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Evaluation and Prediction of Integumental Profile Changes Resulting from Orthognathic Surgery to Correct Mandibular Prognathism

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EVALUATION AND PREDICTION OF INTEGUMENTAL PROFILE CHANGES RESULTING FROM ORTHOGNATHIC SURGERY TO CORRECT MANDIBULAR PROGNATHISM

By

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Dedicated

to

My wife, Margo M. Feller, in

appreciation for her many sacrifices

which have made my education

possible.

VITA

The author, Parley Jack Feller II, is the son of Carl W. Feller and Helen (Hodson) Feller. He was born October 27, 1949, in Salt Lake City, Utah. He graduated from Bountiful High School in Bountiful, Utah, in June, 1967.

After studying one year at the University of Utah, in Salt Lake City, Utah, he served two years in Argentina, South America, as a missionary for the Church of Jesus Christ of Latter-Day Saints.

In December, 1969, he returned to complete his predental education at the University of Utah. While at the University of Utah, he was elected a member of Phi Kappa Phi in 1973.

On March 16, 1972, he was married to Margo Miller in Salt Lake City, Utah. They have three children, Jedediah Michael, born March 12, 1973, in Salt Lake City, Utah, Jamie Michelle, born September 3, 1975, in Chicago, Illinois, and Marci Anne, born November 2, 1976, in Chicago, Illinois.

In September, 1973, he entered Northwestern University Dental School in Chicago, Illinois, and he was graduated with the degree of Doctor of Dental Surgery in June, 1977. He was elected a member of Omicron Kappa Upsilon in 1977.

He began graduate studies in the Department of Oral Biology and post graduate studies in the Department of Orthodontics at Loyola University, School of Dentistry in Maywood, Illinois, in July, 1977.

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CHAPTER I

INTRODUCTION

Orthognathic surgery is performed on patients to improve the esthetics of the face and the function of the masticatory apparatus. Great Psychological and psychological changes can be effected with this type of surgery. Because of this, it would be advantageous to have a reliable method of evaluating the amount and type of surgical correction that is needed. Also, from the standpoint of treatment planning, it should be equally important to know what kinds of integumental profile changes can be expected with a predetermined surgical procedure. This would allow the clinician to more accurately select the appropriate treatment plan to achieve the optimum esthetic and functional result.

The integumental profile has been studied by many investigators to better understand the range of acceptable esthetics and function. Musj (1956) introduced the angle formed by the forehead, subnasale, and gnathion as a guide for evaluating the profile. He determined that the profile may appear normal or abnormal depending on the direction of the forehead. Burstone (1958) defined seven soft tissue profile points, and then he evaluated, in detail, the angles each one of these points made with the others (contour angles) and the angles each two points made with the nasal floor (inclination of parts of the face). Using a sample of forty patients, who were chosen by artists, he arrived at normal values for these angles. Burstone (1959) also studied the thickness of soft tissue over the underlying skeleton. Again using a sample of forty patients, he derived norms for male and female integumental "extension patterns" (thicknesses of the integument from hard tissue landmarks to corresponding soft tissue landmarks). Different malocclusions were found to exhibit considerable variation from means of integumental extension. He also noted changes in these extension patterns with maturation of the face.

Because of the detailed nature of his analysis of the integumental profile and the great numbers of component angles and distances, the Burstone Soft Tissue Analysis has had only limited application from a clinical standpoint. However, it is the pioneer study in the field and the foundation upon which subsequent studies are based.

The main objective of this present study is to develop a method of predicting the soft tissue changes that accompany surgery of the mandibular ramus for correction of mandibular prognathism. By studying pre-operative and post-operative lateral cephalometric radiographs of recent mandibular surgery cases, we can make correlations between the actual hard tissue surgical movement, and the resultant position of certain soft tissue landmarks. Based on the surgical case data, we can then mathematically relate the several hard tissue variables that presumably contribute to each soft tissue profile change in the vertical and horizontal planes. This is a multivariate approach (multiple linear regression analysis), and it yields the prediction method. It must be

CHAPTER II

REVIEW OF LITERATURE

Numerous studies have attempted to measure surgical integumental profile change resulting from mandibular surgery. Much of this early literature contains findings which are quite subjective. Knowles (1956) qualitatively evaluated a number of cases surgically corrected for mandibular prognathism. At three to six months post-operatively, he observed a lengthening of the upper lip, a decrease in the eversion of the upper lip, a greater inferior labial sulcus convexity and a more natural fullness to the lower lip.

Aaronson (1967) evaluated the post-surgical results of sixteen adult patients by studying the lateral cephalograms. He found that as the mandible was repositioned posteriorly, facial convexity was decreased and facial esthetics were improved.

The upper lip, he found, was displaced slightly posteriorly; and "the maxillary lip sulcus contour was more obtusely angulated" after surgery. It was here in the area of the superior labial sulcus and upper lip that the least amount of change and the greatest variation was noted; on the other hand the lower lip and the soft tissue chin had a tendency to be displaced downward and backward, while the "mandibular lip sulcus contour was more acutely angulated". In this part of the facial profile (lower lip and chin), he noted the greatest amount of change and the least amount of variation.

Of six skeletal measurements made, the angles had a decreasing degree of correlation with the posterior displacement of pogonion in the following order: facial plane angle, ANB angle, AB to facial plane, Y-axis, angle of convexity and mandibular plane angle.

Bjork et al. (1971) studied the facial profile of twenty-two patients before and one year after surgery. Ten of the patients were studied eleven years after surgical treatment. His findings were also relatively subjective. A change was noted in the position of the lower lip and chin contour corresponding to the positional change of the underlying mandibular bone and incisors. The upper lip became somewhat elongated and slightly retruded post surgically. The results were considered to be relatively permanent over the long observation period of one to eleven years after treatment.

As early as 1972, Robinson et al. introduced a coordinate method for determining the correlation between the change in one hard tissue landmark and one soft tissue landmark in mandibular surgery cases. Ten surgical cases were evaluated with respect to horizontal and vertical changes of the soft tissue landmarks suggested by Burstone (1958). Changes were measured and evaluated for the following periods: pre-surgical orthodontics, actual surgical movement, and post-fixation movement (relapse). The correlation between hard and soft tissue movement in the horizontal plane was significant at the 0.01 level for all treatment periods. In the vertical plane little significant correlation could be found between soft and hard tissue movement.

These investigators suggested several possible reasons for such low correlation in the vertical plane. The landmarks chosen were more appropriate to evaluate horizontal not vertical change (definitions such as "deepest" and "most prominent"). "Different landmarks or a different type of measurement may better reflect small vertical changes".

Inherent variations between patients in tonicity of the facial musculature may influence integumental response to dental and skeletal changes. Also, important factors may be the variability in mandibular plane angle and anterior face height which necessitate different surgical positioning to either open or close the bite. These investigators mentioned other factors which may contribute to the ambiguous results in the vertical plane; tracing error, differences in muscle tonus in subsequent radiographs of the same patient and error in locating vaguely defined soft tissue landmarks.

These factors suggested a follow-up study in which high and low mandibular plane angle cases might be compared using a similar method of study. Also, the cases might be compared using the surgical method employed as the criteria for differentiation.

Hershey and Smith (1974) carried out a study with twenty-four patients in which they used anterior facial height, sella-nasion to mandibular plane angle and the amount of surgical movement (greater or less than ten millimeters) as the three criteria for comparing each of the cases. They found no significant differences, in the soft tissue movements between groups, in each of these subsamples. They were able to show that mandibular soft tissue structures follow the underlying hard tissue pogonion with the following ratios: 0.2:1.0 for upper lip, 0.6:1.0 for lower lip, 0.8:10 for inferior labial sulcus and the 0.9:1.0 for soft tissue pogonion.

Additional findings showed no correlation between the magnitude of surgical correction at pogonion and the change in morphology of the lips. The upper lip prominence was found to decrease with increase in anterior facial height. Conversely, lower lip prominence increased with the increase in anterior facial height. These statements contrasted with a study by McNeil et al. (1972), which concluded that the thickness of the lips varies inversely with changes in vertical dimension.

Lines and Steinhauser (1974) evaluated changes involving forty-one surgical procedures on thirty-five patients. They studied surgical procedures on the mandible and the maxilla to either advance or set back the jaw. They also differentiated alveolar subapical osteotomies from complete body repositioning procedures. Their results paralleled those of earlier investigators of mandibular surgery. They proposed a rough rule of thumb ratio prediction method for each of the different types of surgery.

