Original Article

The Relationship between Molar Dentoalveolar and Craniofacial Heights

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Abstract: Excessive vertical growth of the posterior dentoalveolar region has been implicated in the etiology of the so-called long-face syndrome. In this study, we tested the hypothesis that molar dentoalveolar heights are positively related to vertical craniofacial features. Cephalometric measurements obtained from 82 adult subjects were entered as independent variables in a multiple regression model. Maxillary and mandibular molar dentoalveolar heights were entered as dependent variables. Approximately 70% of the total variance was explained by anterior lower facial height (ANS-Me) and the mandibular palatal plane angle (PP-MP). Increases of ANS-Me and PP-MP had opposite effects on the amount of molar dentoalveolar heights. The lowest values of molar dentoalveolar heights were found in subjects with a small ANS-Me distance but with a wide PP-MP angle. The findings suggest that individuals with a marked divergence of the jaws may also have a reduced molar dentoalveolar vertical development. (*Angle Orthod* 2005;75:974–979.)

Key Words: Cephalometry; Vertical dimension; Dentoalveolar height; Craniofacial morphology; Multiple regression analysis

INTRODUCTION

Extreme vertical facial types (ie, long-face and short-face subjects) are often accompanied by an abnormal vertical development of the posterior dentoalveolar region.[1–19] Excesses of posterior dentoalveolar heights are a common feature of the long-face syndrome.[3–6,8–16,18,19]

Conversely, Björk and Skieller,[2] in longitudinal implant studies found that a posterior rotational growth pattern is accompanied with a reduced eruption of molar teeth, which has been interpreted as a compensatory mechanism.[2,20] These observations, however, were obtained from only two long-face subjects.

More recently, decreases in maxillary and mandibular posterior dentoalveolar heights in permanent dentition have been reported by Betzenberger et al[17] in high-angle malocclusions. Thus, the relationship between vertical facial development and posterior dentoalveolar heights is still a matter of debate.

In most studies investigating the relationship between craniofacial and dentoalveolar heights, vertical facial types have been selected on the basis of the amount of dental overbite,[3,16] the ratio between upper and lower anterior facial height,[13] the mandibular plane angle,[4] or the visual perception of increased or reduced lower facial height.[9] With such approaches, however, the cephalometric or dental criteria for selection of extreme vertical facial types are inevitably arbitrary.

In a few population studies, a simple correlation analysis between the dentoalveolar heights and several craniofacial features was conducted.[7,13] This approach, however, ignores the simultaneous contribution of multiple factors to the individual variation of dentoalveolar heights.

Therefore, this study was designed to determine the relationship between the molar dentoalveolar heights

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and craniofacial morphology with special emphasis on vertical measurements by means of a multiple regression analysis.

MATERIALS AND METHODS

Sample and clinical records

Complete pretreatment records of 856 patients were selected from the record store of the local department of orthodontics. All the subjects were white Caucasian adults from Campania, Italy. A total of 82 patients were selected from this sample according to the following exclusion criteria: previous orthodontic treatment, unilateral or bilateral posterior crossbite, periodontal diseases, missing teeth (from canine to second molar), morphological tooth anomaly, extensive dental restoration or crown, and mandibular asymmetry. Inclusion criteria were a complete permanent dentition (with the exception of third molars) and an age equal to or more than 15 years for female subjects and equal to or more than 18 years for male subjects.

The investigated sample (25 male subjects, 57 female subjects; mean age $\pm$ standard deviation [SD] $=$ 20.7 $\pm$ 5.4 years) consisted of a group with different vertical and sagittal skeletal discrepancies.

Lateral standardized cephalograms were taken by a single technician using the same X-ray device and a standardized procedure. The cephalograms were made with the mandible in the intercuspal position. The focus to mid-sagittal plane distance was 152 cm, and the film to mid-sagittal plane distance was 10 cm. The values measured were not corrected for linear enlargement (approximately 7% in the median plane).

