Circumpubertal growth spurt related to vertical dysplasia

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Estimating the timing of the facial growth spurt is useful in the planning and timing of orthodontic treatment. Fortunately, the period of accelerated growth in the craniofacial skeleton is correlated with discrete maturational events, such as menarche and ossification of the bones of the hands and wrist, as well as with more variable factors, such as the timing of the circumpubertal spurt in stature.[1-4] These correlations are not perfect, however, and predicting this phase of growth is often difficult due to the variation in facial skeletal growth relative to other developmental events. Even within the same individual, growth of different facial dimensions varies considerably relative to the circumpubertal growth spurt.[1] Moreover, the timing of craniofacial growth and its relationship to other developmental events presents a particular challenge in individuals exhibiting extreme variations in facial form.

Frequently, studies relating craniofacial growth and general physical development only report a description of the "average" or "normal" face. In such studies, individuals with severe malocclusions are either excluded from the analysis or it is assumed that the timing and the magnitude of growth of their facial skeletons are comparable to those subjects described as "normal." There is reasonable evidence, however, to indicate that patterns of facial growth in individuals exhibiting extreme variations in facial form or occlusal relationships are not the same as in individuals with normal facial form.[5-8]

Anterior dimensions of the face demonstrate divergent patterns of development in skeletal open bite and deep bite faces.[8] Deep bite subjects are characterized by larger absolute dimensional attainments of upper face height, while open bite subjects have a more pronounced lower face height.

The question arises as to whether these two distinct patterns of facial type demonstrate differences in developmental patterns during the circumpubertal growth spurt. Do the patterns

Abstract

Analysis of deep bite and open bite subjects demonstrates differences in the timing of growth of various vertical facial dimensions. This article was originally submitted April 1988.

Key Words

Pubertal growth spurt • Open bite • Deep bite • Dysplasia

TABLE 1

PERCENT	MALES			FEMALES		
LFH/TAFH	Mean	S.D.	Range	Mean	S.D.	Range
Open Bite	60.5	1.2	59.48/63.24	59.1	2.4	57.62/62.03
Deep-Bite	54.0	1.3	52.34/54.92	57.0	1.2	48.27/55.45

TABLE 2

	PRE-PEAK		PEAK		POST-PEAK	
GROUP	Mean	Sd	Mean	Sd	Mean	Sd
Male Open(MO)	112.2	5.3	120.5	5.9	126.6	6.9
Female Open (FO)	101.1	4.2	108.8	4.7	114.0	4.8
Male Deep (MD)	109.5	6.2	117.2	7.0	122.3	7.7
Female Deep (FD)	100.7	4.9	108.1	5.1	111.8	5.4

Pairwise Comparisons of Facial Types

TIME	MO-FO	MO-MD	MO-FD	FO-MD	FO-FD	MD-FD
PRE-PEAK	**		**	*		*
PEAK	**		**	*		*
POST-PEAK	*		**			*

* .01 < P .1 ** .001 < P < .01

Table 1
Means, standard deviations and ranges of the percentages of lower face height to total face height.

Table 2
Total anterior face height-absolute values at year of maximum growth and three years prior and subsequent to the attainment of peak values.

of facial proportions become progressively accentuated, attenuated, or are they maintained during the most exuberant growth period? The magnitude of dimensional attainments during this period has profound implications for the accuracy of predicting orthodontic treatment results, as well as for determining the appropriate time for initiating orthodontic therapy and deciding on retention procedures.

The purpose of this study is to determine the difference in the timing and rates of growth of the facial skeleton relative to the circumpubertal growth spurt in individuals exhibiting severe vertical dysplasias. Specifically, this paper presents a longitudinal analysis of craniofacial growth in skeletal deep bite and open bite subjects during the adolescent period. Three fundamental questions are addressed:

1. Does the pattern of growth in each of the vertical dysplasias become intensified, attenuated, or demonstrate a constant relationship during the circumpubertal growth period?
2. Is the timing of the adolescent growth spurt different in each of the facial types?
3. How do the vertical facial dimensions continue to develop subsequent to the year of maximum growth?

Materials and methods

A longitudinal sample based on serial lateral cephalometric radiographs of 16 males and 16 females, ages three through 20 years was used.[6] The data were gathered under the auspices of the Child Research Council in Denver, Colorado. All subjects were caucasian and had received no orthodontic treatment.