They hypothesized a two-fold reason for the differential reaction of soft tissue to hard tissue movement. First, the soft tissue of the upper lip is firmly connected to the base of the nose, thus affecting the upper lips' capability to change. Second, the soft tissue tends to compensate for, or mask the skeletal deformity; so that after surgical correction, the soft tissue does not change as much as the hard tissue.

Wisth (1975) compared the soft tissue profiles of sixteen female patients, who had been surgically treated to correct mandibular prognathism, with a group of normals. Evaluation was based on lateral cephalometric radiographs. The upper lip morphology was found to be generally similar between the surgically treated and control individuals, except for a somewhat shorter lip length in the operated individuals. In the study group the lower lip was characterized by a shallow sulcus.

Surgical correction resulted in a lengthening of the upper lip and a deepening of the lower lip sulcus, which tended to normalize lip morphology. The lip position to the esthetic line, however, was not fully corrected. The chin and soft tissue profile appeared different in the study group as compared to the control group. This difference was apparently related to the failure of the orthodontist to properly torque or decompensate the incisors prior to surgery. This orthodontic treatment goal is necessary because in most cases the lower incisor crowns are tipped lingually and the upper incisor crowns are tipped labially to attempt to compensate dentally for the skeletal discrepancy. Wisth explains: "It is likely, therefore, that a full normalization of the lip position can be acheived only by pre-operatively proclinating the lower incisors by orthodontic means (prior to surgery) thereby facilitating a somewhat greater distalization of the mandible."

Dann _et al_. (1976) studied soft tissue changes for a minimum of six months post operatively on eight patients who were treated with total maxillary advancement. They found that the horizontal change of the upper lip to the upper incisor was 0.5:1.0 showing a significance at the 0.05 level. Also, the decrease in the nasolabial angle was found to be significant in relationship to horizontal change in the upper incisor (-1.2°: 1mm). No relationship could be found to exist between horizontal change in the upper incisor and vertical position of the upper lip. Though the small sample size, the variability of the surgical techniques and the elapsed time post surgically may detract from the usefulness of the above findings, they led to the following conclusions: "It is highly improbable that accurate prediction of soft tissue change can be accomplished relating only single variables with one another. It is more probable that the complex behavior of the anatomic structures comprising the facial soft tissue drape will be described in terms of interaction of several factors within the skeletal framework."

Schendel *et al*. (1976) studied soft tissue-osseous relationships in thirty patients that had undergone maxillary surgery (either LaForte I or simultaneous anterior and posterior maxillary osteotomies) to superiorly reposition the maxilla. They introduced a computerized 180 point cranio-facial mode (soft and hard tissue). Using this mode, the pre-surgery, eight day post surgical, and recall (fourteen months mean) lateral cephalometric radiographs were digitized into the computer and composite diagrams of the various treatment stages were plotted out and compared. They evaluated, separately, cases of bimaxillary protrusion and vertical maxillary excess for stability and found them to be equally very stable. They also found movement of the upper lip to correlate well with movement of the upper incisor in the horizontal plane (r=0.767). The upper lip contour did not change but appeared to rotate about subnasale point. The upper lip also appeared to thicken with posterior movement. Again very low correlation was found in the vertical plane.

Roos (1979) studied the soft tissue changes in thirty patients (mean age twelve years) that were treated only orthodontically with four bicuspid extraction. The pretreatment mean overjet in these cases was 9.5 millimeters. He measured changes in the horizontal plane only and found poor correlation between upper lip and upper incisor. (1.0: 2.5, r=0.42), Point A and sulcus superior (1.0:1.4 r=0.58) and between Point B and sulcus inferior (1.2:1.0, r=0.69). The relationship between the lower lip and the lower incisor was found to be only slightly better correlated (1.0:0.9, r=0.82).

Roos described much greater variability of soft tissue response when compared with other researchers. Because the location of the points was measured from a perpendicular to the sella-nasion line at sella, it is possible some of the ambiguity lies in the variability of the angulation of the sella-nasion plane from one patient to another.

Hohl _et al_. (1978) introduced a technique which allows production of lateral and frontal photographic film transparencies to be superimposed over the corresponding cephalograms. In this pilot study, the dimensions of the photograph and the cephalogram were standardized such that they could be superimposed for correlative measurement. The findings, in comparing presurgical and post-surgical records of patients having undergone different types of craniofacial osteotomies, were purely qualitative. However, subtle changes in the appearance of the soft tissue from the frontal aspect can be evaluated by comparing pre and post surgical photocephalometric overlays. According to the authors, further studies will be undertaken to quantitatively measure soft tissue changes, after all the sources of error in this technique have been evaluated and corrected. These sources may include optical distortion, magnification error and reproducibility of patient positioning.

Suckiel and Kohn (1978) evaluated soft tissue changes associated with surgery for the correction of mandibular prognathism. Cases were accepted only if they exhibited less than three millimeters change in vertical dimension after the surgery. Each case had pre-operative, immediate post operative and later post-operative (three to six months) lateral cephalometric radiographs for evaluation. Drawing the data from the largest sample to date (fifty patients), their results were similar to those of earlier studies, in that a good correlation was found to exist between the movement of the hard tissue mandible and mandibular soft tissue structures (lower lip, inferior labial sulcus, and soft tissue pogonion). They found that soft tissue pogonion moved in a ratio of 1:1 with hard tissue pogonion; inferior labial sulcus moved with Point B in a ratio of 1:0.95; the lower lip moved with the lower incisor according to the ratio 1:0.83; and finally, the lower lip moved in a ratio of 1:0.67 with the hard tissue pogonion. Upper lip, superior labial sulcus and stomion, however, showed very low correlation coefficients to the movement of mandibular hard tissue structures. Vertical changes were not evaluated in this study.

Quan _et al_. (1978) in an unpublished study, introduced a prediction method for maxillary surgery. This method was developed using a sample of nineteen patients that underwent either Le Forte I or anterior alveolar segmental osteotomies. First, an examination was made of simple and multiple correlations between hard and soft tissue movement. No significant differences were found between the Le Forte and alveolar osteotomy groups. Then, using simple correlation coefficients a computer program related various hard tissue point changes to soft tissue point changes. The hard tissue points most closely related to soft tissue change, were then used to generate regression equations. These equations constituted a new prediction method. A stepwise linear multivariate equation was determined for each coordinate of each soft tissue point. The study then compared the accuracy of this method with the Ricketts non-surgical visualized treatment objective (VTO) method for predicting soft tissue changes with treatment. Both methods were then compared for accuracy with the actual surgical change. Since the soft tissue points above subnasale were not significantly affected by the surgery, only points including subnasale and below were utilized in the new method of prediction. These seven soft tissue points included subnasale, superior labial sulcus, upper lip, stomion, lower lip, inferior labial sulcus, and soft tissue pogonion. These were evaluated with horizontal and vertical coordinates of movement. The new method was found to have significantly less mean standard error (less than 1.4 millimeters for all coordinates except lower lip-vertical and pogonion-vertical), than the Ricketts method (mean standard error of approximately three millimeters). The prediction error for the Ricketts method was considered to be quite large since the surgical change usually fell within the range of one to four millimeters.

This new prediction method was then tested for validity by using it on two cases not included in the original sample. The actual postoperative tracing was superimposed with the predicted surgical soft tissue change. Visual examination revealed the predictions for these cases to be "fairly accurate".

CHAPTER III

MATERIALS AND METHODS

A retrospective cephalometric study was conducted on thirty-eight adult patients who underwent surgery for the correction of mandibular prognathism. In each case the surgical method employed was a vertical subcondylar osteotomy (ramus procedure). In every case but one, the patients were being actively treated with conventional fixed orthodontic appliances prior to surgery and after removal of intermaxillary fixation (six to eight weeks post surgery.) The one exception (case #24) had previously been treated orthodontically and was now being treated with surgery alone. In this case arch bars were attached to the buccal surfaces of the maxillary and mandibular dental arches by passing .014 inch dead soft stainless steel wire beneath the interproximal contacts and ligating the arch bar to each tooth. This provided an attachment such that the jaws could be wired together during the post surgical stabilization period.

The majority of the patients records were obtained from cases treated by the following orthodontists in private practice: Drs. George R. Ostenberger, Henry D. Peterson, and Donald A. Carollo, Joliet, Illinois; Dr. Andrew J. Haas, Cuyohoga Falls, Ohio; Dr. Thomas W. Flemming, Olympia Fields, Illinois; Dr. William J. Newell, Libertyville, Illinois; Dr. William D. Petty, Chicago, Illinois; Dr. Harold T. Perry, Elgin, Illinois; Drs. Dan H. and John D. Watkins, Moline, Illinois; and Robert A. Wertz, Kankakee, Illinois. In addition two case records were made available through the Foundation for Orthodontic Research. Also, the records of two cases were used of patients that were treated at Loyola University School of Dentistry, in the Departments of Orthodontics and Oral Surgery.

