ORTHODONTIC INFLUENCE ON SOFT TISSUE PROFILE CHANGES

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INTRODUCTION

The facial profile has long been a point of interest to the orthodontic profession, particularly with respect to how the profile can be changed by orthodontic therapy. Many papers have been written on the subject, with the general conclusion that orthodontic treatment does have an effect on profile changes. However, the vast majority of research conducted to date has not adequately differentiated between the changes due to growth from those due to the orthodontic therapy. As a result, the orthodontist may think he has more or less control over profile changes than he actually does.

The fact that there is often a profile change during orthodontic treatment is well substantiated. Whether this change is due to the mechanics of treatment or to natural growth and maturation is hard to say, however, since both usually occur simultaneously. It would, therefore, be desirable to determine whether there is a significant difference in the profile changes of orthodontically treated individuals as compared with non-treated individuals with similar malocclusions, profiles and growth patterns.

The purpose of this investigation is to make just such a comparison. Two groups of children will be studied: an experimental group which has undergone orthodontic therapy and a control group of untreated subjects. An attempt will be made to match treated and non-treated subjects as closely as possible with respect to age, sex and malocclusion in addition to the profiles at the pretreatment age, in order to minimize the growth differences between the groups. By comparing the change in profile of the control group to the change in the experimental group, an accurate evaluation of the effect that orthodontic treatment has on facial profile changes can be made.

REVIEW OF THE LITERATURE

There has been a myriad of articles written about the human soft tissue profile. Over the centuries various artists and anatomists have described and analyzed the esthetic principles of the profile. Considering the firm foundation that esthetics holds in the decision to begin orthodontic treatment, it is not surprising that the orthodontic profession has also directed so much time and effort to the topic of facial profiles.

Most of what has been written in the orthodontic literature is, from a scientific standpoint, somewhat subjective. Subjectivity is, of course, an inherent part of any esthetic evaluation. Perhaps this is why so many methods of "facial profile analysis" have been proposed[26,32,34,35,41,53]. The objective studies concerning the profile, or more specifically the profile as it relates to orthodontic treatment, can be divided into three types: 1) those that compare the profiles of non-treated people only[38,47,7,9,41,5,35,48,20,37], 2) those that compare a group of orthodontically treated patients before and after the therapy[43,16,6,17,24,14,27,31,23,36,11,1,30], and 3) those that compare non-treated individuals with treated patients[47,40,9,2,28,50]. The most common element of profile change that has been studied is how the soft tissue moves in relation to hard tissue changes[39,48,29,43,16,17,6,24,1,14,27,31]. Other variables that have been studied as they relate to soft tissue profile include: 1) Class I versus Class II malocclusions[12,50,24,30]; 2) age and sex differences[38,5,3,12,22]; and 3) extraction versus non-extraction treatment[51,44].

Up until about 1950, references in the orthodontic literature to facial profile were mostly subjective. Angle related his concepts of "best balance", "best harmony" and "normal occlusion" to the profile. Case (1921) believed one should be able to picture in "the mind's eye" a symmetrical face for which he is striving in the case at hand. He made an outline of a face he considered good in profile and used it as a standard of comparison to demonstrate the disharmonies of facial outline in different cases. Mershon (1935) evaluated facial change approaching it as a problem in growth and development. He stated, "Normal growth produces a normal face," but when "growth has gone wrong" the result is "an abnormal or deformed face." By orthodontic care "the deformed face is transformed into the normal face." Wuerpel (1937) made a plea to the profession to include the facial pattern of the patient as well as the type of malocclusion in the treatment plan, and that if an improvement is not possible in this area, common sense should prevent us from accentuating a disharmony.

By 1950 it became obvious that the profession needed more definite guidelines concerning the profile. In an attempt to study what constitutes "good" or "poor" profiles, Riedel[39] had a group of orthodontists judge a series of 28 profile outlines. By comparing the good profile group to the poor profile group, he found the anterior-posterior apical base relationship, the degree of convexity, and the relation of the anterior teeth to the face and their respective apical bases to be important in esthetic balance. In a later article, Riedel[40] attempted to determine facial esthetic values from the viewpoint of the general public. In this study he compared thirty

Seattle Seafair princesses to established orthodontic norms and found that they were similar except for the axial inclinations of the anterior teeth.

In 1955 Wylie[55], investigating Tweed's theory of lower incisor position, studied twenty-nine malocclusions which had been orthodontically treated by Tweed. He was unable to find a significant correlation between the amount of uprighting of the lower incisors and the amount of straightening of the soft tissue profile. He did, however, find a slight correlation between upper incisor angular change and profile change. In the same year, Stoner[47] developed an analysis of soft tissue profile based on angular relationships taken from photographs or x-rays. In another study the following year, Stoner investigated a series of fifty-seven corrected malocclusions that had been consecutively treated by Tweed. He found that the soft tissue improvement of the face during treatment was due mainly to thinning or flattening of the lips, and that these changes seemed to occur because of the gross lingual movement of the incisor teeth, as well as an increase in vertical height.

It was also in 1955 that Pelton and Elsassar[38] published a cross-sectional study of the soft tissue profile comparing age and sex differences. They studied 6,829 people ranging in age from five to twenty-four and found that facial prognathism increases with age, but that the increase in mandibular prognathism was not as great as in the maxilla. In other words, in that study the convexity of the facial profile increased with age in both sexes.

In 1956 Hasstedt[23] studied the soft tissue profile change of twenty-seven malocclusions during treatment and also after treatment. He found a significant increase in the thickness of the upper lip during treatment but concluded that it was a temporary change, as the correlation was not significant some time after treatment. High correlations between movement of mandibular incisors and movements of the upper and lower lips remained high during treatment and post retention studies. It was also in 1956 that Holdaway[26] and Muzj[34] published papers that set down guidelines for soft tissue profile treatment. Holdaway felt that the proportion between the prominence of the lower incisor teeth and the most anterior point of the mandible was important and that a one-to-one ratio of these two measurements would result in the most harmonious relation of the soft tissue immediately covering these structures. Muzj's analysis is based on a "frontal-facial angle" which places emphasis on the upper face, as well as the lower.

In 1957 O'Reilly[36] studied the profiles of twenty-five orthodontically treated cases before and after treatment and one year post-retention. All types of malocclusions were included and the changes in soft tissue thickness were analyzed statistically. He found 1) a reduction of lip and tooth procumbency, 2) an increase in denture height which decreased again after retention, 3) an increase in mandibular plane angle which also decreased after retention and 4) an increase in mandibular prognathism and concurrent decrease in skeletal profile convexity.

