Original Article

Changes in Dentoalveolar and Facial Heights during Early and Late Growth Periods: A Longitudinal Study

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Abstract: This longitudinal study examined the dentoalveolar structures during early and late growth periods in 62 subjects (26 male, 36 female) with normal facial patterns and acceptable occlusions. Hand-wrist radiographs were assessed and subjects grouped accordingly as either early stage (group 1) or late stage (group 2). Group 1 comprised 30 subjects with skeletal development maturation stages between PP2= and MP3=, H or S. Group 2 comprised 32 subjects with skeletal development maturation stages between MP3u and Ru. Skeletal and dentoalveolar measurements and ratios were assessed at the beginning and end of the observation periods. Differences in measurements and ratios within each group were examined using paired *t*-tests. Differences between the 2 groups were evaluated using Student's *t*-tests. Increases in alveolar heights (except for upper posterior alveolar heights) differed between the groups. Vertical alveolar dimensions increased substantially in group 1 in comparison with group 2. With the exception of upper anterior alveolar heights, all increases in group 2 were statistically significant. As a result of differential growth in alveolar dimensions, lower facial ratio (Co-Go/ANS-Me) and overbite remained constant in both stages. Vertical alveolar growth exhibited regional differentiation according to the pubertal growth periods. Although this growth plays a role in the establishment of normal facial patterns and occlusion, it should also be considered with respect to the treatment and treatment stability of patients showing vertical facial discrepancies. (*Angle Orthod* 2004;75:69–74.)

Key Words: Alveolar height, Longitudinal alveolar growth, Vertical development of the face

INTRODUCTION

Both condylar growth and sutural and alveolar development play crucial roles in the formation of the facial skeleton. Differential growth in these structures is particularly influential in terms of vertical development of facial characteristics. The sensitivity of these structures to mechanical stress or stimuli or both[1–6] provides a basis for functional or orthognathic treatment.

Alveolar structure forms the functional component of jaws and participates in occlusal dynamics by means of the teeth. Alveolar structure plays a compensatory role in establishing sagittal and vertical maxillomandibular relationships.[7–9] Thus, alveolar structure masks skeletal deviations between the jaws.

Longitudinal studies have shown that alveolar growth continues through the fourth and fifth decades of life.[10–12] Forsberg et al[12] have stated that noticeable increases in alveolar heights occur between the ages of 25 and 45 years, with the greatest increase (1.13 ± 0.77) observed in upper anterior alveolar heights (UAAH). There is no doubt that the changes observed at these relatively late ages are adaptive rather than developmental. Therefore, it would not be appropriate to assess these observations in terms of active orthodontic treatment and retention. However, directing dentoalveolar growth is widely accepted as a standard treatment for managing skeletal deviations. Arat et al[13] have indicated that increases in alveolar height vary according to the pubertal growth periods. Experimental[2] as well as clinical studies[14,15] have also shown that the response of alveolar structures to mechanical stimuli varies according to the growth period.

This longitudinal study examines changes in anterior and posterior alveolar heights in early and late growth periods of subjects with normal facial patterns.

MATERIALS AND METHODS

The current study was carried out using cephalometric and hand-wrist radiographs of 62 subjects with normal facial patterns and acceptable occlusions in pre- and post-pubertal growth stages selected from among 78 subjects of an earlier longitudinal study.[13] That study had collected material by following subjects annually for a period of 4 years

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TABLE 1. Hand-wrist Skeletal Maturation Stages[16]

Abbreviation	Maturation Stages
PP2=	Proximal phalanx of second finger: the epiphisis is as wide as its diaphysis
MP3=	Middle phalanx of third finger: the epiphisis is as wide as its diaphysis
S	Ossification of the ulnar sesemoid at the metacarpophalangeal joint of the first finger
Hx	Maximum puberal growth in body height
MP3cap	Middle phalanx of third finger: the epiphisis caps its diaphysis
DP3u	Distal phalanx of third finger: complete epiphyseal union
PP3u	Proximal phalanx of third finger: complete epiphyseal union
MP3u	Middle phalanx of third finger: complete epiphyseal union

to 7 years during puberty. Developmental stages of subjects were determined using the skeletal maturation criteria described by Helm et al[16] (Table 1). On the basis of those criteria, the growth potential of each subject was calculated in percentages using the Greulich and Pyle[17] radiographic atlas.