A sample of 250 individuals was analyzed and 32 subjects were selected to provide four groups representing male and female skeletal open bite and deep bite facial forms. Classification was based on relative lower face height (anterior nasal spine-menton) as a percentage of morphologic face height (nasion-menton). The selection of these subjects was based upon skeletal relationships without reference to clinical evaluation of their occlusions. The individuals analyzed were retrospectively selected based upon lower face height proportions determined at approximately 15 years of age for males and 13 years six months of age for females. Use of these ages for sample selection was based upon the recognized sexual dimorphism in the timing of development.[9-11]

The mean, standard deviation and range of percentage of lower face height to total anterior face height for each group are listed in Table 1. The percentage of lower face height values for the subjects in this study exceeds the values determined by several investigators for characterizing skeletal open bite and deep bite subjects.[12-14]

Serial cephalometric roentgenograms from the selected individuals were traced. Landmarks and planes were then obtained following the description by Krogman and Sassouni.[15] Five vertical linear distances were measured between the following landmarks (Fig. 1): nasion-menton (total anterior face height), nasion-anterior nasal spine (upper anterior face height), anterior nasal spine-menton (lower anterior face height), sella-gonion (total posterior face height), and articulare-gonion (ramal height).

Data were analyzed by graphical and statistical methods to examine individual and group findings. For each dimension in the four groups, the individual absolute and incremental growth curves were plotted. The annual increments covering the three year interval immediately preceding and three years after the peak of the pubertal growth spurt were computed to provide a single average of dimensional attainment during these respective periods. Additionally, the average incremental growth curve for each linear dimension in the four facial-type groups was aligned so that the peak of each group was positioned in the same vertical plane in order to permit a standardized view of the relative circumpubertal changes in each facial dimension.

Multiple studies have demonstrated proportionate growth of vertical facial dimensions in normal control children and adolescents. Our goal was to establish if similar proportionality existed within the vertical dysplasias. As such, issues of proportionate growth within each subgroup were addressed directly and normal controls were not used for such analyses. Intergroup comparisons that were performed were primarily descriptive, demonstrating similarities rather than identifying differences between the groups. Nonetheless, we did perform preliminary intergroup comparisons between the open bite and deep bite groups to evaluate the effects of facial type and sexual dimorphism on circumpubertal development.

The interaction of age and the amount of growth attainment for three years before and after the pubertal growth spurt between open bite and deep bite groups was determined in both males and females using a multivariate analysis of variance (MANOVA). Student's t test using the Bonferroni correction procedure for pairwise comparison was applied to determine the significance of differences between the mean values at a predetermined confidence level of $P<0.01$.

Figure 1

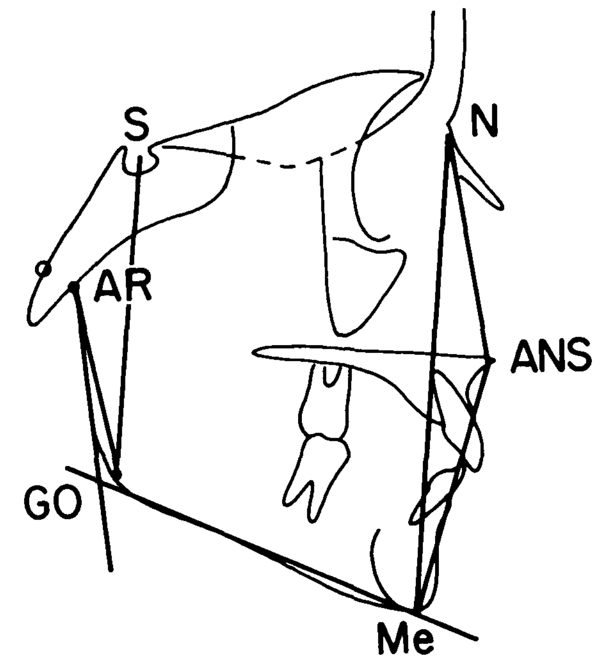

TABLE 3

GROUP	PRE-PEAK Mean	PRE-PEAK Sd	PEAK Mean	PEAK Sd	POST-PEAK Mean	POST-PEAK Sd
Male Open (MO)	46.6	3.2	49.8	3.3	51.5	4.1
Female Open (FO)	42.5	4.6	46.2	4.9	47.8	3.9
Male Deep (MD)	50.7	3.1	54.3	3.2	58.0	4.0
Female Deep (FD)	47.8	3.6	50.9	3.1	51.5	2.8

Pairwise Comparisons of Facial Types

TIME	MO-FO	MO-MD	MO-FD	FO-MD	FO-FD	MD-FD
PRE-PEAK				**	*	
PEAK				**		
POST-PEAK				**		*

* .01 < P .1   ** .001 < P < .01

Figure 1
Cephalometric landmarks and the five linear measurements (N-ME, ANS-ME, N-ANS, S-GO, AR-GO) analyzed in this study.

Table 3
Upper anterior face height-absolute values at year of maximum growth and three years prior and subsequent to the attainment of peak values.

