A Cephalometric Study of Mandibular Development and Its Relationship to the Mandibular and Occlusal Planes*

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Introduction

The introduction of roentgenographic cephalometrics[1] has enabled orthodontic investigators to conduct longitudinal studies of growth and development. This research tool has also made possible the appraisal of pretreatment dentoskeletal disharmonies, subsequent changes due to growth and development, as well as the effects of orthodontic mechanotherapy.

One of the prime objectives of orthodontic therapy is the achievement of acceptable facial esthetics. The position of the chin in relation to the other components of the facial profile is one of the most critical factors in the appraisal of facial esthetics. Hence, anterior development of the mandible is of great concern to the orthodontist. It is obvious, therefore, that orthodontic therapy which inhibits anterior mandibular movement must be avoided. Therapy stimulating mandibular development is generally desirable.

Many dentoskeletal changes have been reported during orthodontic therapy. Some investigators have reported unfavorable changes in the occlusal and mandibular planes, usually from the use of Class II elastics.[2-7] In some situations, Class II mechanics have also caused an inferior and posterior rotation of the chinpoint.[8,9] Others have noted that orthodontic therapy can alter growth potential, with a resultant inhibition of the anterior movement of the mandible.[10,11]

This study was initiated for the purpose of gaining information about these changes which occur in the mandibular and occlusal planes during treatment. An attempt was made to relate these changes to the anterior development of the chinpoint.

Materials and Methods

The sample used in this study consisted of ninety-nine boys and girls subdivided into three groups: Group I, normal untreated occlusions; Group II, Class I malocclusions; and Group III, Class II malocclusions. Each child was examined by means of two lateral cephalometric roentgenograms.

Group I, normal untreated occlusions

The records of forty-five subjects (twenty-five females and twenty males) were obtained from the files of the Philadelphia Institute for Research in Child Growth. The subjects had been classified by the staff at the Growth Center as possessing normal occlusions. An examination of plaster casts and cephalometric roentgenograms indicated that they met the following criteria: Class I molar relationship, no excessive overbite, no excessive overjet, no excessive crowding or spacing of teeth and no previous orthodontic treatment.

At the time of the initial examination the subjects ranged in age from 8 years to 12 years 5 months. The average observation interval was 39.9 months. The lateral cephalometric roentgenograms

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were taken with a Broadbent-Bolton cephalometer.

Group II, Class I malocclusions

The orthodontic records of twenty-eight subjects (fourteen males and fourteen females) were obtained from the private files of Dr. E. Shapiro, Chairman of the Graduate Orthodontic Department, and of Drs. G. Gales and J. DiStasio, members of the staff. By examination of plaster casts the subjects had been classified as Class I malocclusions. Lateral cephalometric roentgenograms were taken of each subject prior to, and at the completion of, orthodontic treatment. The age prior to treatment ranged from 9 years 4 months to 15 years 4 months. The average treatment period was 30.4 months. The cephalometric roentgenograms were taken with a Margolis cephalometer.

Group III, Class II malocclusions

The orthodontic records of twenty-six subjects (thirteen males and thirteen females) were similarly obtained. The subjects had been classified by examination of plaster casts as Class II malocclusions. Lateral cephalometric roentgenograms of each subject were taken prior to, and after treatment. The ages prior to treatment ranged from 8 years to 13 years 8 months. The average treatment period was 34.9 months.

The reference points and planes used are indicated in Figure 1. The linear and angular measurements employed are illustrated in Figure 2. The linear value (mm) of P-P[1] (pogonial movement) was obtained as follows:

1. Measurement was made on the post-treatment cephalogram.
2. Plane NP was transferred from the original tracing using SN as the plane of superimposition and N as the point of superimposition.
3. Distance of pogonion (mm) after treatment to the line obtained in (2) was recorded.