Subjects were divided into 2 groups according to the following skeletal maturation criteria (Figure 1).

Group 1 (early stages, 30 subjects): Skeletal development of subjects in this group ranged from PP2= through MP3=, H (the hamulus of the hamate) or S. Completion of at least 1 maturation stage within these periods was established carefully for each subject. This group contained no subjects in the MP3Cap period, which corresponds to the peak point of the pubertal growth.

Group 2 (late stages, 32 subjects): Subjects in this group had reached at least MP3u or PP3u stages and were followed to the Ru (radius: complete epiphyseal union) period. This group contained no subjects in the DP3u stage, which belongs to an earlier stage of development.

The average chronological age, skeletal development states, and sex distribution of the subjects are given in Table 2. The reference points, lines, and measurements used in the study are shown in Figure 2.

Statistical method

Paired *t*-tests were used to assess the significance of intragroup differences. Student's *t*-test was used to assess the significance of intergroup differences.

Error calculation

All cephalograms were retraced and digitized by the same investigator 3 weeks after the initial measurements were taken. Standard errors were calculated for all measurements, all of which were found to be within acceptable limits (0.947–0.995).

RESULTS

Table 3 shows intra- and intergroup differences in dentoalveolar and skeletal measurements and ratios. In group 1, the greatest increases (2.02 ± 0.28 mm) were found in lower anterior alveolar heights (LAAH), followed by the lower posterior alveolar heights (LPAH) (1.56 ± 0.26 mm), upper posterior alveolar heights (UPAH) (1.26 ± 0.25 mm), and UAAH (0.85 ± 0.24 mm).

In group 2 (late stage), the greatest increases occurred in UPAH (0.83 ± 0.19 mm, $P < .001$), followed by LAAH (0.45 ± 0.12 mm, $P < .001$) and LPAH (0.51 ± 0.20 mm). No changes were observed in UAAH.

With the exception of UPAH, increases in alveolar heights varied between the groups. Total anterior alveolar heights (TAAH) and total posterior alveolar heights (TPAH) increased in both stages. These increases also varied between the groups ($P < .001$).

In group 1, despite increases in alveolar heights, the TPAH/TAAH ratio remained constant. However, in group 2, because of the remarkable increase in TPAH (1.34 ± 0.21 mm), this ratio increased ($P < .001$). However, the differences between the groups were not significant.

In terms of skeletal dimensions, total anterior and posterior facial heights (N-Me, T-Go) increased by 4.35 ± 0.57 mm and 3.83 ± 0.42 mm ($P < .001$), respectively, and the total facial ratio (T-Go/N-Me) also increased ($P < .05$) in group 1. Increases in anterior and posterior facial heights (1.21 ± 0.21 mm, 1.92 ± 0.30 mm) and in total facial ratios continued in group 2.

Although the increase in total facial heights (N-Me, T-Go) varied between the 2 groups ($P < .001$), increases in the Jarabak ratio were found to be similar.

Lower anterior facial height (ANS-Me) increased during both stages (2.25 ± 0.33 and 0.74 ± 0.21 mm). These increases were compensated by increases in the ramal height (Co-Go) (1.58 ± 0.56 and 1.29 ± 0.41), and thus, the Co-Go/ANS-Me ratios remained unchanged.

Symphysis heights increased noticeably during both stages ($P < .001$), with greater increases occurring in group 1 (2.01 ± 0.27). However, no changes occurred in symphysis width. As a result, the symphysis ratio decreased over both periods.

DISCUSSION

The vertical and sagittal relationship of the jaws is not always perfect. In cases where imperfections exist, the relationship between the jaws is secured through the eruption and positioning of the teeth along their own basal arches.