TABLE 4

GROUP	PRE-PEAK Mean	PRE-PEAK SD	PEAK Mean	PEAK SD	POST-PEAK Mean	POST-PEAK SD
Male Open (MO)	67.5	1.8	72.2	2.8	77.9	3.4
Female Open (FO)	61.0	3.1	64.9	3.1	68.2	3.6
Male Deep (MD)	60.3	3.8	63.9	3.2	67.9	6.0
Female Deep (FD)	56.2	1.7	59.1	2.5	61.8	3.1

Pairwise Comparisons of Facial Types

TIME	MO-FO	MO-MD	MO-FD	FO-MD	FO-FD	MD-FD
PRE-PEAK	**	***	***		*	*
PEAK	***	***	***		**	*
POST-PEAK	**	**	**		*	

* .01 < P .1   ** .001 < P < .01   *** P < .001

TABLE 5

GROUP	PRE-PEAK Mean	PRE-PEAK SD	PEAK Mean	PEAK SD	POST-PEAK Mean	POST-PEAK SD
Male Open (MO)	68.3	3.2	74.7	2.3	80.7	2.8
Female Open (FO)	64.2	5.3	70.9	5.5	73.7	6.4
Male Deept (MD)	71.0	3.2	78.5	4.5	82.3	6.7
Female Deep (FD)	64.6	4.8	73.1	8.4	74.5	5.0

Pairwise Comparisons of Facial Types

TIME	MO-FO	MO-MD	MO-FD	FO-MD	FO-FD	MD-FD
PRE-PEAK				*		*
PEAK						
POST-PEAK						

* .01 < P .1

Table 4
Lower anterior face height-absolute values at year of maximum growth and three years prior and subsequent to the attainment of peak values.

Table 5
Total posterior face height-absolute values at year of maximum growth and three years prior and subsequent to the attainment of peak values.

The following comparisons were made:

1. Absolute and proportionate size three years prior to the year of maximum growth between individuals with open bite and deep bite.
2. Comparison of the mean differences between groups during the year of maximum growth.
3. Absolute and proportionate size three years subsequent to the year of maximum growth between individuals with open bite and deep bite.

Results

Dimensional increases in total anterior face height were comparable at each period between open bite and deep bite individuals. The fundamental differences in development were related to pre-peak morphological differences in facial form. Male total anterior face heights were greater than female total anterior face heights at each interval, supporting sexual dimorphism within this dimension (Table 2). There was a trend, although not reaching statistical significance in our small sample, for deep bite individuals to have greater upper anterior face heights than open bite individuals. Upper face heights from deep bite females matched those of open bite males remarkably well at each interval (Table 3). Facial type factors appear to override any sexual dimorphism that might be expected between these groups for upper face height.

Lower anterior face height was the most discriminatory variable between open bite and deep bite between the sexes. For both sexes, open bite subjects demonstrated larger lower anterior face height than deep bite subjects (Table 4). Sexual dimorphism was evident, except female open bite was equal to male deep bite, with facial type overriding sexual dimorphism. The mean values for total posterior face height and ramal length within each sex and type did not differ significantly in each period (Tables 5 and 6).

Because absolute changes may not fully represent proportionate size increase, the percentage change in the various facial dimensions for the six years was computed using the three year pre-peak size of each dimension as a baseline (Table 7). Total anterior face height increased proportionately in male open bite and deep bite. Female deep bite cases demonstrated the smallest proportionate total anterior face height increase, but when compared with female open bite the mean percentage difference for six years did not reach statistical significance. There was no particular pattern of upper face height increase. Male and female open bite groups revealed a larger proportionate increase in lower anterior face height than their deep bite counterparts. Ramal height and posterior face height showed the greatest proportionate increase, but these differences did not reach statistical significance (Table 7).

In general, the differences in proportionate size increases between open bite and deep bite groups were not accentuated during the circumpubertal period. None of the differences in proportionate growth were statistically significant between the groups. The pattern of the face in both open and deep bites was established at least three years prior to pubertal growth spurt and did not change during the adolescent period.

The timing of the adolescent growth spurt for the various facial dimensions in open bite faces was earlier than in deep bite faces (Figs. 2 to 5). Considering the proportionality of growth, underlying factors responsible for the observed differences in the year of maximum growth appear to be related to intrinsic characteristics of each facial form. The patterns of dimensional increase in each facial type affect their maturational level producing different adolescent growth spurt timings.

Correlation coefficients between the year of maximum growth for the five facial dimensions and menarcheal age were examined. The peak age of the pubertal growth spurt for each dimension in the open bite girls was significantly correlated with menarche. However, the deep bite girls showed little correlation between peak growth spurt in facial dimensions and menarche.

Figures 6 to 10 illustrate the rearrangement of the incremental curves with the maximum increment positioned in the same vertical plane. This arrangement demonstrated the differences and similarities between facial form before, during, and after the year of maximum growth of each dimension. The intensity of the adolescent growth spurt in the various dimensions was not obviously related to the tendency for early or late maturing groups nor to sexual characteristics. It appears to have been affected by the specific dimensions within each facial type. The major differences in the incremental curves are manifested subsequent to the year of maximum incremental growth. Each dimension grew variable amounts up to three years after the year of maximum growth. The total face height, upper face height, lower face height, and posterior face height continued to increase three years after the adolescent growth spurt in male deep bites. The lower face height continued to increase in male and female open bite groups. Finally, ramal height continued to increase in the female deep bite group.

