

Maxillary First Molar Vertical and Horizontal Position Based on Sagittal and Vertical Facial Skeletal Growth Patterns on CBCT-Synthesized Cephalograms of Adult Patients with Different Dentofacial Discrepancies but With Normal Overbite

Ruíz-Mora GA¹, Arriola-Guillén LE², Flores-Mir C³

¹Division of Orthodontics, Faculty of Dentistry, Universidad Nacional de Colombia and Universidad El Bosque, Bogotá, Colombia. Universidad Peruana de Ciencias Aplicadas, Lima, Peru. ²Division of Orthodontics, Faculty of Dentistry, Universidad Científica del Sur-UCSUR and Universidad Nacional Mayor de San Marcos, UNMSM, Lima, Perú. ³Division of Orthodontics, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, Canada.

Abstract

Objective: To compare the maxillary first molar vertical and horizontal position based on sagittal and vertical facial skeletal growth patterns on CBCT-synthesized cephalograms of adult patients with different dentofacial discrepancies but with normal overbite.

Methods: Sixty-four CBCTs were examined (30 men and 34 women) divided per skeletal group (16 Class I, 24 Class II and 24 Class III) and per vertical growth tendency (32 normodivergent, 16 hypodivergent and 16 hyperdivergent). The ANB angle and occlusal features were used to evaluate the sagittal skeletal features and Bjork's polygon was used to evaluate the vertical skeletal features. All subject had an adequate overbite. The horizontal position of the upper first molar was evaluated considering the distance of its distal aspect to the vertical pterigomaxilar line, while the vertical position was evaluated considering the distance perpendicular to the Frankfurt plane at the level of the occlusal plane. ANOVA and ANCOVA tests were used to determine the molar position in the different groups with respect to sagittal and vertical patterns.

Results: The molar vertical position was not significantly affected by sagittal and vertical facial growth type, age or their interaction. The first molar horizontal position was 1.91mm more posterior in Class III and 2.23mm more anterior in Class II compared with Class I (20.81mm) ($p < 0.05$).

Conclusions: In patients with normal overbite maxillary molars vertical position was not influenced by vertical or horizontal growth, while the horizontal position of the maxillary first molar varies significantly based on the sagittal skeletal malocclusion.

Key Words: Maxillary molar position, Cone beam computed tomography, Skeletal pattern

Introduction

During the transitional dentition period intermolar occlusal relationships are significantly influenced by the maxilla-mandibular growth differential [1-5]. Nevertheless the literature has revealed little about the changes in molar relationships after the permanent dentition is fully established, when the physiologic mesial shift of the maxillary and mandibular molars is completed after the eruption of the second premolars and second molars; even though longitudinal studies [6-11] have shown that alveolar growth continues through the fourth and fifth decades of life.

Although some studies [6-8,12] have evaluated the relative horizontal and vertical position of the maxillary molars in non-growing adult patients; to our knowledge little has been reported when considering different dentofacial discrepancies in vertical and sagittal direction. An association has been reported between sagittal and vertical growth with the relative horizontal and vertical position of the first molars. Andria et al. [13,14] found that when the Palatal Plane (PPL) increases, the molar's position is usually more forward relative to the cranial base and maxillary complex. In contrast, when the PPL decreases, the molar position is relatively more posterior. In skeletal open bite cases an increase in the molar vertical position was found, likely caused by increased posterior discrepancy; [15,16] Arriola-Guillén and Flores-Mir [15] found that a skeletal open bite group had an increased molar vertical position in comparison to controls. However they only evaluated hyperdivergent cases, where the molar position can

be altered as a result of a marked skeletal divergence between palatal plane and mandibular plane.

None of these studies evaluated the influence of significant maxilla-mandibular divergence in the absence of an open bite. It would be interesting for clinicians to understand the dentoalveolar compensation mechanisms in the maxillary first molar in cases where despite the fact that normal overbite is observed significant vertical and sagittal craniofacial discrepancies are present. Therefore the purpose of the study was to compare the maxillary first molar vertical and horizontal position based on sagittal and vertical facial skeletal growth patterns on CBCT-synthesized cephalograms of adult patients with different dentofacial discrepancies with normal overbite.