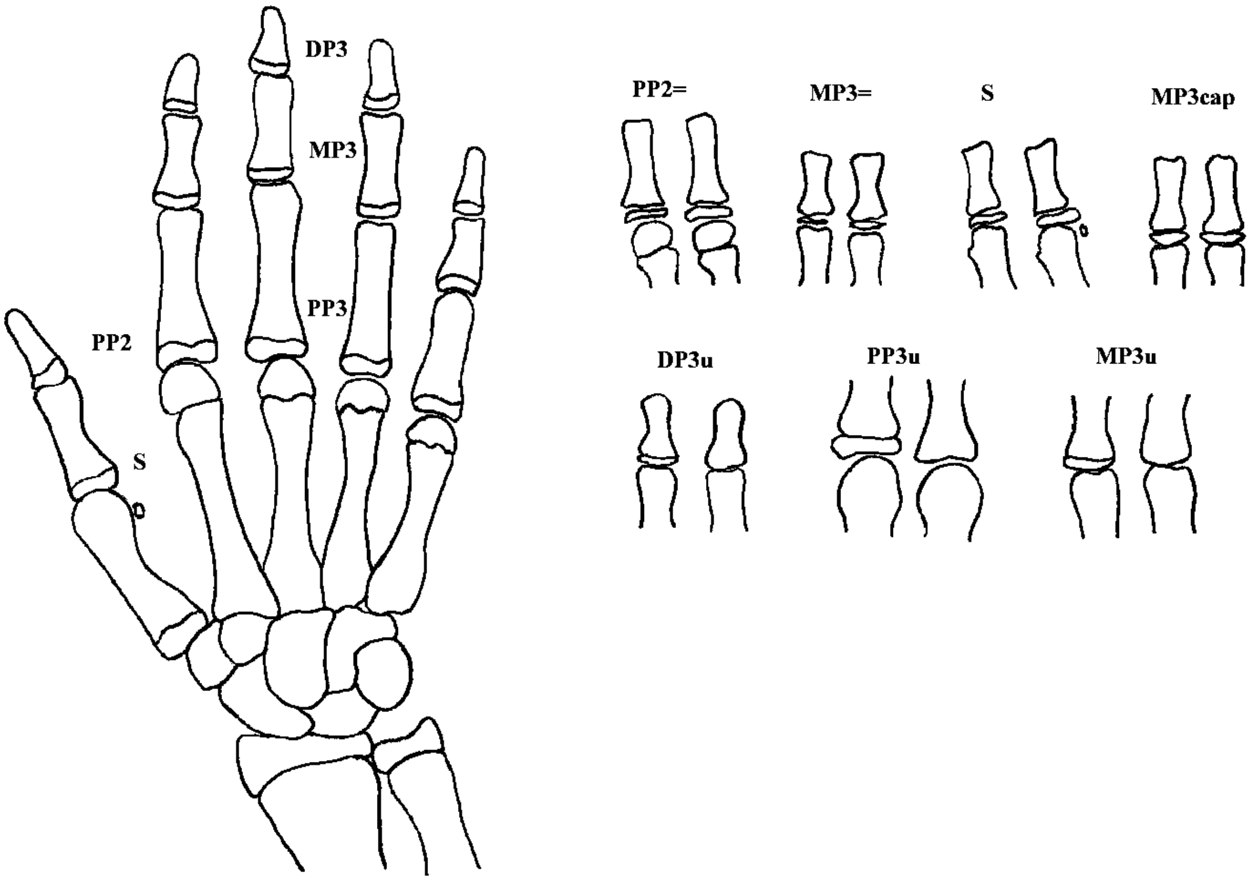

Figure 1. Before and after attainment of skeletal maturation stages.[16]

TABLE 2. The Mean Chronological Ages, Growth Potential, Skeletal Maturation Stages, and Sex Distribution of the Subjects at the Beginning and End of Observation Periods

	Group 1 (Early Stage) n = 30 (7 Female + 23 Male)		Group 2 (Late Stage) n = 32 (29 Female + 3 Male)	
	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$
Chronological ages	10.27 ± 0.24	12.09 ± 0.02	14.98 ± 0.13	16.75 ± 0.15
Growth potential (%)	80.01 ± 0.52	86.34 ± 0.58	98.50 ± 0.11	99.61 ± 0.06
Skeletal maturation stages	PP2	MP3, H, S	MP3u, PP3u	Ru