TABLE 6

Group	Pre-Peak Mean	Pre-Peak SD	Peak Mean	Peak SD	Post-Peak Mean	Post-Peak SD
Male Open (MO)	40.9	3.1	45.5	3.1	49.4	4.3
Female Open (FO)	36.3	2.3	41.4	3.0	43.3	3.1
Male Deep (MD)	42.0	2.9	46.6	4.1	49.1	2.0
Female Deep (FD)	40.1	3.0	43.9	4.4	45.8	3.5

Pairwise Comparisons of Facial Types

Time	MO-FO	MO-MD	MO-FD	FO-MD	FO-FD	MD-FD
PRE-PEAK	*			**		
PEAK				*		
POST-PEAK	*					

* .01 < P .1 ** .001 < P < .01

TABLE 7

Measure	Male Open Mean	Male Open SD	Female Open Mean	Female Open SD	Male Deep Mean	Male Deep SD	Female Deep Mean	Female Deep SD
Total Anterior Face	13.3	2.9	13.9	3.1	13.2	2.5	11.8	2.9
Upper Anterior Face	13.2	3.2	15.2	4.7	13.5	4.4	10.8	3.6
Lower Anterior Face	13.5	4.2	12.5	5.3	11.7	4.3	9.9	2.9
Total Posterior Face	15.8	1.6	17.7	4.2	18.2	3.0	15.7	4.0
Ramus Length	22.5	7.8	24.1	8.6	23.8	4.4	16.6	5.1

Table 6
Ramal length-absolute values at year of maximum growth and three years prior and subsequent to the attainment of peak values.

Table 7
The percentage increase for the six year interval (three years before and three years after the peak) was computed based on the absolute size of pre-peak corresponding facial dimensions.