The presurgery and postsurgery cephalometric radiographs of these cases were evaluated to be of suitable quality and detail to be included in the study. There were, however, twelve cases of those gathered that were determined to be unsuitable for study, due to poor radiographic positioning technique or lack of radiographic clarity. Though the radiographs came from different sources, they were standardized in that the cephalometer holds the head in a fixed reproducible position. In all standard cephalometers the distance from the x-ray source to the mid-sagittal plane is 60 inches; and the distance from the mid-sagittal plane to the film cassette is 15 centimeters.

The cases were included in the sample as they were gathered. The first sample included twenty cases and was used as the experimental or prediction sample. The remaining eighteen cases were used as a test or comparison sample for the original twenty cases. The mean age at surgery for the prediction sample was 23.2 ± 9.9 years. The mean time between presurgery cephalogram and surgery was 6.9 ± 6.5 weeks. The mean time between the surgery and the postsurgery cephalogram was 19.2 ± 9.9 weeks. (Table I)

The mean age at surgery for the comparison sample was 23.7 ± 9.5 years. The mean time between the presurgery cephalogram and the surgery for the second sample was 31.2 ± 27.5 weeks. The mean time between the surgery and the post surgery cephalogram was 30.4 ± 27.1 weeks. (Table II)

Although an attempt was made to gather case records in which the postsurgery cephalogram was taken eight to ten weeks postsurgery and before orthodontics was resumed, it is obvious from the case distribution data that this was not always possible.

For each case, two cephalometric tracings (presurgery = T1 postsurgery = T2) were made with a 0.3mm. tracing pencil on acetate tracing paper. Hard and soft tissue landmarks (Figure 1) were located on both tracings. Eleven soft tissue points were evaluated for change. These points are modified from Burstone (1958) and are defined as follows:

Gl (glabella): The most prominent point in the midsagittal plane of the forehead determined by a tangent to the forehead from a line perpendicular to Frankfort horizontal.

Na (soft tissue nasion): The most concave or retruded point in the tissue overlying the area of the fronto nasal suture measured from a line perpendicular to Frankfort horizontal.

Nc (nasal crown): A point along the bridge of the nose halfway between the soft tissue nasion and pronasale.

Pn (pronasale): The most prominent or anterior part of the nose as measured from a perpendicular to Frankfort horizontal.

Sn (subnasale): The point at which the nasal septum between the nostrils merges with the upper cutaneous lip in the mid-sagittal plane. The point where maxillary lip and nasal septum form a definite angle. If the depression is a gentle curve, subnasale is interpreted as the most concave point in this area as measured by a line angled 45 degrees from Frankfort horizontal.

A point (superior labial sulcus): The point of greatest concavity in the midline of the maxillary lip between subnasale and labrale superius as measured from a perpendicular to Frankfort horizontal.

UL (labrale superius): The most prominent point on the maxillary lip as measured from a perpendicular to Frankfort horizontal.

St (stomion): The median point of the oral embrasure when the lips are closed. If opened or relaxed, it is the midpoint between the most inferior point of the maxillary lip and the most superior point of the mandibular lip.

LL (labrale inferius): The most anterior point on the mandibular lip as measured from a perpendicular to Frankfort horiziontal.

B point (inferior labial sulcus): The point of greatest concavity in the midline of the mandibular lip between labrale inferius and pogonion as measured from a line perpendicular to Frankfort horizontal.

Pog (soft tissue pogonion): The most anterior point on the soft tissue chin as determined by a perpendicular line to Frankfort horizontal.

Eleven hard tissue changes were determined for each tracing. These variables (points, angles and distance) were chosen because of the likelihood of their being contributing factors that resulted in a given soft tissue change. The hard tissue variables are defined as follows:

ANS (anterior nasal spine): The anatomic skeletal landmark.

A point (hard tissue A point): The deepest point on the curve of the maxilla between the anterior nasal spine and the maxillary dental alveolus as determined by a line perpendicular to Frankfort horizontal.

$\underline{1}$ (maxillary central incisor): The maxillary central incisor's incisal edge.

$\overline{1}$ (mandibular central incisor): The mandibular central incisor's incisal edge.

B point (hard tissue B point): The deepest point on the curve of the mandible between pogonion and the dental alveolus as determined from a line perpendicular to Frankfort horizontal.

Pog (hard tissue pogonion): The most anterior point on the hard tissue mandible as measured from a perpendicular to Frankfort horizontal.

F-Axis (facial axis): The angle formed by the lines basion-nasion and facial axis. The change in the angle is measured. Clockwise mandibular rotation is assigned a negative value, while counter-clockwise rotation is assigned a positive value.

LFH (lower facial height): The angle formed from anterior nasal spine to the center of the ramus (XI) to pogonion. The change in this angle is measured. Increases in the angle are assigned positive values and decreases are assigned negative values.

FA (facial plane angle): The angle formed by Frankfort horizontal and the line from hard tissue nasion to hard tissue pogonion. The change in this angle is measured. An increase in the angle is assigned a positive value while a decrease is assigned a negative value.

MPA (mandibular plane angle): The angle formed by Frankfort horizontal and the line that approximates the lower border of the mandible and passes through menton. The change is this angle is measured. An increase in the angle is assigned a positive value, and a decrease is assigned a negative value.

$\underline{1} - \overline{1}$ (interincisal distance): The pre and post-surgery change in the distance between the maxillary and mandibular central incisors' incisal edges. This is measured in millimeters.

If the skeletal and integumental contours were not convex or concave enough to yield one most prominent or most retruded point; the distance along the curve that was most prominent or most retruded was measured and the exact middle of this distance was considered to be the exact point.

To test the accuracy of locating the soft tissue points, four cases were randomly selected and the points were relocated and compared with the original points. This method of locating soft tissue points was found to be accurate within 0.5 millimeters. Horizontal and vertical coordinate changes between the T2 and T1 tracings were then measured with respect to Frankfort horizontal and pterygoid vertical (axes). This was done by placing the tracing paper over millimeter graph paper and recording the changes. Also, the hard tissue point changes were similarly measured, as well as the variable angles and distance.

The next step in the study was to examine correlations (simple and multiple) between soft and hard tissue coordinate measurements. Also, an evaluation of the mean surgical changes for each soft and hard tissue point or variable was made. The purpose of this was to determine if there was a significant difference between the cases that had a greater or lesser amount of time elapse between pre and postsurgery cephalograms. An arithmetic inspection was made of other characteristics such as mandibular plane angle, lower face height, sex, age, and ethnic background with respect to each case to determine whether any of these differences could be correlated to a particular surgical response. No significant mean surgical or correlative differences were noted between cases.

Using the twenty cases in the prediction sample (S1) a computer program* was used to relate the hard-tissue measurement changes to the eleven soft tissue points to be predicted. The hard tissue points which were most closely related to soft tissue surgical movements in these twenty cases were then used to generate** the regression equations which make up the prediction method. A stepwise linear multivariate equation was determined for each coordinate of each soft-tissue point (Table III). These equations were then used to predict the soft

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* UCLA Biomed Series BMD 02D
** UCLA Biomed Series BMD 02R

tissue changes for the prediction sample (S1) and the comparison sample (S2). The soft tissue mean residuals*, that is the mean difference between predicted and the actual profile changes (prediction error), were then calculated for both samples. The prediction residuals were then compared for the experimental (prediction) sample and the control (comparison) samples (Figure 4). The accuracy of the prediction method was then evaluated based on this information.

Additionally, to test the random selection of cases for each sample, the samples were combined and then randomly redivided into a larger prediction sample (N=25) and a smaller comparison sample (N=13). A new set of multivariate equations were similarly derived from the larger sample and applied as a prediction method to both new samples. The prediction error for the new equations and method was then compared to the prediction error for the original method.

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* Mean prediction residual = $\left(\sum_{i=1}^{N} |\text{obser}_i - \text{pred}_i| \right)$

CHAPTER IV

RESULTS

The stepwise multiple regression equations that were generated for each vertical and horizontal soft tissue coordinate are listed in Table III. Though the computer generates the equations by adding in successively significant variables, it was necessary to decide at which point to stop adding variables. This was done by determining the point in the derivation of the equations at which the significance of the resultant equations was not increased. This was arbitrarily defined as the point where there was an 80% level of confidence that the last variable added into the equation had a significant effect on the prediction. This corresponds roughly with the point at which the multiple r coefficient doesn't increase by at least .04, or when the F ratio fails to be greater than 1.5 for the next variable that is added.