In 1959 Burstone[9] published a paper that established norm values to seven horizontal and three vertical measurements. He also examined differences in "contour and extension" with respect to sex and maturation by comparing an adolescent group with a young adult group, all of which had been prejudged as having "acceptable" faces. He found that all measurements were thicker in the male and that the sex difference was more apparent in adults than adolescents. He also found, as O'Reilly had, that the total face becomes less convex with age. In a later article, Burstone[10] found no significant difference in the length of the upper lip when comparing a sample of Class II, division 1 malocclusion cases with a sample of normal faces and occlusions. He suggested that the maxillary incisor is supraerupted in the Class II malocclusion.

It was in 1959 that Subtelny[48] published a longitudinal study of thirty non-treated cases ranging in age from three months to eighteen years. He looked at the relationship between hard and soft tissue changes and found that: 1) the nose continues to grow through the eighteenth year, 2) both lips showed a fairly constant relationship to underlying hard tissues, 3) all parts of soft tissue profile do not directly follow the underlying skeletal profile and 4) the soft tissue did not become more concave with age as the skeletal profile did. Bowker and Meredeth[5] also published a longitudinal study in 1959, in this case investigating profile changes in forty-eight children at age five and fourteen. They found little difference between sexes at those ages, and the only significant changes they found in the profile at fourteen compared to age five was the tip of the nose and the convexity of the chin.

Ricketts[42], in 1960, reported that lip convexity decreases consistently from the deciduous dentition age to adult age. He stated that there is one millimeter of thickening of the upper lip for each three millimeters of retraction of the upper incisors. He felt that the lower lip does not thicken but curls backward as a result of anterior retraction. In addition, he thought that there is an increase of soft tissue chin because lip strain is lost and chin elevation by the mentalis muscle is lost. In a previous study Ricketts[41] had reported that the nose can be expected to grow two millimeters during the course of orthodontic treatment. He also had reported that the upper lip thickens from one to two millimeters depending on the degree of maxillary incisor protrusion and that there is a high correlation between change in lower incisor root position and change in sublabial depression. It was also in the earlier article that Ricketts introduced his "esthetic plane" line, suggesting that the upper lip should fall approximately four millimeters and the lower lip two millimeters posterior to a line drawn from the tip of the nose to the tip of the chin.

Steiner[46] (1960) advocated a different esthetic line; this one from the chin to the middle of the "s" formed by the lower border of the nose and upper lip. He pointed out that lips should fall on this line and that lips anterior to it would be too full and those falling behind it would give too flat an appearance relative to other parts of the profile for a ten to twelve year old.

In 1961 and again in 1966, Baum[3,4] proclaimed a growth differential between boys and girls, indicating that boys grow more and mature later than girls. He also stated that if a boy is treated to an adult at age 14, the chin will continue to grow, leaving the profile even flatter. He speculated that this may encourage some subsequent lower incisor crowding.

In 1963 Matsunaga[31] studied treatment changes in the hard and soft tissue profile of Class II division 1 malocclusions. In his sample, the greatest linear change was found to occur in the total face height. The upper incisor moved posteriorly 6.9 millimeters and the lower incisor decreased 2.3 millimeters. With respect to soft tissue changes, the tip of the nose increased 3.1 millimeters; the upper lip decreased 2.5 millimeters; the lower lip decreased 1.5 millimeters; and the chin increased by 0.6 millimeters. Huerter[27] did a similar study the following year and found that even though the maxillary incisors were retracted less than in Matsunaga's study (4.9 mm), the upper lip decreased more (2.8 mm). He stated that for each 1.7 millimeters of lingual movement of the incisor, the lip was retracted 1 millimeter (this ratio had been previously reported by King[29] to be 2:1). Huerter also found a significant increase in facial height.

Another very similar study was done by Rudee in 1964. He correlated the hard tissue and soft tissue movement of eighty-five randomly selected patients, all of which had worn headgear, and found a high correlation between upper incisor and upper lip (ratio 2.9:1) and between lower incisor and lower lip (ratio 0.6:1). The upper incisor and lower lip had a moderately high correlation (ratio 1:1).

In 1965 B. Ellis[16] reported yet another before and after treatment comparison of hard and soft tissue correlations. In this case, the forty patients were all Class I and all had teeth extracted as part of the treatment. Ellis found that the upper and lower lips showed only slight retraction in his sample and that the soft tissue changes do not necessarily parallel the changes in hard tissue.

In 1966 Chesson[12] investigated age, sex and malocclusion relationships by comparing the profiles of three different groups. Group I was 30 normal twelve year olds; group II was 30 normal twenty-one year olds; and group III was 30 Class II division 1 twelve year olds. He found no sex differences at age twelve but there was a difference at age twenty-one. In addition, males changed more than females from twelve to twenty-one.

Another longitudinal study of non-treated subjects was done by Graves[20] in 1966. Sixteen male and sixteen female subjects were followed at yearly intervals through an age range of seven through eighteen. In general, Graves found an increase in all soft tissue measurements except for the upper and lower lip thickness of the females which fluctuated but did not increase. Males also showed a period of no change in lower lip thickness but only from age ten to fourteen, with increases before and after that. In addition, females were found not to increase in superior labial sulcus to A-point thickness after age nine.

It was also in 1966 that Merrifield[32] offered yet another method of profile analysis - the Z angle. This angle is formed by the intersection of the Frankfort plane and the profile line, which is drawn tangent to the chin and the most anterior point of either the upper or lower lip, whichever is most protruding. Ideally, the upper lip should touch the line and the lower should touch or be slightly behind the profile line. In adults, the normal Z angle is 80 degrees while in children eleven to fifteen years it is 78 degrees.

In 1968 Angelle[2] compared the profiles of thirty-six orthodontically treated patients to sixteen untreated ideals (smile contest winners).

The treatment group were all good cases with no relapse; all were Class II cases or Class I with overjet. Thirteen of the treated cases had been extracted. The control group differed from the experimental in several ways. Besides being ideal cases, the ages were different, and the ratio of males to females differed. Angelle found that the chin and nose increased in all groups. In the treated group, the upper lip was retruded and became thicker. On the whole he found that orthodontic treatment did improve the profile, using Holdaway's, Rickett's and Steiner's analyses as a guide.

In 1969 Williams[53] offered one more method of profile analysis when he reported that the common cephalometric denominator for a harmonious soft tissue profile and lip balance is the position of the incisal edge of the lower incisor relative to the A-pogonion line. He suggests that positioning too far forward of the A-pogonion line makes a protrusive lower lip, and too far back makes for a retrusive lower lip.