Figure 2

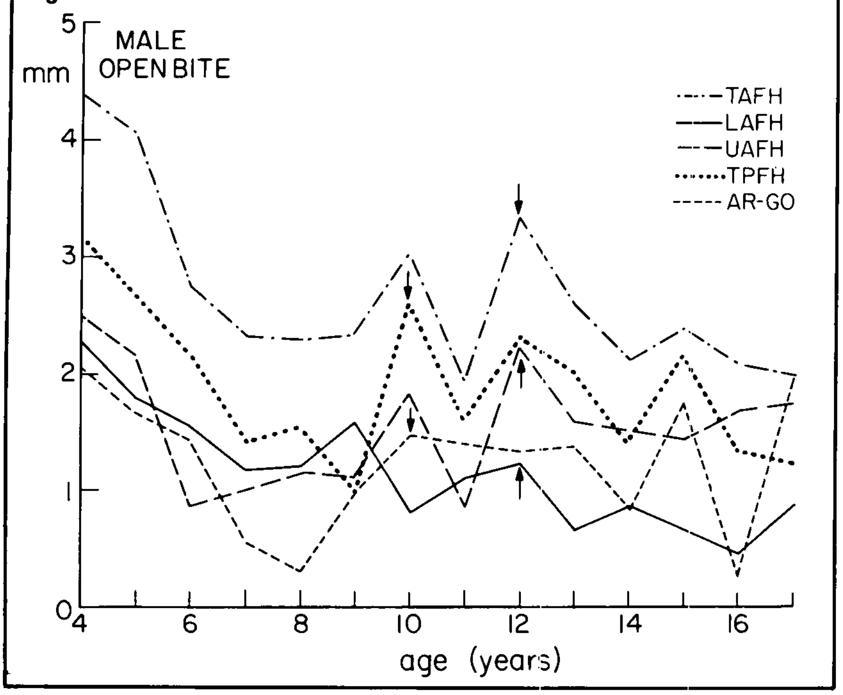

Figure 3

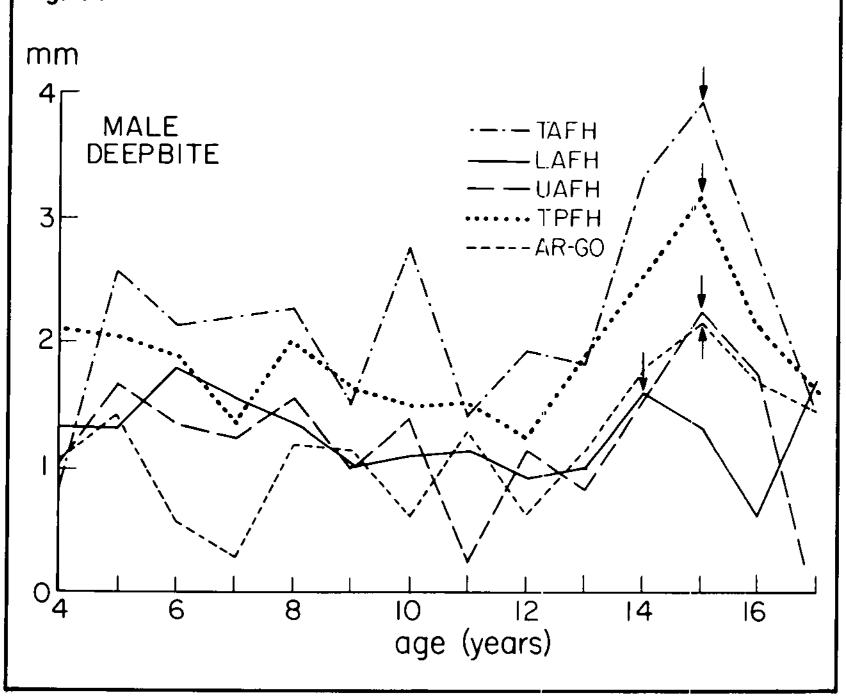

Figure 2
Comparison of timing and magnitude of adolescent growth spurts of five facial dimensions in the male open bite group. The peak velocity of ramal length and components of the posterior face height preceded that of the segments of the anterior face height by two years.

Figure 3
The male deep bite group facial dimensions demonstrate peak velocities shifted to the right (delayed) when compared with the male open bite group.

Discussion

This study suggests that patterns of development as demonstrated by the incremental curves within each vertical dysplasia were established prior to the prepubertal growth spurt. The analysis of the five vertical measures of the face further demonstrated that the relative proportions of the total, upper, and lower face dimensions remained stable within each group during the circumpubertal growth spurt. The larger dimensions remained large and the smaller ones remained small relative to their corresponding pre-peak absolute size. In this respect growth patterns were similar to those expected of children with normal facial patterns.

Male and female adolescents with open bites are characterized by relatively larger lower anterior face heights and relatively smaller upper anterior face heights. In contrast, individuals with deep bites have larger upper anterior face heights and smaller lower anterior face heights. The unequal absolute growth of these anterior facial dimensions during adolescence is necessary to maintain the disproportions inherent in these facial types. On the other hand, the disproportionate absolute increase in posterior dimensions of the face over anterior dimensions may reduce or maintain the severity of a skeletal open bite while accentuating a skeletal deep bite.

Differences in facial form therefore result from fundamental morphologic differences which determine the selective dimensional increase in anterior face height segments. Strong influences of developmental patterns in the two facial forms masked many expected sexual dimorphisms expressed in many other body dimensions.

Patterns generated from alignment of incremental curves along a vertical plane revealed varying growth rates within each facial type and sex, before and after the year of maximum growth. Each facial dimension demonstrated variable growth three years after its year of maximum growth. It becomes apparent that the time required to attain ultimate size of facial dimensions will differ according to facial configuration and sex.

Menarcheal age was strongly correlated with the year of maximal facial growth for each dimension within the female open bite group. However, the failure of deep bite females to show significant correlations between facial maturation and menarcheal age is surprising. This is not in general agreement with findings reported in the literature by Shuttleworth,[9] Simmons and Greulich,[16] and Tanner[17] for timing of menarche in relation to the year of maximum increment of standing height.

It should be noted that the subjects used in this study were never somatotyped. The literature suggests that ectomorph subjects are less advanced in statural attainment at each age, less advanced in skeletal age and later in their timing of adolescent growth spurt when compared to mesomorphs.[9,17-19] Muzj[20] and Shuttleworth[9] associated long and narrow faces ("longilinear") with the ectomorph. The longilinear face approximates the characteristics of open bite subjects. One might therefore expect the maturation schedule of open bite subjects to match that of ectomorph subjects and be relatively delayed. However, the evidence in this study indicates that the open bite groups and by extension, ectomorphs, are earlier maturing groups when compared with deep bite groups. A further possibility is that the observed differences in timing and developmental patterns of the face in individuals with relatively large and relatively small lower face heights might be related to the physical growth of children who are constitutionally tall or short in stature.[21] The tall children are regarded as developmentally advanced, in contrast to children who are small in stature. Perhaps tall stature and open bite faces as well as short stature and deep bite faces may be related in their expression of growth.

The clinical significance of these results can be simply stated. Given variation in facial maturation based on facial type, there are immediate implications for the timing of initiating orthodontic and orthopedic treatment, the direction of forces used and the duration of retention considerations after treatment. For example, open bite patients would benefit from early treatment and force distributions designed to hold, restrict or redirect vertical growth. Given that they also mature earlier, treatment should be initiated at younger ages. Such a protocol is reminiscent of Class III treatment scheduling in that orthopedic treatment may be most appropriately started prior to puberty. Deep bite patients experience later pubertal growth spurts, can be treated later, and often require prolonged retention to ride the wave of continued post adolescent growth. The use of an anterior bite plate during retention may add to the stability of deep bite correction.