This process is referred to as the ‘‘dentoalveolar compensatory mechanism.’’[7] Compensatory adaptations of this type have been discussed in the literature.[8,9,18,19] When this compensation is obstructed for any reason, a skeletodental malocclusion occurs.[7,20,21]

The dentoalveolar structure plays a significant role in treatment of malocclusions. In particular, vertical skeletal discrepancies (open or overbite) are generally treated by either stimulation or inhibition (or both) of vertical development of the dentoalveolar structure.[15,20,22] Despite this, studies of the development of dentoalveolar structure are quite rare in the literature[23,24] and have been mainly conducted using relatively older subjects.[10,12] Awareness of the differential growth in the alveolar structure, particularly during the period in which functional or orthognathic treatment is generally carried out, can be of significant benefit.

Subjects in this study had normal facial patterns and occlusions. Because only subjects with normal dentoalveolar growth were considered, this study can be expected to provide a basis for the examination of cases with skeletal deviations and, therefore, compensatory alveolar growth.

This study undertook a longitudinal examination of vertical alveolar development during early and late stages of growth. Rather than chronological age, skeletal maturation was used as the criteria for determining developmental stage. Subjects in both group 1 and group 2 were examined over a period of 2 years. As seen in Table 3, group 1 showed significantly greater increases in growth (6%) than

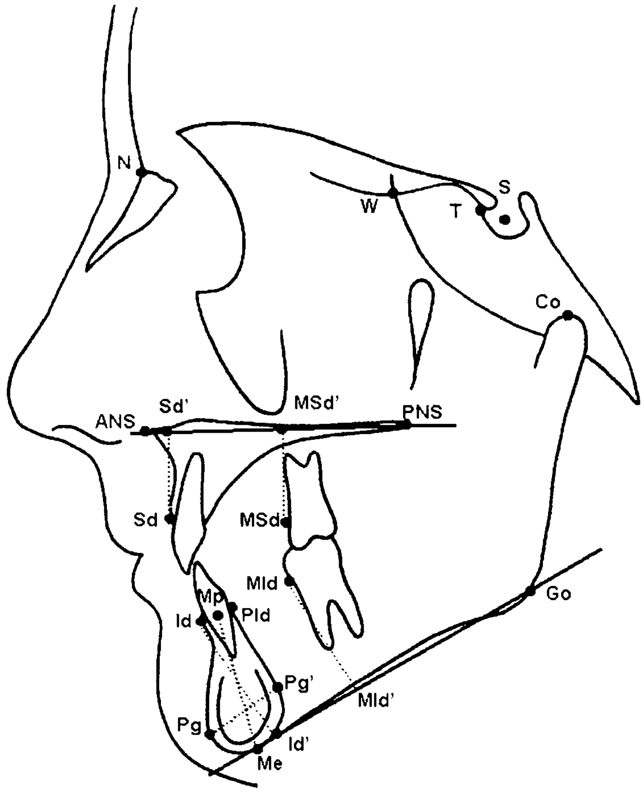

FIGURE 2. The reference points, lines and measurements. Reference points: N, nasion; T, tuberculum sella; W, the point where the middle cranial fossa is intersected by ala major of the sphenoid bone; A, point-A; ANS, anterior nasal spine; PNS, posterior nasal spine; Sd, supradental point; Id, infradental point; PId, posterior infradental point; Mp, midpoint of Id and PId; B, point-B; Pg, pogonion; Pg′, the most pronounced point of posterior contour of the symphisis; Me, menton; Go, gonion; Co, condylion; MSd, supradental point of upper first molar; MId, infradental point of lower first molar; Sd′, projection point of Sd to ANS-PNS; Id′, projection point of Id to Go-Me; MSd′, projection point of MSd to ANS-PNS; MId′, projection point of MId to Go-Me. Alveolar measurements and ratios: Sd-Sd′, upper anterior alveolar height (UAAH); Id-Id′, lower anterior alveolar height (LAAH); MSd-MSd′, upper posterior alveolar height (UPAH); MId-MId′, lower posterior alveolar height (LPAH); symphisis height, Mp-Me; symphisis width, Pg-Pg′, TPAH/TAAH, posterior/anterior alveolar heights ratio; UPAH/TAAH, upper posterior alveolar/total anterior alveolar heights ratio; LPAH/TAAH, lower posterior alveolar/total anterior alveolar heights ratio; CoGo/ANS-Me, lower facial heights ratio.