In 1970 Branoff[6] investigated changes in soft tissue thickness and lip length. His sample consisted of thirty Class I and Class II extraction cases measured before and after treatment. He found only one positive correlation between hard and soft tissue changes, and that was for the soft tissue covering bony A-point. In another similar study, H. Ellis[17] measured the same changes in 50 Class II division 1 patients, and his findings were consistent with those previously reported. Vertical height increased during treatment; nose increased 1.8 millimeters; ratio of upper incisor to upper lip retraction was 2.3 to 1; and the lower incisor to lower lip ratio was 1.26 to 1.

Hammer[22] did nine angular and fourteen linear soft tissue measurements on 129 "acceptable" non-treated adult profiles comparing sex differences, and found, as Burstone had previously, that males have thicker soft tissue than females, and larger chins, too.

It was also in 1970 that Peck and Peck[37] presented an in-depth essay on facial esthetics. They attempted to interpret public preferences in profile by "profilometric analysis" of fifty-two young adults with good faces. They concluded that the general public likes more protrusive faces than orthodontists do, and that there is generally good agreement among the public as to what constitutes a good or bad profile, even crossing nationalistic or racial lines.

In 1971 Wagner[52] compared profile changes between sixteen orthodontically treated and twenty-six non-treated cases. Each of the treated cases showed retraction of the lower incisors of at least 3 mm during treatment (using mandibular superimposition at the symphysis). Dimensional changes of six hard and six soft tissue measurements were compared at the beginning and end of treatment, and also at least three years post-retention. He found significant differences in the amount of change in each soft tissue measurement except the nose and the chin, with the landmarks of the treated group being retracted more than the controls. The average amount of difference between the treated and control groups was 1.5 mm at the superior labial sulcus, 2.5 mm at the upper lip, 2.1 mm at the lower lip, and 1.4 mm at the inferior labial sulcus. The changes appeared to be relatively stable, as no significant difference between the sample means could be demonstrated at the post-treatment time of measurement. Correlations of change in soft tissue with changes in incisal position were also calculated and were found to be too low to be of any clinical significance.

Cassity[11], in 1971, studied changes that occurred in profile after conclusion of orthodontic treatment. Measuring changes in twenty-four patients, he found that the lips and surrounding area remained relatively constant after orthodontic therapy and stated that "the normal forward growth of the mandible and nose caused the lips to appear more retruded at the end of the study period in relation to the post-treatment appearance." In another post-treatment study that year, Tillmanns[50] compared mandibular growth in treated and non-treated individuals. He found that the treated malocclusion subjects continued to exhibit linear growth similar to that shown by the non-treated normal subjects.

Johnson[28] also compared a non-treated sample to a treated sample in an attempt to find a "profile key" to orthodontic treatment. He compared 62 non-treated adults with good profiles to 76 treated Class II division 1 adolescents. Investigating the relationship that the lower incisor tip has to soft tissue changes he found no difference between his samples and concluded that there is no single key to profile changes.

Schwab[49], in 1971, investigated the difference in profile change comparing patients treated with first premolar extractions to those treated with second premolar extractions. Each group was comprised of nine Class I females with three to five millimeters of mandibular anterior crowding. The samples were paired by matching the subjects as closely as possible with regard to facial pattern and dental relationship. He found that both the maxillary and mandibular incisors showed significantly less posterior retraction when second premolars are removed. He found no significant difference in lip retraction, however.

In an attempt to evaluate the differences between "good" and "bad" profiles, Cox and Van der Linden[13] had orthodontists and laymen judge a series of profile photographs. They noted a general agreement between the orthodontist and lay opinions and found that the profiles that were rated "bad" were more convex than the "good" profiles. The following year Millar[33] compared the opinions of parents of orthodontic patients to that of orthodontists and also found that the opinions were essentially the same.

In 1972 Hershey attempted to eliminate the changes in profile due to growth by investigating profile changes in thirty-six non-growing adult females with all types of malocclusions. Only subjects in which upper incisors were retracted were studied. He related four hard tissue and four soft tissue points to the Nasion-pogonion line, t-tested the change before and after treatment, and found that each point had been retracted by a significant amount. He also found a high correlation in the amount of retraction between: 1) superior labial sulcus and maxillary incisor, 2) upper lip and maxillary incisor, 3) upper lip and lower incisor, 4) lower lip and lower incisor and 5) inferior labial sulcus and B-point.

In 1973, Anderson, Joondeph and Turpin[1] investigated profile changes that occur from the time of treatment completion to at least ten years after the removal of retention appliances. In their sample of seventy patients they found that orthodontic treatment resulted in a reduction of dentofacial protrusion, and that following completion of treatment, the soft tissue continued to flatten with additional nasal and chin growth during maturation. Thickness of the upper lip increased considerably during treatment and this change was related to maxillary incisor retraction (1.0 mm lip thickening for every 1.5 mm of maxillary incisor retraction). During and after retention this lip thickness decreased, but not back to the original dimension. A significant increase remained ten years post-retention. Thickness of the lower lip was not affected by orthodontic treatment, nor was soft tissue thickness overlying Down's point A, point B and pogonion affected.

DeLaat[14], in 1974, compared the difference in profile changes between patients treated under three different treatment philosophies. A total of 150 patients were studied; fifty treated according to the Begg method, fifty by the Tweed method, and fifty by the Riedel method. Among other things, he compared before and after profile point changes, subjective profile changes, and also the correlation between the point changes and the subjective evaluation. It was found that the cases treated with the Begg appliances were not retracted as much as those in the edgewise groups. In the subjective judgement, the Begg Class I cases were judged the most esthetic of the three groups, but the Begg Class II cases were the least favorable.

In 1975, Levin[30] studied thirty Class I and Class II Begg treated cases. He divided the sample into three groups: 1) those with convex profiles, 2) those with convex profiles and prominent mandibles, and 3) those with straight profiles. He found that the mean changes were the same for the three groups, namely, that the lips become less prominent relative to chin and nose.

The literature that has been discussed here is by no means all that has been written on the subject of soft tissue profile. It is representative, however, of the work that has been done concerning the effect that orthodontic therapy has on the profile. To summarize the quantitative studies, we find that several investigators have provided some good information concerning profile changes in normally growing non-treated subjects. More numerous investigators have shown what happens to the profile in orthodontically treated subjects.

In only one of these studies, however, was it possible to differentiate between changes due to growth and those due to orthodontic therapy[24]. Of the relatively few studies that compare treated to non-treated subjects, only one compares samples of the same age range, and none differentiates between types of malocclusions. A need still exists, then, to define the effect that orthodontic treatment has on young, growing, Class I and Class II patients.

MATERIALS AND METHODS

The methods employed in this study are divided into two parts. The first part is devoted to sample selection: the matching of treatment and control groups; the second part is concerned with analyzing the differences in profile changes between the treatment and control groups.

