Facial growth during adolescence in early, average and late maturers

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Adolescence is a period during which the rate of growth accelerates, reaches a peak velocity and then decelerates until adulthood is achieved. This pattern can be found in all individuals but there are marked individual variations in the initiation, duration, rates and amount of growth during this period of life. In certain individuals, physiologic development proceeds rapidly and the entire pubertal growth period is short; in others, it is sluggish and occupies a much longer time.[1-3]

Many studies have shown an association between peak velocity of facial growth and peak velocity of statural growth during puberty.[4-7] Previous investigations have demonstrated that the pattern of mandibular growth coincides with increases in body height in adolescents.[8,9] Others have found that maximal craniofacial growth occurs slightly later than maximal statural growth.[10,11] It has also been demonstrated that during the adolescent growth spurt, the rates and magnitudes of growth are different in those who mature early and those who mature late.[12]

Numerous investigators[13-20] have shown that human development is best represented by stages of skeletal maturation rather than by chronologic age. This can be accomplished by using stages in the ossification of bones of the hand and wrist as indicators for the assessment of skeletal maturation. Using such indicators, a relative stage of maturity can be determined for a child by comparing the child's hand-wrist radiographs against known standards of skeletal development.[16,21,22]

Fishman developed a system of skeletal maturation assessment (SMA) based upon skeletal maturity indicators (SMIs) demonstrated on hand-wrist radiographs for the assessment of the pubertal growth spurt.[14,17,18] This sequence of events pro-

Abstract

The relative stage of maturity of a child may be determined by comparing the child's hand-wrist radiograph to known standards of skeletal development. Hand-wrist radiographs of 70 adolescents were used to categorize the individuals by skeletal maturation into early, average and late maturation groups using the Fishman SMA method of assessment. The rates of mandibular and maxillary growth relative to the last stages of the pubertal growth spurt were measured. Statistical evaluation of the data was performed using an analysis of variance. The magnitude of change in growth increments of the mandible was greater in the late maturers than in the early or average maturers. Incremental differences in growth between the maxilla and mandible during the last stages of puberty were noted, with the mandible growing significantly more than the maxilla.

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Key Words

Hand-wrist radiograph • Skeletal Maturity Indicator (SMI) • System of Skeletal Maturation Assessment (SMA) • Stages of Maturation (SMI 1-11) • Levels of maturation (Accelerated, average, delayed)

Table I
Skeletal Maturation Indicators (SMI)

SMI Level	Stage of skeletal development
	Epiphysis as wide as diaphysis
1	Third finger-proximal phalanx
2	Third finger-middle phalanx
3	Fifth finger-middle phalanx
	Ossification
4	Adductor sesamoid of thumb
	Capping of epiphysis
5	Third finger-distal phalanx
6	Third finger-middle phalanx
7	Fifth finger-middle phalanx
	Fusion of epiphysis and diaphysis
8	Third finger-distal phalanx
9	Third finger-proximal phalanx
10	Third finger-middle phalanx
11	Radius

Table II
Sample distribution by SMI, size, gender and chronological age

Group	SMI	Sample size	Male	Female	Age Range
I	8-11	20	10	10	11.951 - 20.857
II	9-11	22	11	11	12.376 - 19.629
III	10-11	28	15	13	13.408 - 21.526

Table III
Mean and S.D. values of SMIs 8, 9, 10 11 for both sexes

SMI:	8	9	10	11
Male	15.11 ± 1.03	15.50 ± 1.07	16.40 ± 1.0	17.37 ± 1.26
Female	$13.10 \pm .87$	$13.90 \pm .99$	$14.77 \pm .96$	16.07 ± 1.25

vides a methodological approach for identifying specific maturational stages that cover the entire adolescent period. For example, a close association exists between the age at ossification of the ulnar sesamoid and the age at maximum pubertal growth in body height.[22] It has also been demonstrated that the late stages of adolescent skeletal growth coincide with fusion of the third finger, as described by SMIs 8, 9, 10 and fusion of the radius as identified by SMI 11.[17,18]

The purpose of this investigation was twofold. The primary purpose was to study mandibular growth during the late stages of puberty for early, average and late maturers. The second purpose was to evaluate and compare the anteroposterior growth of the maxilla and mandible during the late stages of puberty. Such information is valuable for craniofacial growth evaluation, growth prediction, treatment and retention planning in orthodontics.

