Skeletal maturation of the cervical vertebrae: association with various types of malocclusion

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Abstract: The identification of the skeletal maturation stage of the cervical vertebrae has proven an important reference for orthodontic diagnosis. The aim of the present study was to determine the association between the skeletal maturation stage of the cervical vertebrae and types of malocclusion according to the age and gender of participants. A total of 361 individuals (168 males and 193 females) between 8 and 14 years of age were selected from a convenience sample. Malocclusions were diagnosed through study models using the Angle classification. Maturation stages of the cervical vertebrae were determined using the method proposed by Hassel and Farman. Statistical analysis involved the chi-square test ($p \leq 0.05$) and multiple logistic regression (forward stepwise procedure). Significant differences were observed between the stage of skeletal maturation of the cervical vertebrae and gender at ages 11, 12 and 14 years. Males with Class II malocclusion were twice as likely to be in Stage 1 or 2 of cervical vertebra maturation than individuals with Class I malocclusion (OR = 2.1 [CI 95%, 1.33-3.18]). There were no differences between individuals with Class I and Class III malocclusions. The association between skeletal maturation of the cervical vertebrae and type of malocclusion was significant, suggesting a skeletal component in the determination of Class II malocclusions.

Descriptors: Malocclusion; Cervical Vertebrae; Growth and Development.

Introduction

Malocclusions are characterized as a developmental problem capable of causing alterations in the dental occlusion. Thus, the correct identification of a child's developmental stage is a decisive factor in considering the manifestation of different types of malocclusion, as well as their diagnosis and treatment.[1]

Stages of development can be assessed through a number of different growth indicators, including chronological age, dental development, height/weight, secondary sexual characteristics and skeletal age.[2] In this context, identification of the skeletal maturation stage of the cervical vertebrae has proven an important benchmark for orthodontic diagnosis, as it allows distinguishing children of the same chronological age but with different skeletal ages.[3] Moreover, it is considered by some authors as valid as the radiographic analysis of the hand and wrist, while offering

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the advantage of reducing the radiation of growing patients.[4-7]

The objective of the present study was to determine the association between the skeletal maturation stage of the cervical vertebrae and types of malocclusion according to the age and gender of participants.

Methodology

The initial sample was composed of 984 lateral cephalometric radiographs, along with the respective study models and clinical charts of patients who had never undergone any type of orthodontic treatment. All documentation was taken from the archives of the Orthodontic Center S/C Ltda., a private orthodontic and facial orthopedic clinic in the city of Varginha, MG, Brazil. Exposures were made using the Funk Orbital ×15 radiographic unit using the following settings: 84 kVp, 80 mA, 0.6-second exposure time, for film and Lanex Screens GMT. The films were developed in a Rubzomatic 130-EMB automatic processor, whose factors were set at 35.5 and 2.1 minutes. After inspection of the materials, 361 patients were selected – 168 males and 193 females between 8 and 14 years of age.

The radiographs were observed by means of an x-ray film viewer with standard light intensity for inspecting the morphology of the second (C2), third (C3) and fourth (C4) cervical vertebrae, following the classification proposed by Hassel and Farman.[8] Figures 1a through 1f illustrate the vertebral bodies with respective descriptions of each maturation stage of the cervical vertebrae according to these authors' classification. The study models and ANB angles were used to identify Class I (ANB = 0-4 mm), Class II (ANB ≥ 4 mm) and Class III (ANB < 0 mm) malocclusions. Visual inspection was performed on both sides of the models.

The following were considered exclusion factors:

- radiographs lack quality,
- patients with different malocclusions on each side,
- those with no first premolars,
- history of early loss of deciduous teeth and consequent displacement of the permanent molars,
- permanent first molars that failed to completely erupt and
- models exhibiting a dubious evaluation as a result of movement when in occlusion.