The non-treated control group was selected from the records of the Child Study Clinic at the University of Oregon Health Sciences Center. Longitudinal records, taken biannually until age fourteen and annually after that age, were available for 424 individuals. Of that group, 106 were found to have a bilateral Class I or Class II molar relationship, no history of orthodontic treatment, and records available from age ten through eighteen. Eighteen Class I and eighteen Class II individuals were then randomly selected from the 106 cases. The orthodontically treated experimental group was selected from the records of the Orthodontic Department at the University of Oregon Health Sciences Center. Approximately 1000 cases with complete before and after treatment records were available. Of this group, 240 were found to have bilateral Class I or Class II malocclusions and full-banded orthodontic treatment at an early adolescent age. Males selected had initial (pre-treatment) records between ages eleven years six months and thirteen years six months while the female initial records ranged from ages eleven through thirteen. This resulted in a total of 36 male Class I; 63 female Class I; 50 male Class II; and 91 female Class II individuals from which an experimental sample was selected. The average initial records age was twelve years and six months for the males and twelve years for the females. The age of the initial records for the untreated controls were selected so that they also averaged twelve years six months for males and twelve years for females.

All of the information used in the study was obtained from lateral cephalograms. For each of the 36 control and 240 experimental initial cephalograms, a computer card was punched for the location of three hard tissue and six soft tissue points. This was done on an Oscar model E digitizer and model F decimal converter (Benson-Lehner

Corporation, Los Angeles). With this machine, it is possible to translate each hard and soft tissue landmark into x and y coordinates which are automatically punched on the computer cards. No tracings were made; the cephalograms were placed directly on the digitizer viewing screen, cross-hairs were lined up over each landmark, and a button was pushed to record the x and y coordinates on the cards.

In addition to the hard tissue landmarks sella, nasion and pogonion, the following soft tissue points were recorded on each card (fig. 1):

1) Nose. The most anterior point on the convexity of the nose.

2) Superior labial sulcus (SLS). The deepest point of the concavity between the upper lip and nose.

3) Upper lip (UL). The most anterior point on the convexity of the upper lip.

4) Lower lip (LL). The most anterior point on the convexity of the lower lip.

5) Inferior labial sulcus (ILS). The deepest point

of the concavity between the lower lip and chin.

6) Chin. The most anterior point of the convexity of the chin.

Each of the soft tissue points was related to the nasion-pogonion line, which represented the y-axis in the x-y coordinate system. Each horizontal measurement was made perpendicular to this line and each vertical measurement was made parallel to this line.

A computer program was developed to match the closest treatment profile to each of the control profiles. The computer cards were first separated according to sex and class (I or II). Each control case was then compared to each treatment case employing the formula in Figure 2. The differences in each of the six horizontal variables (soft tissue point to N-Po line), were squared and doubled, and the differences in the five vertical distances between each soft tissue point were squared. The lowest total difference was considered to be the closest profile match. The computer identified the five closest treatment profiles for each control. The final selections were made by visually comparing each of the five computer matches with each control. Other factors, including incisor angle and position, amount of incisal overjet, distances S-N and N-Po, angle S-N-Po, mandibular plane angle, and dental age were then considered. In addition, the three poorest matched controls in each Class were eliminated leaving a total of fifteen matched Class I cases and fifteen matched Class II cases (eight males and seven females in each class).

To determine whether the samples were similar at the initial age, t tests were used to compare the control to the treatment groups in each of the six horizontal soft tissue measurements and the nasion-pogonion distance. No measurement in either the Class I or Class II group was significantly different at the 0.05 level of confidence using either the paired or unpaired t test (Tables I and II). The initial record ages were also tested using paired and Student's t test and they were not found to be significantly different. The average initial ages of the samples were twelve years and four months for the Class I control and treatment groups, and for the Class II control group. The average age of the Class II treatment group was twelve years and five months (Table III).

Each of the thirty treatment group cases that were in the final selection was treated by graduate dentists under staff supervision, using an .022 edgewise bracket technique. Each treatment case had all four first premolars extracted as a part of the orthodontic therapy. In addition, an extraoral appliance was used in each case at some time during treatment to hold or retract the maxillary denture. This was usually a Kloehn-type cervical headgear, but in several cases high-pull or j-hook types of extraoral traction were used. It should also be noted that selection of cephalograms showing grossly incompetent lips or forced lip closure was avoided. For inclusion in the sample, both pretreatment and post-treatment cephalograms had to exhibit 1) good definition of both hard and soft tissues, 2) molar teeth in occlusion, 3) soft tissues subjectively judged to be in relaxed habitual repose, and 4) no orthodontic appliances in place. The patients were all Caucasians from a middle socio-economic group.

Once the initial samples had been selected, the end of treatment cephalograms were digitized in a manner similar to the initial sample. Instead of using the new nasion-pogonion line as the plane of reference, however, the initial sella-nasion pogonion angle was constructed on the post-treatment cephalograms. An acetate tracing of the initial S-N-Po lines were placed directly on the post-treatment films, superimposed on the new sella-nasion line and on the sella point (figure 3). The original N-Po line then became the new y-axis and vertical reference line. In this way, it was possible to note any changes at nasion and pogonion as well as the six soft tissue measurement changes.

The average pre-treatment to post-treatment time spans for the treated samples were 28.3 months for the Class I group and 30.6 months for the Class II group. The post-treatment cephalogram ages for the control samples were selected by matching the treatment time of each treated individual to the control individual with which they were initially matched. The average post-treatment ages in the control samples were 28.7 months for the Class I group and 29.7 months for the Class II group (Table III). The treatment times comparing control to treated samples were tested using Student's t test and found to be not significantly different at the 0.05 level of confidence for both Class I and Class II samples.

The digitizer measured each distance to the nearest 0.1 mm. The reliability of the landmark determination was tested for each of the six horizontal soft tissue measurements, the nasion-pogonion distance and the nasion and pogonion horizontal measurements on the post-treatment cephalograms. Twenty-four (20%) of the 120 cephalograms originally measured were re-digitized two weeks later. The standard error of the measure was calculated for each of the variables using the formula:

$$\text{S. E. Meas.} = \sqrt{\frac{\Sigma d^2}{2n}}$$

The measurement error ranged from 0.3 mm to 0.5 mm for the horizontal measurements and was 0.9 mm for the longer N-Po distance (Table IV).

All of the post-treatment cephalograms were taken on the same cephalometer as the corresponding pre-treatment films. Film image enlargement was not accounted for in the measurements. The cephalometer used to take the treated sample cephalograms had a fixed target to film distance and, therefore, no enlargement changes were encountered in comparing before and after treatment films. The control group cephalograms were taken on a Broadbent-Bolton cephalometer which has a variable target to film distance. The increase in pre- to post-treatment film enlargement was measured in the selected controls. The average increase for the Class I cases was by a factor of 0.0021 per mm, while the Class II control cases increased in enlargement by a factor of 0.0007 per mm. This resulted in dimension changes well below the above mentioned measurement error and the differences were considered insignificant.