group 2 (1%). It is most likely that earlier studies did not capture these differences because they used chronological age rather than developmental growth as criteria to differentiate between subjects.

Previously published studies have usually examined alveolar heights in connection with lower facial heights and open or overbite. Despite contradictory results,[25,26] one point commonly agreed on is that posterior alveolar heights are greater in long-faced subjects.[27–31] Although these studies considered anterior facial lower heights (LAFHs) as absolute values, it was indicated that the ratio of the lower facial height to the upper facial height (LAFH/UAFH) or total facial height (LAFH/TAFH) would more appropriately describe the vertical deviations of the face.[31,32] However, this ratio cannot suffice to describe vertical facial patterns.

Facial height, particularly LAFH, is well known to be a result of the interplay between condylar growth and sutural and alveolar development.[19,33–36] Therefore, along with anterior facial heights, posterior facial heights should also be taken into account in defining vertical characteristics of the face, with the use of posterior/anterior facial height ratios rather than absolute values more appropriate in determining facial patterns.

A similar approach should also be taken to alveolar heights; ie, it is the ratio between anterior and posterior alveolar heights that affects lower facial height. Accordingly, this study considered alveolar heights in terms of both absolute and proportional values. Beckmann et al[37,38] used area measurements (midsagittal cross-sectional area) and maxillomandibular alveolar index (depth-height ratio) to investigate the relationship between alveolar structure and overbite. This approach brings a wider view to the examination of alveolar structures.

This study found much greater increases in alveolar dimensions during the early stage compared with the later stage of growth. At the same time, with the exception of UAAH, all increases in the late stage were found to be statistically significant (Table 3). In this study, the late stage corresponded to the final phase of pubertal growth and comprised subjects between the ages of 15 to 16.75 years. Despite the smaller changes (1%) in alveolar structure observed during the late stage, they should still be taken into consideration in terms of treatment possibilities as well as treatment stability.

Except for UPAH, increases in alveolar heights varied between the groups. Differences were greatest in the lower anterior and posterior regions. UAAH also showed slight differences between the groups, whereas no significant differences were observed in UPAH. UPAH is an important criterion in the formation of vertical facial patterns.[27,30,31,39] Control of UPAH is often advised in the treatment of open-bite cases.[15,40] The increases in UPAH observed in the late stage can be considered as advantageous with respect to treatment at this stage. However, for early stage treatment, increases in UPAH should be taken into consideration with respect to treatment stability.

Increases in UAAHs remained limited in group 1 (0.85 ± 0.24 mm) and almost no increases were observed in group 2. However, remarkable increases occurred in LAAHs during both stages. Accordingly, symphyseal heights also increased. Naumann et al[24] have indicated that increases in the lower alveolar heights play a crucial role in the development of overbite. Arat et al[15] have shown that open-bite cases treated with an activator resulted in increases in alveolar heights during both early (2.2 mm) and late (1.8 mm) stages. In light of these findings it can be said that LAAH, particularly in the early stage, plays an impor-