Upon analysis of the prediction sample data (Table IV) the mean prediction residuals (mean prediction error) for each of the soft tissue coordinates were found to be quite small (less than one millimeter average). It should also be noted that for this sample the actual surgical change of the forehead, nose and upper lip was relatively small when compared to the much larger changes in the lower lip and chin area. Indeed it can be shown graphically (Figure 2) that in this sample, at least for the first seven soft tissue points (Gl, Na, Nc, Pn, Sn, A, UL) the prediction method would not be significantly more accurate than simply using the presurgical profile. The remaining mandibular soft tissue points appear to be predicted with reasonable accuracy (1 millimeter or less average residual or error). For example, looking at the values for pogonion on the graph (Figure 2), it can be noted that the actual mean surgical change in the horizontal plane was over 8 millimeters; whereas the mean prediction error for that coordinate was less than 0.5 millimeter. For this soft tissue coordinate the error was very small as compared to the actual surgical movement. In the vertical plane, however, the actual mean surgical change was 1.7 millimeters, while the mean prediction error was almost 1.4 millimeters. For pogonion vertical, the prediction error was very close to the amount of surgical movement. It is evident then, that when the difference between the prediction residual and the actual surgical movement is great (pog h), the accuracy of the prediction for that soft tissue point is greater than for the point which has little or no difference between the prediction residual and the surgical movement (pog v).

An examination of the comparison sample data (Table V) shows the mean prediction residuals to be much greater (2.0-2.5 millimeters average). Like the data from the first sample, the mean surgical change for the forehead, nose and upper lip in this sample appear to be small (1 - 1.5 millimeters average) when compared with the surgical change in the lower lip and chin. Comparison of the actual surgical movement with the mean prediction residuals (Figure 3) shows that for almost every case the mean prediction residuals are greater than the actual surgical change for each corresponding point. The notable exceptions to this are Pog h, B h, and LL h, which represent the soft tissue overlying the mandible where the greatest horizontal change is effected. However, even for these three points the mean residuals (or prediction error) are 1.5 - 2.0 millimeters.

Graphically comparing (Figure 4) the accuracy of the multivariate prediction method when applied to both samples, it can be seen that the mean prediction residuals for the comparison sample are approximately double those for the prediction sample.

Table VI shows mean prediction residuals for the new prediction sample ($N1'$=25) and the new comparison sample ($N2'$=13). Using new equations generated from these twenty-five prediction cases a new prediction method was developed and applied to both new samples. It is evident that the residuals are equally high (2 millimeters average) for both samples; and in fact for several points the residual or prediction error was greater for the prediction sample than for the comparison sample. This is illustrated graphically in Figure 5.

CHAPTER V

DISCUSSION

Just as Aaronson (1967) found, qualitatively, it appears that as a result of mandibular surgery to correct prognathism, the upper lip exhibits the greatest amount of variation and the least amount of change, while the lower lip and chin exhibit the least amount of variation and the greatest amount of change. The amount of change and the variability are most easily seen when examined visually for individual cases (case number 1 - 20 are the prediction sample and case numbers 21 - 38 are the comparison sample). For case number 1 (Figure 6) it appears that the prediction was very close to what actually happened. Also it is evident that with the surgery the upper lip seemed to rotate downward and backward about subnasale. This is contrasted with case number 4 (Figure 7) in which the entire upper lip including subnasale appears to have been translated backwards bodily. A possible explanation for this may be that the morphology of upper lip for case number 4 prior to surgery was much more distorted than for other cases. Also there was a greater amount of surgical change for this case.

Cases number 14 (Figure 8) and number 25 (Figure 9) are representative cases from both samples in which the upper lip remained unchanged. One might conclude here that when the morphology of the upper lip appears to be relatively normal, not puckered as a result of a very poor vertical relation or a more severe skeletal problem prior to surgery, it changes very little if any.

Contrasted with the preceeding two cases, case number 19 (Figure 10) and case number 26 (Figure 11) the upper lip elongates and moves downward and backward (Similar to case number 1). This behavior is similiar to the results of several previous studies (Knowles, 1965 and Bjork, 1971).

An evaluation of some of the cases from sample number 2 that had the greatest prediction error might provide some insight as to why these cases were not predicted well by the equations. Case number 33 (Figure 12) had a very sharply delineated crease at subnasale prior to surgery. This appeared to be abnormal (at least for this patient) because after surgery the subnasale area was smoothed out to a gentle curve. Also in this case the upper lip moved down and backward further than predicted; and the lower lip and soft tissue point B were retracted a greater amount that expected. With case number 34 (Figure 13) the very large change in the hard tissue mandible predicted a greater change downward and backward in the maxillary lip structures than actually happened. It appears that mathematically for a given amount of surgical change the soft tissue should change a proportional amount; but biologically this is not the way it happens.

For two of the cases that were predicted the worst (case number 30, Figure 14 and case number 31, figure 15) the prediction dictates that the maxillary lip should have come downward and backward with surgery, but interestingly enough the upper lip moved downward and forward instead.

In case number 22 (Figure 16), as in the preceeding 2 cases, the upper lip went forward instead of backward; but the lower lip stayed relatively unchanged. A variation of this behavior was shown in case number 29 (Figure 17). Here the upper lip moved downward and backward while soft tissue point A moved forward. Also irregularities in the lower lip position resulted in a prediction that didn't move the mandibular lip back far enough. Similarly in case number 37 (Figure 18) soft tissue point A moved forward but the upper lip remained basically unchanged (slightly forward). The lower lip was also not posteriorly positioned as much as predicted.

Finally in case number 32 (Figure 19) the upper and lower lips appear to have been affected to a greater extent than was predicted. In other words a greater fullness of the lips was expected. With surgery point A appears to have come forward, while the upper lip came downward and backward. Also, soft tissue point B retained much of its original contour while the prediction indicated that it should come forward with respect to the lower lip and pogonion making its contour less concave.

In trying to explain the variability between cases and the apparent poor fit of the prediction method to the comparison sample (S2) several alternatives come to mind. First it was thought that the cases might somehow be significantly different in some important characteristic. For example, if a group of cases with a similarly small or large mandibular plane angle, exhibited a particular type of response to surgery; and if these cases happened to be included in one sample and not the other, then the samples would respond differently because they are different. In fact, there were cases in which the mandibular plane angle was small or large, but they appeared to be randomly distributed in both samples; and no specific surgical response could be attributed to this characteristic. This kind of reasoning might be applied to other factors as well, such as amount of surgical change, sexual differences, or ethnic differences. However, upon evaluation of each case with respect to the above characteristics, no correlation could be found between any of them and a particular surgical result.

Inspite of this, it was still considered possible that the cases in the samples might not be randomly distributed. To test this, the samples were combined and then randomly redivided into two new samples. The new equations that were generated from one of the new samples were then applied to both of them as a prediction method for surgical change. The prediction error or mean residuals were then compared for the two new samples (Table VI). Graphically it appears that both samples had an average mean prediction residual of 1.5 to 2.0 millimeters (Figure 5). For some points, however, the prediction residuals are as high as 2.5 - 4.3 millimeters, particularly in the areas below subnasale (SN) where the greatest surgical change occurs.

Apparently the cases within the original samples as they were grouped were more similar in their surgical behavior within samples and more dissimilar between samples than the new samples. Consequently, the original equations predicted very well to the sample from which they were generated and very poorly to the comparison sample, while the new equations did not predict very well to either of the new samples. This very clearly illustrates the danger of using too small a sample for developing a surgical soft tissue prediction method or for testing the universal application of this method. What might appear to be a good prediction for the twenty cases used to generate the method may not predict well at all the general surgical population. It also cannot be said that because the method predicts well for eighteen cases not included in the sample that it will be accurate for all surgical cases.

Another problem is that lateral cephalometric radiographs are necessarily studied in the sagittal plane, which facilitates the evaluation of horizontal rather than vertical profile changes. In addition to this the definitions of the landmarks themselves are much more appropriate for the evaluation of horizontal change ("greatest concavity" or "most prominent"). All of these factors contribute to the relatively small amount of accuracy in prediction of changes in the vertical plane.

There may also have been some error in appropriately locating the soft and hard tissue points. In past studies these points have been rather vaguely defined. Although an attempt was made in this study to clearly define and standardize the method for locating these points, it may be impossible to develop a scheme that does not incorporate significant error in the location of these points. Tracing error is another factor which may introduce variability, however, this is a problem common to all studies of this type.

