A Cephalometric Evaluation of Fifty-Seven Consecutive Cases Treated by Dr. Charles H. Tweed*

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INTRODUCTION

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The progress of clinical orthodontics has developed rapidly through the short life of our specialty. Such progress is due to accumulated knowledge developed by refinements in appliance techniques and better methods of analysis.

A very popular diagnostic device in current use is the cephalometer. Through the past several years the universities at first and now many in private practice have accumulated a library of cephalometric records on treated cases. There have been several major efforts made to analyze these records.

The first comprehensive cephalometric survey of orthodontic treatment results was written in 1938 by Brodie, Downs, Goldstein, and Myer.[1] The findings reported at that time have served for years to explain expected response to orthodontic forces. Recently, Silverstein[2] presented a report on the effects of treatment on the growth rates of certain bony facial profile areas in Class II, Division I malocclusions. This was compared to untreated Class II, Division I cases. Both of the preceding surveys were made on cases treated by the students in the graduate department of the University of Illinois. Graber[3] reported on a large group of cases treated by using extra-oral forces directed against the maxillary arch. There have been many case reports published demonstrating comprehensive cephalometric analysis of specific change in individual cases. These have been reported by the many fine clinicians whom our profession is proud to possess. We are gradually adding to our concept a cross-sectional survey of the possibilities and limitations of orthodontic treatment.

At the present time, there is little information concerning the varying possibilities of treatment when different types of treatment mechanics are followed. It seems reasonable that useful information could be derived from an assessment of a large number of cases treated in a similar manner by the same individual. We could then compare the results of different treatment methods as well as judge properly whether or not certain clinical procedures will repeatedly produce the same results.

The favorable effect of the orthodontic service on the soft tissue profile has long been recognized. However, the

*Read before the Charles H. Tweed Foundation in Havana, Cuba April, 1955.

specific areas affected within the hard tissue structures which produce soft tissue change are still uncertain.

One of the foremost proponents of controlling orthodontic treatment to change the soft tissue profile is Dr. Charles H. Tweed. Most of his recent writings[4, 5, 6] have repeatedly referred to the possible beneficial effects of his basic concepts on the soft tissue profile.

A great deal of emphasis has been placed by Tweed in his treatment on the position of the lower incisor. Tweed's philosophy originally evolved around a concept of the lower incisor being over basal bone[4]—empirically to begin, gradually being refined through the "plus or minus" equivalents[5] to his present guide of the Frankfort-mandibular incisor angle (FMIA)[6]. As it now stands, nothing has been changed. The lower incisor is still over basal bone, but Dr. Tweed feels that a more accurate system of placing it clinically has been suggested. It is his feeling that, as more is learned concerning the effects of treatment, more refinements in positioning of the incisor can and will be made.

According to the most recent statements of Tweed,[6] the FMIA control has helped him improve the soft tissue profile in a higher percentage of cases. Certainly, it would be well to assess which structures affected by the treatment produced the change in the soft tissue.

Our project was to be a comprehensive survey of the exact nature of change produced by his method of treatment and how that change affected the soft tissue profile.

Through the generosity of Dr. Tweed, complete cephalometric records of fifty-seven consecutively treated cases were sent to us. These cases did not represent any particular type, but were a cross-section of his routine practice. The treatment time varied from five months to twenty-nine months, averaging fifteen months.

Wylie[7] very recently presented his interpretations of treatment changes based on an analysis of twenty-nine of Dr. Tweed's case. His analysis represents a great deal of thought, and in it he takes issue with Tweed concerning the validity of the inclination of the mandibular incisor as the determining factor in the success of Dr. Tweed's treatment. Wylie states that Tweed is more successful in obtaining the kind of facial change he advocates than he is in explaining his own successes. The purpose of this paper is not to take issue with Wylie but to render an impartial and scientific analysis of the changes brought about in these treated cases. We were especially interested in determining how this treatment produced the dramatic changes in soft tissue contour that so often followed Dr. Tweed's treatment.

A great deal of thought must be given to the method of superimposing the before and after radiographic tracings so that they exactly demonstrate the nature of change produced. There should be no distortion of the structures due to growth changes in areas not involved in the treatment. On the cases that Wylie analyzed, he superimposed the tracings on what he called "registration points." These "registration points" were located in three separate areas: - a set of cranial points to record gross changes in growth; maxillary registration points to show changes in and around the maxilla; and a third set of points within the body of the mandible to record changes influenced by treatment or growth in the mandible. There is a great deal of merit in varying the location of superimposition of points to assess changes in a given area. We were primarily interested in the effects of treatment on the soft tissue and the relative change of the teeth to their original position. It was felt by our group that in order to assess soft tissue change properly, we would have to measure the change within the contour of the soft tissue itself. Vertical changes should be made by superimposing radiographs on a point in the same vertical plane to be measured. Hard tissue changes that influence soft tissue should be assessed in such a manner as to demonstrate their effect on soft tissue.

Steiner[8] recently made the following statement in a discussion of his method of case analysis, "All changes in the positions of anatomic parts must be expressed in terms of their relationship to something else. If we desire to record changes due to orthodontic treatment alone, we must offset or at least minimize the records of the changes that are due to growth in the areas we wish to judge."

In keeping with this type of thinking, if we record changes by superimposing the radiographs on the SN plane at sella, we are doing this relative to a cranial plane on a point far removed from the front of the face. For overall growth analysis, this is an excellent way in which to study skeletal change. (Fig. 1). However, to determine how the lower incisor changed relative to the mandible, one would not use this type of superimposition but would superimpose the two mandibles. Does it not seem reasonable, that in order to study change in the profile outline, some method of superimposing the profile outline should be employed? An area unaffected by treatment should be used to relate changes in the treated area. In this study we were interested in the effect of changes on the structures that influenced the front of the face. We, therefore, superimposed the radiographs on the SN plane at nasion. (Fig. 2). By so doing, growth changes unaffected by treatment are minimized. The relative change in parts influenced by treatment is clearly demonstrated. In noting Figure 2 one can now see that point A, relative to the rest of the face went posteriorly. The chin stayed the same and the lips came back, an entirely different inference than might be derived from Figure 1. Changes in soft tissue due to treatment are very clearly demonstrated. Growth changes that influence treatment parts are now not obscured by growth changes in areas not involved in the treatment. It can be readily noticed on the soft tissue profile

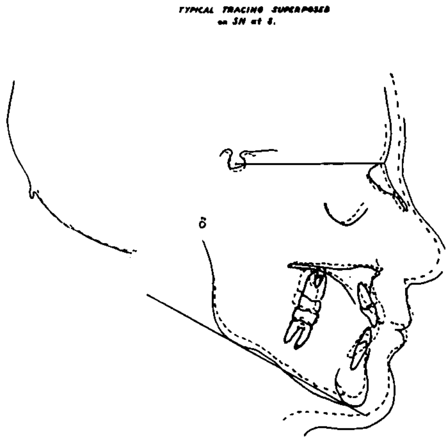


Fig. 1. Typical before and after treatment tracings superimposed on the SN plane at sella.

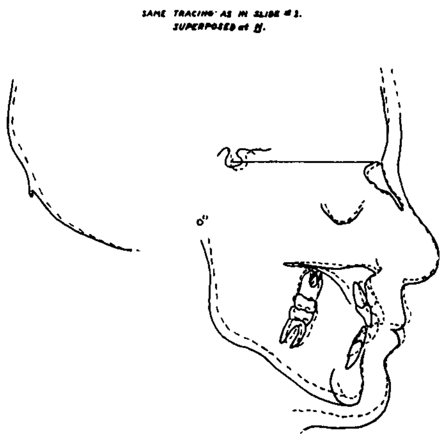


Fig. 2. The same case shown in Fig. 1 superimposed on SN plane at nasion.

how the forehead and nose have not changed much. These are areas unaffected by treatment. We are concerned with the effects of treatment on the structures that it influences. Consequently, we think that superimposing at nasion is a more valid way to study treatment changes.

If we want to study growth of the skull, our problem of analysis is different. A consideration of the variation of growth both in amount and direction must be made. The different parts of the head and their separate growing areas must be studied individually. This was done in our study when relating the teeth to their denture bases. The maxilla and mandible were measured individually to show what happened in each structure.

However, the total effect of such a study alone does not show the specific effect of treatment on the overall pattern. To neutralize dimensional changes of the skeletal structures in areas not affected by mechanics the gross effect of treatment was studied by superimposing the radiographs at nasion.

The following measurements represent the material which will be reported. (Fig. 3). Four main groups of measurements were made. Composing the first group were the angular skeletal and dental readings which included the FMA, ANB, SNA, FMIA, FNP, and the upper and lower incisor inclination. Figure 3 shows a typical tracing of the various points and planes drawn in. The before and after tracings were superimposed on the SN plane at nasion. The linear changes between all movable parts in an anteroposterior direction were measured. These were our horizontal measurements. They included A, B, pogonion, upper incisor, lower incisor and the first molars.

A similar group of measurements were made in a vertical direction projected on the NP plane. These readings

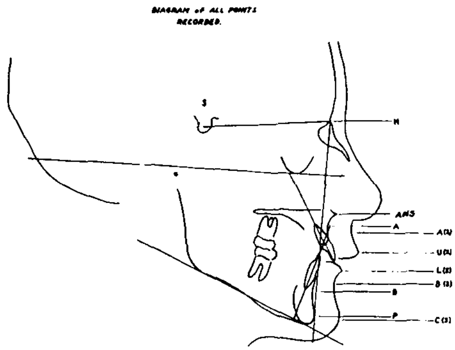


Fig. 3. Diagram of a tracing showing the various points and planes used in this study.

also included a measurement at the anterior nasal spine.

Measurements of the lower incisors and molars were made while the mandible was superimposed at the symphysis.

Five points of the soft tissue were selected. Points A and B, corresponding to the skeletal A and B points, and the anterior limits of upper lip, lower lip and chin were used. These were measured in a horizontal and a vertical plane and related to the underlying changes in the denture and skeleton.

A total of about five thousand measurements was made. The following sections of this paper will present the results of these measurements.

Horizontal Hard Tissue Changes

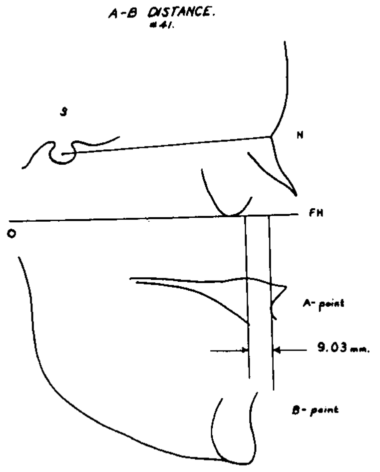
John T. Lindquist
Jack M. Vorhies

Most of us are in agreement that Dr. Tweed can and does effect drastic changes in tooth position. We are also aware that dramatic improvement of soft tissue features result. When we try to analyze how these changes are brought about, the agreement ends.

Some feel that Tweed's treatment influences mandibular growth—others feel that the changes are brought about principally by tooth movements—while a recent thought is that the whole or anterior portion of the maxilla is held or moved posteriorly.

Let us analyze for a moment the development of Tweed's treatment concepts. Placement of the lower incisor over the mandibular base bone was the first step in the evolution of the FMIA angle. Now he relates the lower incisor, not to the mandible, but to the Frankfort horizontal plane. In doing so we cannot help but focus our attention on the most forward limits of the maxilla and mandible as represented on the headplate by the points A and B. (Fig. 4). We are interested in the relationship of these points before treatment as an index to the discrepancy between the denture bases, and also equally important, as to what changes can be brought about during treatment. To study these two points we make use of what we call the A-B distance. Perpendiculars are dropped from Frankfort plane to points A and B, and the linear distance between these points is measured in millimeters. The Frankfort plane on post-treatment tracings was copied from the original tracing by superimposing on the SN plane. The mean from the entire group of fifty-seven cases demonstrated this original A-B distance was 9.03 mm. The A-B change, or the after treatment readings subtracted from the original readings, was a mean of only 1.8 mm., which is a surprisingly small amount of denture base change for the group as a whole.