Cephalometric measurements

The cephalometric analysis aimed to evaluate the dentoalveolar, the vertical, as well as the sagittal craniofacial dimensions. Cephalometric landmarks, lines, and measurements are shown in Figure 1. A single examiner performed all cephalometric measurements. This examiner had been extensively trained in cephalometric analysis and did not get any information about the aim of the study.

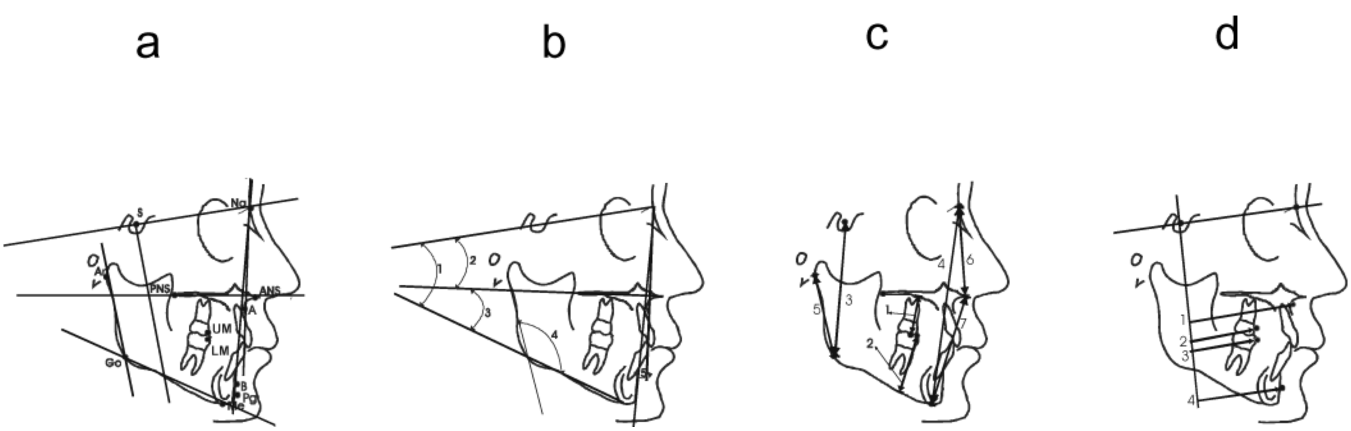

FIGURE 1. Skeletal landmarks, lines, and measurements used for cephalometric analysis. (a) Landmarks and lines[30]: sella (S), the midpoint of the cavity of sella turcica; nasion (Na), the anterior point of the intersection between the nasal and frontal bones; point A (A), the most posterior point on the anterior surface of the maxilla; point B (B), the most posterior point on the anterior surface of the symphyseal outline; menton (Me), the intersection point of the posterior symphysis contour and the inferior contour of the corpus; pogonion (Pg), the most anterior point of the contour of the chin; gonion (Go), the point on the contour of the mandible determined by bisecting the angle formed by the mandibular and ramal planes; articulare (Ar), the intersection point of the inferior cranial base surface and the averaged posterior surfaces of the mandibular condyles; ANS point (ANS), the most anterior point of the bony hard palate in the mid-sagittal plane; PNS point (PNS), the most posterior point of the bony hard palate in the mid-sagittal plane. S-vertical plane, a line perpendicular to Na-S line, through S point; palatal plane (PP), a line that connect ANS to PNS; mandibular plane (MP), a line that connects Go to Me; Na-S, a line that connects Na to S; Na-A, a line that connects Na to A; Na-B, a line that connects Na to B. (b) Angular measurements: (1) SNa-MP, the angle between the SNa plane and MP; (2) SNa-PP, the angle between the SNa plane and PP; (3) PP-MP, the angle between PP and MP; (4) ArGo-MP, the angle between the ArGo plane and MP; (5) ANB, the angle between Na-A plane and Na-B plane. (c) Vertical measurements: (1) MxMDH: maxillary molar dentoalveolar height, the distance between the mesiovestibular cuspid of the upper first molar and the palatal plane along the long axis of the molar; (2) MdMDH, mandibular molar dentoalveolar height, the distance between the mesiovestibular cuspid of the lower first molar and the lower border of the mandible along the long axis of the molar; (3) S-Go, posterior facial height, the distance between the S point and the Go point; (4) Na-Me, anterior facial height, the distance between the Na point and the Me point; (5) Ar-Go, ramus length, the distance between the Ar point and the Go point; (6) Na-ANS, anterior upper facial height, the distance between the Na point and the ANS point; (7) ANS-Me, anterior lower facial height, the distance between the ANS point and the Me point. (d) Horizontal measurements: (1) Vert-A, distance between A and the S-vertical plane; (2) Vert-UM, distance between the upper molar mesial profile and the S-vertical plane; (3) Vert-LM, distance between the lower molar mesial profile and the S-vertical plane; (4) Vert-Pg, distance between Pg and the S-vertical plane.