Materials and methods

The material for this investigation was obtained from patients treated at the private practice of one of the coauthors (L.F.) and also from the records of the Orthodontic Department of the Eastman Dental Center. The sample consisted of 34 adolescent females (age range : 11-19 yrs.) and 36 adolescent males (age range: 12-22 yrs.). In order to minimize the effect of orthodontic therapy on facial growth, none of the subjects in the study had been treated with extraction or orthopedic forces such as maxillary headgear therapy. No attempts were made to either stimulate or restrict mandibular growth. The subjects were selected based on their correlation with specific stages of pubertal growth using Fishman's Skeletal Maturity Indicator (SMI) standards (Table I).[17,18]

To evaluate the rate of maxillary and mandibular growth during the last stages of adolescence, 70 patients were divided into three maturation groups representing progressively later stages of maturation (SMI 8-11, SMI 9-11 and SMI 10-11), as indicated in Table II. The female and male individuals were combined into one group since previous studies based on the system of skeletal maturation assessment (SMA) demonstrated no significant differences between the sex groups, relative to percentages of completed total growth at comparable stages of maturation.[17,18]

Each of the three groups were divided into three levels of maturation sub-groups: early, average and late maturers. The method used to subdivide the three groups was based on individual chronologic age values plotted against the individual's SMI stage of maturation.[17] Values that deviated more than one standard deviation from mean values were designated as either early or late maturers. Individuals who did not deviate more than one standard deviation from standard mean values were considered average maturers.

Hand-wrist and lateral cephalometric radiographs were available for each individual in the study at the different SMI levels of late pubertal growth, beginning with SMI 8-11, SMI 9-11 and SMI 10-11 respectively. All records were taken pre- and post-orthodontic treatment. Table III illustrates the mean and standard deviation of chronologic age values for male and female SMI stages 8, 9, 10 and 11.[17]

All cephalometric radiographs were traced and six linear measurements were recorded on each film, as illustrated in Figure 1: Sella-Point A (S-A), Articulare - Point A (Ar-A), Sella -Gnathion (S-Gn), Articulare - Gnathion (Ar-Gn), Articulare -Gonion (Ar-Go), and Gonion - Pogonion (Go-Po).

Because of the relatively small sample size, the linear measurements were recorded in millimeters and the increments were represented in percentage change values. All increments for each group were statistically analyzed using Analysis of Variance (ANOVA) at the 5% probability level.

Results

The results of Group I demonstrated statistically significant growth differences between the sub-groups (Figure 2). Late maturing individuals demonstrated larger growth increments in all mandibular and maxillary measurements as compared to average and early maturing individuals. When comparing growth increments of average maturers and early maturers, the results show a difference between these sub-groups. The average maturing individuals demonstrated slightly larger growth increments in all mandibular and maxillary measurements than early maturing individuals. It should be noted that these differences were not as great as they were for the late maturing individuals.

The results of group II also showed statistically significant growth differences between late, average and early maturing individuals (Figure 3). The growth increments of the late maturing individuals were greater in all maxillary and mandibular measurements with the exception of one mandibular measurement (Go-Po), which was the same for all the sub-groups. The results of comparing growth increments between average and early maturing individuals were different in this group. The average maturers demonstrated significantly larger growth increments in all mandibular measurements with the exception of Go-Po being the same for all sub-groups. However, there were no statistically significant differences among the maxillary measurements for average and early maturing individuals.

There were also statistically significant differences between late, average and early maturing individuals in Group III (Figure 4). The late maturers showed significantly higher rates of growth in all maxillary and mandibular measurements with the exception of the Ar-Go measurement which increased at the same rate as the early maturers. When comparing average to early maturers in Group III, the growth increments were the same for all measurements with the exception of the Ar-Go measurement which was greater in early maturers than the average maturers.

Growth of the mandible, as measured by increases in S-Gn and Ar-Gn dimensions, was significantly larger than the growth rate of the maxilla as measured by increases in S-A and Ar-A. This growth difference was consistent throughout the late stages of the pubertal growth spurt in late and average maturers with the exception of Ar-Gn measure-