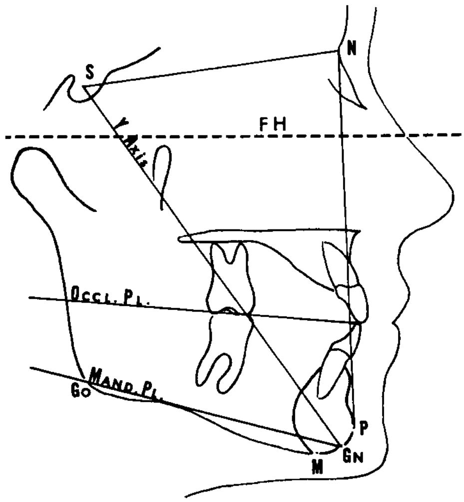

Fig. 1 Reference points and planes employed.

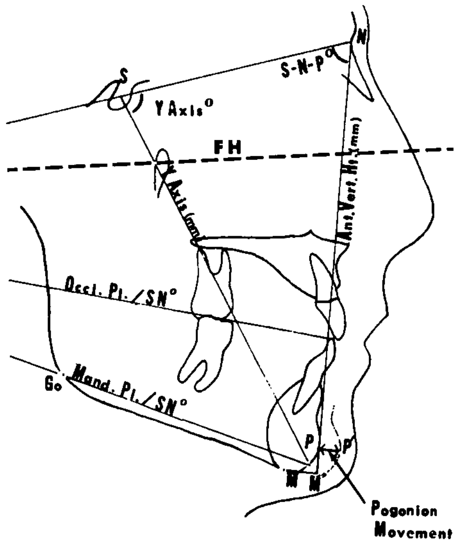

Fig. 2 Linear and angular measurements used.

Fifteen variables were established for each of ninety-nine subjects. A total of 2079 measurements were made on these subjects, after which the measurements were transferred to IBM cards and analyzed at the Boston University Computer Center. Statistical testing of the results was also done at the Computer Center under the supervision of Professor John Alman. The fifteen variables tested were:

1. Initial mean age (months)
2. Observation or treatment span (months)
3. Initial occlusal plane angle
4. Occlusal plane angle change
5. Initial mandibular plane angle
6. Mandibular plane angle change
7. Initial sella-nasion-pogonion angle
8. Sella-nasion-pogonion angle change
9. Pogonion movement (mm)—measured by superimposition of cephalometric x-rays on SN line at nasion
10. Initial Y axis angle
11. Y axis angle change
12. Initial Y axis length (mm)
13. Y axis length change (mm)
14. Initial anterior vertical height (mm)
15. Anterior vertical height change (mm)

Findings

Correlation coefficients were computer-calculated for all measurements; however, they are not included for several reasons. High correlation coefficients may tend to suggest a cause-effect relationship which may or may not exist. Furthermore, the results were tested for statistical significance, and it was reasoned that this was a more valid evaluation procedure.

The findings were evaluated for statistical significance by use of the Dunnett's test,[12] which permits separate comparison of several treatment groups with a control. The Dunnett procedure is as follows:

1. Calculate s = "Mean square within the group tested"
2. Calculate $\phi = Nc + Ne$ where Nc= number of subjects in the control group NcNe where Ne = number of subjects in group tested
3. Calculate s.e. = $s\phi$
4. Calculate

$$t = \frac{\text{Mean difference of control and group tested}}{\text{s.e.}}$$

$$t = \frac{\text{Normal Group—(Group Tested)}}{\text{s.e.}}$$

From Dunnett's tables the critical value of *t* was obtained for males and females at the 1% and 5% levels of confidence. Group II was compared with Group I (Normal) and Group III was compared with Group I (Normal). The results are illustrated in Table I.

Group II (Class I) and Group III (Class II) were subdivided into males and females before Dunnett's procedure was applied, since pooling males and females within a given group would mask any linear and/or angular sex differences. The fifteen variables were tested for both groups with a total of sixty tests. Twenty-two results were statistically significant, seven of which pertained to differences in original ages and observation periods. The remaining fifteen significant findings were related to changes induced by treatment.

The initial pretreatment ages (Variable 1) differed statistically for Group II males and females and Group III males, compared with those in Group I. This finding reflects the inability to closely match the ages of these subjects to those of the corresponding control group. Group III females, however, were almost identical in age composition to their control (Group I) counterpart and the Dunnett test, therefore, showed no statistical difference between those two groups (Table I).