Materials and Methods

The study was approved by a local ethics committee. The sample was selected from patients that attended a radiological diagnostic center during 2011 to obtain diagnostic orthodontic and/or surgical treatment records. Sample size was calculated considering a mean difference of 2.5 mm as a relevant difference between study groups (obtained from a preliminary pilot study where the mean of the sagittal position of the first molar in class I and II was assessed) and a variance of 8 mm. With a one-sided significance level of 0.05 and a power of 80%, a minimum of 16 patients per skeletal group was required. Finally the sample was divided per skeletal group (16 class I, 24 class II and 24 class III) and the same sample was also divided according to the vertical growth (32 normodivergent

patients, 16 hypodivergent and 16 hyperdivergent). (Table 1) Their age range was between 16 and 40 years (CV6) [17]. CBCT-synthesized lateral cephalograms from these 64 subjects (30 men, 34 women) were produced.

Inclusion criteria were adult patients with different dentofacial deformity with complete permanent dentition (included from 3rd molars). Patients were in centric occlusion (maximum intercuspation) during the CBCT examination, and no chin positioner was used to avoid compression of the mandibular condyles and soft tissues overlap on swallowing with no active deglutition during radiation exposure, and overbite between 1mm to 3mm. In addition to these inclusion criteria, patients with significant transversal skeletal asymmetries including posterior cross bites, with craniofacial syndromes, under orthodontic treatment at the time of CBCT acquisition, with severe dentoalveolar anomalies (number or shape of teeth), or with prior history of orthognathic surgery were not considered in this investigation.

Imaging was performed with Picasso Master 3D (Vatech, E-WOO Technology Co, Ltd, Republic of Korea). Device settings were set at 8mA and 90 kV. CBCT images were acquired with a (25 X 20) flat panel detector. Each field of view mode was 20 cm X 19 cm. Then the tomographic and cephalometric image was processed with EZ Implant 3D software. The ray-sum technique was used to create 2D simulated lateral skull projection images of the right side with the CBCT system. An excellent visualization of the tooth with the Frankfort plane parallel to the floor was selected on Multi Planar Reconstructions (MPR) and Volume Rendering (VR) views (Figure 1).

Patients were classified into 3 groups according to sagittal skeletal pattern and malocclusion according Angle: Class I ($ANB = 2^\circ \pm 2^\circ$, °, Class I angle malocclusion and bilateral Class I molar relations). Class II ($ANB \geq 5^\circ$, Class II-1 angle malocclusion, bilateral Class II molar relations and over jet greater than 6 mm), Class III ($ANB \leq -1^\circ$, Class III angle malocclusion, bilateral Class III molar relations and over jet lower than -2 mm). The definitions of points and angles used in this study are according to those described by Steiner [18] and Riolo et al. [19]

Vertical skeletal divergence was defined based on Björk [8] and Jarabak [20] values as normodivergent ($396^\circ \pm 6^\circ$), hypodivergent ($<390^\circ$) or hyperdivergent ($>402^\circ$). These values were defined as the sum of the following angles: N-S-Ar (sella angle), S-Ar-Go (articular angle) and Ar-Go-Me (gonial angle).

The horizontal position of the maxillary first molar was evaluated considering the horizontal distance from the first molar distal contact point to a perpendicular line to the

Pterigomaxilar Point (Ptm) with respect to the Frankfort Plane (FP) and its distal surface [21] (Figure 2).

Finally a vertical perpendicular line to FP distance and the buccal groove of the two molars at the level of the Occlusal Plane (OP) were considered for measuring the vertical distance of the first and second maxillary molars [21] (Figure 3).

Statistical analysis

All statistical analyses were performed using SPSS ver.20 for Windows (IBM SPSS, Chicago, Illinois, USA). If normality and homogeneity of variance assumptions were satisfied a One-way Analysis of Variance (ANOVA) was performed to determine whether there were differences in the 3 groups with respect to sagittal and vertical growth patterns. When these assumptions were no satisfied then the equivalent