The ranges or extremes are also shown and are worthy of some careful consideration. Consider the before treatment range of 0 to 17.0 mm. No one can question the severity of a case with an A-B distance of 17.0 mm.; however, this same case exhibited the greatest change during treatment in A-B distance, a reduction of 13.3 mm. We can clearly see that although the mean change was slight, the potentialities are tremendous.



	BEFORE TREATMENT (mm.)	CHANGE (mm.)
MEAN	9.03	1.8 decrease
RANGE	0 to 17 mm.	13.3 decrease to 4.0 increase
S.D.	3.8	2.7

Fig. 4. The A-B distance. Method of measuring the difference between the forward limits of the maxilla and mandible.

In order to measure the change of point B occurring during treatment, we superimposed tracings on SN at N and measured the linear distance in millimeters between the B points before and after treatment by dropping perpendiculars from the Frankfort plane and measuring the distance between them. (Fig. 5). Point A and point P were measured in the same manner. A minus number indicated a posterior movement, and plus was treated as an anterior movement. Point P, pogonion, was selected to represent movement of the mandible since it was felt that point B might be affected through movement of the lower incisors by changing the contour of the alveolus.

Let us first examine the amount and direction of changes in points B and P. For the fifty-seven cases as a whole, point B moved forward only .08 of a millimeter as represented by the mean. Point P moved forward approximately .6 mm. or more than six times farther anterior than point B. (Fig. 6). The

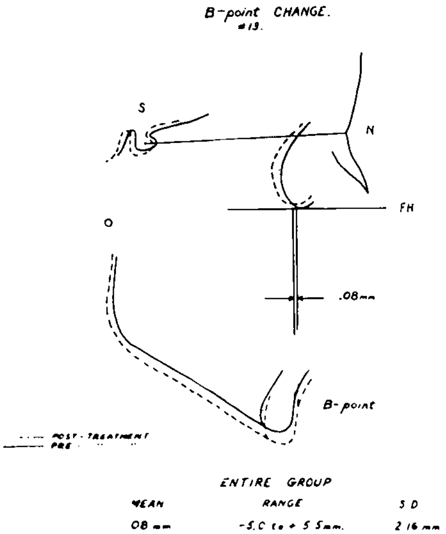


Fig. 5. Change of point B occurring during treatment.

forward movements of these two points are surprisingly small, but it is noted that P moves forward much more than B which tends to confirm our assumption that point B can be affected or

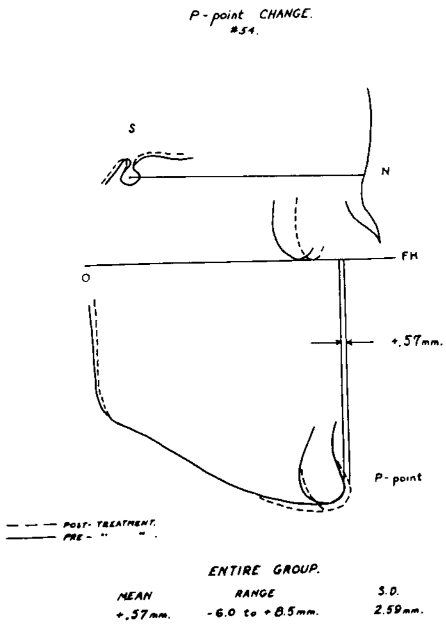


Fig. 6. Change of point P.

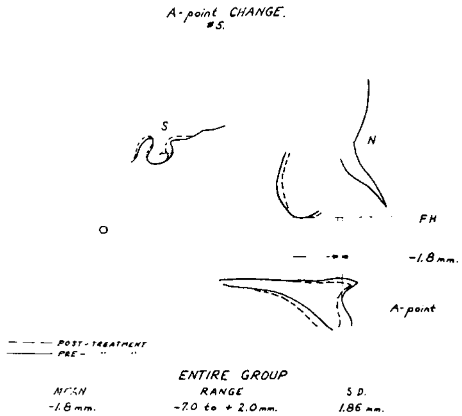


Fig. 7. Change of point A.

moved slightly posteriorly when the lower incisors are moved lingually, or that appositional growth occurs on the chin point. These figures are more valid in view of the fact that the FMA change was negligible in most cases.

Our remaining denture base measurement is point A, which for the group as a whole, moved back or posteriorly 1.8 mm. When compared with B and P points this is a most significant change. (Fig. 7). The ranges for these readings are also important in that they represent cases showing the greatest changes as the result of treatment. The following table shows the range, mean, and standard deviations for the group of fifty-seven cases of points A, B, and P. (Table 1). Let us remember that a minus figure indicates posterior movement and plus means anterior.

A look at the ranges, as well as the means, shows many interesting changes. Let us study these figures for a moment and then reflect as to whether point A can be moved posteriorly or whether the mandible can come forward. Both these things can and do occur as well as combinations of the two. In fact, at the conclusion of treatment, in twelve cases points A, B, and P were all posterior to their original positions when related to SN at N. The question is,

TABLE I

Point	Mean	Range	Standard Deviation
A	—1.8	—7.0 to +2.0	1.86
B	+.08	—5.0 to +5.5	2.16
P	+.57	—6.0 to +8.5	2.59

what is the likelihood of these things happening on any given case that we may have to analyze before starting treatment. Here statistics offer the best method of predicting possibilities. For the group as a whole, statistics show us that point A moved posteriorly a significant amount, point B a very slight, perhaps insignificant amount and point P also slight but more than B.

However, all cases did not need forward movement of the mandible or backward movement of point A. How can we determine whether the distance between points A and B can be favorably improved when needed? Here again we call upon statistics to shed light upon the question.

Let us assume that the cases with the greatest A-B distance before treatment are the ones needing the most improvement. With this in mind, a correlation test was made comparing the original A-B distance to the A-B changes. In other words, does the A-B distance decrease, or get better on the severe cases that need it? A perfect statistical correlation would yield a figure of 1. Or in other words, a direct correlation on every case. The result of this test revealed that there was a correlation, a moderate but significant one. The figure was .48. Thus, we learn that in many cases where the original A-B distance was large, a corresponding reduction of this distance existed at the end of treatment. This does not mean that in every case with a large A-B distance before treatment a reduction or improvement resulted; however, a moderate but significant correlation exists.

With the knowledge that a correlation exists between the original A-B distance and the amount of change, our next problem was to determine whether A or B or both were responsible for the change, and to what degree each accounted. Again using a correlation test we first correlated the amount of point A change in these cases to the amount of the original A-B distance. We may restate the problem by asking, "Is there a significant posterior movement of point A in the cases that need it?" The result of this revealed that there was a small but significant correlation, the figure being .33. The movement of point B was considered next and revealed a correlation of .18 which is a very slight, almost negligible correlation and is not significant. Therefore, the movement of point B is unpredictable, it may go forward or backward and exhibits no correlation to the severity of the case. In fact, point B at the end of treatment was posterior to its original position in ten cases with unfavorable A-B distances. Point P movement demonstrated a slightly better correlation than did point B to A-B distance, but again the correlation was not significant, being .21.

Let us now summarize the results of the foregoing—what do they actually tell us?

1. When Dr. Tweed has a severe case as represented by a poor relation of denture bases or points A and B, he can expect a moderate chance that this poor relationship may be improved in varying degrees during treatment.

2. The cases that do result in an improvement are much more likely to have resulted from a posterior movement of point A than a forward positioning of the mandible.

3. Forward positioning of the mandible is unpredictable even in cases with severe A-B discrepancies.

4. The post-treatment position of the

mandible may even be located posteriorly to its pretreatment position in these severe A-B cases.. It would be logical to assume that the more severe the A-B discrepancy, the more Class II elastics would be worn during treatment. Therefore, we might expect a consistent forward positioning of B, but such was not always the case.

The possibilities of tooth movement as demonstrated by Tweed are most amazing as revealed by this study. The tooth changes were measured on the entire group in a similar manner as the bony bases. The point of orientation was derived by using the intersection of the axial line of the tooth with its incisal edge. (Fig. 8).

As might be expected the upper incisor was moved the greater distance

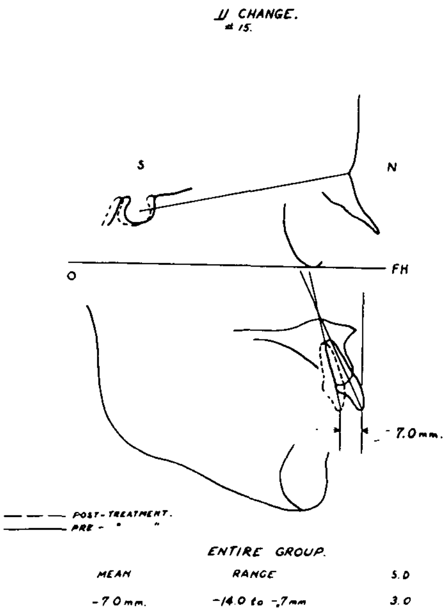


Fig. 8. Movement of upper incisors during treatment. The accompanying illustrations of tooth movements are composites representing change in axial inclination of upper and lower incisors and movement of the crowns at the incisal edge. The drawings do not necessarily represent bodily tooth movement because the relative position of the denture bases may change during treatment.

as compared with the lower. The mean movement was 7.0 mm. in a posterior direction. The upper incisor range was a posterior reduction of as much as 14.0 mm. to a reduction of only 0.7 mm. The mean movement of the lower incisor was changed 3.6 mm. in a posterior direction, approximately half the distance of the upper incisor. The range of the lower incisor was a reduction of 8.0 mm. to a protrusion of 2.0 mm. (Fig. 9).

To determine the behavior of the upper incisors when the overjet problem was severe, a correlation test was made between the upper incisor movement and the overjet change. The results demonstrated a moderate and significant relation between the two of 0.61. On the other hand, the lower incisor movement did not demonstrate a significant correlation to the overjet problem. On this basis, Dr. Tweed could be reasonably sure he would have a fairly consistent and considerable movement of the upper incisors in those cases with a large overjet. The response of the lower incisors would be unpredictable.

To supplement the linear method, angular readings were recorded as illustrated by Figure 10. First let us consider the FMIA before and after treatment and the change. The mean FMIA before treatment was 58.7 degrees. The mean at the conclusion of treatment was 67 degrees. However, the dispersion was appreciable with 68 percent of the cases falling between 60 and 74 degrees. The change in this angle ranged from a decrease of 26 degrees to an increase of 15.3 degrees.

As might be expected some of the greatest changes occurred in the axial relation of the upper incisors to the lower incisors during treatment. Tweed's cases demonstrated a mean of 126.3 degrees at the beginning of treatment and a mean of 146.0 de-

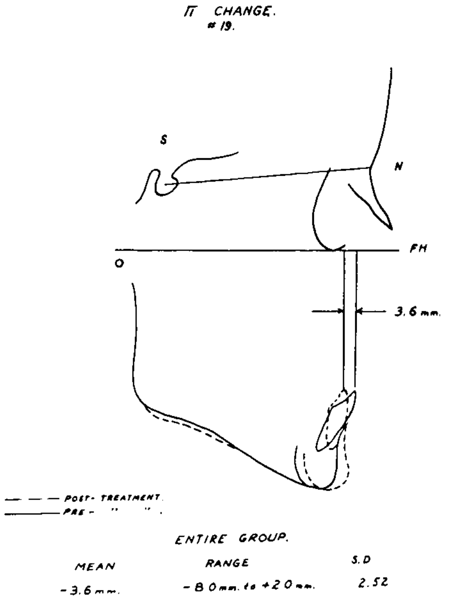


Fig. 9. Movement of lower incisors.

grees at the conclusion of treatment. The mean change was 19.3 degrees. (Fig. 11).