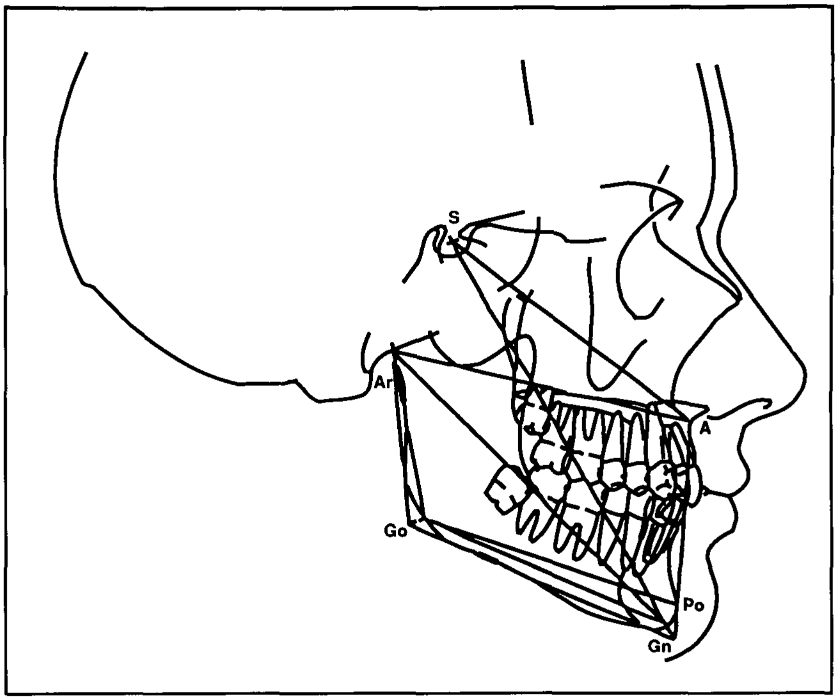

Figure 1

Figure 1
Cephalometric linear measurements used to assess maxillary and mandibular growth increments

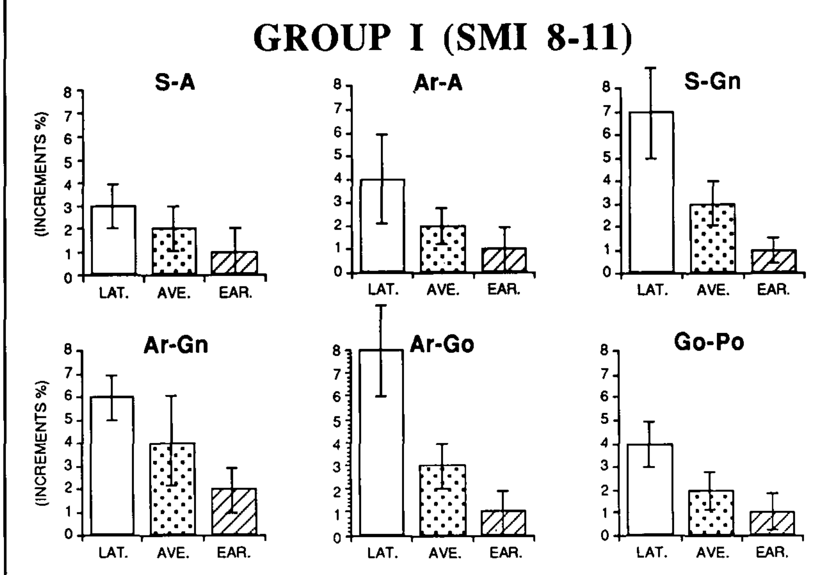

Figure 2 • Incremental differences (Mean ± Standard Deviation) between late, average and early maturers in Group I

Figure 2

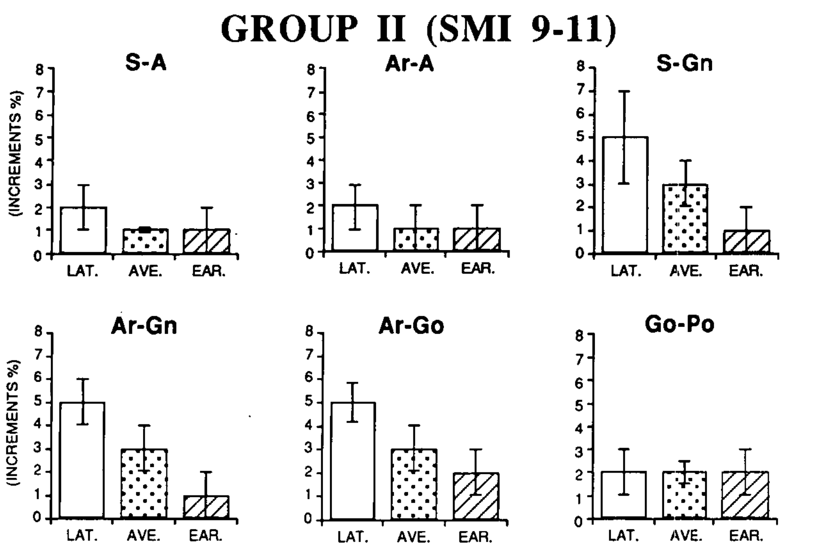

Figure 3 • Incremental differences (Mean ± Standard Deviation) between late, average and early maturers in Group II

