.05$, Table 4) in PsAD-HA individuals ($n = 33$, 76.7%) than in PsAD-LA and PsAD-NA individuals (LA, $n = 11$, 36.7%; NA, $n = 22$, 73.3%). Moreover, there was no significant relationship between vertical skeletal growth patterns and the STB anomaly in the AD and PsAD periods ($p > 0.05$, Table 5), while a significant relationship was found in the PrAD period ($p < 0.05$, Table 5). The prevalence of STB-complete form in PrAD-LA individuals ($n = 6$, 20.0%) was higher ($p < 0.05$, Table 5) than that in PrAD-NA and PrAD-HA individuals (NA, $n = 3$, 10.0%; HA, $n = 1$, 3.3%).

Discussion

To the best of our knowledge, this was the first study that showed the difference between CVAs and vertical skeletal growth patterns of the face in different growth periods. In the previous studies, anomalies in the first four vertebrae, also known as CV and sella turcica, and their relationship with medical and dental subjects, such as dental anomalies [17, 18, 22], craniofacial morphology [1, 5, 31], condylar morphology [32], cleft lip and palate anomaly [6], migraine [27], obstructive sleep apnea [33], elongated styloid process [28], neurosurgery [23], and TMDs [16] were showed.

The incidence of CVAs significantly varied with the pubertal growth stage. From the pre-pubertal period to the post-pubertal period, the prevalence of fully calcified PP increased. Our study found that the incidence of fully calcified PP and STB was higher in the PsAD period compared to the PrAD period. However, this finding was different from that of the study conducted by Giudice et al. [14]. This difference was probably caused by racial and hereditary transmission differences in the data obtained from the previous studies in a similar society [7, 12, 19, 21, 35]. According to Geist et al., since

Table 3 Ponticulus posticus in different growth periods according to vertical growth patterns

Ponticulus posticus	Low angle		Norm angle		High angle		Statistics	
	N	%	N	%	N	%	Value	p
Preadolescent								
No calcification (absent)	16	53.3	15	50.0	18	60.0	2.945	0.611[FE]
Incomplete calcification	11	36.7	10	33.3	11	36.7		
Completely calcified	3	10.0	5	16.7	1	3.3		
Total	30	100.0	30	100.0	30	100.0		
Adolescent								
No calcification (absent)	21	70.0	17	56.7	19	63.3	2.112	0.742[FE]
Incomplete calcification	8	26.7	11	36.7	8	26.7		
Completely calcified	1	3.3	2	6.7	3	10.0		
Total	30	100.0	30	100.0	30	100.0		
Postadolescent								
No calcification (absent)	16	53.3	15	50.0	15	50.0	0.498	0.974[PC]
Incomplete calcification	8	26.7	7	23.3	7	23.3		
Completely calcified	6	20.0	8	26.7	8	26.7		
Total	30	100.0	30	100.0	30	100.0		

N number of subjects, [PC]Pearson's chi-square test, [FE]Fisher's exact test

Statistical significance is *p<0.05*

Table 4 Posterior ach of the atlas bone in different growth periods according to vertical growth patterns

	Low angle		Norm angle		High angle		Statistics	
	n	%	n	%	n	%	Value	p
Preadolescent								
Absent	17	56.7	14	46.7	15	50.0	0.623	0.733[PC]
Present	13	43.3	16	53.3	15	50.0		
Total	30	100.0	30	100.0	30	100.0		
Adolescent								
Absent	6	20.0	3	10.0	2	6.7	2.446	0.366[FE]
Present	24	80.0	27	90.0	28	93.3		
Total	30	100.0	30	100.0	30	100.0		
Postadolescent								
Absent	19	63.3	8	26.7	7	23.3	12.574	*0.002[PC]*
Present	11	36.7	22	73.3	33	76.7		
Total	30	100.0	30	100.0	30	100.0		

*n n*umber of subject, [PC] Pearson's chi-square test, [FE] Fisher's exact test

Statistical significance is *p<0.05*

cervical vertebral anomalies/variations can be affected by genetic background, they differ according to the ethnies or geographic origin and not according to demographic or site variables [12]. Li et al. also reported that different variants and anomalies in the atlas bone occur frequently with hereditary inheritance [19]. Thus, genetic variations can be seen more frequently in families, even if living in different populations and regions. The relationship between skeletal malocclusions (classes I, II, and III) in the sagittal dimension with PP, STB, and/or PAA has been shown in the previous studies [2, 5, 6, 14, 20]. In the study of Meyer-Marcotty et al. [20], there is a significant

relationship between sella turcica morphology and skeletal class III individuals. However, in the study by Alkofide [5], there is a significant relationship between sella morphology and both class II and class III malocclusions.