TABLE 3. The Results of Paired and Student's *t*-Tests

Parameters	Group 1[a] (Early Stage) n = 30				Group 2 (Late Stage) n = 32				Test
	D^{test}	±Sd	Min	Max	D^{test}	±Sd	Min	Max	
UAAH	0.85**	0.24	−2.34	3.91	0.05	0.16	−2.25	1.80	*
UPAH	1.26***	0.25	−1.08	4.90	0.83***	0.19	−0.97	4.19	NS
LAAH	2.02***	0.28	−1.77	5.90	0.45***	0.12	−1.00	1.65	***
LPAH	1.56***	0.26	−0.42	4.59	0.51*	0.20	−4.14	2.05	***
TAAH	2.87***	0.47	−4.11	7.33	0.50*	0.22	−2.30	2.70	***
TPAH	2.82***	0.38	−0.88	7.57	1.34***	0.21	−3.88	4.72	***
TPAH/TAAH	0.01	0.01	−0.11	0.21	0.02**	0.01	−0.04	0.07	NS
UPAH/TAAH	0.01	0.01	−0.04	0.10	0.01**	0.00	−0.03	0.08	NS
LPAH/TAAH	0.00	0.01	−0.07	0.11	−0.00	0.00	−0.07	0.06	NS
Overbite	0.08	0.14	0.96	1.27	−0.02	0.10	−1.38	1.33	NS
N-Me	4.35***	0.57	0.51	13.05	1.21***	0.21	−1.15	3.61	***
T-Go	3.83***	0.42	−10.33	8.57	1.92***	0.30	−3.57	6.46	***
T-Go/N-Me	0.01*	0.00	−0.04	0.06	0.01**	0.00	−0.02	0.05	NS
Co-Go	1.58**	0.56	−4.76	6.47	1.29**	0.41	−3.37	7.80	NS
ANS-Me	2.25***	0.33	−0.75	6.40	0.74**	0.21	−1.67	3.01	***
Cd-Go/ANS-Me	−0.00	0.01	−0.09	0.06	0.01	0.01	−0.09	0.12	NS
Symphysis height	2.01***	0.27	−1.44	5.68	0.58***	0.15	−0.69	2.99	***
Symphysis width	0.31	0.16	−1.63	2.46	0.10	0.09	−0.96	1.60	NS
Symphysis ratio	−0.03***	0.01	−0.12	0.06	−0.01	0.00	−0.05	0.04	**
Growth potential (%)	6.32***	0.53	1.90	12.30	1.11***	0.10	0.10	2.60	***

[a] D indicates mean of differences; Sd, standard error of mean differences; NS, not significant.
* $P < .05$; ** $P < .01$; *** $P < .001$.

tant role both in the development and treatment of open or overbite.

This study found that increases in posterior alveolar heights (UPAH, LPAH) were balanced by increases in anterior alveolar heights in the early stage, and thus the UPAH/TAAH ratio remained unchanged. Nonetheless, because of increases in UPAH observed in the late period, the UPAH/TAAH ratio increased. During this differential growth in the alveolar structure, the lower facial ratio (Co-Go/ANS-Me) did not change, the total facial ratio (T-Go/N-Me) increased, and the overbite remained unchanged in both groups.

Because this study was carried out on subjects with normal facial patterns and normal overbites, it is not surprising to find a balance between alveolar and skeletal growth. However, the results of our study will provide a basis for the assessment of subjects with vertical discrepancies.

SUMMARY AND CONCLUSIONS

Vertical alveolar dimensions showed substantial increases in the early stage of pubertal growth. With the exception of UPAH, increases in alveolar heights differed between the groups. In the early stage, the highest increase occurred in the LAAH and the least was observed in the UAAH. Despite increases in alveolar heights, the TPAH/TAAH ratio did not change. In the late stage, whereas a substantial increase occurred in UPAH, no change was observed in UAAH. Subsequently, a small increase was observed in the TPAH/TAAH ratio. Differential alveolar development was balanced by an increase in facial heights during both growth stages. Thus, total facial ratio (T-Go/N-Me) increased but lower facial ratio (Co-Go/ANS-Me) remained stable. Increases observed in UPAH were balanced by increments of LAAH, so that overbite did not change.

Vertical alveolar development exhibits regional differentiation during pubertal growth. These changes are crucial for establishing normal occlusal relations. They should also be taken into consideration with respect to the treatment and the stability of the treatment of vertical discrepancies. Because of the differential alveolar growth, treatment of vertical deviations should differ in early and late stages of growth.

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