The treatment span (Variable 2) was statistically significant for Group II males and Group III males compared with Group I (Control) males. Group

TABLE I

DUNNETT'S PROCEDURE RESULTS

VARI-ABLE #		GROUP II Males t=	vs. GROUP I Females t=	GROUP III Males t=	vs. GROUP I Females t=
1	Initial Mean Age	26.95**	21.10**	28.82**	.6254
2	Treatment Span	28.00**	20.88**	20.40**	5.45**
3	Initial Occlusal Plane Angle	1.54	.0636	.588	.276
4	Occlusal Plane Angle Change	.217	2.06	1.805	2.19
5	Initial Mandibular Plane Angle	3.00**	.584	.819	.394
6	Mandibular Plane Angle Change	2.06	2.73*	.397	3.80**
7	Initial S-N-Pog Angle	3.116**	.3458	1.53	2.02
8	S-N-Pog Angle Change	2.21	3.31**	1.907	3.22**
9	Pogonion Movement (mm)	.9858	2.759*	.906	2.98**
10	Initial Y Axis Angle	3.16**	.215	1.61	1.535
11	Y Axis Angle Change	.617	3.37**	1.33	4.41**
12	Initial Y Axis (mm)	.1047	.1318	.0958	.046
13	Y Axis Length Change (mm)	.129	.894	.9831	.9731
14	Initial Anterior Vertical Ht. (mm)	6.84**	5.407**	5.318**	3.76**
15	Anterior Vertical Height Change (mm)	.458	.096	1.621	1.16

Critical values for males from Dunnett's tables with 44 degrees of freedom (47-3)
t = 2.29 at .05 level
t = 2.96 at .01 level

Critical values for females from Dunnett's tables with 49 degrees of freedom (52-3)
t = 2.28 at .05 level
t = 2.92 at .01 level

* statistically significant at the .05 level ** statistically significant at the .01 level

II females and Group III females were also statistically significant compared with Group I (Control) females. The statistical significance of Variable 2 measurements reflected the fact that the observation periods were of varying lengths (Table I).

Variable 3 and Variable 4 values were not significantly different for either males or females.

The initial mandibular plane angle (Variable 5) was significant for Group II males compared with Group I (Control) males. This group was the only one that differed significantly from Group I prior to treatment. The value for this group (Group II males) was 36.14°, which was greater than all other Variable 5 measurements. The subsequent mandibular plane angle change (Variable 6) was significant for females in Groups II and III when compared with the value changes in Group I (Control) females. Group II females showed an increase in the mandibular plane angle of 0.357° and the Group III females showed an increase of 1.12°. In direct contrast, Group I females showed a mandibular plane *reduction* of 1.44° during the observation period.

The initial S-N-Pogonion angle (Variable 7) was significant only for Group II males compared with Group I males. The value for this group was 75.39° which was less than the values for the males in Groups I and III.

The S-N-Pogonion angle change (Variable 8) was significant for females in Groups II and III compared with the value changes for Group I females. Group II females showed an increase of 0.10°, and Group III females increased 0.11°. Group I females showed an increase of S-N-Pogonion of 1.7° Therefore, the females in Groups II and III showed a statistically significant *lack* of increase in angle S-N-Pogonion as compared with Group I females.

Pogonion movement (Variable 9) was significant for females in Groups

II and III compared with Group I females. Group I females demonstrated an anterior movement of pogonion of 2.58 mm during the observation period. Group II females showed an anterior movement of pogonion of 0.17 mm during the treatment span, and Group III females showed an anterior movement of pogonion of 0.11 mm during the treatment period. Females in Groups II and III, therefore, demonstrated a statistically significant *lack* of pogonion movement compared with Group II females. There was no significant difference in the pogonion movement of males.

The Y axis angle change (Variable 11) was significant for the females of Groups II and III compared with Group I females. Group II females showed an increase of 0.67°, and Group III females showed an increase of 1.23°. Group I females showed a reduction of the Y axis angle of 0.96°. Females in both Groups II and III showed, therefore, a significant increase (opening) of the Y axis. This was in direct contrast to the Y axis angle decrease (closure) observed in Group I females.