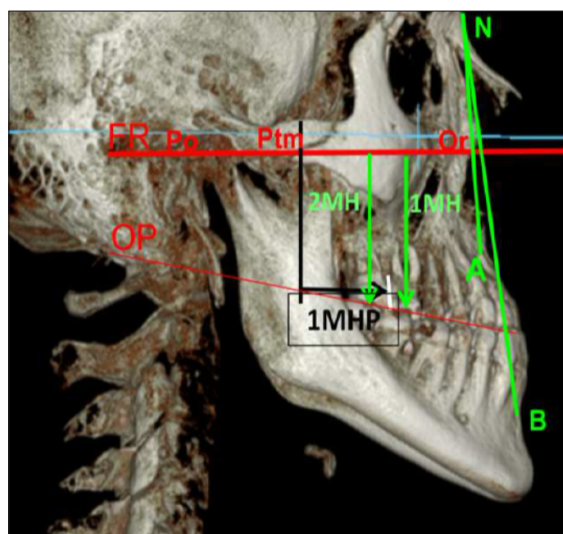


Figure 1. CBCT landmarks used in the (Multi planar reconstruction) and VR (Volume Rendering). Localization of the Frankfort plane. Ptm indicates pterigomaxilar; 1MHP, first molar horizontal position; 1MH, first molar height; 2MH, second molar height.

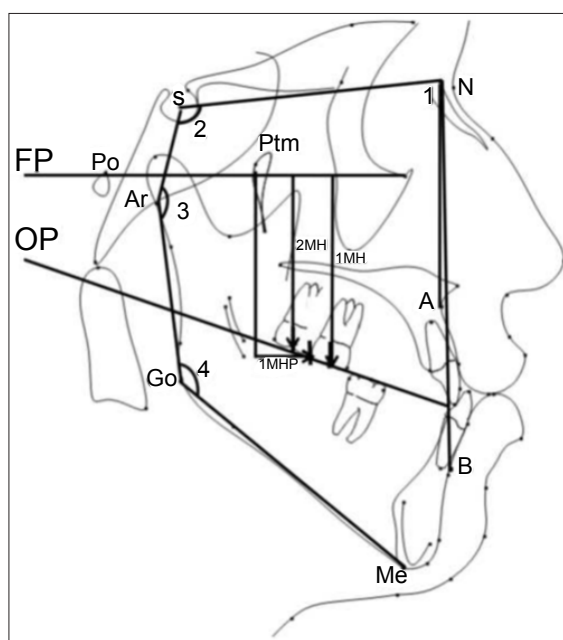


Figure 2. FP: Frankfort plane (horizontal reference); OP: Occlusal plane; Ptm: Pterigomaxilar perpendicular line from FP; 1MH: First molar maxillary horizontal height from FP; 2MH: Second molar maxillary horizontal height from FP; 1MHP: First molar horizontal position. *1.ANB: ANB angle; 2.N-S-Ar: Sella angle; 3.S-Ar-Go: Articular angle; 4.Ar-Go-Me: Goniac angle.

Table 1. Descriptive statistics of the sample by skeletal pattern and sex.

Skeletal growth patterns		Sex		Total
		Female	Male	
Sagittal growth	Class I	8	8	16
	Class II	12	12	24
	Class III	14	10	24
	Total	34	30	64
Vertical growth	Normodivergent	18	14	32
	Hypodivergent	8	8	16
	Hyperdivergent	8	8	16
	Total	34	30	64

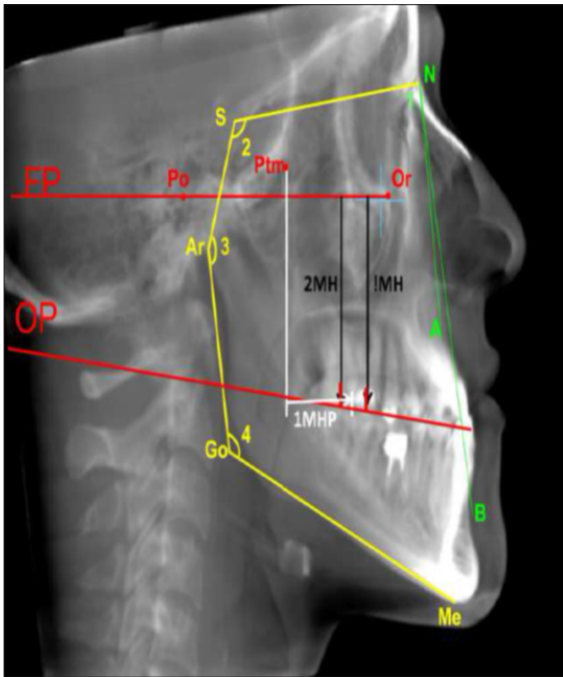


Figure 3. Tracings of Bjork angles on CBCT synthesized cephalograms. 1.N-S-Ar: Sella angle; 2.S-Ar-Go: Articular angle; 3.Ar-Go-Me: Goniac angle.

nonparametric Kruskal-Wallis H test was used. ANCOVA test was performed to evaluate the effect of the pattern sagittal, vertical, age and their interaction on the molars height and first molar position.