Limitations and suggested future studies

This study does not address the accuracy of identifying subjects with skeletal dysplasias at prepubertal ages. Subject identification was based on postpubertal measures with a subsequent retrospective analysis of data culled from

Figure 4

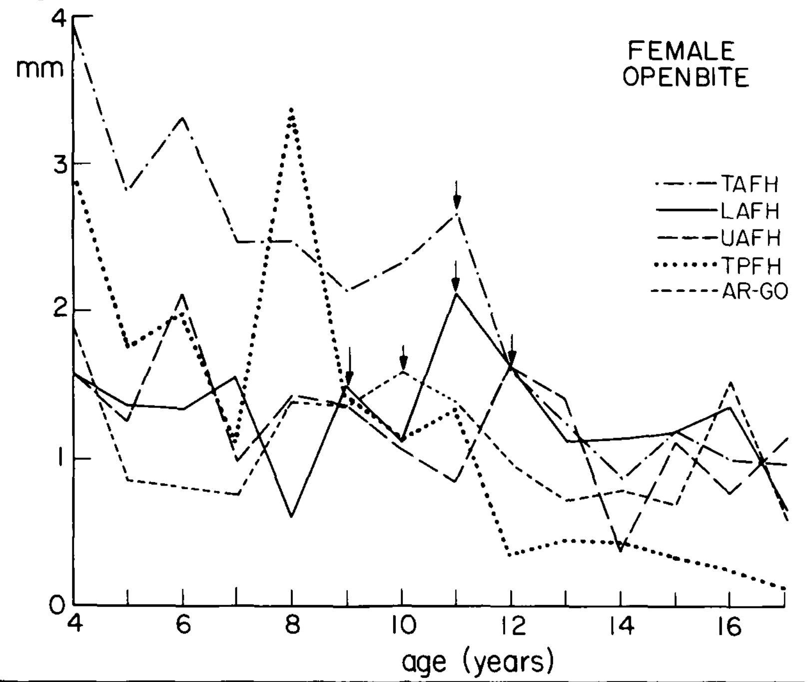

Figure 5

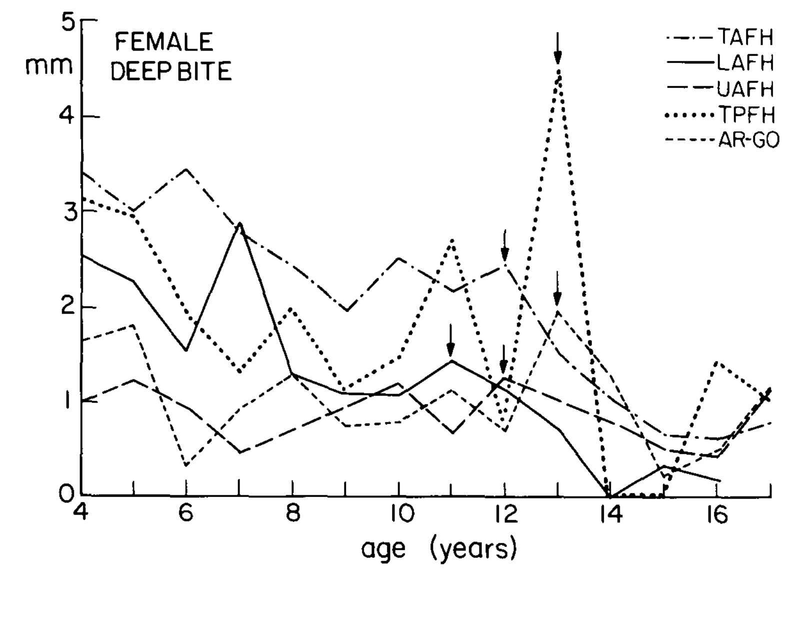

Figure 4
Mean incremental growth curves for the female open bite group. Similar to the male open bite group, peak velocities for the posterior segments preceded those of the anterior face segments.

Figure 5
Incremental growth curves for the female deep bite group. Compared to the female open bite group, the year of maximum increments shifted to the right.