Our investigation to this point has

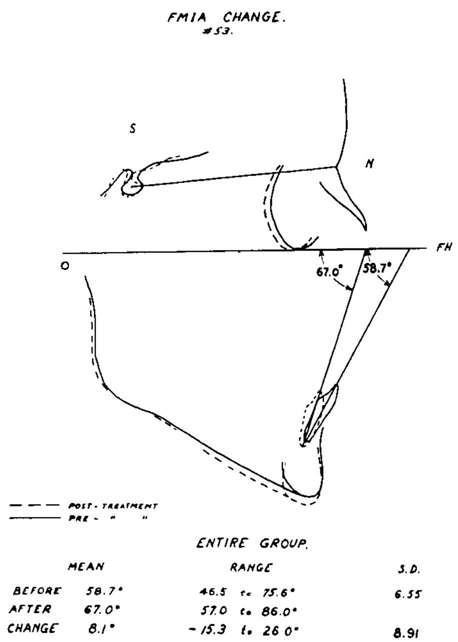


Fig. 10. Change of the FMIA.

dealt with the group of fifty-seven cases as a whole. For proper elucidation it was thought advisable to divide these cases into groups with some common denominators. Consequently, they were divided into Class I, Class II Division I, and Class II Division II cases, as classified by Dr. Tweed.

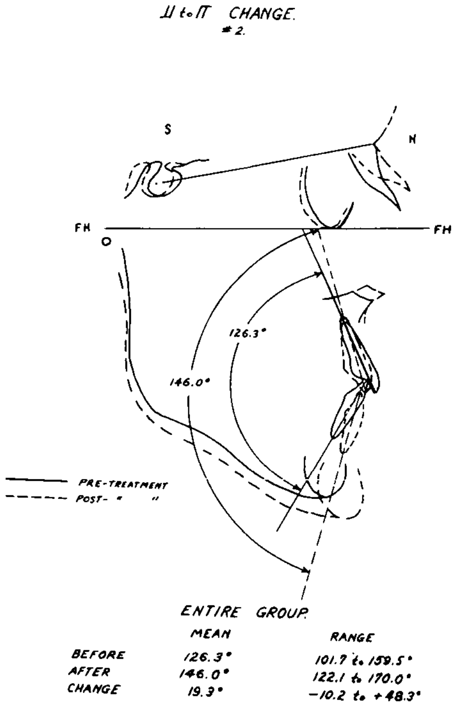


Fig. 11. Changes of the axial inclinations of upper and lower incisors to each other.

Since only five cases were classified as Class II Division II, the sample was too small to justify presenting statistically. Each division as based on the Angle classication was compared to each other on the basis of denture and skeletal changes. It was thought that this would give us some insight into the behavior and potentialities of treatment of each group.

Denture base changes will be considered first. In the Class II cases point A moved posteriorly more than twice the distance it did in Class I cases. (Fig.

12). Point B on the other hand, in Class I cases exhibited almost no change, whereas in Class II cases it moved anteriorly 0.5 mm.

What are the changes in tooth movement between the different classes? In the Class II cases the lower incisors moved back a mean distance of over 3 mm. and since many Class II cases had considerable overjet, it follows that the upper incisors have moved back the distance of the original overjet plus the amount of posterior movement of the lower incisors. (Figs. 13-14). Looking now to the inclination of upper incisor to lower incisor we find that the original readings varied according to the classification as expected and that Dr. Tweed has attained similar readings for each class at the end of treatment.

Recently attention has been given to the 65-degree FMIA angle as a desirable goal in treatment, so the logical question is—can this goal be attained? The results disclose that for Class I cases the mean after treatment is 69.6 degrees and for Class II's 63.5 degrees, but the general tendency shows more difficulty in obtaining this objective in Class II cases. A question which may logically follow is the role of extraction or non-extraction in effecting changes. The entire group was broken down into extraction and non-extraction treatment. There were thirty-nine extraction and eighteen non-extraction cases.

Denture base changes reveal that there was practically the same amount of posterior repositioning of point A in non-extraction cases (1.8 mm.) as in extraction cases (1.7 mm.). Point B indicates very little forward movement in either type of treatment. When examining the linear changes of upper and lower incisors it is apparent that there is a considerable posterior movement of both upper and lower incisors in non-extraction cases as well as ex-

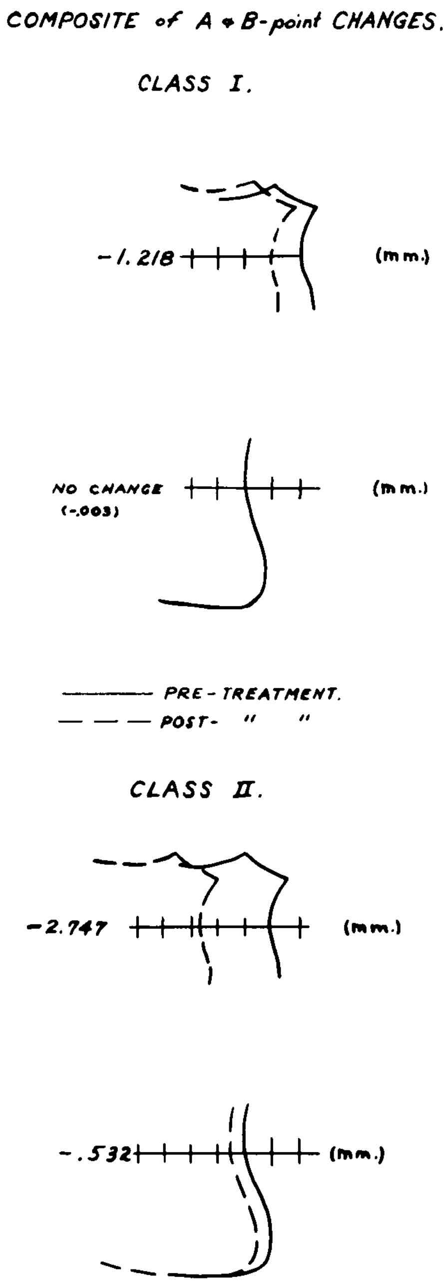


Fig. 12. Composite of mean denture base changes of Class I and Class II cases. The diagram of changes in the maxillary area was made to show change at point A only. Inaccuracies in the position of ANS may exist in this drawing.

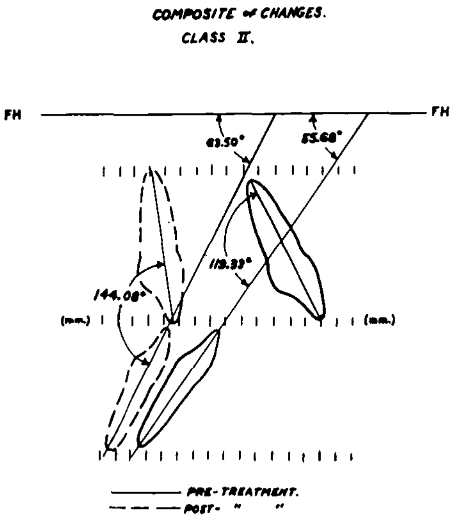


Fig. 13. Composite of incisal movement of Class II cases.

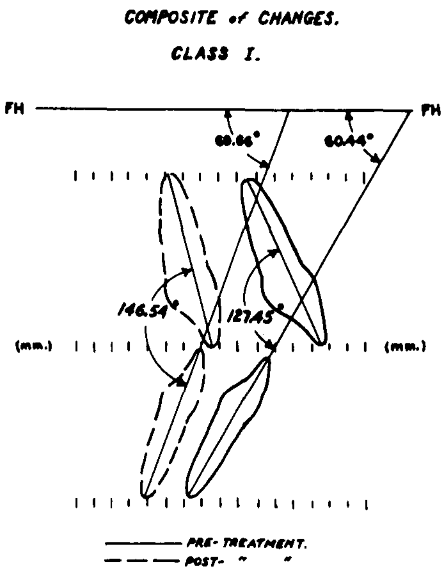


Fig. 14. Composite of incisal movement in Class I cases.

traction cases. The FMIA mean readings show a 4-degree reduction of the lower incisors without resorting to the extraction of teeth (Figs. 15 - 16).

A summary of the tooth changes in Dr. Tweed's cases point out these conclusions:

1. All anterior teeth, both upper and lower in the treatment procedure are capable of being moved great distances and usually in a posterior direction.
2. The upper anterior teeth usually contribute to a greater extent than the lower in the reduction of overjet by being repositioned the sum of the original overjet plus the distance the lower incisors moved posteriorly.
3. The lower incisors are usually positioned in a posterior direction but the extent of the change is not as predictable as the upper incisors in reducing overjet.
4. Demonstrable changes in an anteroposterior direction may be accomplished in non-extraction cases as well as those in which it is necessary to extract.

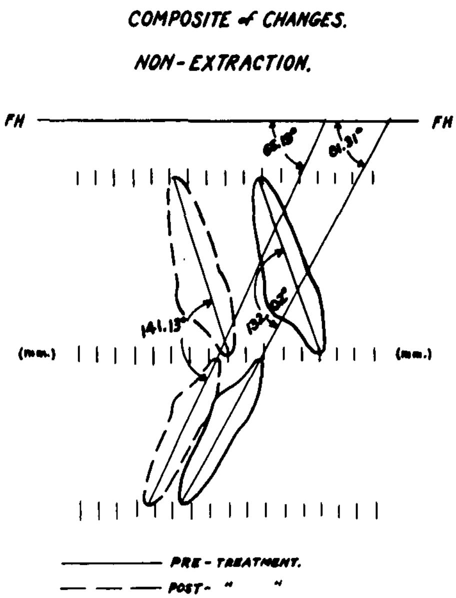


Fig. 15. Incisal movement in non-extraction cases.

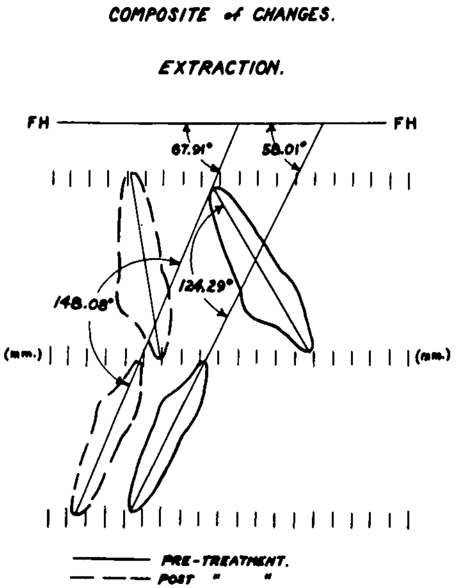


Fig. 16. Composite of incisal movement of extraction cases.

Vertical Hard Tissue Changes and Soft Tissue Changes

Rolenzo A. Hanes
Frank M. Hapak

This portion of our paper is a report of the hard tissue changes occurring in the vertical plane and of the soft tissue changes in both vertical and horizontal directions. The data for analysis were obtained from cephalometric headplates and photographs taken before and after treatment. When this study was undertaken we had in the back of our minds an idea that we might find some one thing responsible for the exceptional and dramatic facial changes Dr. Tweed accomplishes during treatment. We hoped that we might apply this result in our practices and get the same type facial changes. We suppose that at some time or another every orthodontist has thought that there must be some Utopia wherein we might follow one specific rule and accomplish one particular change during treatment, thereby resulting in the facial improvement which we are all striving to get. The measurements used in this study were obtained by superimposing before and after treatment tracings on nasion with the sella-nasion plane superposed. All vertical measurements were made parallel to the original Downs facial plane and the horizontal soft tissue measurements were taken perpendicular to the original facial plane. The average treatment time for these fifty-seven cases was fifteen and one-tenth months, varying from five to twenty-nine months. In reporting the vertical changes that occurred, the structures are grouped in three categories:

1. The major structures involved; namely, the maxilla and the mandible.
2. The teeth and their movements when related to:
   a. The maxilla
   b. The mandible
   c. The cranium
3. The soft tissue changes in the lower third of the face.