In addition, U-Mann Whitney and the Tukey HSD post-hoc test were used for multiple comparisons of parametric and nonparametric data.

Statistical significance was set at $p < 0.05$ for all the tests.

Results

Cephalometric tracings were performed by an orthodontist previously calibrated for the Björk and Jabarak analysis, with 10 years of experience drawing cephalograms. The intra-examiner reliability was assessed with the Intra class Correlation Coefficient (ICC), which gave a result greater than 0.90 in all measurements. In addition, the Dahlberg error was less than 1 mm. (0.5 to 0.8) in the linear measurements. (Table 2)

Sample descriptive characteristics are described in Table 3.

When compared to Class I (20.81mm), the first molar horizontal position was 1.91 mm more posterior in Class III (18.90mm) and 2.23mm more anterior in Class II (23.04mm). These differences were statistically significant across the sagittal skeletal relations ($p = 0.005$) (Table 4). The Tuckey post-hoc test showed significant statistical differences between Class I and II ($p = 0.021$), I and III ($p = 0.047$) and II and III ($p = 0.005$).

There were no significant differences for the first ($p = 0.591$) and second ($p = 0.539$) molar heights according to sagittal and vertical growth.

Also the ANCOVA analyses showed that the first and second molar heights were not influenced by the type of sagittal and vertical facial type, neither by age or their interaction (Tables 6,7).

Only the horizontal position of the first upper molar was influenced by the interaction of the sagittal and vertical growth ($p = 0.010$) (Table 8)

Discussion

This is the first study reporting the horizontal and vertical position of the maxillary first molar when simultaneously assessing vertical and sagittal facial skeletal variations among adult patients with normal overbite. This information should be useful to clinicians as knowledge of variations from the expected norms could affect how the orthodontic dentoalveolar modification is approached in class II or class III and/or hypo- and hyperdivergent facial types. Recent longitudinal studies [9,10] have shown that alveolar growth continues through the fourth and fifth decades of life. Our results indicated that once facial growth is completed among subjects with normal overbite the sagittal position of the maxillary first molar varies significantly based on the sagittal skeletal malocclusion, but there were no differences for the maxillary molar position based on vertical skeletal tendencies. This research pointed out that in the absence of an open bite, the facial bio-type is not significantly associated with molar vertical position. Previously it has been shown [11,15] that molar vertical position is only increased in subjects with a skeletal open bite in comparison with their counterparts with an adequate overbite. Our research may indicate that successful management of patients with vertical tendencies should not only be focused on attaining normal overbite but also in positioning the maxillary first molar in its expected normal vertical position. At least this is what can be extrapolated from this sample of untreated patients with normal overbite.

The physiological displacement of the first maxillary molar plays an important role on the horizontal and vertical maxillo-mandibular relationship [2-5]. It has been shown in growing individuals that sagittal and vertical growth can be influenced by the horizontal and vertical position of the first molar [5-7]. The horizontal and vertical position of the maxillary molars was different in each of the sagittal skeletal relationships [1,13,14]. An intermaxillary angle increment was associated with a more anterior position of the first maxillary molar that increased with age on skeletal class II relations [13].

The horizontal position of the first molar was clearly affected according to the sagittal pattern, our study showed that the horizontal position of the first molar was 1.91mm more posterior in Class III and 2.23mm more anterior in Class II compared with Class I (20.81mm) ($p < 0.05$). This value is within the range proposed by Ricketts (age plus three millimetres) considering that a subject grows up to 16 years old on average [21]

The importance of the vertical position and inclination of maxillary molars in the mandibular plane variation has also been recognized [5-7,14,22]. It has been reported that vertical alveolar dimensions increased further during the early and late stage of pubertal growth periods [7,8,22] with a magnitude that varies in proportion to the facial type. Finally the vertical position of the maxillary molars has been analyzed to predict changes in the mandibular plane [7]. Forsberg et al. [10] found a significant increase in the alveolar height between the ages of 25 and 45 years with the largest increase (1.13 mm \pm 0.77) for the anterosuperior alveolar height.