The findings for initial Y axis (mm) (Variable 12) and for Y axis growth (mm) (Variable 13) were not significant. This indicates that the males in Groups II and III were initially similar to those in Group I and that subsequent changes in Groups II and III were not significantly different when compared with the value change in the controls. The females were initially similar and their changes were not significant.

The initial anterior vertical height (mm) (Variable 14) was significant for males in Groups II and III compared with Group I (Control) males as were female values. The values for both males and females in Groups II and III were larger than Group I. Group II males and females and Group III males were initially at least one year older than Group I males and females. Because Variable 14 is a linear measurement during a growth period, it would be expected that the older groups (Groups II and III) would demonstrate larger values. Therefore, the statistically significant findings were not unexpected. In Groups II and III, the values were not significant. This indicated that the changes measured for males and females in Groups II and III were not significantly different compared with value changes for Group I. The males in all three groups demonstrated a greater increase than did the females.

Discussion

The initial motivation for this investigation came from the observation of orthodontists[6,13] that the patients of Dr. Charles Tweed seemed to develop better chins during treatment than did the patients at other offices. Tweed's treatment procedures utilize extensive Class III forces to the mandibular arch in anchorage preparation. These forces result in a reduction or flattening of the mandibular and occlusal plane angles which is considered desirable by most orthodontists (except in Class III malocclusions). The utilization or lack of utilization of Class III forces is a treatment factor under control of the orthodontist. It was reasoned that it would be important, if possible, to establish a definite relationship between the behavior of the occlusal and mandibular planes and the amount of chin development. If a relationship exists, there would be compelling motivation for orthodontists to select mechanotherapy that would favorably influence the behavior of the occlusal and mandibular planes. Excluding Class III malocclusions, a chin (as viewed in profile) that has increased in prominence during treatment generally results in dental and esthetic improvement. It is recognized that the increase in chin prominence noted after orthodontic treatment is often an *apparent* change because of the reduction of a dental protrusion which flattens the middle face.

This investigation was designed to statistically evaluate changes in pogonion during orthodontic treatment compared with such changes in a control group selected for their lack of malocclusion. To exclude relative or apparent changes, the reference for pogonion movement (Variable 9) was selected as line NPog of angle SNPog. This angle was taken from the pretreatment cephalometric x-ray and was transferred to the posttreatment x-ray superimposed at nasion. Posttreatment pogonion (Variable 9) was measured (mm) to the transferred NPog line and recorded as an advance (+) or retreat (—). The anteroposterior movement of pogonion, therefore, was measured relative to nasion and pogonion; it was then evaluated as to its effect on the profile without consideration for changes in the middle face.

In implementing this study it seemed necessary to include other measurements in addition to the occlusal and mandibular plane angles. Angle SNPogonion (Variable 7) and Y axis angle (Variable 10) were selected as indicators of the direction of growth. Y axis length (Variable 12) and anterior vertical height (Variable 14) were used to represent actual growth increments.

In a longitudinal study involving the influence of orthodontic forces on cranial growth, it is necessary to have a nontreatment reference (control) group that has demonstrated harmonious cranial growth. Ideally, subjects that are to be tested against a control group should be matched closely with respect to age, size, and observation period. In this study, however, Dunnett's procedure showed a statistically significant difference in the initial age and treatment span of Groups II and III compared with Group I (Control). This demonstrated the inherent difficulty in clinical studies of closely matching the subjects in the three groups. Groups II and III subjects were generally from twelve to sixteen months older than their Group I counterparts. Group II patients (Class I malocclusions) were treated for a shorter period of time than the Group I children were observed. Group III (Class II malocclusions) males were treated for a shorter period, and females for a longer period than their Group I counterparts. This lack of uniformity within the three groups with respect to initial age and treatment span (Variables 1 and 2) might, at first, seem to lessen the significance of findings for subsequent Variables 3-15. Dunnett's procedure, however, tests only numbers before and after treatment. It does not consider what is important to this study, i.e., growth and growth direction. It is acknowledged that Group I subjects were initially examined at a younger age than those in the two malocclusion groups. However, the initial younger age of the control group was in an age span (10-11) that is not likely to include a growth spurt. They were also observed for a longer period of time; despite a statistical disparity in initial age and treatment span, both males and females in all three groups were tested through the years from ages 11 to 13. These years are generally within the period of pubertal growth, although the growth changes in males may be more pronounced later.[14-17]