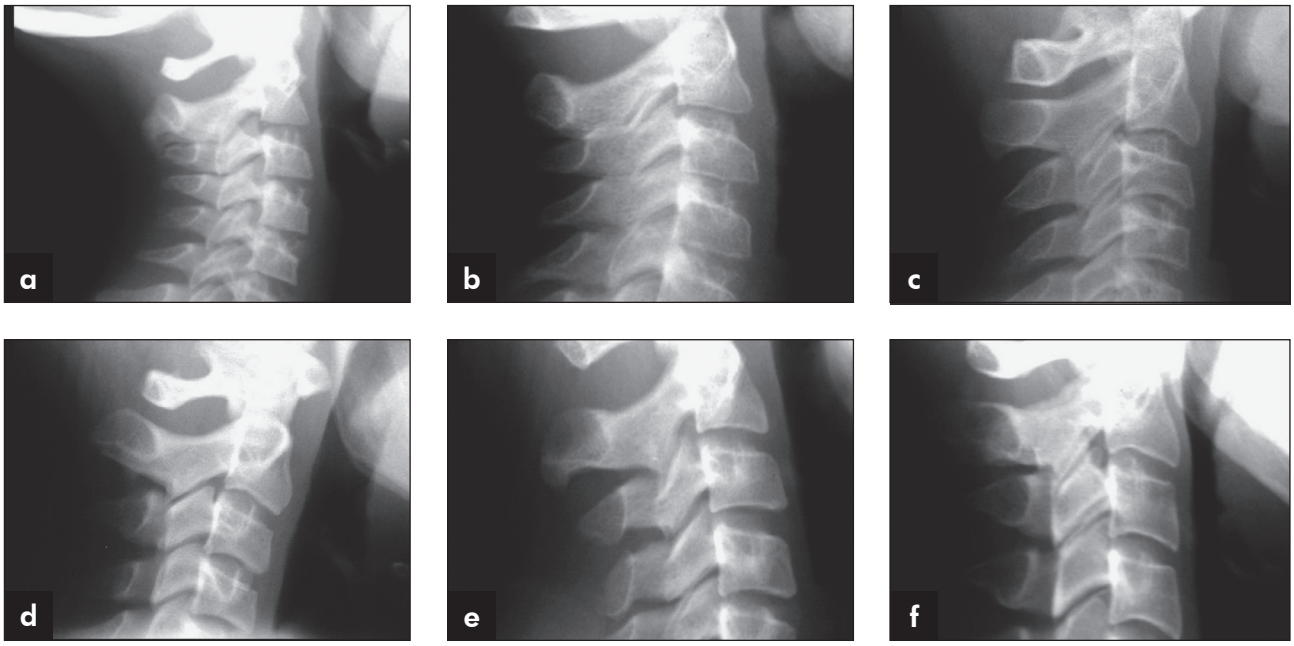

Figure 1 - Vertebral bodies with respective descriptions of each maturation stage of cervical vertebrae according to the Hassel and Farman[8] classification (1995). **a** – Initiation; **b** – Acceleration; **c** – Transition; **d** – Deceleration; **e** – Maturation; **f** – Finalization.

Three weeks after the initial records, 20 radiographs were randomly selected, retraced and new measurements were made. When the *t* test for paired samples was applied, differences between the first and second sets of 20 radiographs proved non significant.

Statistical analysis

The results were organized and entered into a database using the Statistical Package for Social Science (SPSS for Windows, version 14.0, SPSS Inc., Chicago, USA). For the statistical analysis, we initially carried out a description of the absolute and relative frequencies of the variables. Associations were then tested using the univariate analysis (chi-square test) between independent variables and the outcome (skeletal maturation stage of cervical vertebrae). The nonexistence of an association between variables (significance value > 0.05) was considered as the null hypothesis. Variables with a *p*-value ≤ 0.010 in the univariate analysis were included 1-by-1 into a multiple logistic regression model. The final model was adjusted for the effect of all the variables. The odds ratio (OR) and confidence intervals (CIs; 95%) were estimated for each variable in the logistic model.