Our study involved subjects without skeletal open bites. Arriola-Guillén and Flores-Mir [15] showed that subjects

Table 2. Intra-observer concordance and error analysis.

Measurement	Intra-observer concordance			Dahlberg error $S_x = \sqrt{\frac{\sum D^2}{2N}}$
	ICC	CI inferior limit	CI superior limit	
Horizontal position of the first molar	0.950	0.930	0.989	0.8 mm
First molar height	0.996	0.990	0.998	0.5 mm
Second molar height	0.902	0.900	0.910	0.7 mm
ICC = Intraclass correlation coefficient				
ICI = Confidence interval				

Table 3. Characteristics of the sample by horizontal and vertical growth pattern.

Skeletal growth pattern	Measurement	n	Mean	SD	Min	Max	
Sagittal growth (ANB)	Class I	Age	16	27.6	5.97	18.00	39.00
		ANB		2.51	1.26	0.23	4.50
	Class II	Age	24	27.71	6.9	20.00	37.00
		ANB		7.50	1.7	5.71	10.60
	Class III	Age	24	26.50	6.59	16.00	35.00
		ANB		-2.90	2.34	-6.82	-1.00
Vertical growth (Björk's sum)	Normodivergent	32	394.94	3.85	390	402	
	Hypodivergent	16	386.35	1.90	384	389	
	Hyperdivergent	16	407.50	3.39	403	412	

Table 4. Horizontal position and maxillary molars height by horizontal growth pattern.

Measurement	Skeletal class	n	Mean	SD	Min	Max	S ²	p
First molar horizontal position	Class I	16	20.81	2.84	18.00	29.00	8.05	0.005*(+)
	Class II	24	23.04	4.08	15.00	30.00	16.67	
	Class III	24	18.90	3.75	14.00	27.00	14.05	
First molar height	Class I	16	47.08	3.86	41.50	53.80	14.89	0.591*
	Class II	24	47.37	2.55	40.80	51.40	6.50	
	Class III	24	45.36	5.80	26.30	52.30	33.64	
Second molar height	Class I	16	44.46	3.40	39.10	50.30	11.57	0.539**
	Class II	24	45.44	2.75	38.30	48.50	7.56	
	Class III	24	43.89	4.31	36.70	50.10	18.57	

*Anova test

**Kruskall Wallis H test

(+) Tuckey test (p=0.021 Class I and Class II) (p=0.047 Class I and Class III) (p=0.005 Class II and Class III)

Table 5. Horizontal position and maxillary molar heights according to vertical growth pattern.

Measurement	Vertical growth	n	Mean	SD	Min	Max	S ²	p
First molar horizontal position	Normodivergent	32	20.34	3.41	14.80	27.70	11.61	0.169
	Hypodivergent	16	24.25	4.50	19.00	29.00	20.25	
	Hyperdivergent	16	22.50	4.90	14.00	30.00	24.01	
First molar height	Normodivergent	32	45.94	5.07	26.30	53.80	25.65	0.395
	Hypodivergent	16	47.95	3.50	44.80	52.50	12.25	
	Hyperdivergent	16	48.00	3.30	42.60	51.50	10.89	
Second molar height	Normodivergent	32	43.83	3.72	36.70	50.10	13.82	0.341
	Hypodivergent	16	45.10	3.65	42.00	50.30	13.32	
	Hyperdivergent	16	45.38	2.9	41.30	50.00	8.41	

ANOVA test

Table 6. Multivariate analysis of co-variances of the factors involved in the Height First Molar.

Dependent variable	Co-variables and fixed factors	F	p
Height First Molar	Corrected Model	5.004	<0.001
	Intercept	0.019	0.890
	Age	0.864	0.359
	ANB	3.544	0.068
	Bjork's polygon	0.935	0.760
	Height Second Molar	35.988	<0.001
	First molar horizontal position	7.709	0.009
	Sagittal growth	0.414	0.664
	Vertical growth (Björk's sum)	0.022	0.978
	Sagittal growth * Vertical growth (Björk's sum)	0.755	0.561

* ANCOVA test

Table 7. Multivariate analysis of co-variances of the factors involved in the Height Second Molar.