The control samples were compared to the treated group by recording the differences between pre- and post-treatment measurements for each of the six soft tissue horizontal measurements, the nasion and pogonion horizontal measurements, and the N-Po distance. The amount of change in the controls was compared to the change in the treated cases in each of the variables and t tests were done to see if the samples were significantly different. This was done for both the Class I and Class II samples (Tables V and VI).

FINDINGS

The magnitude of pre- to post-treatment change in each of the nine measured variables is summarized in Tables V and VI. In the Class II cases, no significant differences were found between the control and treatment groups at the nose, inferior labial sulcus and chin soft tissue measurements, or at nasion and pogonion. Significant differences in the amount of change were noted at the superior labial sulcus, upper lip, lower lip and N-Po distance. The superior labial sulcus measurement increased an average of 2.4 mm more in the control group than in the treated group. The upper lip increased an average of 3.0 mm more in the control group and for the lower lip the difference was an average of 2.4 mm more for the controls. Conversely, the nasion-pogonion distance increased more in the treated group than in the controls, an average of 3.2 mm.

Interpreting the results of the Class I comparisons is more difficult. Significant differences were found in all the soft tissue measurements except the nose. Differences between controls and treated cases ranged from 4.3 mm at the lower lip to 2.7 mm at the chin; in each case the controls increased more than the treated group. In addition, the t values comparing changes in nasion and pogonion were also very high. Since these two dimensions are not normally expected to be affected by orthodontic treatment, each of the soft tissue and N-Po changes were also compared as a ratio of the nasion plus pogonion changes (Table VII). When the data is analyzed in this way, the changes at the nose, superior labial sulcus, chin and N-Po distance are not significant, while the upper lip, lower lip and inferior labial sulcus changes are significant; in each case the control group had a higher ratio of change than the experimental group. The Class II samples were also tested using the ratio of nasion and pogonion change (Table VIII) and the results were similar to those found by testing the pre- to post-treatment changes with significant differences noted at the superior labial sulcus, upper lip, lower lip and N-Po distance.

DISCUSSION

The objective of this investigation was to determine whether orthodontic treatment has any significant effect upon changes of the soft tissue profile. Previous studies have indicated that such changes do occur. The finding that the amount of soft tissue change is significantly different when comparing closely matched orthodontically treated and untreated samples would lead to the assumption that orthodontic treatment was responsible for the difference.

The methods utilized in this study appear to have been sound. The initial samples were considered to be well matched; none of the variables were significantly different, nor were the ages of the records significantly different when comparing the treated and control groups (Tables I, II, III). Assuming the sample sizes were large enough, there was no reason to expect any significant difference in the amount of growth between the control and treated groups, and any difference in soft tissue change could, therefore, be attributed to the orthodontic treatment.

Analysis of the Class II data (Table VI) shows that even though the changes at nasion and pogonion were slightly greater in the treated sample, the changes at the superior labial sulcus, upper lip and lower lip were significantly greater in the control sample. The difference in change at these three points was reinforced when the soft tissue changes were analyzed as a ratio of the growth at nasion and pogonion (Table VIII). The same variables were significantly different when this was done. The magnitude of the differences (2-3 mm less change in the treated sample than in the control) was similar to those previously reported for the superior labial sulcus, upper lip and lower lip[52]. In addition to the differences in soft tissue change, it was found that the N-Po distance increased significantly more in the treated group than in the controls for the Class II samples. This finding is also consistent with previously reported increases in dental height during orthodontic treatment. O'Rielly[36] noted that this increase is apparently temporary since in his study the N-Po length decreased after a period of retention.

Analysis of the Class I data (Table V) shows significant differences in the amount of change in all of the soft tissue variables except the nose. Noting the very high t values of the differences in change at nasion and pogonion and once again assuming that these changes are not affected by the orthodontic appliances, it can be speculated that this difference is due to unequal growth of the treated and control samples. If the control group did grow more than the treated group, the changes due to growth would accentuate any changes that occur as a result of the orthodontic therapy. When the Class I soft tissue changes are analyzed as a ratio of the growth at nasion and pogonion, the only significant differences occur at the upper lip, the lower lip and the inferior labial sulcus (Table VII).

The reason for the apparent inequality in growth between the Class I samples is unclear. Several factors may have contributed. Firstly, judging by the initial N-Po distance (Table I), the control group was slightly smaller initially, giving them a possibly greater growth potential. Secondly, even though the mean initial ages of the two groups were the same (Table III), the control males (which grew more than the females) were slightly younger than the treated males. Thirdly, although the enlargement error of the control group was small, all changes in enlargement tended to accentuate the growth differential. In the final analysis, though, the difference in growth of the Class I samples can probably be attributed to the small sample size.

The measurement errors that were calculated (Table IV) represent two kinds of errors. Firstly, they measure landmark location error, which includes uncertainty on the part of the operator in locating the landmark directly on the unmarked cephalogram, and errors due to variation in film sharpness. Secondly, they measure the mechanical error of the digitizer. The measurement errors not accounted for in this study are those due to variances in positioning of the subject in the cephalometer, and changes in tonacity of facial musculature. Wagner[52] measured this error by comparing films taken of ten subjects at 11 and 11.6 years of age. For the six horizontal soft tissue measurements, he found the S. E. Meas. ranged from 0.28 mm at the inferior labial sulcus to 0.71 at the upper lip. Wisth and Boe[54] compared cephalograms with a three week time difference and, using angular measurements, found a significant difference only in the inferior labial sulcus measurement.

The findings of the investigation show with a reasonable amount of certainty that orthodontic therapy does affect the soft tissue profile in both Class I and Class II cases, at least when full banded treatment, four premolar extraction and extraoral traction are employed. More important, perhaps, is the fact that these results were found in randomly selected "average" cases. The sample was not limited to good headgear wearing patients, cases showing large amounts of incisor retraction or to cases showing dramatic profile changes. The differences seen in this study indicate the average amount of change that orthodontic therapy produces in the average, growing, young adolescent patient.

An important question that should also be answered is whether or not the amount of change indicated is clinically significant. Is a 2-3 mm difference in the superior labial sulcus noticeable? Figure four shows a composite tracing of all the initial

Class II profiles used in this study, along with composites of the subsequent treated and control profiles. The differences illustrated were based on average measurements and only horizontal changes were included. Further investigation is needed to determine whether this amount of change is clinically or subjectively significant.