Other factors that contribute to the variability in the response to surgery of different cases are the inherent differences in tonicity of the facial musculature from one patient to the next. These characteristic differences may influence the integumental response to various skeletal and dental changes. In other words patients with similar skeletal problems and similar amounts of surgical correction needed may respond differently to the same treatment due to the inherent genetic characteristics of the soft tissue (muscle tonus etc.). The obstacle one encounters here is that it is very difficult to quantify the tonicity of musculature in a way that would allow use of this characteristic as a variable for prediction. When this is accomplished, however, it should then be possible to more accurately describe the post surgical behavior of soft tissue.

A similar factor that may introduce error is the possible difference in tonus of the musculature between subsequent radiographs of the same patient. Hillesund et al. (1978) studied the reproducibility of the soft tissue profile in the lateral cephalogram at three week intervals on 35 children with overjet of greater than eight millimeters and 32 children with normal overjet. He recorded lip thickness, size of the interlabial gap and the difference between relaxed and closed lip positions. He showed that differences in facial expression between cephalograms may introduce variability. The reproducibility of soft tissue was not definitely dependant upon whether the lips were closed or relaxed. He found most soft tissue registrations in the horizontal plane were within 1.0 - 1.5 millimeters of the original soft tissue registration. He concluded that for both groups (normal and abnormal overjet) the teeth should be in occlusion and the lips relaxed to accurately evaluate soft tissue profile change. This method was found to have the best reproduction of lip position and morphology. Burstone (1967) in a similar study found that the relaxed lip position is reasonably reproducible but somewhat variable. Also, normally in the relaxed lip position there is a small vertical space (inter-labial gap). He also stated that lip length, whether short or redundant, may lead to facial disharmony without a dental or skeletal discrepancy. He also concluded that soft tissue changes following movement of incisors can be more easily predicted if the relaxed lip position is used as basis for prediction.

The implications of the conclusions of these studies with respect to the ambiguous results obtained in the present study are obvious. First, the varied sources from which the case records were gathered did not allow for standardization of the way the cephalograms were taken. Though the lips are generally closed and the teeth in occlusion, there is no way of knowing whether each time the patients lips are relaxed, unless each time a cephalogram is taken the patient is asked to relax. This is a problem in all soft tissue studies. There are obviously many cases in which the lips can not relax and touch one another simultaneously.

Also, the inherent length of the upper lip is an important factor that should be considered as a variable when predicting the soft tissue change. When the upper lip is short it may be held in a retruded position by a more procumbent lower lip. This may explain why in some cases the upper lip came forward after surgery. It seems apparent that a short upper lip would tend to change much less than a longer one, though to be sure the relationship between upper lip length and surgical change should be established quantitatively. The actual value of upper lip length, however, can only be reliably measured when the lips are relaxed. Anatomically the upper lip is firmly attached to the base of the nose such that although variable, the changes that take place in the upper lip area are limited in magnitude. Another factor limiting the amount of soft tissue change is the tendency of the soft tissue drape to mask the underlying hard tissue discrepancy.

There are several other sources of soft tissue variability that are common to all surgical studies. Postsurgical edema may be a factor; though in mandibular surgery, evaluated from the lateral aspect at 19 weeks (mean), it seems to be an insignificant problem as compared to maxillary surgical edema. Also, there may be a difference in the amount of subcutaneous adipose tissue after surgery. It is not uncommon for patients in intermaxillary fixation to lose a considerable amount of weight thus possibly affecting the soft tissue profile in some minor way postsurgically.

If we compare the results of the present study and those of the similar study involving maxillary surgery by Quan et al. (1978), we find that in both cases it is possible to obtain a set of multivariate equations that predict well (less than 1.0 millimeter error) for the small sample from which they were derived. A cursory evaluation of either prediction method when applied to several cases not in the original sample might lead one to believe that we have a universally applicable prediction method for either type of surgery. Further, comparing the predictions for a larger number of cases, it is soon noted that although mathematically the tissue is predicted to behave in a certain way, biologically there are other variables that must be considered before the complexity of soft tissue surgical changes can be understood and predicted accurately.

This suggests that before any surgical prediction methed is adopted it must be based on clinical pre and postsurgical data, from a large enough sample to be universally applicable. Also, further investigations need to be carried out as to the contributing effect of previously overlooked soft tissue variables when applied to surgical prediction. An evaluation of soft tissue changes from the frontal aspect is another important study which ought to be initiated. Many times the changes that the patient notices most, are those he sees as he looks in the mirror, not those noted in the profile of which he is seldom aware.

CHAPTER VI

SUMMARY AND CONCLUSIONS

A retrospective study of soft tissue changes following vertical subcondylar osteotomies preformed on the mandible for the correction of mandibular prognathism was undertaken. Two adult surgical samples were evaluated (38 patients). In the prediction sample (N1=20) several hard tissue coordinates were correlated to each coordinate of eleven soft tissue points by multivariate regression analysis. This multivariate prediction method was then evaluated for accuracy by applying the prediction method to the comparison sample (N2=18). The random distribution of the cases in each sample was then tested by combining the two samples and redividing the cases into two new groups (prediction sample $N1'=25$, comparison sample $N2'=13$). A similar prediction method was generated from the new prediction sample ($N1'=25$) and applied to both new samples. The mean prediction residuals or prediction error was then evaluated for all the samples.

The following results and conclusions were obtained:

1. For all samples the multivariate prediction procedure was not very accurate for the horizontal and vertical coordinates of the seven soft tissue points (Gl, Na, Nc, Pn, Sn, A, UL). This was because the mean surgical change for these points was so small and the variability of the soft tissue response so great that the presurgical profile was as close to the final result as the prediction

method (approximately 1.5 millimeters).

2. The prediction method predicted very well for the original prediction sample (N1=20) having approximately 1 millimeter mean prediction residual (or error) for each point.

3. The prediction method predicted much worse for the original comparison sample (N=18), having approximately 2.0-2.5 millimeters mean prediction residual or error for each point.

4. The prediction method using the new equations generated from the new "more random" sample did not predict well to either sample (prediction or comparison), with the exception of Pog h and B h. The overall prediction residuals were 2.0 - 2.5 millimeters, as compared to prediction residuals for Pog h and B h of approximately 1.0 millimeters.

5. No correlation could be found between characteristics such as lower facial height, mandibular plane angle, amount of surgical change, sex, or ethnic background (stock), and the different responses to similar surgery.

6. It is important that before a multivariate prediction method is considered to be useful; the sample size must be increased to make it more universal, soft tissue variables should be considered as prediction factors, (i.e. muscle tonicity, soft tissue thickness, and upper lip length as measured from a cephalogram with the lips in a relaxed position, and the method of taking cephalograms must be standardized as to the reproducibility of soft tissue (teeth in occlusion and lips relaxed).

CHAPTER VII

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CHAPTER VIII

TABLES

TABLE I - DISTRIBUTION FOR PREDICTION METHOD SAMPLE

CASE	AGE (YEARS)	SEX	TIME BETWEEN PRESURGERY CEPHALOGRAM AND SURGERY DATE (WEEKS)	TIME BETWEEN SURGERY DATE AND POSTSURGERY CEPHALOGRAM (WEEKS)
1	15.1	F	21.3	8.5
2	18.2	M	2.1	27.6
3	18.3	F	2.1	19.1
4	31.5	F	4.3	14.9
5	18.4	M	12.8	8.5
6	17.3	M	21.3	25.5
7	15.3	F	2.1	16.6
8	17.8	F	2.1	23.4
9	20.0	F	8.5	12.8
10	20.1	F	17.0	12.8
11	15.1	F	4.3	23.4
12	19.2	F	2.1	23.4
13	17.0	M	1.3	45.5
14	19.1	F	0.8	33.2
15	18.2	F	6.4	6.4
16	53.8	M	4.3	8.5
17	30.0	M	4.3	23.4
18	39.3	F	4.3	17.0
19	30.4	F	4.3	25.5
20	29.1	F	12.8	8.5

Mean age at surgery = 23.2 ± 9.9 years
Mean time between presurgery cephalogram and surgery = 6.9 ± 6.5 wks.
Mean time between surgery and post surgery cephalogram = 19.2 ± 9.9wks.