Error study

The errors of the method were calculated from 25 randomly selected subjects. A second examiner retraced the cephalograms and performed all the measurements again. The second examiner was a teacher of cephalometric techniques at the Dental School of Naples Federico II. The method error (ME) for all these measurements was assessed by means of the formula $ME = \sqrt{\Sigma d^2/2n}$ where d is the difference between the two measurements and n is the number of recordings. Systematic differences between replicate measurements were tested with paired Student's *t*-test setting the alpha error at 0.1.[21] Mean errors were, in general, low. The mean errors for the distances varied between 0.2 and 0.8 mm and for the angles between 0.3 and 0.6 degrees. There was no systematic error for duplicate cephalometric measurements (Student's *t*-test; $P > .1$).

Statistics

Data were first analyzed with conventional descriptive statistics, and the means, SDs, standard errors of the mean, and ranges (minimum-maximum) were calculated for all the cephalometric measurements. The normal distribution fitting of data collected was tested by means of Kolmogorov-Smirnov test. The hypothesis that data were normally distributed could not be rejected for any variable and, therefore, subsequent analyses were performed by means of parametric statistical tests.

Multiple linear regression analyses with a stepwise backward elimination were performed. The multiple regression analysis is a technique used to model or to predict one variable (dependent variable) from multiple explanatory variables (independent). The stepwise backward approach starts entering all explanatory variables and then sequentially eliminates the variable that contributes the least to the model. The partial regression coefficients, referred to as *B* (beta weights), indicate the variation in the dependent variable that is explained by each predictor variable, adjusting for all the other predictor variables entered into the model. The R^2 indicates the proportion of overall variance that is explained by the predictor variables.

The maxillary and mandibular posterior dentoalveolar heights were considered as the response variables (dependent variables). Explanatory variables (independent variables) entered into the model were ''gender,'' ''age,'' and the cephalometric measurements set described previously. The amount of explained variance (R^2) was calculated by collinearity diagnostics and multivariate methods. All the analyses were carried out by means of statistical software for Windows (SPSS 10.0, Chicago, Ill; MATLAB 5.3, The MathWorks, Inc, Natick, Mass). In the statistical evaluation, the following levels of significance were used: *** = $P < .001$, ** = $P < .01$, * = $P < .05$, and ns = $P \geq .05$ (not significant).

TABLE 1. Descriptive Statistics for the Cephalometric Measurements (n = 82)[a]