This study was approved by the research ethics committee of UNINCOR.

Results

Significant differences were observed between the stage of skeletal maturation of the cervical vertebrae and gender at ages 11, 12 and 14 years (Table 1).

Male individuals and patients with Class II malocclusion exhibited twice as much chance of being

Table 1 - Bivariate analysis of the relationship between stage of skeletal maturation of cervical vertebrae and gender according to age **(continued on next page)**.

		Stage of skeletal maturation of cervical vertebrae					p*
		Phase 1 n (%)	Phase 2 n (%)	Phase 3 n (%)	Phase 4 n (%)	Phase 5 n (%)	
8 years	Gender						
	Male	10 (43.5)	14 (51.9)	-	-	-	0.344
	Female	13 (56.5)	13 (48.1)	2 (100.0)	-	-	
	Malocclusion						
	Class I	4 (17.4)	4 (14.8)	-	-	-	0.802
	Class II	19 (82.6)	23 (85.2)	2 (100.0)	-	-	
	Class III	-	-	-	-	-	
9 years	Gender						
	Male	10 (43.5)	14 (51.9)	-	-	-	0.613
	Female	13 (56.5)	13 (48.1)	2 (100.0)	-	-	
	Malocclusion						
	Class I	3 (15.8)	2 (9.1)	-	-	-	0.405
	Class II	12 (63.2)	18 (81.8)	2 (100.0)	-	-	
	Class III	4 (21.1)	2 (9.1)	-	-	-	
10 years	Gender						
	Male	7 (63.6)	14 (41.2)	2 (20.0)	-	-	0.183
	Female	4 (36.4)	20 (58.8)	8 (80.0)	1 (100.0)	-	
	Malocclusion						
	Class I	2 (18.2)	10 (29.4)	1 (10.0)	-	-	0.691
	Class II	9 (81.8)	22 (64.7)	9 (90.0)	1 (100.0)	-	
	Class III	-	2 (5.9)	-	-	-	

* Chi-square test

Table 1 *(continued)*

11 years	Gender					
	Male	3 (75.0)	15 (71.4)	11 (32.4)	1 (11.1)	-	0.004
	Female	1 (25.0)	6 (28.6)	23 (67.6)	8 (88.9)	2 (100.0)	
	Malocclusion						
	Class I	-	6 (28.6)	13 (38.2)	5 (55.6)	-	0.202
	Class II	4 (100.0)	14 (66.7)	16 (47.1)	3 (33.3)	1 (50.0)	
	Class III	-	1 (4.8)	5 (14.7)	1 (11.1)	1 (50.0)	
12 years	Gender						
	Male	3 (75.0)	11 (78.6)	10 (50.0)	2 (16.7)	-	0.008
	Female	1 (25.0)	3 (21.4)	10 (50.0)	10 (83.3)	3 (100.0)	
	Malocclusion						
	Class I	1 (25.0)	5 (35.7)	9 (45.0)	3 (25.0)	2 (66.7)	0.787
	Class II	2 (50.0)	7 (50.0)	9 (45.0)	7 (58.3)	-	
	Class III	1 (25.0)	2 (14.3)	2 (10.0)	2 (16.7)	1 (33.3)	
13 years	Gender						
	Male	-	4 (57.1)	12 (60.0)	4 (36.4)	1 (11.1)	0.080
	Female	-	3 (42.9)	8 (40.0)	7 (63.6)	8 (88.9)	
	Malocclusion						
	Class I	-	2 (28.6)	6 (30.0)	6 (54.5)	2 (22.2)	0.774
	Class II	-	3 (42.9)	8 (40.0)	2 (18.2)	4 (44.4)	
	Class III	-	2 (28.6)	6 (30.0)	3 (27.3)	3 (33.3)	
14 years	Gender						
	Male	-	-	10 (90.9)	7 (77.8)	2 (20.0)	0.003
	Female	-	1 (100.0)	1 (9.1)	2 (22.2)	8 (80.0)	
	Malocclusion						
	Class I	-	-	1 (9.1)	2 (22.2)	2 (20.0)	0.643
	Class II	-	-	3 (27.3)	4 (44.4)	5 (50.0)	
	Class III	-	1 (100.0)	7 (63.6)	3 (33.3)	3 (30.0)	

* Chi-square test

in stages 1 or 2 of cervical vertebra maturation than individuals with Class I malocclusion (OR= 2.1 [CI 95%, 1.33 to 3.18]). There were no differences between individuals with Class I and Class III malocclusions (Table 2).