The nasal floor and the maxilla moved downward an average of 1.5 mm. (Fig. 17) in the fifty-seven cases, varying from 0.0 to 4.5 mm.; this vertical increase could most likely be explained as growth. The mandible dropped an average of 4.0 mm., varying from 0.0 to 10.0 mm. (Table II). It was expected that there would be more increase in vertical height in those cases having the most severe Frankfort-mandibular plane angle. As some have said, these "sledrunner" cases will tend to develop an open bite during treatment, whereas a severe overbite in the case with a low Frankfort-mandibular plane angle is more difficult to correct. To confirm this the Frankfort-mandibular plane angle before treatment was plotted against the amount the chin descended vertically. No relationship

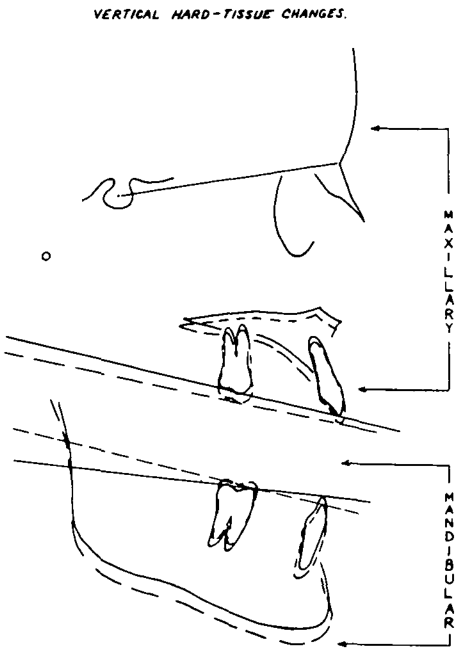


Fig. 17. Drawing of vertical hard tissue changes. Maxilla and maxillary denture descend in parallel planes, along with the mandible. Mandibular denture plane tips with elevation of molars and depression of incisors.

could be established between the two. The average change in the Frankfort-mandibular plane angle was very slight, plus 0.15 degree. There was an almost equal number of cases showing improvement of the Frankfort-mandibular plane angle as there were those that got worse. Change in the Frankfort-mandibular plane angle varied from an opening of 3 degrees to a closing of 4.3 degrees. Change in the angle was plotted against the change in vertical positioning of the mandible, and a relationship between the angle opening and an increase in vertical dimension was shown.

The vertical change in the maxillary teeth as related to the cranium was almost identical to the change in the nasal floor. Both the incisors and the molars descended in very nearly the same amount as the maxilla. Therefore the occlusal plane of the maxillary denture remained essentially the same as before treatment. The two extremes of vertical upper incisor movement as related to the maxilla were: depression of 4.5 mm. and elongation of 4.0 mm.

Results of the vertical measurements relating mandibular teeth to cranium were not considered significant, since the mandible is a movable part. The measurements of mandibular tooth movements were made by superposing mandible on the symphysis and mandibular plane.

The mandibular first molars were elevated an average of 1.5 mm.. This measurement varied from a depression of 4.0 mm. to an elevation of 5.0 mm., showing an overall tendency for elevation. The largest amount of change in vertical positioning of teeth occurred in the mandibular incisors. This incisor change varied from 7.5 mm. depression to an elevation of 2.0 mm.

TABLE II

Averages and ranges of vertical hard tissue movements during treatment.

	Mean	*Range*	
Maxilla	↓ 1.5 mm.	0	↓ 4.5 mm.
Mandible	↓ 4.0 mm.	0	↓10.0 mm.
Mandibular Plane Angle	+0.15°	+3.0°	—4.3°
Upper incisors related to Cranium	↓ 1.5 mm.	↓ 7.0 mm.	↑ 4.5 mm.
Upper molars to Cranium	↓ 1.5 mm.	↓ 6.0 mm.	↑ 4.5 mm.
Upper incisors to Maxilla	↓ 0.3 mm.	↓ 4.0 mm.	↑ 5.0 mm.
Upper molars to Maxilla	↓ 0.13 mm.	↓ 3.5 mm.	↑ 5.0 mm.
Lower molars to Mandible	↑ 1.5 mm.	↓ 4.0 mm.	↑ 3.5 mm.
Lower incisors to Mandible	↓ 2.2 mm.	↓ 7.5 mm.	↑ 2.0 mm.

The average was 2.2 mm. depression. This combination of elevation of the molars and depression of the incisors indicates the tipping of the occlusal plane in the mandibular denture. Perhaps this explains wherein the correction of overbite tends to occur, that is, the opening of the bite by elevation of the lower molars combined with depression of the lower anteriors, with little if any change in the occlusal plane of the upper denture. A graph was made plotting the depression of the anterior teeth with the elevation of the molars in the mandibular denture. No correlation between the two movements could be established.

In considering the changes which are measured in the soft tissues, it must be borne in mind that probably all cases were not in the same state of muscular repose during the time the headplates were taken. Because of this, some of the relationships which we attempted to establish showed wide variations, and possibly cannot be relied upon as truly indicative of any specified pattern.

In examining the vertical soft tissue changes that occurred during treatment, soft tissue C point, the chin, moved downward in about the same degree as hard tissue P point (Fig. 18) (Table III). The vertical increase in dimension was reflected proportionately in the soft tissue when compared to the change effected in the hard tissue. The vertical change in the lips was comparable and fitted in with the increase in overall vertical dimensions. The upper lip dropped down in the vast majority of cases. In three cases upper lip elevation ranged up to 2.0 mm. In all remaining cases the upper lip dropped as much as 6.0 mm.. In the majority of cases the lower lip also descended. However, its descent averaged much less than was found for the upper lip. The average vertical drop of the upper lip was 2.0 mm. compared to 0.3 mm. in the lower lip.

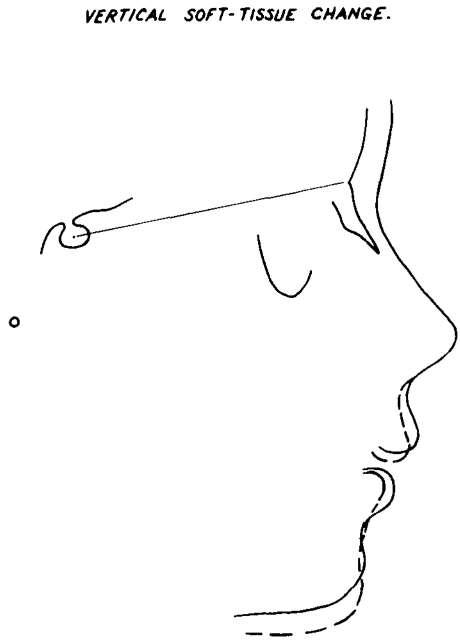


Fig. 18. Soft tissue recontouring during treatment (composite).

In measuring the horizontal soft tissue changes the following were considered: the chin, the upper lip, the lower lip, and soft tissue A and B points. Soft tissue A and B points corresponded to the same points on the maxilla and the mandible; namely, the most posterior part of the tissue below the lower lip referred to as B point, and the most posterior part of the tissue above the upper lip referred to as A point. The anteroposterior change in the soft tissue chin was measured. The chin tended to come forward very slightly, averaging 1.1 mm.. Twelve of the cases showed posterior positioning

TABLE III

Averages and ranges of vertical soft tissue movements during treatment.

	Average	*Range*
Chin	↓ 4.5 mm.	0.0 mm.– ↓13.0 mm.
Upper Lip	↓ 2.0 mm.	↑ 2.0 mm.– ↓ 6.0 mm.
Lower Lip	↓ 0.3 mm.	↑ 5.0 mm.– ↓ 4.5 mm.

of the soft tissue chin.

Before checking further into horizontal changes in the soft tissue, the photographs were used to classify the cases into Class I, Class II, and Class III types (Fig. 19). These groupings were made on the basis of gross observations of the original photographs, noting chin position as related to the facial profile. There was only one case demonstrating what might be called a Class III profile and as this was very mild it was eliminated. It was found that there was roughly three times as much anterior positioning in the Class II type cases as was found in the Class I type. The averages showed 2.0 mm. forward positioning in the Class II cases and .75 mm. in the Class I cases. This would seem to indicate that the soft tissue chin was moved or grew forward in those cases wherein it was most essential to treatment.

To assess total facial improvement two measurements were integrated arriving at one value in millimeters. These two factors were the forward positioning of soft tissue chin combined with the posterior positioning of the upper lip. (Fig. 20). It was felt that the gross changes in these two parts would combine to show the overall tendency toward achieving a straight line profile.

The average total improvement was 3.5 mm.; the upper lip moved back 2.4 mm., and the chin came forward 1.1 mm.. The reduction of the upper lip accounted for two-thirds of the total improvement. In the Class II group the chin and the lip change were more nearly equal, 2.6 mm. reduction of upper lip and 2.1 mm. forward positioning of chin. (Table IV). In the Class I group there was relatively more change in the upper lip, it being reduced 2.2 mm. while the chin came forward 0.75 mm.. The total improvement in the Class II group was 4.1 mm., and in the Class I group 2.3 mm. as compared to 3.5 mm. in the combined group. This shows the same result that was found in grouping the changes in soft tissue chin into these two groups. The total facial improvement derived by this method in the Class II faces was almost twice as great as in the Class I faces.

We realize that the reduction in the prominence of the upper and lower lips can greatly improve facial appearance. In order to assess the improvement, or flattening of the lips, measurements in a horizontal plane were made of soft tissue B point and the most anterior

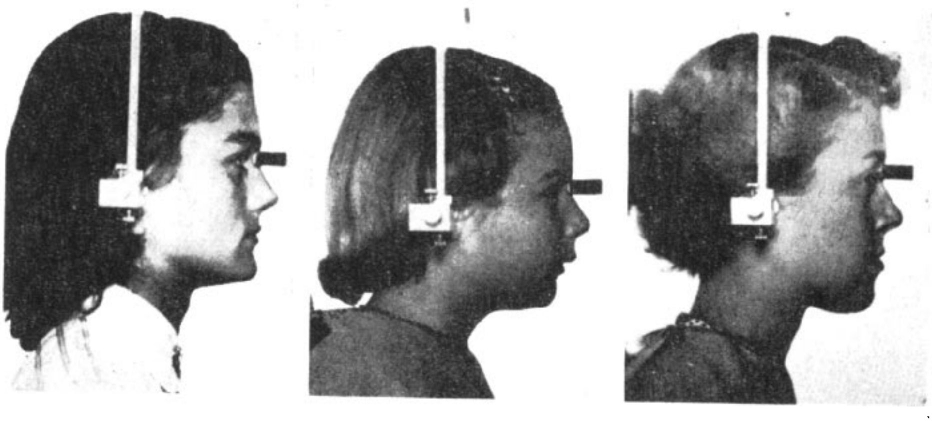


Fig. 19. Examples of case classification according to profile photographs. Class I, Class II and Class III.

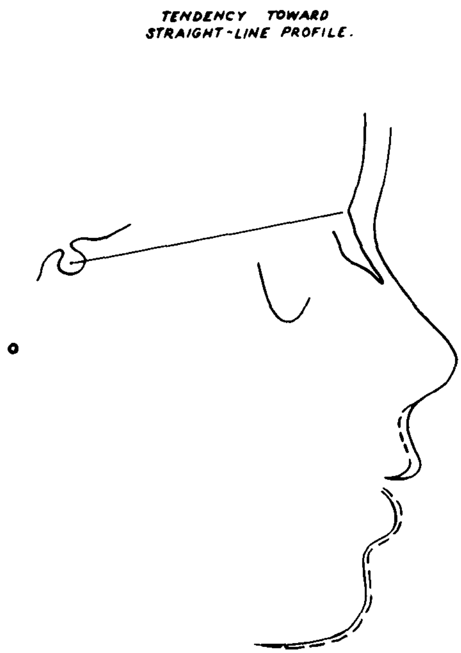


Fig. 20. Combination of maxillary area moving back and mandibular area moving forward to approach a straight line profile. Composite of entire group with maxillary area back 2.4 mm. and mandibular area forward 1.1 mm. A total of 3.5 mm. improvement.

point on the lower lip. The same measurements were made on the upper lip, measuring soft tissue A point and the most prominent portion of the upper lip. (Fig. 21). Not only is the lip appearance improved by the lip itself going back, but also by either A point or B point coming forward. In combining these values, the forward movement of A point was added to the backward movement of the lip itself. Thus, a total figure in millimeters was derived indicating the degree of flattening of the upper lip. The same procedure was then applied to determine the flattening of the lower lip. The average of the figures thus obtained was 0.8 mm. reduction in the upper lip and 2.1 mm. for the lower. The Class II cases again showed more flattening, having a 0.9 mm. average reduction of the upper lip as compared to the Class I cases which had a 0.6 mm. average reduction. The lower lip in the Class II cases showed 2.2 mm. reduction while the Class I cases showed 2.0 mm. (Table V).