Measurement	Mean	SD	SEM	Minimum	Maximum
SNa-MP (°)	33.3	8.3	0.9	15.0	56.0
SNa-PP (°)	9.10	3.5	0.4	5.0	17.0
PP-MP (°)	24.4	7.4	0.8	10.0	45.0
ArGo-MP (°)	126.9	7.5	0.8	113.0	151.0
ANB (°)	3.1	3.3	0.4	−6.0	11.0
MxMDH (mm)	35.7	3.8	0.4	27.0	44.0
MdMDH (mm)	25.0	3.1	0.3	18.0	32.0
S-GO (mm)	83.5	8.1	0.8	69.0	104.0
Na-Me (mm)	125.1	9.9	1.0	105.0	146.0
Ar-GO (mm)	52.7	6.8	0.7	40.0	66.0
Na-ANS (mm)	55.5	3.9	0.4	44.0	63.0
ANS-Me (mm)	71.0	8.1	0.8	54.0	91.0
Vert-A (mm)	62.0	6.2	0.6	50.0	77.0
Vert-UM (mm)	35.3	6.2	0.6	23.0	53.0
Vert-LM (mm)	34.3	7.4	0.8	20.0	52.0
Vert-Pg (mm)	50.8	11.0	1.2	25.0	74.0

[a] MxMDH indicates maxillary molar dentoalveolar height; MdMDH, mandibular molar dentoalveolar height.

RESULTS

Descriptive statistics for the cephalometric measurements obtained from the whole sample investigated are given in Table 1. After the stepwise elimination, maxillary molar dentoalveolar height (MxMDH) remained significantly influenced by the following variables: ANS-Me (lower anterior facial height) ($P < .001$), PP-MP (divergence of the jaws) ($P = .002$), and ANB (sagittal skeletal relationship) ($P = .007$). Mandibular molar dentoalveolar height (MdMDH) was significantly influenced by ANS-Me ($P < .001$) and PP-MP ($P < .001$). No significant relationship was found between both MxMDH and MdMDH and the remaining cephalometric measurements. MxMDH and MdMDH were not significantly influenced from the age and the gender of the subjects investigated ($P > .05$). The results of MxMDH and MdMDH regression analysis are summarized in Table 2.

The pattern of relationship between posterior dentoalveolar heights and the cephalometric significant features that resulted from the regression models is given in Figure 2. The orientation of the regression planes indicates that both maxillary and mandibular posterior dentoalveolar heights were positively influenced from the length of anterior lower facial height and negatively from the width of the mandibulopalatal plane angle. The negative influence of the mandibulopalatal plane angle on dentoalveolar heights was

TABLE 2. Stepwise Multiple Regression Analysis for Maxillary and Mandibular Molar Dentoalveolar Height (n = 82)[a]

Dependent Variable	Independent Variable	*B*	SE *B*	*t*	*P* Value
MxMDH	1 (Costant)	3.06	1.84	1.67	.100
	ANS-Me	0.31	0.03	11.97	.000
	2 (Costant)	1.07	1.83	0.58	.561
	ANS-Me	0.38	0.03	11.94	.000
	PP-MP	−0.11	0.03	−3.35	.001
	3 (Costant)	2.68	1.85	1.45	.152
	ANS-Me	0.36	0.03	11.50	.000
	PP-MP	−0.10	0.03	−3.17	.002
	ANB	−0.16	0.06	−2.77	.007
MdMDH	1 (Costant)	10.74	2.58	2.58	.000
	ANS-Me	0.35	0.04	0.04	.000
	2 (Costant)	6.07	2.2	2.2	.008
	ANS-Me	0.51	0.04	0.04	.000
	PP-MP	−0.27	0.04	0.04	.000

[a] MxMDH indicates maxillary molar dentoalveolar height; MdMDH, mandibular molar dentoalveolar height. *B* is the unstandardized regression coefficient; and SE *B* is the standard error of *B*.

more pronounced for the mandibular posterior dentoalveolar height than for the maxillary posterior dentoalveolar height (ie, the regression plane of MdMDH was steeper than that of MxMDH). The total variance explained by the regression models amounted to 71% and 70%, respectively, for MxMDH and for MdMDH. Variation of MxMDH was mostly explained by ANS-ME ($R^2 = 0.67$), partly from PP-MP ($R^2 = 0.39$), and to a minor extent by ANB angle ($R^2 = 0.02$). The contribution of ANS-Me and PP-MP to the variance of MdMDH reached 68% and 32%, respectively.