TABLE II - DISTRIBUTION FOR COMPARISON SAMPLE

CASE	AGE (YEARS)	SEX	TIME BETWEEN PRESURGERY CEPHALOGRAM AND SURGERY DATE (WEEKS)	TIME BETWEEN SURGERY DATE AND POSTSURGERY CEPHALOGRAMS (WEEKS)
21	28.5	F	4.3	68.0
22	17.0	F	12.8	44.6
23	23.2	F	76.5	102.0
24	18.1	F	29.8	59.5
25	27.0	M	17.0	46.8
26	17.3	F	63.8	12.8
27	16.6	F	76.5	17.0
28	26.7	F	68.0	21.3
29	17.5	F	68.0	17.0
30	18.5	M	42.5	59.5
31	16.8	F	21.5	12.8
32	17.9	M	34.0	12.8
33	20.0	M	12.8	8.5
34	23.8	M	4.3	4.3
35	41.0	F	17.0	8.5
36	15.6	F	4.3	25.5
37	29.4	F	4.3	5.6
38	51.5	M	4.3	20.3

Mean age at surgery 23.7 ± 9.5 years
Mean time between presurgery cephalogram and surgery = 31.2 ± 27.5wks.
Mean time between surgery and post surgery cephalogram 30.4 ± 27.1 wks.

TABLE III

STEPWISE MULTIPLE REGRESSION EQUATIONS

SOFT TISSUE LANDMARK			MULT. R
Gl	h	=-0.17(LFH) - 0.29(A-V) + 0.29 ($\underline{1}$-H) + 0.69	0.65
	v	=0.86(A-V) -1.03($\underline{1}$-H) + 1.25($\underline{1}$-V) + 0.54($\overline{1}$-V)+ 0.39(ANS-H) + 0.09	0.75
Na	h	=-0.21($\underline{1}$-$\overline{1}$) + 0.40($\underline{1}$-V) + 0.46($\overline{1}$-H)-0.32(B-H) + 0.17(F AXIS) + 0.05FMA + 1.51	0.86
	v	=0.33($\underline{1}$-$\overline{1}$) - 0.17(FA) - 0.20(ANS-H) - 0.11	0.79
Nc	h	=0.18($\underline{1}$-$\overline{1}$) + 0.11(FA) + 0.31($\underline{1}$-H) + 0.48	0.78
	v	=0.20($\underline{1}$-$\overline{1}$) + 0.28(ANS-V) + 0.53	0.70
Pn	h	=-0.60(POG-V) + 0.75($\underline{1}$-H) + 0.41	0.50
	v	=-0.99($\underline{1}$-V) + 0.26($\underline{1}$-$\overline{1}$) - 0.45(ANS-H) - 0.77(POG-H) + 0.68(B-H) + 0.32(B-V) - 1.82	0.91
Sn	h	=-0.33(ANS-H) - 0.11(FA) + 0.13($\overline{1}$-H) + 0.63(A-H) - 0.26(B-V) - 0.15(LFH) + 0.28	0.89
	v	=-0.19(ANS-H) - 0.25(FA) + 0.24(B-H) -0.20(A-V) + 0.09(LFH) + 0.53	0.79
A	h	=-0.32(ANS-H) - 0.56(ANS-V) - 0.32(B-V)+0.27($\overline{1}$-H)-0.20($\underline{1}$-$\overline{1}$)+0.10FMA+0.17(F AXIS)+0.97	.85
	v	=0.61($\underline{1}$-H) - 1.44($\overline{1}$-V) + 0.49(POG-H) - 0.41($\underline{1}$-$\overline{1}$) + 2.83	0.76
UL	h	=-0.43(ANS-H) + 0.38($\overline{1}$-H) - 0.23(B-V) + 0.82	0.78
	v	=-0.21(LFH) - 0.27(A-V) + 0.29 ($\underline{1}$-V) - 0.12	0.58
ST	h	=0.36($\overline{1}$-H) + 1.57($\underline{1}$-H) - 1.33($\underline{1}$-V) - 1.70	0.77
	v	=-0.40(LFH) - 0.40(A-V) - 1.40	0.79
LL	h	=0.82($\overline{1}$-H) + 1.02(POG-H) + 0.26 (FMA) - 0.84(B-H) + 0.93	0.93
	v	=0.45(B-V) - 0.22(FMA) - 0.45(POG-H) + 0.46($\overline{1}$-H) - 0.32($\underline{1}$-V) - 0.11(ANS-H) - 1.97	0.94
B	h	=-0.49(B-H) + 0.82(POG-H) + 0.63($\overline{1}$-H) + 0.63(ANS-V) -0.24($\overline{1}$-V) - 0.40	0.98
	v	=0.44(B-V)+1.11(POG-V)-0.13(FMA)-0.43(A-H)+0.49($\overline{1}$-V)-1.07(B-H)+0.85(POG-H)-0.29(FA) -0.73(ANS-V) -4.13	0.97
Pog	h	=0.92(POG-H) + 0.32(POG-V) - 0.44	0.99
	v	=-0.41(LFH) - 0.39($\overline{1}$-H) - 2.51	0.51

TABLE IV - PREDICTION SAMPLE N = 20

SOFT TISSUE COORDINATES	MEAN OBSERVED SURGICAL MOVEMENT (PREDICTION SAMPLE) (m m.) ± S.D.	MULTIVARIATE METHOD MEAN PREDICTION RESIDUAL (m m.) ± S.D.
Gl h	0.50 ± 0.79	0.50 ± 0.50
v	1.40 ± 1.31	1.12 ± 0.83
Na h	0.45 ± 0.46	0.27 ± 0.17
v	1.13 ± 0.92	0.72 ± 0.51
Nc h	0.63 ± 0.60	0.45 ± 0.34
v	0.48 ± 0.66	0.42 ± 0.40
Pn h	0.98 ± 1.78	1.11 ± 1.34
v	1.08 ± 1.36	0.89 ± 0.60
Sn h	0.65 ± 0.49	0.40 ± 0.27
v	0.63 ± 0.46	0.41 ± 0.24
A h	0.75 ± 0.82	0.36 ± 0.28
v	2.13 ± 2.36	1.47 ± 0.86
UL h	1.68 ± 1.38	0.69 ± 0.63
v	1.15 ± 1.04	0.73 ± 0.61
St h	4.20 ± 2.27	1.25 ± 1.08
v	2.50 ± 1.53	0.84 ± 0.58
LL h	6.38 ± 3.26	1.00 ± 0.63
v	2.45 ± 1.11	0.43 ± 0.31
B h	8.25 ± 3.12	0.40 ± 0.32
v	2.83 ± 2.49	0.61 ± 0.45
Pogh	8.40 ± 3.72	0.46 ± 0.34
v	1.70 ± 1.22	1.37 ± 1.12

TABLE V - COMPARISON SAMPLE N = 18

SOFT TISSUE COORDINATES		MEAN OBSERVED SURGICAL MOVEMENT (COMPARISON SAMPLE) N = 18 (mm) ± S.D.	MULTIVARIATE METHOD MEAN PREDICTION RESIDUAL (mm.) ± S.D.
Gl	h	0.39 ± 0.27	0.73 ± 0.63
	v	1.69 ± 1.47	3.57 ± 3.04
Na	h	0.86 ± 1.04	0.93 ± 1.01
	v	1.81 ± 1.48	2.24 ± 1.50
Nc	h	0.53 ± 0.58	0.92 ± 0.85
	v	0.64 ± 0.54	1.14 ± 0.72
Pn	h	0.58 ± 1.02	1.51 ± 1.83
	v	0.64 ± 0.64	1.95 ± 0.99
Sn	h	1.08 ± 0.73	1.41 ± 0.92
	v	0.92 ± 1.13	0.98 ± 0.84
A	h	0.89 ± 0.70	1.67 ± 1.08
	v	1.86 ± 1.88	3.45 ± 2.96
UL	h	1.61 ± 1.01	2.41 ± 1.02
	v	1.36 ± 1.16	1.20 ± 0.88
St	h	2.33 ± 2.14	2.48 ± 2.31
	v	2.08 ± 1.55	1.66 ± 1.54
LL	h	4.61 ± 2.54	2.12 ± 1.57
	v	2.22 ± 2.00	2.49 ± 2.20
B	h	6.75 ± 2.89	1.94 ± 1.46
	v	2.31 ± 1.54	2.85 ± 2.55
Pog	h	6.81 ± 2.93	0.88 ± 0.76
	v	1.64 ± 1.49	2.14 ± 1.62