TABLE IV

Comparison of the horizontal soft tissue changes in Class I and Class II groups.

	Maxillary Area	*Mandibular Area*
Class I Group	...Back 2.2mm.	Forward 0.7mm.
Class II Group	...Back 2.6mm.	Forward 2.1mm.

The variation in millimeters between the Class II and the Class I cases was comparable in both upper and lower lip. However, due to the slight amount of flattening in the upper lip, the variation, percentage-wise, was much greater in the upper lip. The major improvement in lip flattening occurs in the

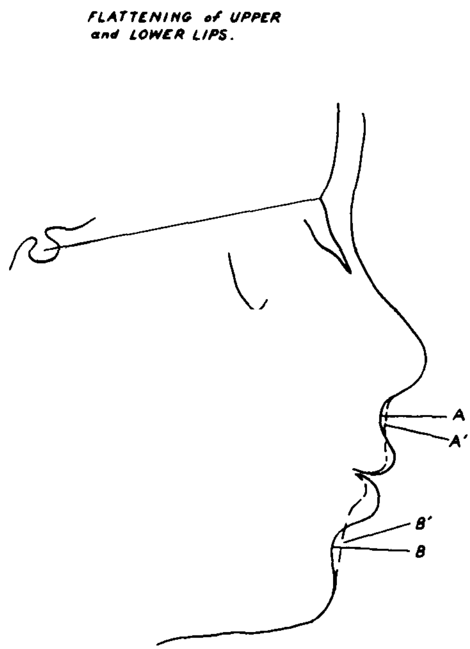


Fig. 21. Flattening of the lips as determined by measuring the variation between A and A1, and between B and B1 before and after treatment.

TABLE V

Flattening of the lips as measured by the difference between A and U on the upper lip: and between B and L on the lower lip.

	Upper Lip	*Lower Lip*
Class I Group	0.6 mm.	2.0 mm.
Class II Group ...	0.9 mm.	2.2 mm.
Entire Group	0.8 mm.	2.1 mm.

lower lip, and this might be due to the fact that Dr. Tweed's concentration during treatment is upon the positioning of the lower incisors, or an increase in vertical dimension or both.

The amount of change in the upper lip was related by correlation test to the amount of change in the lower lip. The result was —.033 indicating practically no correlation between the two changes.

Various correlation tests were made in an attempt to establish relationships between changes occurring in the different parts. One of the most interesting of these was the test relating the angular change in the lower incisor, the FMIA angle, to the amount of flattening of the lower lip when measured as was previously described by adding the posterior movement of the lip to the forward movement of soft tissue B point. (Fig. 22) This correlation is —.372, small but significant at better than the one per cent level. Thus there is a tendency for a large incisal angular change to be accompanied by a large lip change. However, this relationship is not as positive as might be expected.

Some of the other relationships we felt significant were checked. The change in the horizontal position of the chin was plotted against the change in the mandibular incisor angle. No relationship was shown. The change in the Frankfort-mandibular incisor angle was related to the posterior movement of the lower lip, ignoring any change in soft tissue B point or the lip sulcus. In this correlation there again appeared some relationship between the two changes. However, there were also cases which were exceptions to the rule. The posterior movement of the upper lip was related to the forward movement of the soft tissue chin. Some correlation was indicated. In most of the cases the chin came forward slightly and the upper lip moved back slightly. In no case was this combination reversed. The change in incisor angulation, upper to lower, was compared to the total reduction in both upper and lower lips. No relationship was found. Also the total lip reduction was related to the increase in vertical dimension, the amount the chin descended during treatment. Here some relationship was indicated, though not really specific. Some relationship was demonstrated between the total improvement in the facial plane (the forward positioning of the chin plus the reduction in upper lip) when plotted in relation to the FMIA angle after treatment. The same facial improvement was also plotted in comparison with the increase in vertical height. As the vertical height increased

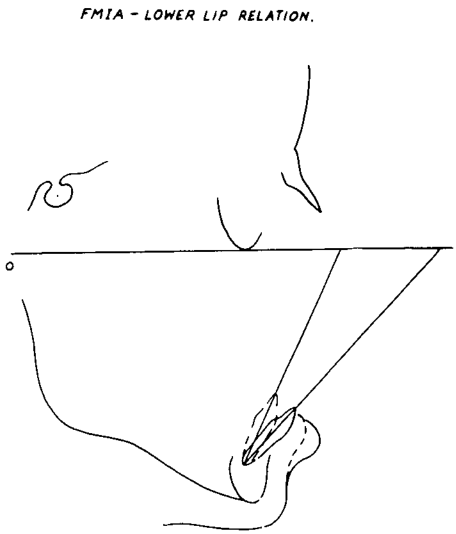


Fig. 22. Diagrammatic illustration of improvement in FMIA and corresponding flattening of lower lip.

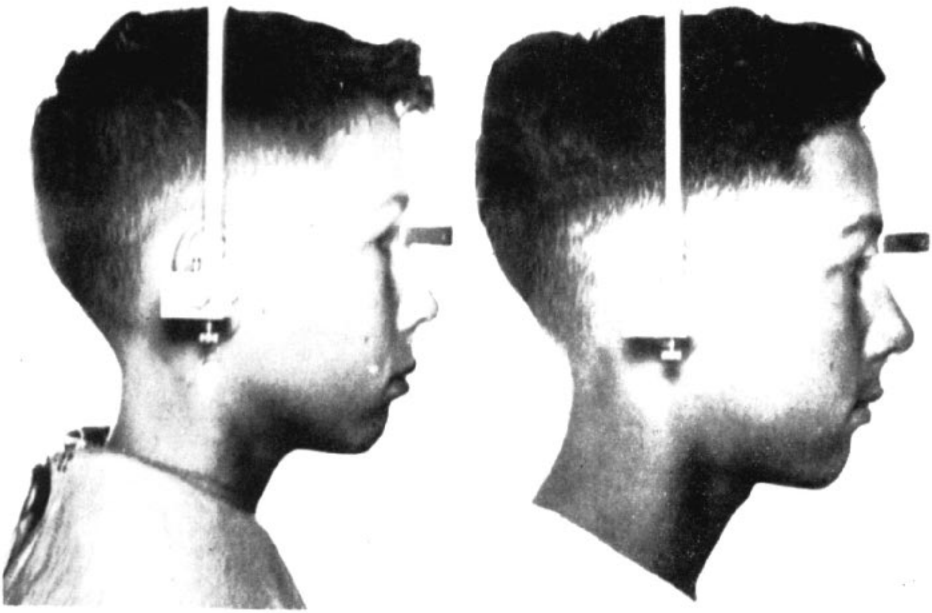


Fig. 23. Before and after treatment photographs of a case demonstrating reduction in protrusion largely due to increased vertical dimension.

there seemed to be some improvement in the flattening of facial profile. In fact, some cases appear to have been improved only by increasing the vertical dimension. (Fig. 23). No relation could be shown between the change in angulation of the lower incisor and horizontal movement of the upper lip. The change in the lower lip was related to the angulation of the upper and lower incisors to one another. Here, as in the majority of these correlation tests, there appeared some tendency toward a relationship, but it could not be called significant.

In conclusion, a brief summary of the movements found in all of these cases shows that the vertical dimensions were increased partly due to growth and partly due to elevation of the lower molars. Overbite correction was accomplished through a combination of depression of the lower anteriors and a slight elevation of the lower molars. The soft tissue improvement of the face was not particularly due to forward positioning of the chin, although this was a major factor in selected cases, but was due more to recontouring of the lips. This recontouring was accomplished by thinning or flattening of the lips, and these changes seemed to occur because of the gross lingual movement of the incisor teeth, as well as an increase in vertical height. Also, the change in the angulation of the lower incisors seems to have some bearing on the desirable recontouring of the lower lip.

General Discussion

Morris M. Stoner

In addition to the previously mentioned angular changes described there were three other significant findings:

1. The ANB relationship was reduced as much as 7 degrees.
2. The Frankfort mandibular plane angle varied inversely with the

facial angle (FNP) at the end of treatment. This means that the smaller the FMA the more vertical the facial plane.

3. The FMIA tended to vary directly with the facial plane, meaning the more upright the incisor, the more forward the position of the chin point.

From the horizontal measurements we found that the post-treatment A-B difference was often reduced. We refer to the relationship between the anterior limits of the upper jaw and the anterior limits of the lower jaw. Point A and the premaxillary area moved posteriorly to a greater degree than the forward movement of B. These measurements were taken by superimposing the tracings on SN at nasion. We have stated that the reason for using nasion as the point of superimposition rather than sella was to show the effects of treatment relative to the front of the face minimizing the growth changes due to gross enlargement of the head. Incidentally, the average increase in growth on the SN plane was less than 1.0 mm.

The overjet was reduced by the upper incisor moving back considerably more than the forward movement of the lower incisor. In fact, usually the lower incisor relative to the cranium went back even farther than it had been originally, thereby permitting the upper incisor in many cases to travel a greater distance than the original overjet. This was especially true in the bimaxillary protrusion cases.

The lower incisor, when superimposed on the mandible, moved considerably, but its net effect was reduced by the forward movement of the mandible in some of the Class II cases when P came forward. In most cases the greatest change occurring in the correction of the Class II, Division 1 malocclusions was due to a recontouring of the maxilla when measured by the change at A.

The vertical measurements showed that the vertical change of the chin was produced partially by growth and partially by elevation of the lower molars. The overbite correction was accomplished by depression of the lower incisors with a slight elevation of the lower molars.

Soft tissue improvement was produced by four main changes, singly or in combination—a reduction of the apparent prominence of the lips relative to the rest of the face; a reduction of the curl in the lower lip; vertical opening at the chin; and some forward positioning of the chin.

When we first started to work on this project, we really did not know what direction to follow in attempting to evaluate this data properly. We had hoped perhaps to find one or two outstanding correlations which we would be able to call the key to treatment. Many correlations of changes were made and were found to be negative.

In mentioning important negative findings, we must state that on correlation graphs FMIA showed only mild correlations to the change produced in the upper lip and the position of the lower lip. This seems startling enough when we realize that the Frankfort-mandibular incisor angulation has been the basis for the treatment of Dr. Tweed. Wylie[7] felt because of a similar finding on the cases he examined that the FMIA had secondary significance in the explanation of the success of Dr. Tweed's cases. Our explanation is somewhat different, and we feel that, indirectly, change in the lower incisor position has a great deal of influence on the rest of the case. We shall present a possible explanation of why FMIA control or change definitely can influence soft tissue and why such type of change represents considerable improvement. However, before we go into that, we would like to present our correlated statistical data in an analysis of several cases.

Case Analysis

Case No. 15 (*Figure* 24)

This is a case in which Dr. Tweed felt a very high Frankfort-mandibular incisor angle, FMIA, was necessary to produce a satisfactory result. On careful analysis of this case, we find there are some very dramatic changes. On the tracing the solid line represents the pretreatment radiograph and the dotted line the post-treatment change.

From our horizontal measurements we find that the chin came forward 3.0 mm. The upper incisors were moved posteriorly 7.0 mm. and the lower incisors 8.0 mm. The net result was that the chin at the end of treatment, relative to the dentition, was farther forward in space than at the beginning.

Vertically, the lower molars were elevated slightly and the lower incisors depressed considerably. The chin point descended 3.0 mm.

It is well to note that by superimposing the structures at nasion, the forehead and nose are not changed. The relative changes in the soft tissue are clearly demonstrated.

This case exhibited a low FMA of 16 degrees, which correlates with the high FMIA of 86 degrees. This is in accordance with the trend shown in these treated cases of Dr. Tweed.

