ORTHODONTIC ROLE OF DENTOALVEOLAR HEIGHTS IN CRANIOFACIAL GROWTH

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ABSTRACT

Aim of the study: Vertical craniofacial development results from complex interactions between skeletal growth and dentoalveolar adaptation. The contribution of dentoalveolar heights to facial height development, particularly in untreated malocclusion, remains insufficiently elucidated. This study aimed to evaluate the orthodontic significance of dentoalveolar heights in relation to anterior and posterior facial height development in untreated Class I and Class II subjects across distinct developmental stages. **Materials and methods:** A retrospective mixed-longitudinal study was conducted using 408 lateral cephalograms from 86 untreated subjects aged 6–18 years. The sample included 47 Class I and 39 Class II subjects. Cephalometric measurements included anterior facial height, posterior facial height, and dentoalveolar heights of incisors and molars. Multiple linear regression analyses were performed to assess predictive relationships. **Results:** Both malocclusion groups demonstrated progressive increases in facial and dentoalveolar heights with growth. In Class I subjects, upper molar vertical position showed strong predictive value for both anterior and posterior facial heights across developmental phases (R^2 up to 0.84). In Class II subjects, dentoalveolar variables demonstrated weaker and less consistent associations, with upper incisor height showing significant predictive value primarily for posterior facial height in later developmental stages. **Conclusions:** Dentoalveolar heights play a significant role in vertical craniofacial development, particularly in Class I individuals. The vertical position of the upper molar represents a key orthodontic determinant of facial height growth, whereas Class II malocclusion demonstrates greater variability and reduced dentoalveolar influence.

Key words: Orthodontics; dentoalveolar height; craniofacial growth; vertical facial dimension; malocclusion; cephalometry.

INTRODUCTION

Craniofacial growth is a highly coordinated biological process governed by complex interactions among skeletal development, dentoalveolar adaptation, neuromuscular function, and genetic regulation [1]. This multifactorial process involves continuous remodeling and spatial reorganization of craniofacial structures, ensuring functional harmony between the jaws, dentition, and surrounding soft tissues. The timing, direction, and magnitude of growth changes are influenced by both intrinsic genetic programming and extrinsic environmental factors, including occlusal forces, muscular activity, and functional demands.

Among the various dimensions of facial growth, the vertical component holds particular orthodontic importance due to its direct influence on occlusion, facial esthetics, mandibular rotation patterns, and long-term treatment stability [2,3]. Vertical facial proportions determine not only the spatial relationships between maxillary and mandibular structures but also the functional balance of the stomatognathic system. Disruptions in vertical development can alter occlusal plane orientation, modify mandibular posture, and affect airway dimensions, thereby exerting broad functional and morphological consequences.

Variations in vertical facial proportions are strongly associated with malocclusion

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development and frequently determine the complexity of orthodontic intervention [4]. Excessive vertical growth is typically associated with increased lower anterior facial height, clockwise mandibular rotation, reduced bite force efficiency, and a tendency toward anterior open bite. Conversely, reduced vertical facial development is commonly linked to deep bite patterns, counterclockwise mandibular rotation, and increased muscular loading of the dentition [5,6]. These vertical discrepancies not only influence occlusal relationships but also affect treatment planning, stability, and relapse potential. Consequently, understanding the determinants of vertical facial growth remains a fundamental prerequisite for accurate diagnosis, reliable growth prediction, and effective orthodontic treatment planning [5–7].

Within this biological framework, dentoalveolar structures play a fundamental and dynamic role. Tooth eruption and alveolar bone growth contribute not only to the establishment of occlusal contacts but also to the broader regulation of craniofacial morphology [7,8]. The vertical positioning of incisors and molars directly influences occlusal plane inclination, mandibular rotation, and the equilibrium between anterior and posterior facial heights. Posterior dentoalveolar development, in particular, is considered a key factor in determining the direction of mandibular growth rotation and the maintenance of vertical facial balance [9,10].

The relationship between dentoalveolar and skeletal growth is neither linear nor purely compensatory; rather, it is dynamic and reciprocal [11]. Dentoalveolar adaptation may occur in response to skeletal discrepancies, functioning as a compensatory mechanism aimed at preserving occlusal efficiency. However, dentoalveolar structures may also exert an independent influence on skeletal morphology by modulating mandibular posture and vertical facial proportions [12]. This bidirectional interaction is mediated through complex biomechanical and functional pathways, including occlusal loading, periodontal ligament responses, and neuromuscular feedback mechanisms.