Dependent variable	Co-variables and fixed factors	F	p
	Corrected Model	5.484	<0.001
	Intercept	0.169	0.684
	Age	0.014	0.907
	ANB	2.981	0.093
	Björk's polygon	0.423	0.520
Height Second Molar	First Molar horizontal position	14.169	0.001
	Height First Molar	35.988	<0.001
	Sagittal growth	0.770	0.471
	Vertical growth (Björk's sum)	0.149	0.862
	Sagittal growth * Vertical growth (Björk's sum)	1.285	0.295

*ANCOVA test

Table 8. Multivariate analysis of co-variances of the factors involved in the First Molar horizontal position.

Dependent variable	Co-variables and fixed factors	F	p
First Molar horizontal position	Corrected Model	4.439	<0.001
	Intercept	0.172	0.681
	Height First Molar	7.482	0.010
	Height Second Molar	14.697	0.001
	ANB	0.138	0.713
	Age	0.018	0.885
	Björk's polygon	0.062	0.805
	Sagittal growth	1.714	0.195
	Vertical growth (Björk's sum)	0.430	0.654
	Sagittal growth * Vertical growth (Björk's sum)	3.923	0.010

*ANCOVA test

with skeletal open bite had around an extra 4 mm of maxillary molar eruption and 3 mm more for the mandibular molars compared to patients with adequate overbite. It is unclear if the increased molar height is a consequence of skeletal open bite by their altered facial growth or that the skeletal open bite occurs as result of an maxillary molar over eruption caused by an increased posterior discrepancy [15,16]. Also Kucera et al. [11] established that there was no significant difference in upper or lower molar vertical position between dentally compensated open bite group and dentally non-compensated open bite group, but that there were differences with the control group with adequate overbite. Apparently an increased molar eruption is common only in subjects with skeletal open bite. In our study the ANB angle, age, sagittal position and Bjork polygon values had no influence in the maxillary molars vertical position as cases where dentoalveolarly compensated.

One drawback in our study was that the dentoalveolar and basal mandibular component was not measured. Furthermore, only unilateral (right) height and horizontal measurements were studied and transverse measurements were not included. These features could be taken into account in future studies.

References

1. Kim YE, Nanda RS, Sinha PK. Transition of molar relationships in different skeletal growth patterns. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2002; **121**: 280-290.
2. Haruki T, Kanomi R, Shimono T. The differences in the chronology and calcification of second molars between angle Class III and Class II occlusions in Japanese children. *ASDC Journal of Dentistry for Children*. 1997; **64**: 400-404.

Also CBCT-specific research on the transverse position of the maxillary molars, left and right differences, intermaxillary vertical relations and dento-alveolar and basal influence of the mandible should be executed [23].

Finally, CBCT is believed to reduce sources of measurements error due to its isotropic characteristics [24]. Furthermore, CBCT-synthesized cephalograms can be successfully used for assessing the accuracy of linear measurements [24-26]. Recent studies have shown that the measurements from in vivo CBCT synthesized cephalograms are similar to those based on conventional radiographic images [26,27].

Conclusions

- The maxillary molars vertical position was not influenced by vertical or horizontal facial growth in cases with normal OB.
- The horizontal position of the maxillary first molar varies significantly based on the sagittal skeletal malocclusion. It was more anteriorly positioned in Class II cases with normal OB.

3. Suda N, Hiyama S, Kuroda T. Relationship between formation/eruption of maxillary teeth and skeletal pattern of maxilla. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2002; **121**: 46-52.

4. Bishara SE, Hoppens BJ, Jakobsen JR, Kohout FJ. Changes in the molar relationship between the deciduous and permanent dentitions: a longitudinal study. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1988; **93**: 19-28.

5. Buschang PH, Carrillo R, Liu SS, Demirjian A. Maxillary

and mandibular dentoalveolar heights of French-Canadians 10 to 15 years of age. *Angle Orthodontics*. 2008; **78**: 70-76.

6. Arat ZM, Rubenduz M. Changes in dentoalveolar and facial heights during early and late growth periods: a longitudinal study. *Angle Orthodontics*. 2005; **75**: 69-74.