Case No. 32 (*Fig.* 25)

Let us consider a case with a relatively high FMA, 36 degrees. On this boy the facial plane angle is relatively low. It measured 79.5 degrees before treatment and increased 0.5 degrees. The ANB relationship was 4.0 degrees before treatment which is usually considered as being within tolerable limits. This was changed, however, to 0.5 degrees by moving A back 1.5 mm. and B forward 0.5 mm. SNA changed 2.5 degrees, indicating some maxillary reduction. The chin point moved forward 1.0 mm.

On examining the tooth movements we find that the upper incisor went lingually 8.0 mm. There was a 2.0 mm. descent of the maxillary base as measured at the anterior nasal spine, and the upper molars erupted 2 mm. in addition, or a total of 4.0 mm. from the cranium and the original position of the upper molars. The lower incisors were depressed 6.0 mm. The net opening of the mandible was 3.0 mm.

In this case we believe that facial improvement resulted from posterior movement of the upper incisors, a recontouring of the premaxillary area, and opening the bite.

The correlation of the low facial plane angle (FNP) 79.5 degrees to FMIA 60.0 degrees is the other extreme of Case No. 15 above.

Case No 16 (*Fig.* 26)

As has been previously stated many A-B discrepancy cases were reduced according to the demands of the case. Here is a young lady who, among other recordings, showed an ANB relationship at the beginning of treatment of 8.5 degrees. This was reduced at the end of treatment to 2.5 degrees. The SNA was reduced 7.0 degrees, changing from 81.0 degrees to 74.0 degrees. Point A, on the horizontal relationship, moved back 7.0 mm.

Points B and P both came forward, 5.5 mm. for B and 8.5 mm. for P. Without considering dental change, there has been a tremendous skeletal response. There is a decided recontouring of the labial and lingual alveolar plates in the premaxillary area.

In addition to the skeletal changes, tooth movements were also dramatic. The upper incisors were moved posteriorly 11.0 mm. bodily. The lower incisors were depressed 5.5 mm. Elevation of the lower molars opened the

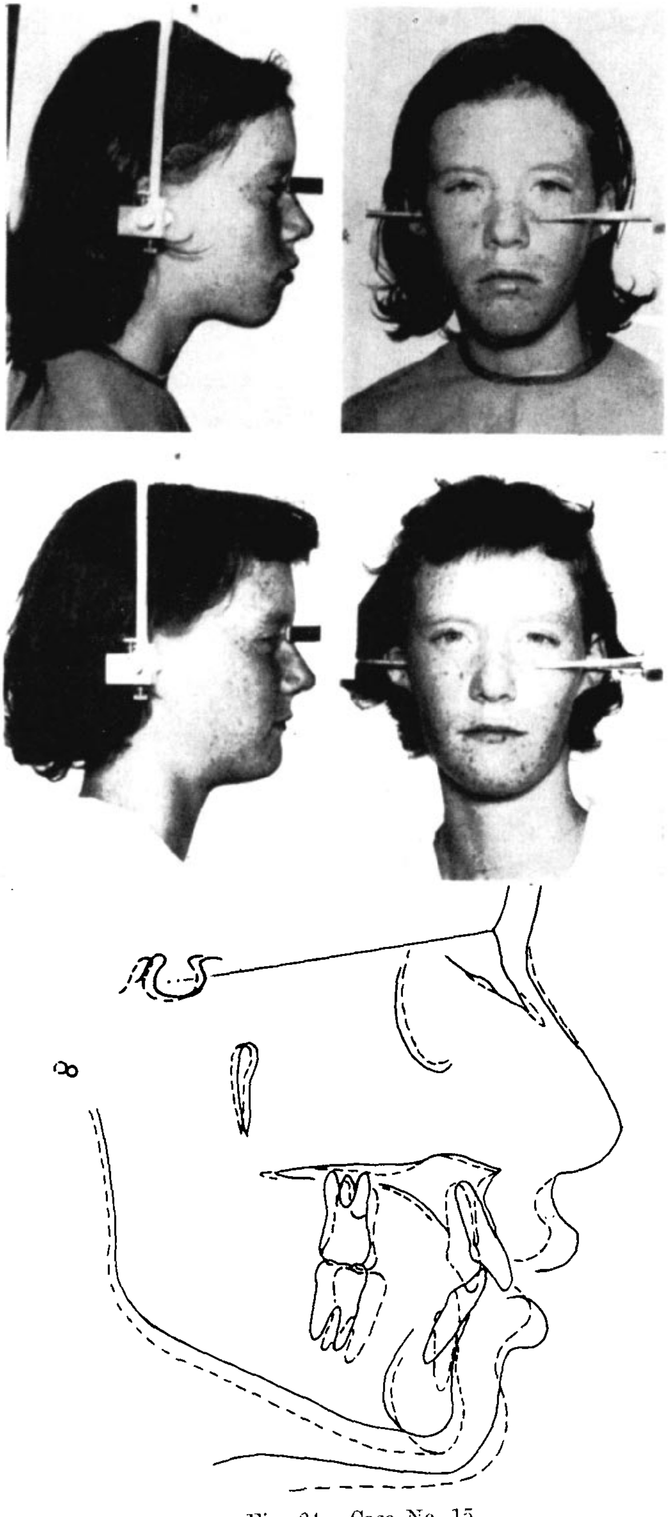


Fig. 24. Case No. 15.

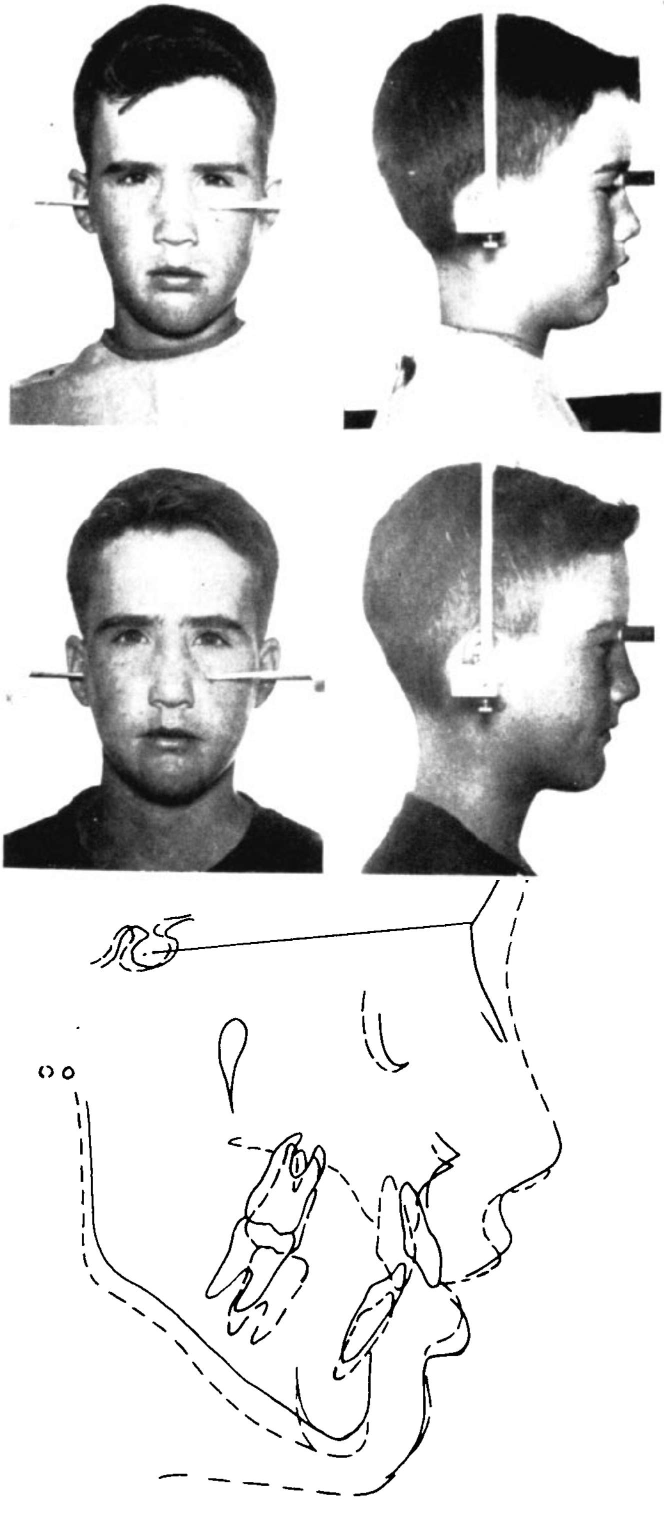


Fig. 25. Case No. 32.

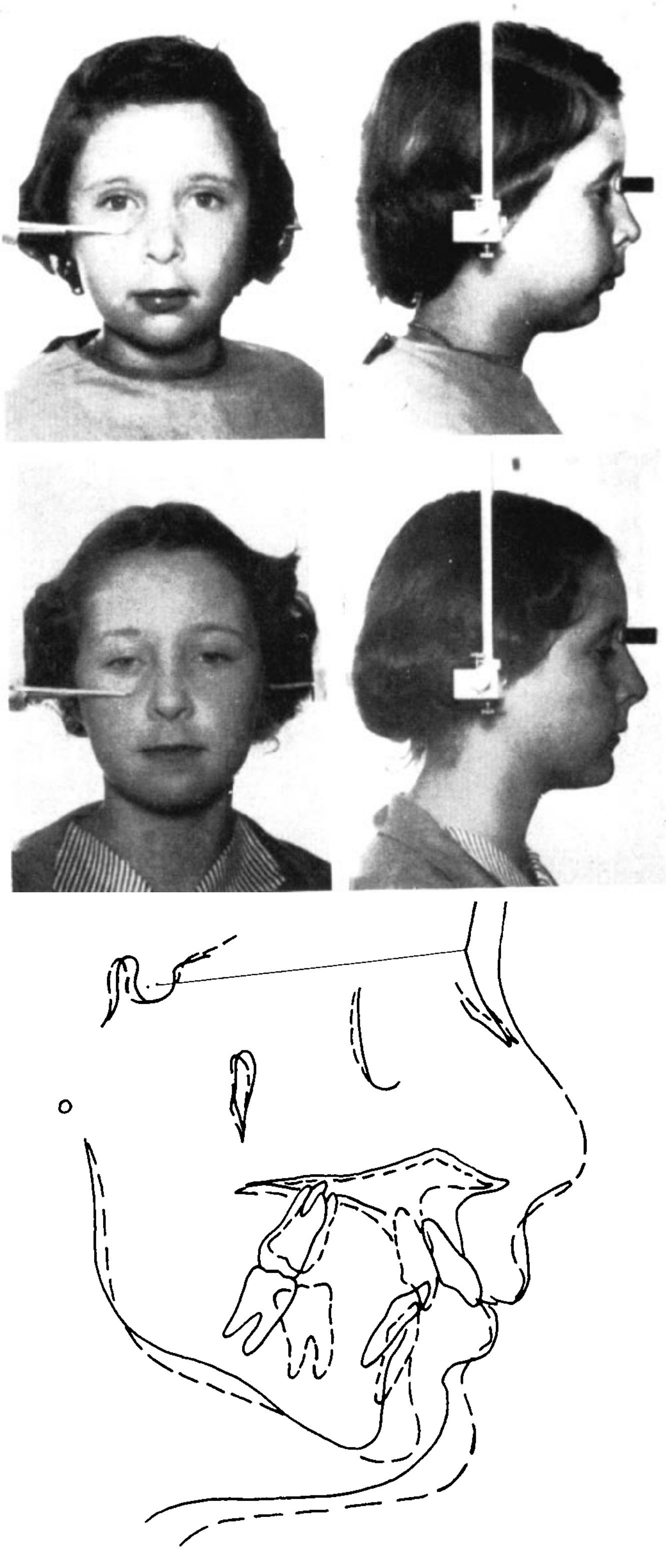


Fig. 26. Case No. 16.