The importance of this interaction becomes particularly evident in the context of malocclusion, where skeletal patterns, functional environments, and growth trajectories exhibit substantial variability [11,12]. In individuals with Class I malocclusion, skeletal relationships are generally more harmonious, allowing dentoalveolar structures to participate more directly in the regulation of vertical facial development. The vertical positioning of molars and incisors in these individuals may therefore play a decisive role in establishing and maintaining facial height proportions [13].

In contrast, Class II malocclusion is frequently characterized by mandibular retrusion, altered growth direction, and functional adaptations that may modify the influence of dentoalveolar structures. Compensatory dental eruption patterns, changes in occlusal plane orientation, and variations in mandibular rotation are commonly observed in these patients, potentially reducing the regulatory capacity of dentoalveolar heights in controlling vertical facial development [14]. The heterogeneity of Class II growth patterns further complicates the interpretation of dentoalveolar–skeletal relationships and underscores the need for detailed longitudinal investigation.

Despite extensive research addressing skeletal determinants of craniofacial growth, relatively few studies have specifically

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examined dentoalveolar contributions in untreated populations using longitudinal designs. Most existing investigations rely on cross-sectional data or include subjects who have undergone orthodontic intervention, thereby limiting the ability to distinguish natural growth mechanisms from treatment-induced changes. Consequently, the true extent to which dentoalveolar heights contribute to vertical craniofacial development remains incompletely understood.

The present study was therefore designed to address this knowledge gap by evaluating the influence of dentoalveolar heights on anterior and posterior facial height development in untreated Class I and Class II subjects across multiple growth stages. By analyzing longitudinal changes in dentoalveolar and skeletal dimensions, this investigation aims to clarify the orthodontic significance of dentoalveolar vertical development and its role in shaping craniofacial growth patterns.

MATERIALS AND METHODS

This retrospective mixed-longitudinal study utilized cephalometric records from the archives of Dental University Clinics of "George Emil Palade" and "Dimitrie Cantemir". The study protocol was reviewed and approved by the institutional review board. All included patients signed an Informed Consent for using their personal medical data in this study.

From an original dataset of 408 cephalograms representing untreated subjects, 258 cephalograms from 86 individuals met inclusion criteria.

Inclusion Criteria

Subjects were required to present with:

- Angle Class I or Class II malocclusion
- No prior orthodontic treatment
- High-quality lateral cephalograms
- Fully erupted permanent first molars at baseline
- Absence of craniofacial anomalies

Sample Characteristics

The final sample consisted of:

- Total subjects: 86
- Males: 34
- Females: 52
- Class I subjects: 47
- Class II subjects: 39

Subjects were categorized into three developmental phases based on age and dentition stage:

Phase A – early mixed dentition

Phase B – late mixed dentition

Phase C – permanent dentition

Cephalometric Analysis

All cephalograms were standardized to 150 dpi and analyzed using Viewbox 4 software. Images were oriented using the SN-7° reference line.

A total of 51 digitized points were used to generate geometric curves to enhance landmark identification accuracy.

Measurements

Dependent Variables

- Anterior facial height (Na–Me)
- Posterior facial height (S–Go)

Independent Variables

- Upper molar height (U6-PP)
- Lower molar height (L6-GoMe)
- Upper incisor height (U1-PP)
- Lower incisor height (L1-GoMe)

Error Analysis

Repeated digitization of 30 randomly selected cephalograms demonstrated method errors ranging from 0.17 mm to 1.63 mm, confirming measurement reliability.

Statistical Analysis

Descriptive statistics were calculated for all variables. Multiple linear regression analyses were performed separately for each malocclusion group and developmental phase to evaluate predictive relationships. Statistical significance was set at $p < 0.05$.

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RESULTS

Both Class I and Class II subjects exhibited progressive increases in facial heights and dentoalveolar measurements across developmental phases. The results are shown in Table 1 and graphically illustrated in Fig.1 for a better comparative relevance.