Another important question that is left unanswered in this investigation is whether or not the variables that are altered during the orthodontic treatment continue to be significantly different after the retention period. Wagner[52] reported an increase in significance at the post-retention stage for the superior labial sulcus, upper lip and lower lip variables, and a decrease in significance for the inferior labial sulcus, indicating that the changes are relatively stable.

SUMMARY AND CONCLUSIONS

The influence that orthodontic treatment has on the soft tissue profile was investigated by comparing changes between a non-treated control and a closely matched treated group for both Class I and Class II samples. Differences in the amount of change was measured for each of six horizontal variables: nose, superior labial sulcus, upper lip, lower lip, inferior labial sulcus, and chin. Differences for each variable were t tested, comparing absolute differences and also ratios of change to growth at nasion and pogonion.

Considering the sizes of the samples and the problems inherent in the design of the experiment, it was difficult to arrive at any absolute conclusions concerning the effect that orthodontic treatment has upon soft tissue profile changes. However, the findings do support the theory that there is a definite relationship between orthodontic therapy and a decreased amount of anterior movement of the oral soft tissue structures.

In the Class II sample, orthodontic treatment resulted in a statistically significant reduction in protrusion of the superior labial sulcus, the upper lip and the lower lip. There was a 2-3 mm difference in the amount of change between the treated and control groups for these variables. In addition, the nasion to pogonion distance showed a significant increase in the treated sample.

In the Class I sample, orthodontic treatment resulted in a statistically significant reduction in protrusion of the upper lip, the lower lip, and the inferior labial sulcus. The amount of difference in change was difficult to estimate due to a differential in growth between the treated and control sample, but it was probably also in the 2-3 mm range for the significantly different variables.

More investigation will be necessary to determine whether this amount of difference is clinically significant, and to see if the changes are stable in the post-retention period.

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Fig. 1. Landmarks recorded on each computer card.

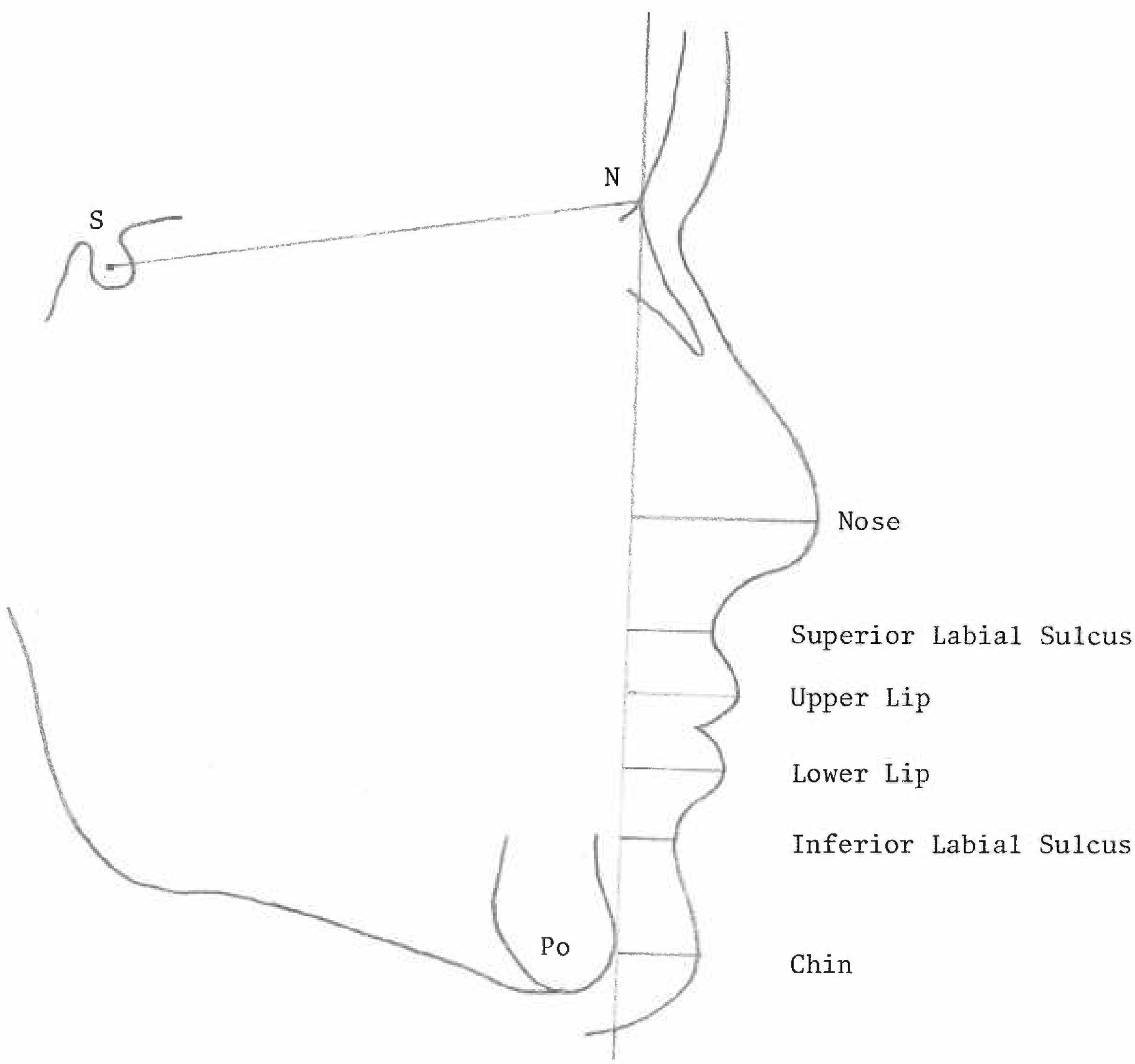
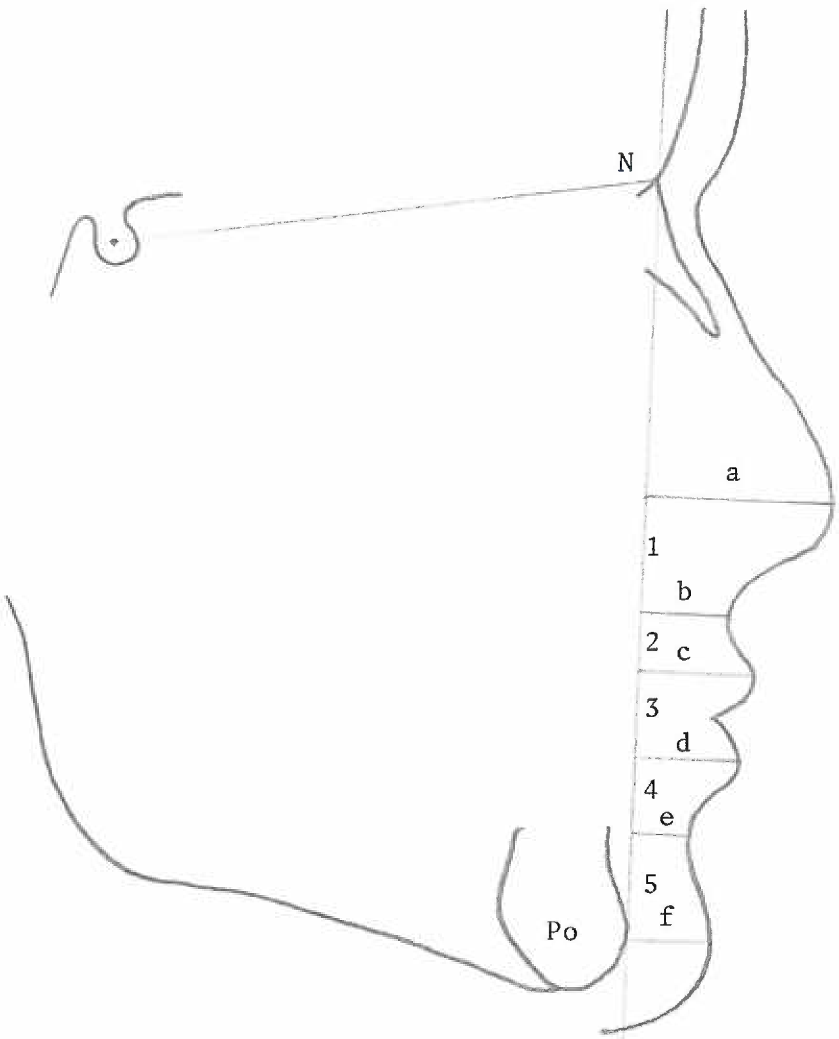