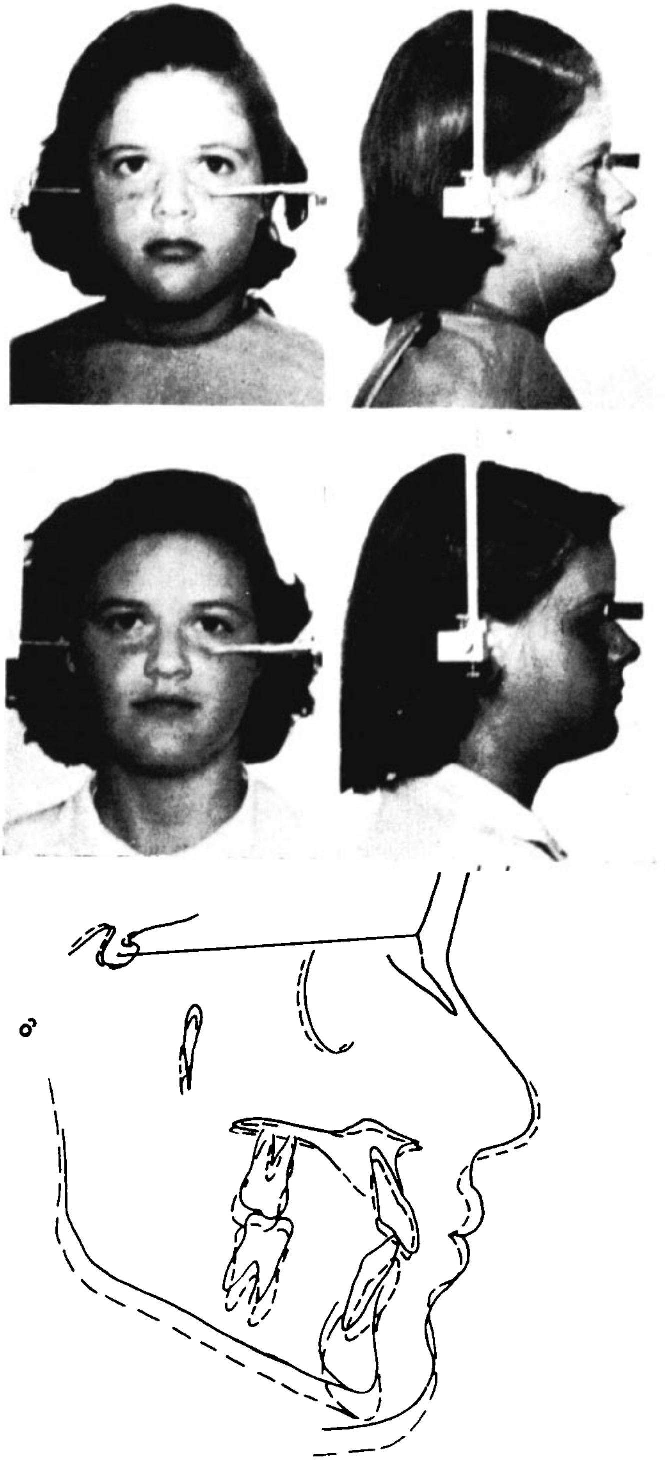


Fig. 27. Case No. 9.

bite 2.0 mm.

The FMIA was increased from 50 degrees to 70 degrees. The lingual movement of the lower incisor to the mandible was 7.0 mm. This measurement was made by superimposing the mandible at the symphysis. If we consider that the growth response carried the mandible forward, the upper incisors could not have been reduced nor could the A-B discrepancy have been helped nearly as much if the lower teeth had not been tipped lingually to permit change in the other structures.

Case No. 9 (*Fig.* 27)

It has been pointed out how increase in vertical height favorably influenced soft tissue contour. In the case of this young lady there were very slight horizontal hard-tissue changes. Yet, on measuring the *soft* tissue contour, we found that upper lip was back 3.0 mm. and the chin was down 5.0 mm. This was correlated with pogonion which opened 6.0 mm. The greatest change in the dental area was an elevation of the upper and lower molars. The increase in vertical height reduced compression of the lips. Consequently, the convexity of the lip area was reduced.

Case No. 52 *and Case No.* 23 (*Fig.* 28)

It would not be fair to imply that all cases responded alike when treated in the same manner. In Figure 28 there are shown photographs of two boys, Case No. 52 in the upper photograph and Case No. 23 in the lower. Though they are not identical, they have several problems in common. Most of their basic skeletal readings before treatment measured within two or three degrees of each other. The original malocclusions were similar and they both treated the same way with similar responses in tooth movement.

After scrutinizing the post-treatment photographs of this case with the previous one, Figure 29, it is quite evident that the change is very gratifying for Case No. 23 but a bit disappointing for Case No. 52. Why? Perhaps we should explain this by a lack of horizontal growth, but actually chin point and angular readings show that the two pretreatment tracings are not far apart.

In Figure 30 are the tracings of the boy in the lower photograph. The dotted line represents the post-treatment change. The upper incisors were moved back bodily 11 mm. ANB was reduced 5 degrees and point A was moved posteriorly 5 mm..

On the tracings of the other boy, in Figure 31 we find even greater bodily movement of the upper incisors, 14 mm.; ANB was reduced 6.4 degrees, and point A was moved back 7.5 mm.

What then is the difference?

If we superimpose the post-treatment radiographs of Case No. 23 on those of Case No. 52 (Figure 32) we find a possible answer. We see that there is considerable discrepancy in dental height between the two tracings. The distance from nasion to anterior nasal No. 52 the lower face has insufficient vertical development as compared to spine is identical in both boys. In Case Case No. 23. We find that both maxillary and mandibular structures on the boy in Case No. 52 disproportionately small. Vertical response to treatment was maximum, but it needs a lot more. Horizontal positioning of teeth in his case had limitations. Despite the extremes of tooth movement in this case, unless a corresponding vertical development could be created, further improvement was limited. Perhaps this boy would have been better if the overbite correction had been accomplished by more elevation of the lower molars instead of depression of the lower incisors. Of course, this might be an impossibility if compensating growth did not occur in the ramus to permit change in the mandibular plane. However, if it is true that growth responds in many

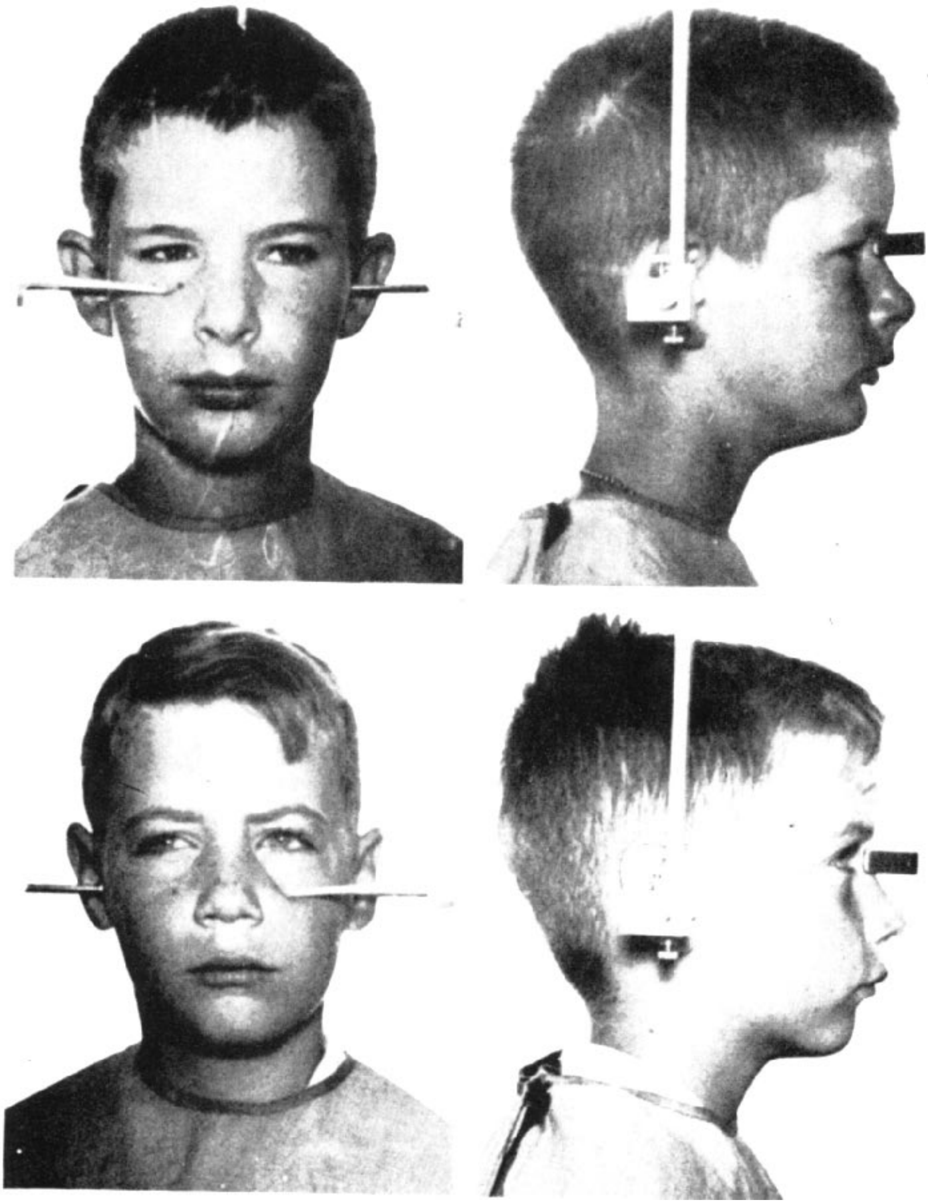


Fig. 28. Case No. 52 and Case No. 23. Pretreatment photographs of two boys with similar malocclusions.

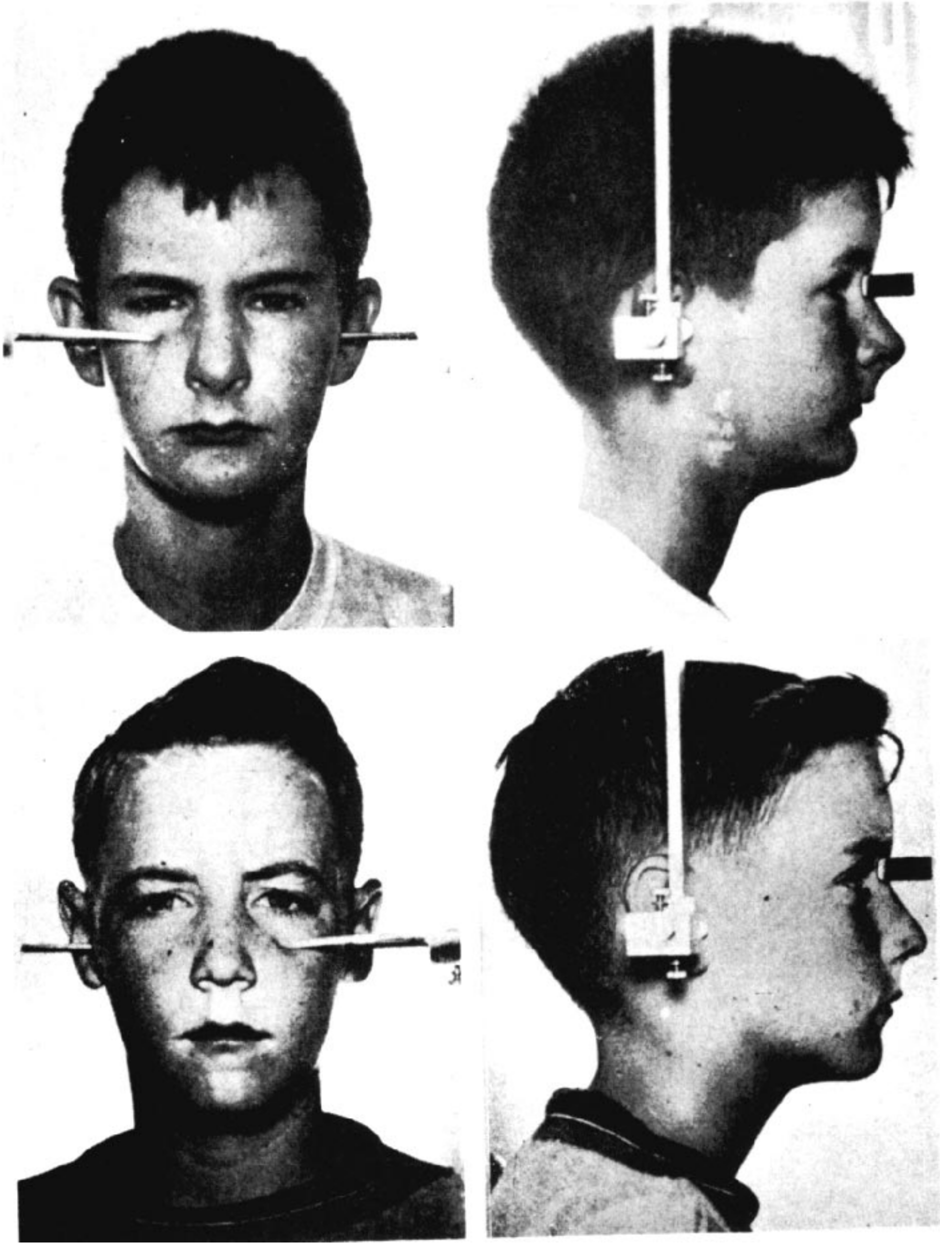


Fig. 29. Post-treatment photographs of Case No. 52 and Case No. 23.