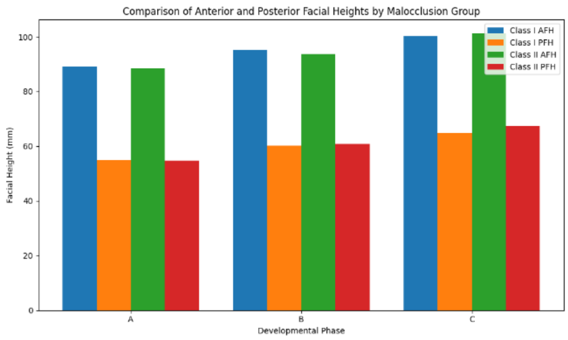

Figure 1. Comparison of Anterior and Posterior Facial Heights

Fig.1 clearly shows changes of the facial and posterior face dimensions along the three developmental phases.

Table 1. Mean Facial Heights by Malocclusion Group and Developmental Phase

Group	Phase	AFH (mm) Mean ± SD	PFH (mm) Mean ± SD
Class I	A	89.1 ± 5.3	5.0 ± 4.1
Class I	B	95.2 ± 6.2	60.2 ± 4.6
Class I	C	100.3 ± 6.8	64.9 ± 5.3
Class II	A	88.4 ± 4.2	54.7 ± 3.9
Class II	B	93.6 ± 4.7	60.9 ± 4.8
Class II	C	101.2 ± 5.5	67.3 ± 5.7

Regression Analysis

In Class I subjects, regression models demonstrated strong predictive capacity for both anterior and posterior facial heights.

The upper molar vertical position consistently emerged as the strongest predictor of facial height development across all growth phases, with R^2 values ranging between 0.72 and 0.84 for anterior facial height.

In contrast, Class II subjects exhibited more variable predictive relationships. Dentoalveolar variables demonstrated weaker associations overall, with upper incisor height showing significant predictive value primarily for posterior facial height during later developmental phases (Table 2).

Table 2. Significant Predictors from Regression Models

Group	Phase	Dependent Variable	Significant Predictor	R^2
Class I	A	AFH	U6-PP	0.72
Class I	C	AFH	U6-PP	0.84
Class I	All	PFH	U6-PP	0.55–0.61
Class II	B	PFH	U1-PP	0.63
Class II	C	PFH	U1-PP	0.79

DISCUSSION

The present investigation provides a comprehensive and biologically grounded evaluation of dentoalveolar contributions to vertical craniofacial growth in untreated individuals, offering important insights into the mechanisms that regulate facial height development during active growth. By analyzing longitudinal changes across distinct developmental stages, this study moves beyond static morphological descriptions and instead explores dynamic interactions between dental eruption, skeletal growth vectors, and functional adaptation.

The findings clearly demonstrate that dentoalveolar heights exert a substantial influence on vertical facial growth in Class I subjects [4-7]. The strong predictive relationship identified between upper molar vertical position and both anterior and posterior facial heights supports the concept that posterior dentoalveolar development functions as a key regulator of mandibular rotation and vertical facial balance [15].

From a biomechanical perspective, molar eruption plays a pivotal role in determining occlusal plane inclination, which in turn influences mandibular positioning and rotational patterns during growth [9,10]. As posterior teeth erupt vertically, they effectively modulate the spatial relationship between the maxilla and mandible, guiding mandibular rotation and contributing to the proportional development of anterior and

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posterior facial heights. This mechanism aligns with classical growth theories that describe posterior dentoalveolar eruption as a primary driver of vertical facial dimension regulation [2,3,7].

The predictive strength observed during early and mid-growth stages appears to diminish during the late mixed dentition phase. This transient reduction likely reflects the biological instability inherent to transitional dental periods characterized by exfoliation of primary molars, delayed eruption of premolars, and temporary occlusal disequilibrium [16-18]. During this interval, vertical occlusal relationships undergo continuous adjustment, which may obscure stable correlations between dentoalveolar and skeletal parameters. Once permanent dentition is established, however, the regulatory influence of posterior dentoalveolar structures appears to regain consistency, reinforcing the concept that occlusal stabilization is essential for predictable vertical growth modulation.