TABLE VI - MEAN PREDICTION RESIDUALS

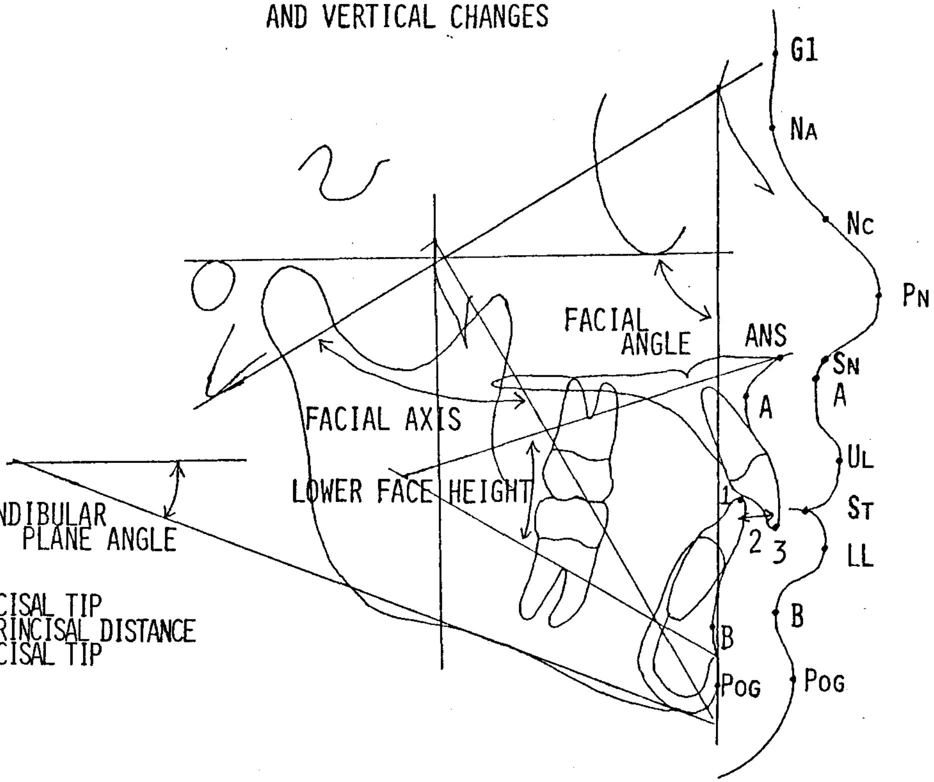
SOFT TISSUE COORDINATES		NEW PREDICTION SAMPLE N = 25 (MM.+ S.D.)	NEW COMPARISON SAMPLE N = 13 (MM. + S.D.)
Gl	h	0.49 ± 0.47	0.70 ± 0.63
	v	1.91 ± 2.31	2.23 ± 1.58
Na	h	0.48 ± 0.52	0.83 ± 0.65
	v	1.20 ± 1.41	2.40 ± 1.71
Nc	h	1.00 ± 1.00	0.98 ± 0.82
	v	0.53 ± 0.61	1.01 ± 0.58
Pn	h	2.50 ± 3.62	2.15 ± 2.53
	v	1.09 ± 0.90	0.96 ± 0.78
Sn	h	0.99 ± 1.20	1.28 ± 0.76
	v	0.61 ± 0.37	1.09 ± 1.17
A	h	0.68 ± 0.84	1.37 ± 0.88
	v	1.60 ± 1.68	3.86 ± 2.45
UL	h	1.60 ± 1.75	2.39 ± 1.76
	v	1.19 ± 1.32	1.12 ± 0.92
St	h	4.33 ± 6.75	2.13 ± 2.80
	v	1.00 ± 1.06	1.69 ± 1.41
LL	h	1.56 ± 1.27	1.75 ± 1.70
	v	2.13 ± 1.88	2.13 ± 1.17
B	h	0.70 ± 0.77	1.01 ± 0.89
	v	2.11 ± 2.58	1.89 ± 1.72
Pog	h	0.50 ± 0.52	0.96 ± 0.55
	v	3.19 ± 1.75	2.63 ± 2.20

CHAPTER IX

ILLUSTRATIONS

FIGURE 1.

SOFT AND HARD TISSUE LANDMARKS MEASURED FOR HORIZONTAL AND VERTICAL CHANGES



1. LOWER INCISAL TIP
2. THE INTERINCISAL DISTANCE
3. UPPER INCISAL TIP

FIGURE 2.