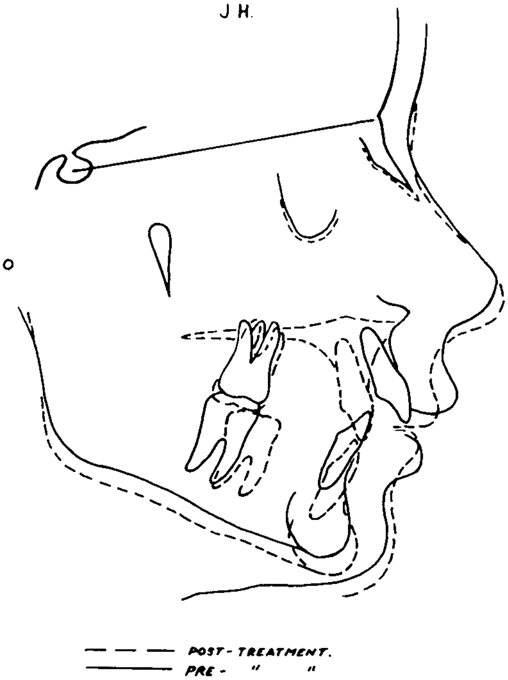


Fig. 30. Tracings of Case No. 23.

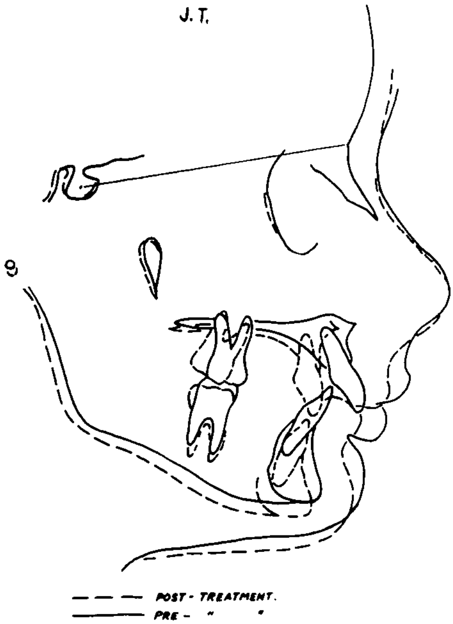


Fig. 31. Tracings of Case No. 52.

instances to orthodontic pressures, such a response might occur in a vertical direction provided the attempt to accomplish this were made.

Conclusion

At this point we would like to explain why we think changing the Frankfort-mandibular incisor angle is effective. Facts are facts and cannot be altered. Dr. Tweed, using his present methods directed along FMIA control,

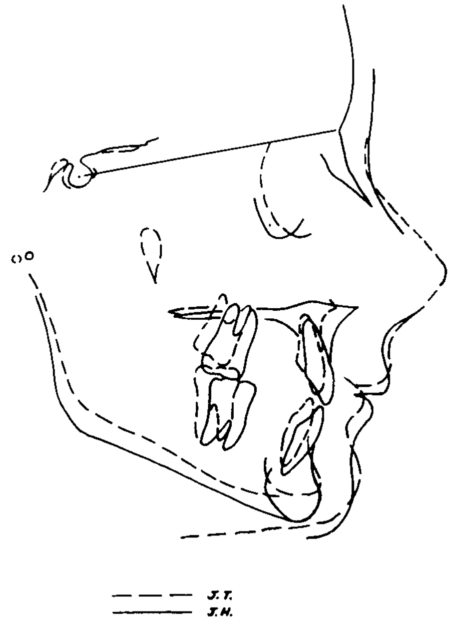


Fig. 32. Superimposed post-treatment tracings of Case No. 52 (broken line) and Case No. 23 (solid line).

is producing startling facial changes. Through the great maze of measurements and statistical data we have not yet explained why it works. However, we believe the explanation is simple when all the facts are carefully considered.

Let us review the direct and indirect effect the inclination of the lower incisor has on the facial structures. The lower incisor is the key to many things.

It can affect upper lip, lower lip, or chin. Its position shows a slight correlation (—.372) to lower lip protrusion. If the incisor is tipped lingually, the lower lip tends to retract in some cases. The position of the lower incisor shows a slight but significant correlation to position of chin point (—.36). As the FMIA approaches a higher reading the chin tends to be more prominent in some cases. The farther back the lower incisor moves, the greater the distance the upper incisor can travel, thereby permitting greater influence on the upper lip.

A most important statement concerning the FMIA is that from all our measurements it seems that this angle is an indication of the anchorage preparation which is necessary to produce the startling changes in the maxilla. This is especially true since we find that the mandible is so unpredictable. Although a slight correlation does exist between FMIA and chin point, the mandible can go back almost as much as it comes forward.

Now how do these facts tie together to explain changes in the soft tissue? The bodily retraction of the upper incisor definitely permits the upper lip to move back. The higher FMIA is an indication of the anchorage preparation necessary to create this movement. Change in the FMIA toward the higher reading tends to permit the lower lip to be moved back. That extra lingual movement of the lower incisor over and above the forward movement of the chin (if and when the chin does move) allows added change to occur in the upper incisor area, permitting further reduction of the lip profile. This added bodily retraction of the upper incisor including the retraction of the anterior limits of the maxillary base tends to emphasize a forward positioning of the chin even when it does not occur. As a result of all this, the front of the face appears to be less convex. The chin appears to be forward, and the lips appear thinner or less protrusive. Certainly then, the importance of the lower incisor as a guide to Dr. Tweed's treatment is clearly demonstrated.

The change in soft tissue contour may be diagrammatically explained in Figure 33. Here is demonstrated how soft tissue appears when the individual parts affected are changed. The first outline (on the left) is an outline of an unbalanced soft tissue profile. The next outline demonstrates how the profile changes by retracting the upper lip only. The lower lip and the chin are the same. As indicated by our figures, this is correlated with retraction of the upper incisors.

The next outline demonstrates the effect of "bite opening" without bringing chin forward. At this time, the greatest improvement in the soft tissue outline occurs, especially when it is combined with the retracted upper lip. Notice how the curl of the lower lip sulcus is changed.

The last outline shows the change that would occur if chin were brought forward. According to recent latent growth studies, there seems to be a tendency for this to develop in the years following treatment.

Summary

1. Our analysis has shown that Dr. Tweed's treatment is very effective. It moves teeth, and it moves them far.
2. The tracings demonstrate bodily movement of the upper incisors in a posterior direction.
3. A decided depression of the lower incisors is obtained.
4. Tracings depict dramatic reduction in the differences of the anterior limits of points A and B in many cases.

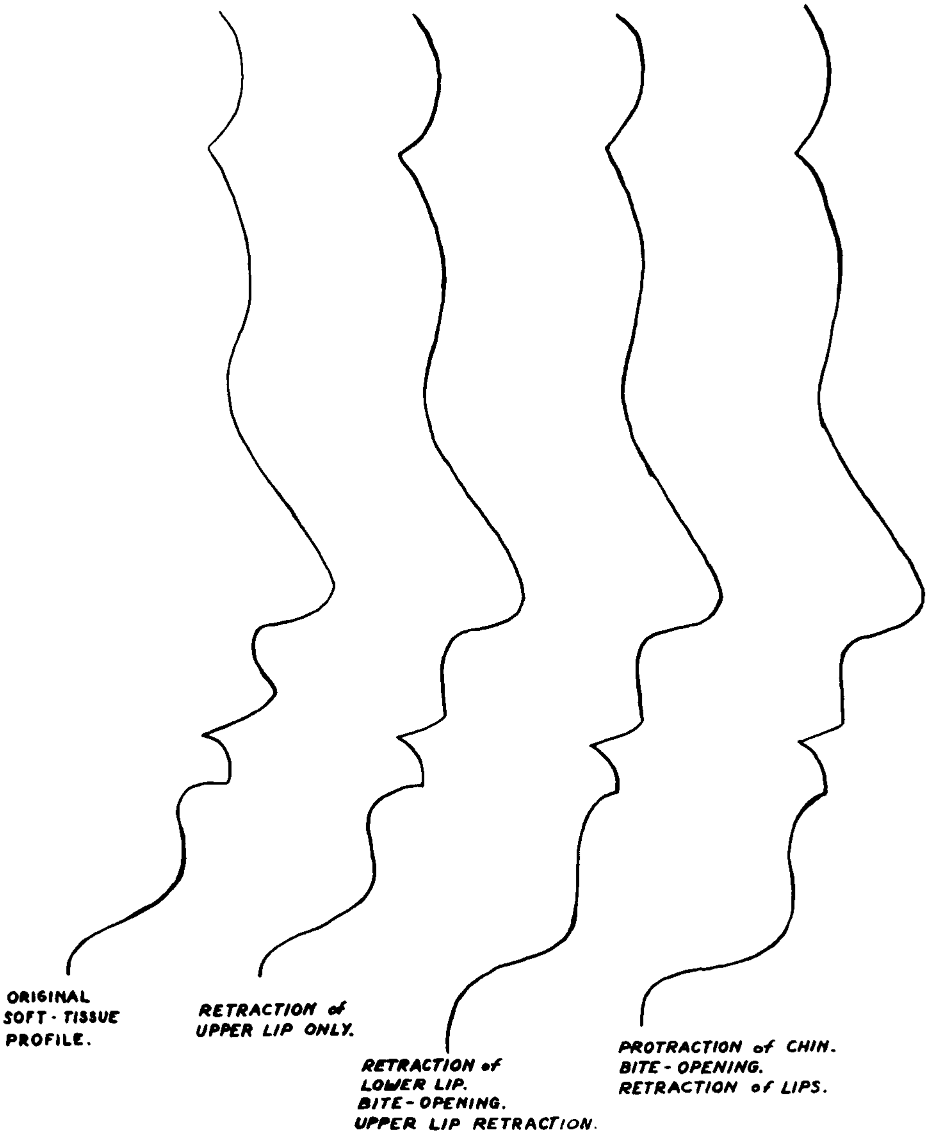


Fig. 33. A series of soft tissue profile outlines showing possible changes that might be effected as a result of deliberate control of orthodontic service.

5. The incisors at point A demonstrate as much change in the non-extraction cases as we found in the cases in which bicuspids were removed.
6. According to our analysis, which is relative to the front of the face, the anterior portion of the maxillary base appears to have been moved backward in a posterior direction to a greater degree than the so-called forward growth at the chin point.
7. The post-treatment change in the mandible is unpredictable. It can go backward as much as it comes forward. In many cases where the mandible did not come forward a great posterior recontouring at A was demonstrated.
8. The Frankfort-mandibular incisor angle, when moved to the higher readings, permitted other structures to be moved into a position which favorably influenced the soft tissue profile. This improvement was due mainly to posterior bodily movement of the upper incisor and premaxillary area, the reduction of the overbite, and in some cases the forward positioning of the chin.

No doubt, many other interpretations may be placed on this data. What we have presented to you is our considered opinion of what happened in Dr. Tweed's cases and why he has been able to produce the changes in the face that he has demonstrated.

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