The males in the control group were last observed at a mean age of 13 years 4 months. The males in Group II were last observed at a mean age of 13 years 10 months, and the males in Group III were last observed at a mean age of 14 years and 1 month. Thus, Group II males, when last observed, were six months older compared with Group I males; Group III males, when last observed, were nine months older than their controls. This difference could suggest that the results of this study might be influenced because of the growth potential of males in the teenage years. [15-19] This additional growth would not likely change the growth pattern of the males in Groups II and III.[16,19,20-22] It was expected that the linear measurements of Groups II and III males might show greater change than the Group I males. The results of Variable 13 (Y axis length change) and Variable 15 (anterior vertical height change), however, were not statistically significant. It was concluded that this study was not influenced by the 6-9 month older ages of the males in the malocclusion groups. The results of this investigation were, therefore, felt to be valid expressions of the influence of orthodontic treatment superimposed on growth. In particular, the effect of treatment on the anteroposterior position of pogonion with respect to the skeletal profile was believed to be meaningful.

In a pilot study by the authors an apparent correlation was noted between the occlusal plane and the movement of pogonion. In this pilot study an occlusal plane angle that decreased during treatment appeared to develop a more prominent chin. In the current investigation the changes in occlusal plane (Variable 4) of treated cases showed a distinct difference as compared with the control group. Statistical testing of the findings (Variable 4), however, showed that the treated groups were not significantly different from the untreated group. It was, therefore, not possible to establish a meaningful correlation between changes in occlusal plane and positional changes of pogonion.

The behavior of the mandibular plane angle during treatment was striking. Both males and females in Group I demonstrated a reduction of the mandibular plane angle change (Variable 6) during the observation period. In direct contrast, the treated youngsters showed an increase (opening) in the mandibular plane angle; the Group III opened more than II. The linear growths of the Y axis (Variable 13) and the anterior vertical height (Variable 15) were not significant indicating that the amount of growth alone was not responsible for the behavior of the mandibular plane. The findings strongly indicated that mechanotherapy in the females of Groups II and III had inhibited and reversed behavior of the mandibular plane angle demonstrated by Group I.

The findings for mandibular plane angle change (Variable 6) were statistically significant only for the females of Groups II and III; however, the males followed a similar pattern. The difference in response of Group II as compared with Group III is not readily explained. It might suggest that different skeletal patterns respond differently to mechanotherapy, or that the mechanotherapy in the Class I malocclusions may have been different from that employed in the treatment of Class II malocclusions.

The behavior of angle SNPog (Variable 8) also appeared to be altered in Groups II and III. The concept that the mandible becomes more prognathic with growth[18,21,23-25] is borne out by the findings for Group I. The males and females of Groups II and III also become more prognathic during the treatment period, but to a lesser degree than did Group I. Although only the findings for females in Groups II and III were statistically significant, the implication is that mechanotherapy had reduced the increase in prognathism that could be expected without the treatment.

Pogonion movement (Variable 9)

showed a direct contrast between the treated groups and the control group. Both the males and females of Groups I, II, and III showed an advance of pogonion relative to nasion. All of the treated groups, however, showed less pogonion advance than did the untreated group. Although only the values for females proved to be statistically significant (Table I), it seems reasonable to consider that orthodontic treatment had altered the position of pogonion.

The Y axis angle change (Variable 11) followed the same pattern as the mandibular plane angle changes. Groups II and III demonstrated an increase in the Y axis angle after treatment which was in direct contrast to the angular decrease noted in Group I (Control). Once again, the values for females only, in Groups II and III, were significant.

The Y axis length and change (Variables 12 and 13) proved to be nonsignificant statistically.