Fig. 2. Profile matching.



1) N-Po line is y axis; horizontal measurements made perpendicular to this line and vertical measurements made parallel to it.

2) Compare each of the control cases to all of the treatment cases of the same sex and class.

3) Sum of the differences: $2(a^2 + b^2 + c^2 + d^2 + e^2 + f^2) + (1^2 + 2^2 + 3^2 + 4^2 + 5^2)$

4) Lowest total difference is the closest match.

Fig. 3. Superimposition of the initial N-Po line on end-treatment cephalogram on a representative Class II control case. Superimposition is at Sella and on the S-N line.

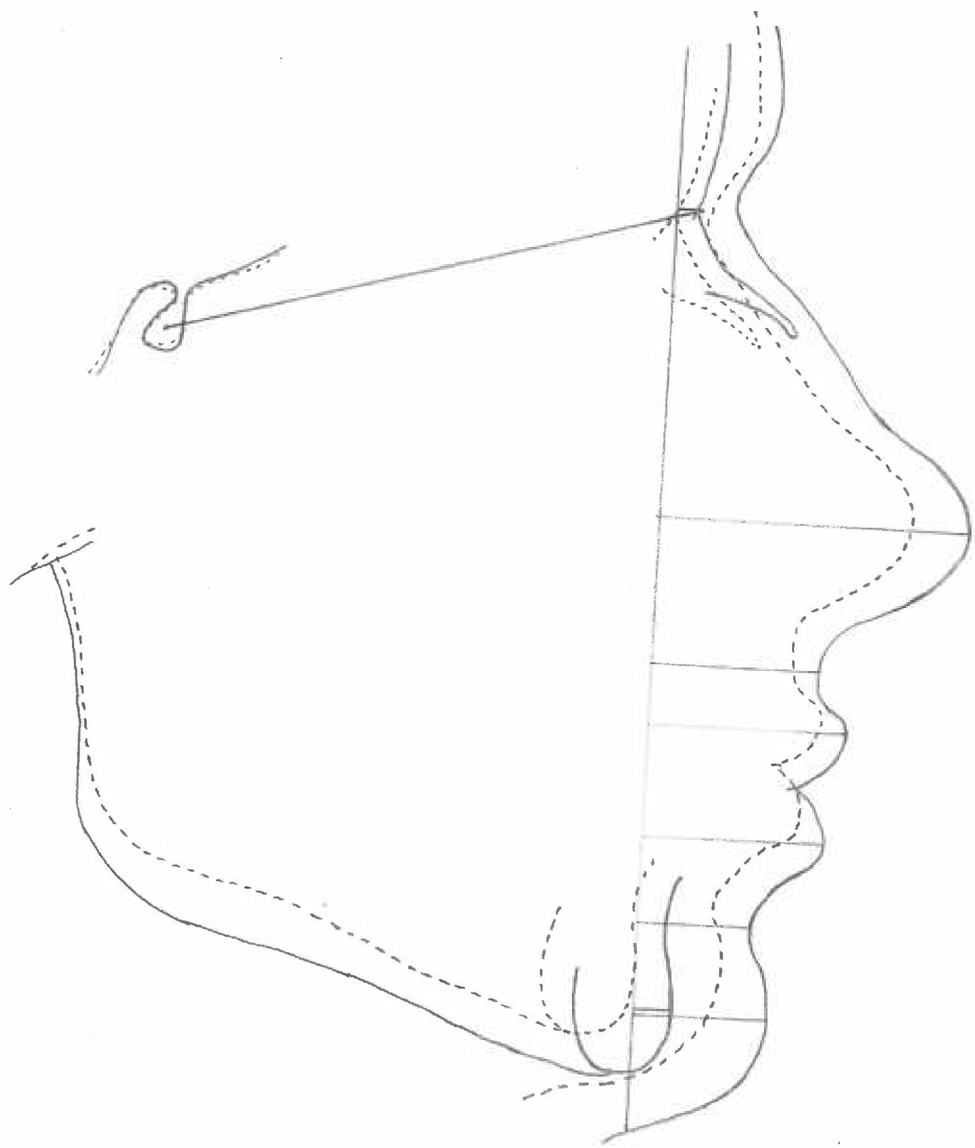


Fig. 4. Differences in the amount of soft tissue change comparing composites of the post-treatment control (blue) and treated (red) profiles to a composite of all the initial profiles (black).