DISCUSSION

The regression model used in this study has shown that two out of 14 cephalometric features (ie, length of the anterior lower facial height and width of the mandibulopalatal plane angle) explain roughly 67% of the variations of MxMDH and MdMDH. MxMDH was also positively influenced, in a negligible extent (ie, 2%) from the reciprocal position of the lower and upper jaw in the sagittal plane (ie, ANB angle).

From the analysis of partial correlation coefficients, the length of the anterior lower facial height had a positive influence on the amount of molar dentoalveolar heights, and this result supports a positive relationship between dentoalveolar and craniofacial heights. However, the amount of molar dentoalveolar heights was negatively influenced from the divergency of the jaws (ie, mandibulopalatal plane angle), which is considered one of the most common cephalometric features for definition of vertical facial types. This finding is in contrast with the widespread belief that hyperdivergent facial types have an excessive posterior dentoalveolar development and that these hypodivergent facial types have a deficient dentoalveolar development.

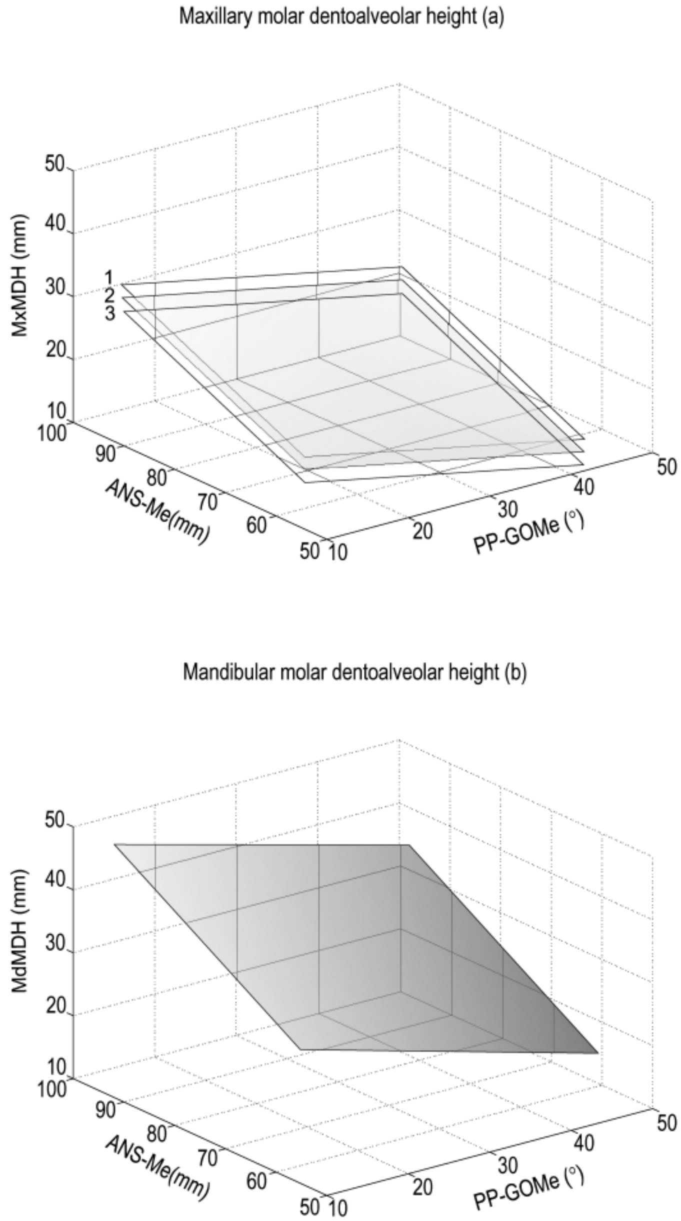

FIGURE 2. Regression planes resulting from multiple regression analysis of (a) maxillary molar dentoalveolar height (MxMDH) and (b) mandibular molar dentoalveolar height (MdMDH). MxMDH and MdMDH were positively influenced from the ANS-Me distance and negatively from the PP-MP angle. The three regression planes of MxMDH (a) have been obtained by varying the ANB angle as follows: mean ANB − 2 SD (3), mean ANB (2), and mean ANB + 2 SD (1).