The anterior vertical height (Variable 14) was statistically significant for Groups II and III. Because this was a linear measurement, it reflected the fact that males of Groups II and III were initially a different size compared with Group I males, and the females of Groups II and III were also a different size, initially, compared with Group I females. The differences can be explained by the fact that Groups II and III were initially older than Group I and would, therefore, be larger. Nevertheless, subsequent changes in Groups II and III during treatment proved to be similar when compared with Group I; consequently, results were not statistically significant.

The most interesting and unexpected finding of this investigation was related to the skeletal changes measured. The findings for males in Groups II and III were similar to those for the females. When the findings were subjected to Dunnett's test, however, not a single significant skeletal change for the treated males, as compared with Group I, was noted. In every instance where Dunnett's procedure showed a significant finding, females were involved. An explanation may be related to the timing and duration of growth differences in males and females. The females in this study were in a period of active growth; some had completed pubertal growth. During this active growth period the influence of therapy on growth direction was established by this investigation. The similarity between the treated males and the untreated males cannot be easily explained. It is possibly related to the prolonged growth period of males past ages 12-13.[17,19,25-27] Furthermore, it suggests that growth in males from ages 11-13 is not nearly as significant as that of the females during the same years.

This investigation suggests that future studies of orthodontic influences on growth should not be designed utilizing males and females of the same chronological age. It is possible to match individuals based on dental maturation but this would be of questionable value, however, as it has been reported that the time of tooth eruption is not related to skeletal maturation.[29,30] In designing such a study it would be more appropriate to compare subjects at the same level of skeletal maturation. This maturation level, as described by Krogman,[14] is the biological or skeletal age of the individual and is the true growth age. This growth age, or maturation level, can be determined by utilization of indices of skeletal maturation as determined by radiographs of the wrist.[31]

Summary

This investigation was designed to study the influence of orthodontic therapy on mandibular growth. It was based upon serial cephalometric radio-

graphs of ninety-nine subjects from ages 10-13. A control group of untreated normal occlusions was established. A group of treated Class I malocclusions was compared, by sex, to the control group. A second group of treated Class II malocclusions was compared, by sex, to the same control group. The findings were tested for statistical significance; they seem to justify the following conclusions:

1. Orthodontic treatment of Class I and Class II malocclusions tended to reverse the normal growth tendency of the occlusal plane angle by increasing instead of decreasing it. This effect, however, was not statistically significant.
2. Orthodontic treatment of Class I malocclusions and Class II malocclusions reversed the normal growth pattern of the mandibular plane angle. This effect was statistically significant for the females in both malocclusion groups.
3. Orthodontic treatment on angle SNPog inhibited the increase in the angle compared with the untreated normal occlusions. Findings in the two malocclusion groups were significant in the females only.
4. In the control group the females showed a greater increase in prognathism than did the males. This is to be expected in subjects aged 10-13. The effect of orthodontic treatment, however, caused an inhibition of the forward movement of pogonion for males and females of the Class I malocclusion and Class II malocclusion groups. The females of both groups showed more inhibition of pogonion than did the males and only the findings for the females were significant.
5. The Y axis angle showed a reduction in the normal occlusion group. The angle increased in the treated groups. Only the findings for females in the Class I malocclusion group were significant.
6. Growth increments along the Y axis and the anterior vertical height change were not statistically significant for males or females in the two malocclusion groups.
7. This study reveals that the response of female patients in the 10-13 age group is different from that of males in the same age span. This may be related to the fact that the females in this study were nearing the end of their growth spurt; however, the males were actively growing, or just beginning their pubertal growth spurt. This explanation is not entirely satisfactory because the growth increments of males and females in both malocclusion groups were not statistically significant compared with the control group. This means the growth increments for the three groups were similar. The males and females in the malocclusion groups were both growing and at a similar rate compared with the control group. The implication is that the response to orthodontic treatment noted in the females, which in this study was more significant than the male response, cannot be fully explained by the concept that the females were in a more active growth period than were the males.
8. In future research an attempt should be made to match the subjects based on their maturation level as determined by radiographs of the wrist, rather than by chronological age.

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