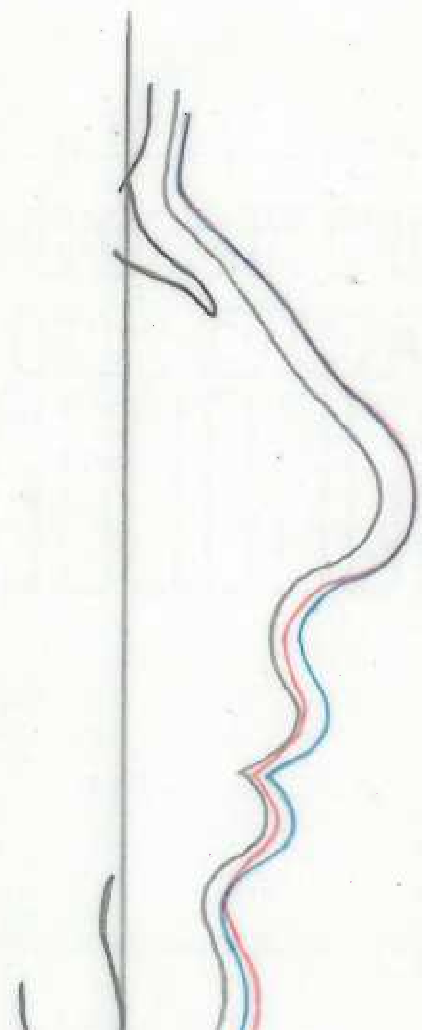


Table I. t test for independent samples between Class I groups (measured in millimeters to the N-Po line).

Variable	Control		Treated		t*
	Mean	S.D.	Mean	S.D.	
Nose	30.25	3.42	30.03	2.74	0.200
SLS	17.24	2.70	17.36	2.89	0.118
U. Lip	20.36	3.46	20.80	4.02	0.321
L. Lip	18.33	3.05	18.85	3.79	0.408
ILS	9.99	1.90	10.61	2.31	0.812
Chin	11.08	1.82	11.83	2.53	0.936
N-Po Distance	109.96	8.61	113.33	7.65	1.132

* At alpha = 0.05, the critical value of t_{28} is 2.048.

Table II. t test for independent samples between Class II groups (measured in millimeters to the N-Po line).

Variable	Control		Treated		t*
	Mean	S.D.	Mean	S.D.	
Nose	32.61	2.51	32.32	3.02	0.290
SLS	19.08	2.25	19.30	2.56	0.250
U. Lip	22.57	2.63	22.79	2.71	0.219
L. Lip	18.11	3.38	19.35	2.92	1.075
ILS	9.43	2.18	10.06	2.55	0.730
Chin	12.65	2.07	12.79	2.19	0.188
N-Po Distance	111.53	6.57	111.15	6.51	0.162

*At alpha = 0.05, the critical value of t_{28} is 2.048.

Table III. Age of sample (in years), and time span (in months) between initial and final records.

Group	Initial Age		Finish Age		Time Span	
	Mean	S.D.	Mean	S.D.	Mean	S.D
Cl. I Control	12.35	0.40	14.83	0.85	28.67	8.23
Cl. I Treated	12.46	0.62	15.01	1.00	28.27	6.22
Cl. II Control	12.36	0.34	14.74	0.78	29.73	7.22
Cl. II Treated	12.31	0.74	14.63	0.92	30.60	7.67

Table IV. Standard error of the measure* (redigitizing 20% of the cephalograms) measured in millimeters.

Nasion	Nose	S.L.S.	U.L.	L.L.	I.L.S.	Chin	Pog.	N-Po
0.428	0.441	0.344	0.403	0.397	0.404	0.541	0.482	0.921

$$* \text{ S. E. Meas.} = \sqrt{\frac{\Sigma d^2}{2n}}$$

TABLE V

Unpaired t test comparing change from pre-treatment to post-treatment between Class I groups (measured in millimeters to the initial N-Po line).

Variable	Control		Treated		t*
	Mean	S.D.	Mean	S.D.	
Nasion	2.18	1.22	1.44	0.83	1.965
Nose	5.56	3.38	4.57	2.20	0.954
SLS	4.03	2.61	1.32	1.68	3.382*
U. Lip	4.30	2.78	0.59	2.16	4.084*
L. Lip	4.45	2.86	0.11	2.13	4.712*
ILS	4.00	2.46	1.08	2.40	3.285*
Chin	5.19	2.84	2.49	2.48	2.772*
Pogonion	4.35	2.27	2.86	2.41	1.739
N-Po Distance	6.10	3.80	5.41	3.32	0.532

*At alpha = 0.05, the critical value of t_{28} is 2.048, and at alpha = 0.01, the critical value is 2.763.

TABLE VI

Unpaired t test comparing change from pre-treatment to post-treatment between Class II groups (measured in millimeters to the initial N-Po line).

Variable	Control Mean	Control S.D.	Treated Mean	Treated S.D.	t*
Nasion	1.63	1.08	1.85	1.39	0.486
Nose	4.95	2.44	4.81	2.83	0.138
SLS	3.48	2.34	1.07	2.59	2.672*
U. Lip	3.35	2.66	0.38	2.65	3.059*
L. Lip	3.48	2.46	1.05	3.32	2.280*
ILS	2.99	2.92	3.06	3.26	0.065
Chin	3.54	2.71	4.66	4.03	0.893
Pogonion	3.77	2.64	4.25	3.11	0.450
N-Po Distance	4.44	2.98	7.59	2.56	3.109*

*At alpha = 0.05, the critical value of t_{28} is 2.048, and at alpha = 0.01, the critical value is 2.763.

TABLE VII

Unpaired t test comparing change from pre-treatment to post-treatment between Class I groups measured as a percentage of the changes at nasion and pogonion (measured to the initial N-Po line).

Variable	Control		Treated		t*
	Mean	S.D.	Mean	S.D.	
Nose	97.24	42.27	180.90	244.79	1.304
SLS	56.79	24.29	38.33	94.47	0.740
U. Lip	59.42	46.62	-12.59	65.05	3.485*
L. Lip	63.71	37.50	-53.42	149.85	2.937*
ILS	60.27	18.64	-16.21	101.93	2.859*
Chin	79.87	21.87	65.59	76.43	0.696
N-Po Distance	103.61	76.33	267.29	427.78	1.459

*At alpha = 0.05, the critical value of t_{28} is 2.048, and at alpha = 0.01, the critical value is 2.763.

TABLE VIII

Unpaired t test comparing change from pre-treatment to post-treatment between Class II groups measured as a percentage of the changes at nasion and pogonion (measured to the initial N-Po line).

Variable	Control		Treated		t*
	Mean	S.D.	Mean	S.D.	
Nose	104.85	36.22	80.01	43.65	1.696
SLS	72.51	57.28	-23.99	130.09	2.629*
U. Lip	71.11	80.86	-45.93	177.95	2.319*
L. Lip	74.01	72.90	-28.21	144.60	2.445*
ILS	43.72	61.37	26.91	76.73	0.662
Chin	64.88	36.80	57.39	72.80	0.356
N-Po Distance	85.32	48.17	197.64	192.42	2.193*

*At alpha = 0.05, the critical value of t_{28} is 2.048, and at alpha = 0.01, the critical value is 2.763.