Because we investigated the simultaneous contribution of multiple craniofacial features on molar dentoalveolar heights, the findings cannot be directly compared with previous studies. Indeed, extreme vertical facial types may have multiple cephalometric expressions, and the current criteria for definition of long faces or short faces are not univocal.[1,3–9] Nevertheless, it may be argued that the results of this regression analysis do not support previous suggestions that an excessive dentoalveolar development is a general characteristic of subjects with long-face morphology,[3–6,8–16,18,19] and that a deficient dentoalveolar development is a characteristic of subjects with short-face morphology.[1,7]

Variations of anterior lower facial height and of mandibulopalatal plane angle had, therefore, opposite results on the amount of molar vertical dimensions. The shortest molar dentoalveolar heights were found in subjects with the upper and lower jaws extremely divergent, but with a markedly reduced anterior lower facial height (see Figure 2; lower right corner of the regression plane), whereas the longest molar dentoalveolar heights were found in subjects with the upper and lower jaws little diverging but with a markedly increased anterior lower facial height (see Figure 2; upper left corner of the regression plane). These results are consistent with previous observations[2] obtained by means of a longitudinal implant study carried out in a few growing subjects and with other observations obtained by means of a cross-sectional study.[17]

A limitation of any cephalometric analysis is that the cause–effect relationships between measurements are difficult to establish and, thus far, the causal chain of events between molar dentoalveolar and facial vertical development has not been clearly understood. The amount of vertical growth of the craniofacial complex is probably controlled by both genetic and environmental factors.[22,23] Dentoalveolar regions are considered more prone to environmental influences than to inherited influences,[18,24] and it has also been suggested that during growth, the teeth erupt adapting to the space resulting from the growth pattern of the upper and lower jaws.[25] Furthermore, it is a common experience that dentoalveolar heights can be modified, to some extent, by orthodontic treatment. For these reasons, in our regression model, the molar dentoalveolar heights have been considered as response variables (ie, independent variables). On the other hand, it has also been suggested that an increase in face height may be the result of an excessive eruption of the molar teeth, which take place during childhood and even during adulthood.[9,26] Differences in the level of jaw elevator muscle function between subjects with different vertical craniofacial features are also supposed to play a role in the vertical craniofacial development.[27,28]

These findings suggest that the amount of both upper and lower molar dentoalveolar heights was neither influenced by the sex of the subjects nor by their age. This is in contrast with previous reports.[13,26,29] A potential explanation may be the different statistical approach used in this study, which took into account the simultaneous contribution of multiple factors to the individual variation of the molar dentoalveolar heights. Furthermore, the variability of age of the subjects selected for this study was rather restricted because most of the patients investigated were young adults.

The results of this study could be of interest in view of their potential clinical implications in orthodontics or orthognathic surgery because orthodontic or surgical correction of extreme vertical face discrepancies are often based on the assumption that excessive vertical facial types are characterized by excessive dentoalveolar development and vice versa.[19]

It must be stressed that this study investigated a sample of subjects who were referred to an orthodontic department for clinical consultation because of dental or skeletal malocclusions. Therefore, the results cannot be inferred to a general population. Future studies may provide normative values for the relationship between molar dentoalveolar heights and craniofacial morphology in individuals without malocclusion.

CONCLUSIONS

The regression model used in the present study has shown that two out of 14 cephalometric features (ie, the length of anterior lower facial height and width of the mandibular palatal plane angle) explain more than two third of the variations of MxMDH and MdMDH:

- The length of the anterior lower facial height had a positive influence on the amount of molar dentoalveolar heights.
- The amount of molar dentoalveolar heights was negatively influenced from the divergency of the jaws (ie, mandibulopalatal plane angle).
- MxMDH was also positively influenced to a negligible extent (ie, 2%) from the reciprocal position of the lower and upper jaw in the sagittal plane (ie, ANB angle).

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