Discussion

Vertebral analysis of a lateral cephalogram has been shown to be as valid as the hand-wrist bone analysis, with the advantage of reducing the radiation exposure to growing subjects.[7] Some studies have examined the effectiveness of techniques for assessing bone maturation through the analysis of cervical vertebrae.[5,7] The present study used the Hassel and Farman[8] method. This method has yielded the same results as that of Baccetti *et al.*[9] and Seedat and Forsberg[10,6]

Results of the present study demonstrate that individuals of the same age can exhibit different stages of skeletal maturation and that there are differences between genders. These results are consistent with those of another study that evaluated mandibular length and verified differences between genders in comparing bone maturation and Class I and II malocclusion.[11] This evidence must be considered in clinical orthodontic practice, since skeletal maturity

Table 2 - Unconditional multiple logistic regression analysis between independent variables and skeletal maturation of cervical vertebrae.

	Unadjusted OR (CI 95%)	*p*	Adjusted OR (CI 95%)	*p*
Malocclusion				
Class I	1.00		1.00	
Class II	2.22 (1.35-3.64)	0.002	2.37 (1.43-3.94)	0.001
Class III	0.56 (0.27-1.16)	0.120	0.60 (0.29-1.25)	0.175
Gender				
Female	1.00		1.00	
Male	1.96 (1.29-2.99)	0.002	1.82 (1.0-3.3)	0.001

must be expressed in terms of stage and level of maturity. The maturity level is used to associate a person's maturational stage with chronological age to determine whether development is advanced or delayed. Two children having the same maturity stage but different maturity levels will, in the future, demonstrate significant differences in total percentage of mandibular and maxillary growth.[3]

In determining a Class II, Division 1, malocclusion, there is a large number of possible combinations of relationships between the maxilla and mandible as well as between these bones and the cranial base. The most common combinations are maxillary protrusion with normal mandible, mandibular retrusion with normal maxilla, maxillary protrusion combined with mandibular retrusion and posterior rotation of the mandible.[12] It is therefore essential for orthodontists to be aware of the diverse dentoskeletal aspects of a malocclusion, because diagnosis dictates treatment. The results of the present study suggest that there is a skeletal component in determining a Class II malocclusion, especially when mandibular growth is slower than maxillary growth.

Baccetti *et al.*[9] designed an improved method of using cervical vertebrae maturation to evaluate mandibular growth and found that the maturation stage of cervical vertebrae occurs at least 2 years after peak growth. In the present study, there were no differences between individuals with Class I and Class III malocclusions with regard to the skeletal maturation stage of the cervical vertebrae. However, Reyes *et al.*[13] observed that increases in mandibular length were greater in individuals with Class III malocclusion than in those with normal occlusion, even during the interval of greater skeletal maturation (15 to 16 years). A possible explanation is the different methodological criteria used in studies as well as different sample sizes and the heterogeneity of study populations.

The results of this study confirm the importance of individualized diagnoses for the treatment of orthodontic patients, since the growth of the facial bones and periods of intensive or accelerated physiological growth should be analyzed individually in order to make better use of bone remodeling and the correction of skeletal discrepancies.

Conclusions

- There were significant differences between the stages of skeletal maturation of the cervical vertebrae and gender of the participants.
- Males with Class II malocclusion have a two times greater chance of being in the initiation and acceleration stages of cervical vertebra maturation.

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