According to the findings of our study, there was no significant relationship between vertical skeletal growth patterns of the face and PP, PAA, and STB in individuals in the AD period. However, while there was no significant relationship between the vertical skeletal growth pattern of the face and PP and STB in individuals in the PsAD period, it was found that the prevalence of PAA was particularly high in HA individuals. In individuals in the PrAD period, there was

Table 5 Posterior ach of the atlas bone in different growth periods according to vertical growth patterns Sella turcica bridging in different growth periods according to vertical growth patterns

Sella turcica bridging	Low angle		Norm angle		High angle		Statistics	
	n	%	n	%	n	%	Value	p
Preadolescent								
Initial form	5	16.7	11	36.7	19	63.4	14.771	0.004[FE]
Partial form	19	63.3	16	53.3	10	33.3		
Complete form	6	20.0	3	10.0	1	3.3		
Total	30	100.0	30	100.0	30	100.0		
Adolescent								
Initial form	9	30.0	4	13.3	7	23.3	5.079	0.271[FE]
Partial form	20	66.7	23	76.7	19	60.0		
Complete form	1	3.3	3	10.0	5	16.7		
Total	30	100.0	30	100.0	30	100.0		
Postadolescent								
Initial form	8	26.7	10	33.3	7	23.3	2.734	0.603[PC]
Partial form	16	53.3	16	53.4	14	46.7		
Complete form	6	20.0	4	13.3	9	30.0		
Total	30	100.0	30	100.0	30	100.0		

n number of subjects, [PC] Pearson's chi-square test, [FE] Fisher's exact test

Statistical significance is *p<0.05*

no significant relationship between vertical skeletal growth patterns of the face and PP and PAA, whereas STB prevalence was found to be significantly higher in LA individuals. In this study, the relationship between the CVAs and the vertical skeletal growth pattern of the face is assumed to be due to the close relation between the notochord structure and the vertebral and head structures formed by direct induction in the embryological period, as described by Kjaer in the previous studies for the relationship between sagittal skeletal malocclusion (in relation to PP or STB, separately) [2, 5, 14, 15, 23]. However, in these studies, the researchers evaluated CVAs independent of each other, and regardless of the differences, they may show according to their growth periods [25]. In the study by Sonnesson and Kjaer [30], a significant relationship is found between cervical vertebral morphology and skeletal open closure in an extremely wide age range. Although only skeletal open bite and control groups were evaluated in this study, unlike the findings of our study, there was no significant relationship between PAA and skeletal open bite. This was thought to be due to the small sample size and wide age range. In addition, the previous studies have shown a correlation between cervical skeletal maturation and chronological age from pre-adolescence to post-adolescence period [26, 36]. For this reason, we evaluated the co-relations according to the growth periods of the patients. In our study, it was observed that PAA deficiency was significantly higher in LA individuals in the PsAD period than in other individuals in the PsAD period. Similarly, in another study by Sonnesen and Kjaer [29], an insufficient relationship between CVAs and skeletal deep closure was more common, although there was no significant

relationship between skeletal deep closure and PAA; this too was thought to be due to the small sample size and wide age range.

Various studies have shown a relationship between CVAs and dental and craniofacial anomalies and skeletal malocclusion and TMDs [1, 2, 16–18, 22, 31]. However, the current results obtained from our study found that CVAs differed between individuals in different growth periods and between individuals with different vertical skeletal growth patterns. It can be assumed that the presence of dental anomalies and PP, which is a clinically valuable finding for the clinical evaluation of the neck and cervical region, surgical procedures, and cervicogenic headache migraine, is more acceptable in the AD and PsAD periods than in the PrAD period [3, 23, 27]. Unlike others, there is a relationship between PAA deficiency and TMD, and it can be used clinically in this regard [16]. When PAA deficiency, which is also a CVA, is evaluated in the PsAD period, LA is more common in individuals, whereas HA is less common. This shows that while individuals with different vertical skeletal growth patterns are evaluated for TMD, PAA deficiency can be considered as an additional factor.

The limitations in our study need to be acknowledged. In our study, unlike other studies [6, 7, 14, 23], instead of cone-beam computed tomography (CBCT) evaluation, LCRs that provide less harmful ionized radiation compared with the ALARA (As Low As Reasonably Achievable) principle were evaluated [10]. The use of CBCT is not possible in every clinic and facility, and because of its high radiation rate, it is less desirable, especially during the initial radiographic evaluation [24]. However, LCRs are easier to

access and evaluate and safer for patients [13]. Although this is a limitation for us, it is an extremely valuable finding for the first radiographic examination. Nevertheless, the use of CBCT may be recommended for more detailed clinical examination and three-dimensional definitive evaluation [1]. In this study, only vertical skeletal growth pattern differences in terms of skeletal malocclusion were evaluated. Additionally, with further studies, evaluations can be made by creating different groups of malocclusions in sagittal and vertical dimensions.

In conclusion, new relationships not previously mentioned between CVAs and facial vertical skeletal growth pattern were described. The prevalence of the completely calcified PP and STB increased from the PrAD period to PsAD period. Evaluation of PAA deficiency was more meaningful in individuals with different vertical skeletal growth patterns in the PsAD period. Evaluation of STB anomaly was more meaningful in PrAD individuals with different vertical skeletal growth patterns. Evaluation of PP, STB, and PAA anomalies was more meaningful in the PsAD period. The clinical significance of PAA deficiency was significant in NA and HA individuals in the AD and PsAD periods. LCR evaluation was found to be used in the diagnosis of CVAs. This information would be useful in the future in not only orthodontic treatment planning but also other diagnostic areas.

Compliance with ethical standards

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