In contrast, Class II subjects demonstrated markedly less consistent dentoalveolar influence on vertical facial development. This observation is consistent with extensive literature describing the heterogeneity of Class II growth patterns, which are often characterized by mandibular retrusion, altered functional environments, and variable growth vectors [4,5,7]. In such conditions, skeletal growth direction appears to exert a dominant influence over facial height development, thereby diminishing the regulatory capacity of dentoalveolar structures. Rather than acting as primary determinants of vertical growth, dentoalveolar changes in Class II individuals may function predominantly as compensatory adaptations that attempt to maintain occlusal contact and functional equilibrium despite underlying skeletal discrepancies [5,7,14].

The limited predictive role of molar heights in Class II subjects supports this compensatory interpretation. Posterior dentoalveolar development in these individuals may be constrained by skeletal morphology and mandibular positioning, reducing its capacity to influence overall facial height patterns. Interestingly, the significant association identified between upper incisor height and posterior facial height during later growth stages suggests the presence of adaptive eruption mechanisms aimed at preserving occlusal function [19-22]. Incisor eruption may therefore represent a secondary compensatory response that contributes to vertical occlusal balance when skeletal relationships restrict posterior dentoalveolar regulation.

Collectively, these findings underscore the complexity of interactions between dental eruption, mandibular rotation, and skeletal growth. Vertical craniofacial development should therefore be conceptualized as an integrated biological process rather than the product of isolated structural components [2-8,21,22]. Dentoalveolar structures do not merely respond passively to skeletal growth but actively participate in shaping facial proportions through continuous adaptation to functional and occlusal demands. This reciprocal interaction highlights the dynamic nature of craniofacial growth and reinforces the importance of considering dentoalveolar variables in comprehensive growth analysis.

A major strength of the present study lies in its mixed-longitudinal design and the inclusion of untreated subjects, which allowed observation of natural growth patterns without the confounding influence of orthodontic intervention [23,24]. Such untreated datasets remain relatively rare in contemporary research due to ethical constraints, yet they provide invaluable

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insight into intrinsic growth mechanisms. Furthermore, the balanced representation of Class I and Class II malocclusion enhances the validity of comparative analyses and strengthens the generalizability of the findings.

Nevertheless, several limitations should be acknowledged. The retrospective nature of the study inherently restricts control over data acquisition conditions and limits the availability of functional parameters that may influence vertical growth. Variables such as muscular activity, airway function, and tongue posture were not assessed, despite their recognized role in craniofacial development. Additionally, two-dimensional cephalometric analysis, although widely accepted, cannot fully capture the three-dimensional complexity of dentoalveolar-skeletal interactions. Future prospective investigations integrating three-dimensional imaging technologies, functional assessments, and biomechanical modeling would provide a more comprehensive understanding of the regulatory mechanisms underlying vertical facial growth.

From a clinical perspective, the results have significant diagnostic and therapeutic implications. The strong predictive value of upper molar vertical position in Class I subjects suggests that careful monitoring of posterior dentoalveolar development is essential for early identification of vertical growth tendencies. In contrast, the variability observed in Class II individuals highlights the need for individualized treatment strategies that address both skeletal growth direction and compensatory dental adaptations. Understanding the differential role of dentoalveolar structures across malocclusion types may therefore improve growth prediction accuracy and enhance long-term treatment stability.

In summary, the present findings reinforce the concept that dentoalveolar heights represent a critical component of vertical craniofacial growth regulation. Their influence is particularly pronounced in skeletal patterns characterized by balanced jaw relationships, whereas in malocclusions dominated by skeletal discrepancies, dentoalveolar changes primarily reflect adaptive responses rather than primary growth determinants. These insights contribute to a more nuanced understanding of craniofacial growth biology and support the integration of dentoalveolar analysis into contemporary orthodontic diagnostic frameworks.

CONCLUSIONS

Dentoalveolar heights represent a significant determinant of vertical craniofacial growth, particularly in untreated Class I subjects. The vertical position of the upper molar emerges as the most consistent predictor of facial height development. In Class II malocclusion, dentoalveolar contributions are less predictable, reflecting greater variability in skeletal growth patterns and compensatory dental adaptation.

These findings emphasize the importance of evaluating dentoalveolar vertical relationships during orthodontic diagnosis and highlight their relevance for growth prediction and treatment planning.

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