Figure 6

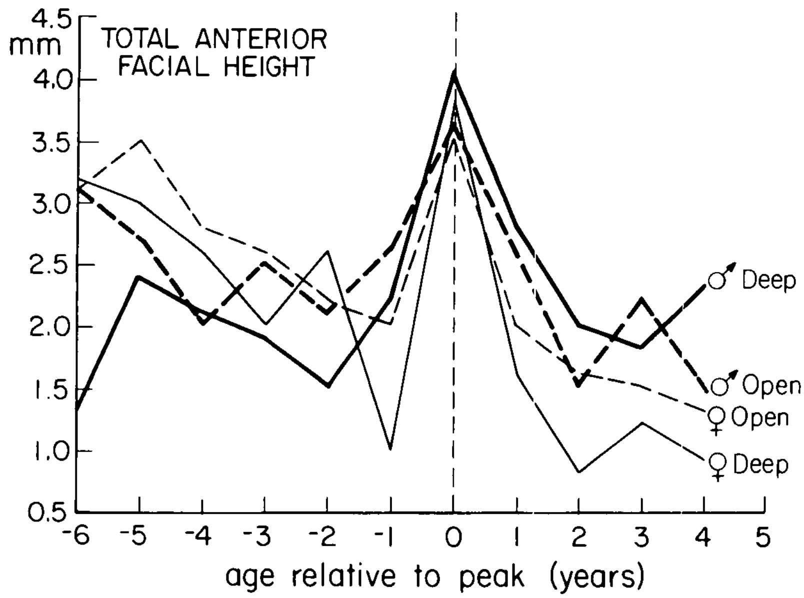

Figure 7

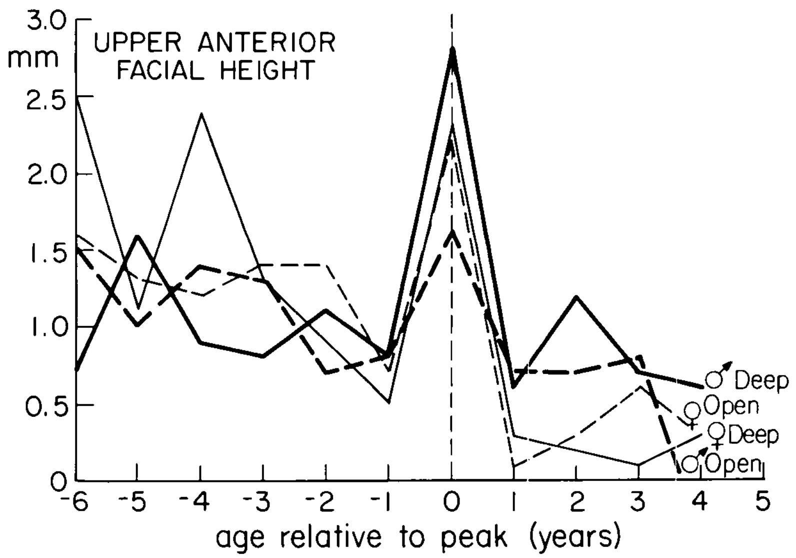

Figure 6
Rearranged incremental growth curves for total anterior face height with the peak for each group in the same vertical plane. Magnitude of the growth spurt is approximately equal within all four groups. Subsequent to the year of maximum growth, the male deep bite group tended to increase even after four years, while the other curves approached their final values.

Figure 7
Incremental growth curves for upper anterior face height arranged similar to Figure 6. Comparing the magnitude of peak velocities for growth increments demonstrates no sexual dimorphism. The female deep bite curve tends to increase four years after the adolescent growth spurt.

a larger longitudinal population sample. A prospective study with prepubertal baseline classification categories would be needed to appropriately test hypotheses of growth prediction.

Similarly, having suggested that implications for timing of treatment result from this study, one must be careful not to interpret the data as aggressively supporting a particular early intervention for vertical skeletal dysplasias. We did not examine the ability of any treatment to alter a growth pattern and as such cannot discern the effectiveness of various modalities on "normalizing" or reversing divergent growth patterns. Moreover, the tendency for patients to outgrow any proposed early treatment was not addressed.

At best, we suggest that early recognition of skeletal patterns is critical to avoid inappropriate, unnecessary and potentially prolonged treatment. However, we do hold out the possibility that the future early identification or detection of skeletal dysplasias and realization of their subsequent proportionate growth could lead to effective early interventions. Clearly, further studies are needed to address these fundamental and topical concerns.

Future studies could also address issues of compensatory morphological changes associated with divergent facial growth patterns such as mandibular and maxillary dentoalveolar height changes. Similarly, soft tissue growth analyses would complement these observed skeletal changes since soft tissue adaptations inevitably serve as the ultimate compensator.

Summary

A longitudinal study of 32 individuals representing male and female open and deep bite was examined to determine the relationship between subjects who are characterized by proportionately large and small lower anterior face heights and adolescent facial growth spurts. Open bite individuals matured earlier than deep bite individuals. Morphologic differences between the groups were maintained during the adolescent growth spurt. Further studies are needed to examine the relationships between adolescent growth spurt to stature and somatotype.