Figure3

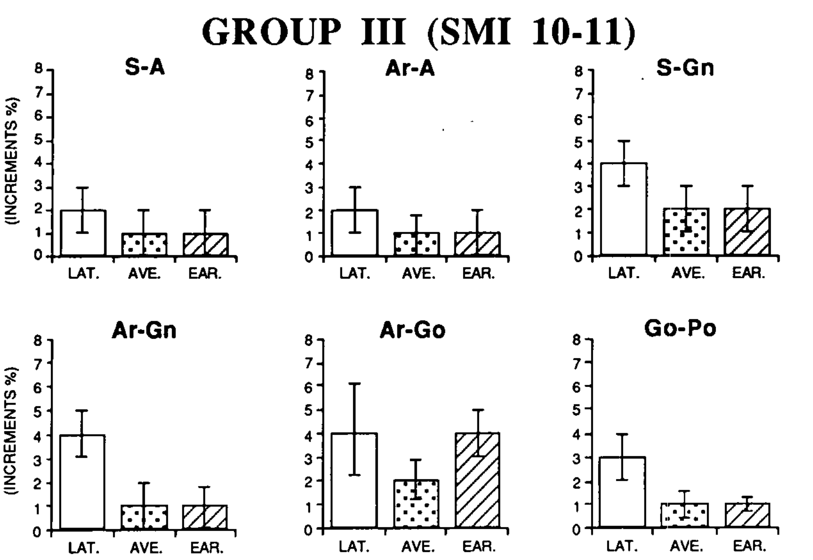

Figure 4 • Incremental differences (Mean ± Standard Deviation) between late, average and early maturers in Group III

Figure 4

ment in Group III (Figures 2, 3 and 4). The early maturing individuals did not show a statistically significant difference between the growth rate of the mandible to the maxilla.

Discussion

The results of the present investigation demonstrated incremental growth differences during the late stages of adolescent development. Individuals who are late maturers demonstrated statistically significant greater growth increments in all mandibular measurements as compared to the average and early maturers in all groups in the study. When the average and early maturers were compared, the average maturing individuals showed significantly more mandibular growth than the early maturing individuals in all groups. The mandibular posterior facial height, as measured by Ar-Go, also demonstrated statistically significantly greater growth in the late maturers as compared to the average and early maturers. However, the same measurements on individuals in Group III (SMI 10-11) did not demonstrate a statistically significant difference between late and early maturers.

Maxillary growth increments were also higher in the late maturing individuals in all groups. However, the growth increments of average and early maturing individuals did not demonstrate statistically significant differences between the sub-groups, with the exception of Group I, which showed larger maxillary growth increments in the average maturers than in the early maturers. One possible reason for this observation was that individuals within Group I (SMI 8-11) had a longer period between pubertal growth events.

The second purpose of this investigation was to evaluate the growth rate difference between the maxilla and mandible during the late stages of pubertal growth. The mandibular growth increments were significantly larger than the growth increments of the maxilla during the late stages of the pubertal growth spurt in the late and average maturers. This difference was consistent throughout the different stages of Fishman's skeletal maturity indicator stages (SMI 8-11, 9-11 and 10-11).

These results concur with previous studies [23-26] that have shown the tendency for the skeletal profile to become less convex during pubertal growth. The chin will tend to assume a more forward position relative to the forehead than the maxillary complex.

The results of this study provide meaningful information for practical application in clinical orthodontics, such as growth prediction, retention, and the timing and efficacy of orthodontic treatment. For example, the time and utilization of extraoral traction forces, functional appliances, extraction versus nonextraction treatment and time of orthognatic surgery are strongly based on growth considerations of the craniofacial complex. If the success of orthodontic therapy lies in the correct timing of treatment, the magnitude of growth changes during late adolescence should be well understood. It is of great importance to obtain a hand-wrist radiograph when treating adolescents as a routine part of diagnostic records.

Conclusions

In conclusion, the findings of the present study demonstrate that the mandibular growth rates of early and late maturers are significantly different during the late stages of pubertal growth. Late maturing individuals showed larger growth increments as compared to average and early maturing individuals. This study supports the findings of other studies, that there is a difference between growth of the mandible and maxilla during the late stages of the pubertal growth spurt. The mandible grew significantly more than the maxilla.

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