7. Isaacson JR, Isaacson RJ, Speidel TM, Worms FW. Extreme variation in vertical facial growth and associated variation in skeletal and dental relations. *Angle Orthodontics*. 1971; **41**: 219-229.

8. Bjork A. Variations in the growth pattern of the human mandible: longitudinal radiographic study by the implant method. *Journal of Dental Research*. 1963; **42**: 400-411.

9. Tallgren A, Solow B. Age differences in adult dentoalveolar heights. *European Journal of Orthodontics*. 1991; **13**: 149-156.

10. Forsberg CM, Eliasson S, Westergren H. Face height and tooth eruption in adults--a 20-year follow-up investigation. *European Journal of Orthodontics*. 1991; **13**: 249-254.

11. Kucera J, Macera I, Ticova H, Baccetti T. Molar height and dentoalveolar compensation in adults subjects with skeletal open bite. *Angle Orthodontics*. 2011; **81**: 564-569

12. Siritwat PP, Jarabak JR. Malocclusion and facial morphology is there a relationship? An epidemiologic study. *Angle Orthodontics*. 1985; **55**: 127-138.

13. Andria LM, Reagin KB, Leiter LP, King LB. Statistical evaluation of possible factors affecting the sagittal position of the first permanent molar in the maxilla. *Angle Orthodontics*. 2004; **74**: 220-225.

14. Andria LM, Leite LP, Dunlap AM, Cooper EC, King LB. Mandibular first molar relation to variable lower face skeletal components. *Angle Orthodontics*. 2007; **77**: 21-28.

15. Arriola-Guillén LE, Flores-Mir C. Molar height and incisor inclinations on adult subjects with skeletal open bite class II and III. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2014; **145**: 325-332. doi: 10.1016/j.ajodo.2013.12.001.

16. Arriola-Guillén LE, Flores-Mir C. Anterior maxillary dentoalveolar and skeletal cephalometric factors involved in upper incisor crown exposure in subjects with Class II and III skeletal open bite. *Angle Orthodontics*. 2014. [Epub ahead of print]

17. Baccetti T, Franchi L, McNamara J. The Cervical Vertebral Maturation (CVM) Method for the Assessment of Optimal Treatment

Timing in Dentofacial Orthopedics. *Seminars in Orthodontics*. 2005; **11**: 119-129.

18. Steiner C. Cephalometric for you and me. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1953; **39**: 729-755.

19. Riolo ML, Moyers RE, McNamara JA, Hunter WS. An atlas of craniofacial growth: cephalometric standards from the University School Growth Study, Monograph No 2. Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development; University of Michigan; 1974.

20. Jarabak JR, Fizzel JA (Editors). Technique and treatment with lightwire appliances. CV Mosby (2nd edn.). St Louis, 1972.

21. Ricketts RM. Cephalometric Analysis And Synthesis. *The Angle Orthodontist*. 1961; **31**: 141-156.

22. Baldrige JP. A study of the relation of the maxillary first permanent molar to the face on Class I and Class II malocclusions. *Angle Orthodontics*. 1941; **11**: 100-109.

23. Janson G, Bombonatti R, Cruz KS, Hassunuma CY, Del Santo M, Jr. Buccolingual inclinations of posterior teeth in subjects with different facial patterns. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2004; **125**: 316-322.

24. Moshiri M, Scarfe WC, Hilgers ML, Scheetz JP, Silveira AM, Farman AG. Accuracy of linear measurements from imaging plate and lateral cephalometric images derived from cone-beam computed tomography. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2007; **132**: 550-560.

25. Hilgers ML, Scarfe WC, Scheetz JP, Farman AG. Accuracy of linear temporomandibular joint measurements with cone beam computed tomography and digital cephalometric radiography. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2005; **128**: 803-811.

26. Kumar V, Ludlow J, Soares Cevidanes LH, Mol A. In vivo comparison of conventional and cone beam CT synthesized cephalograms. *Angle Orthodontics*. 2008; **78**: 873-879.

27. Nguyen T, Cevidanes L, Cornelis MA, Heymann G, de Paula LK, De Clerck H. Three-dimensional assessment of maxillary changes associated with bone anchored maxillary protraction. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2011; **140**: 790-798.