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Figure 8

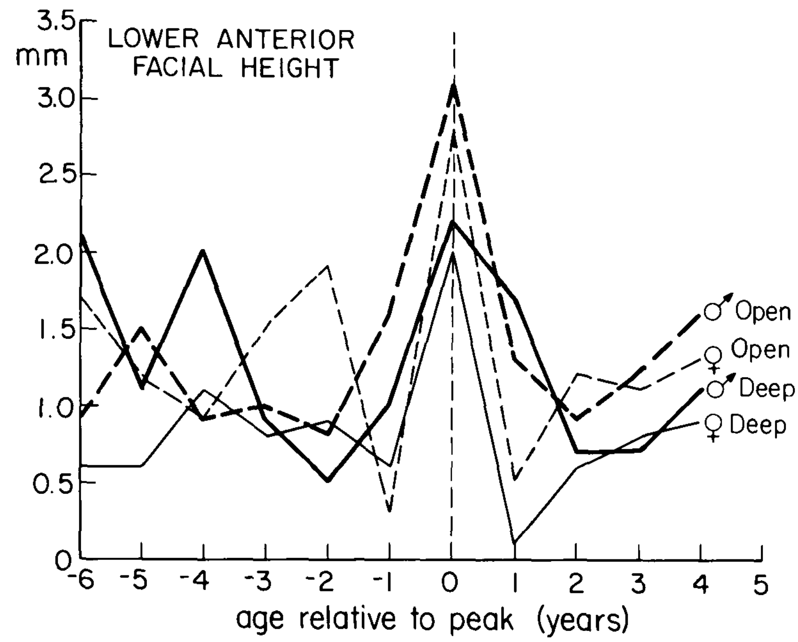

Figure 9

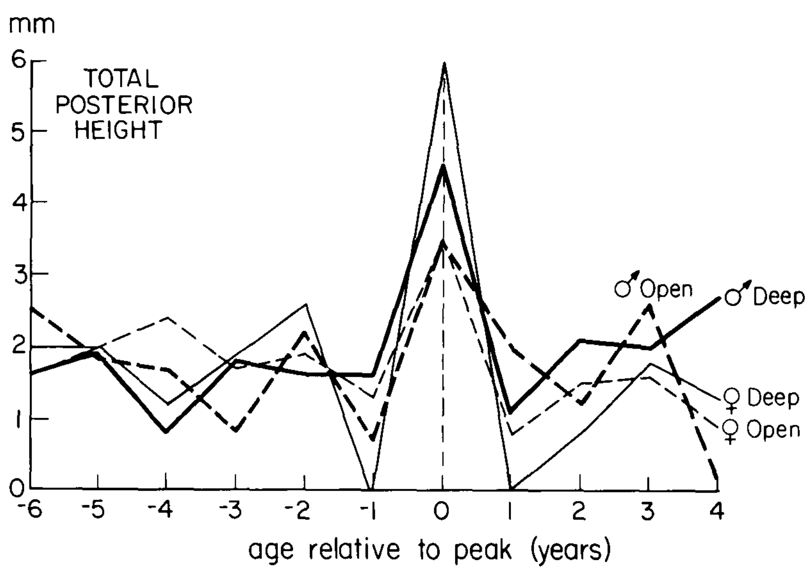

Figure 8
Incremental growth curves for lower anterior face height arranged similar to those in Figure 6. For each sex, incremental curves show typological differences in spurt magnitude. Note that four years subsequent to the year of maximum growth no group curve has leveled off.

Figure 9
The total posterior vertical height in both male and female deep bite groups increased more in comparison to the open bite groups. The male deep bite group tended to increase in this dimension even after four years of adolescent growth spurt.

Figure 10

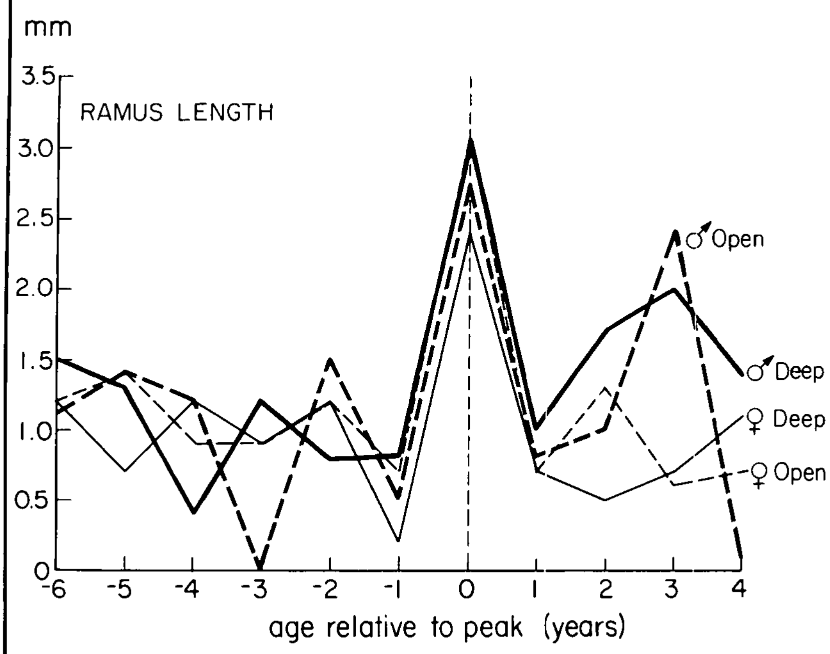

Figure 10
The comparison of the ramal length spurt does not demonstrate any specific order of magnitude either by sex or typology. However, the female deep bite curve continues to increase four years after the year of maximum growth.

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