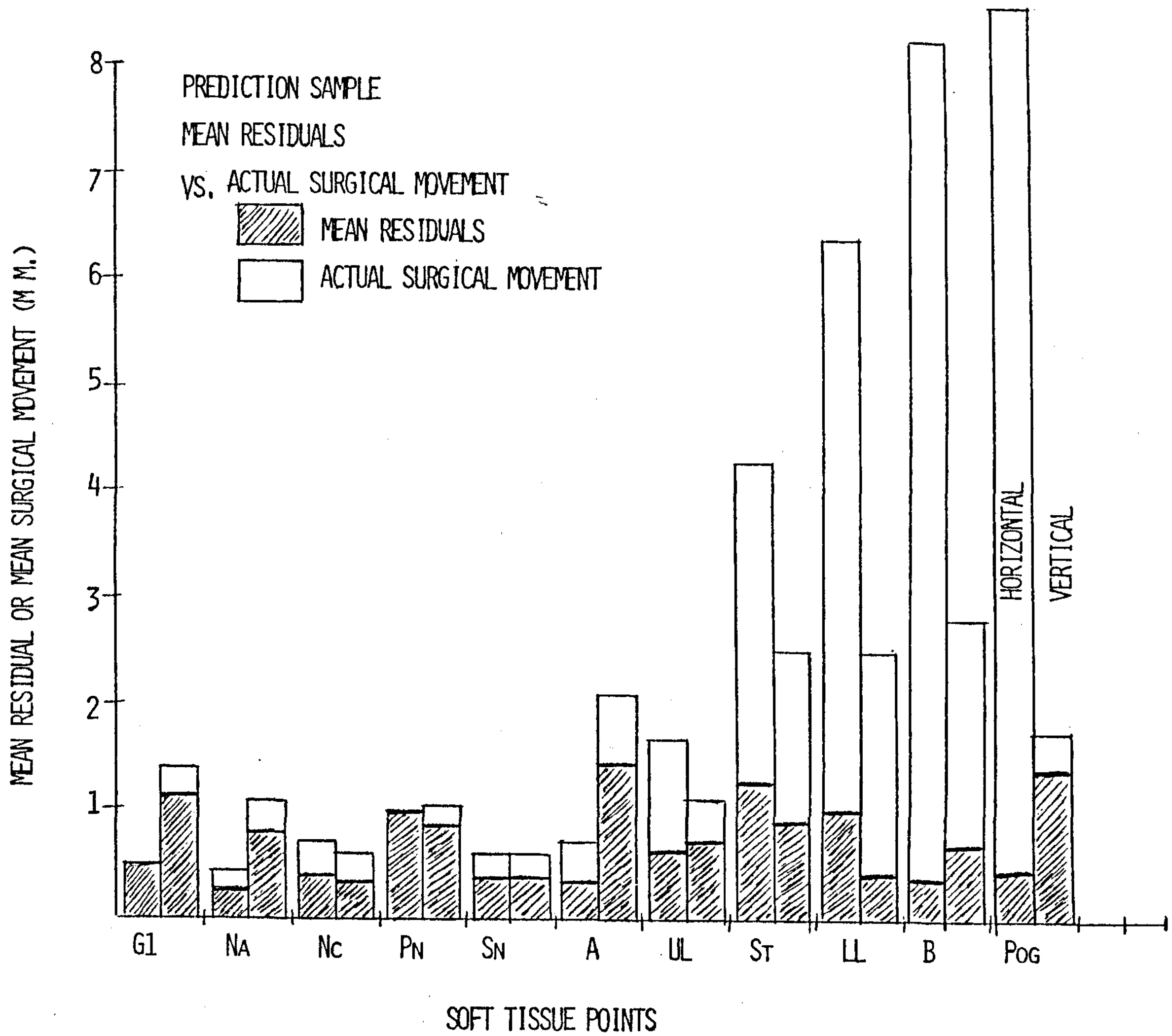
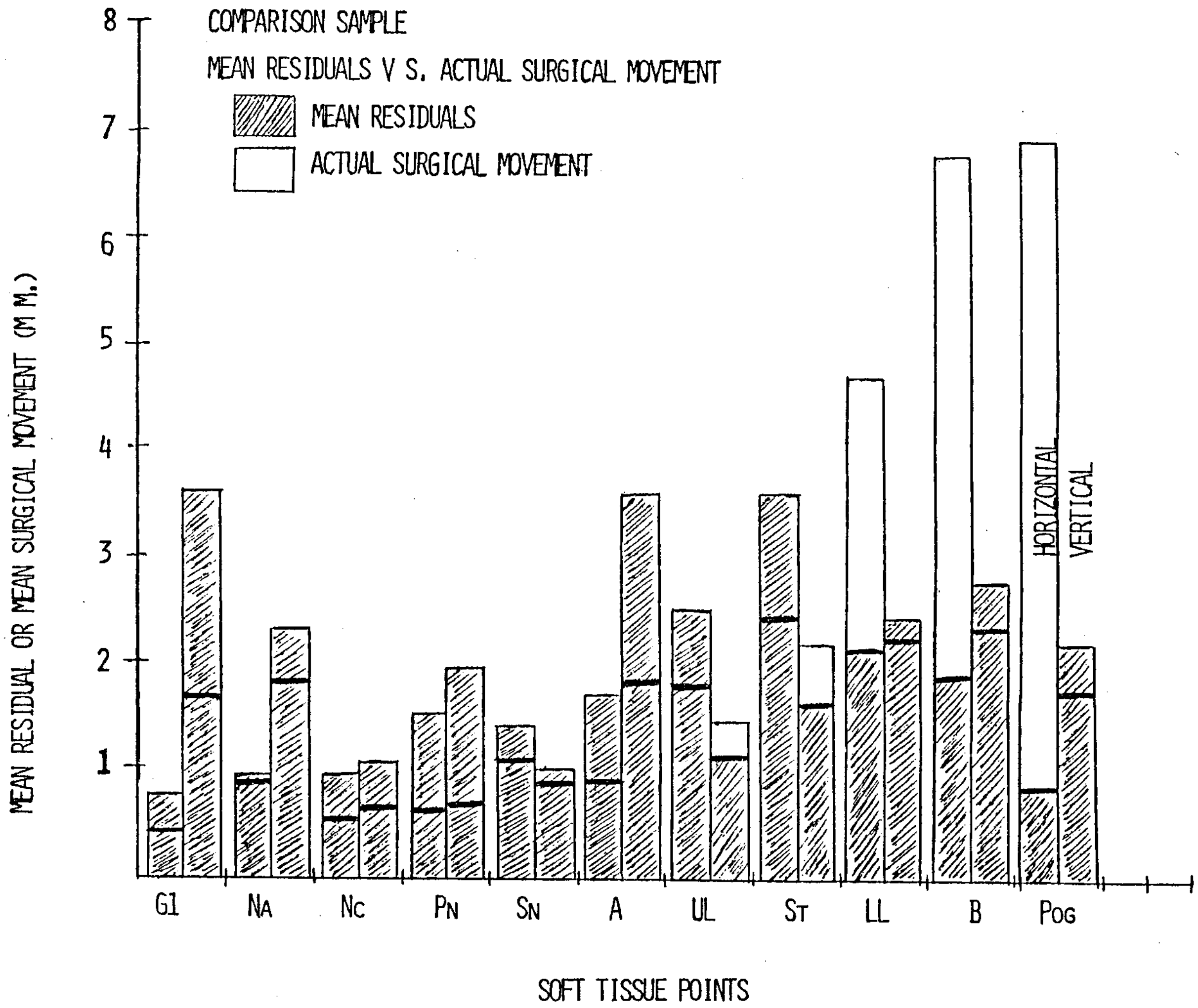
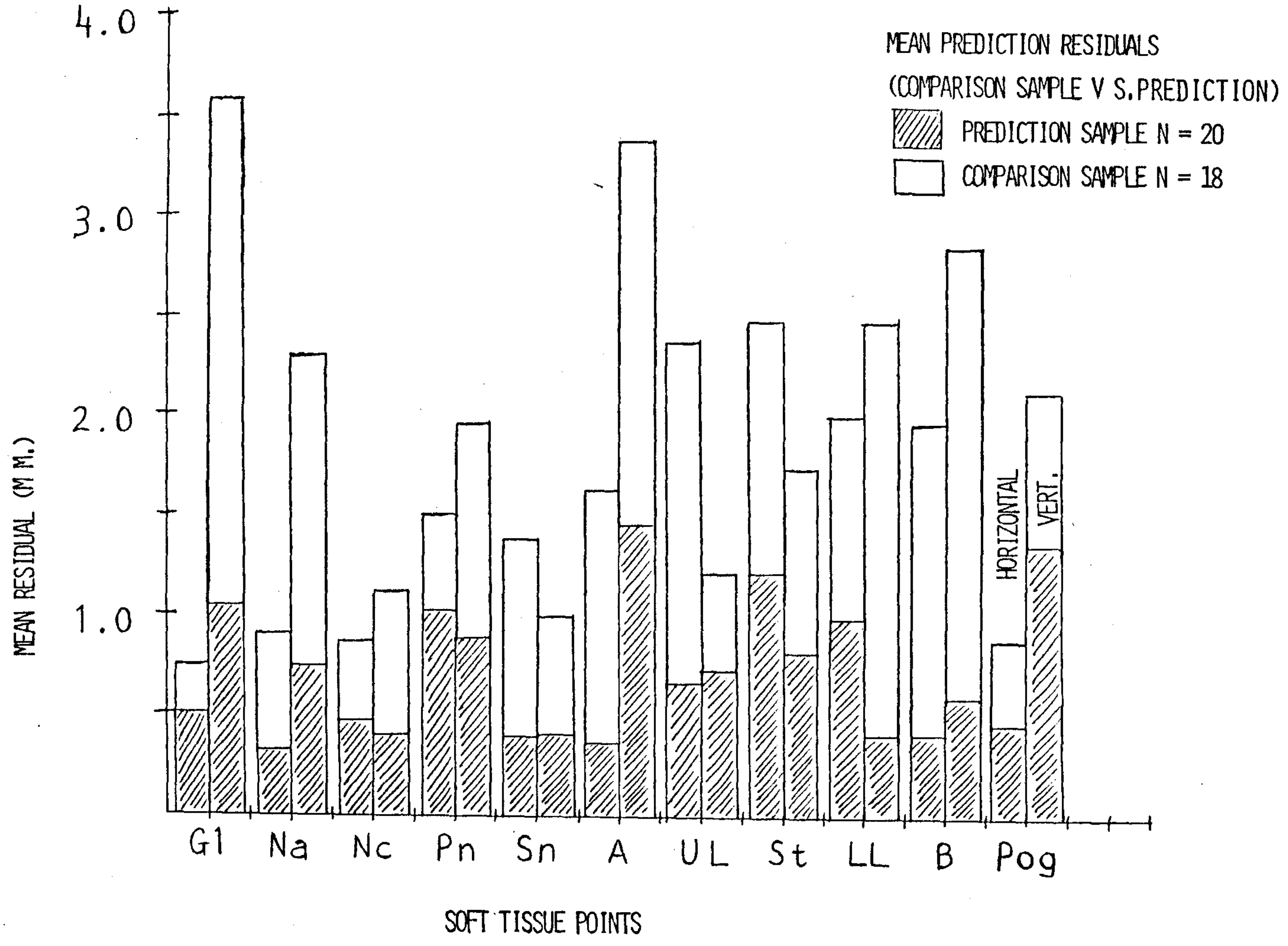

PREDICTION SAMPLE
MEAN RESIDUALS
VS. ACTUAL SURGICAL MOVEMENT
MEAN RESIDUALS
ACTUAL SURGICAL MOVEMENT
MEAN RESIDUAL OR MEAN SURGICAL MOVEMENT (M M.)
8
7
6
5
4
3
2
1
HORIZONTAL
VERTICAL
Gl
NA
Nc
PN
SN
A
UL
ST
LL
B
POG
SOFT TISSUE POINTS

FIGURE 3.



COMPARISON SAMPLE
MEAN RESIDUALS V S. ACTUAL SURGICAL MOVEMENT
MEAN RESIDUALS
ACTUAL SURGICAL MOVEMENT
MEAN RESIDUAL OR MEAN SURGICAL MOVEMENT (M M.)
8
7
6
5
4
3
2
1
HORIZONTAL
VERTICAL
Gl
NA
NC
PN
SN
A
UL
ST
LL
B
POG
SOFT TISSUE POINTS

FIGURE 4.



4.0
3.0
2.0
1.0
MEAN RESIDUAL (M M.)
MEAN PREDICTION RESIDUALS
(COMPARISON SAMPLE V S.PREDICTION)
PREDICTION SAMPLE N = 20
COMPARISON SAMPLE N = 18
HORIZONTAL
VERT.
Gl
Na
Nc
Pn
Sn
A
UL
St
LL
B
Pog
SOFT TISSUE POINTS

FIGURE 5.

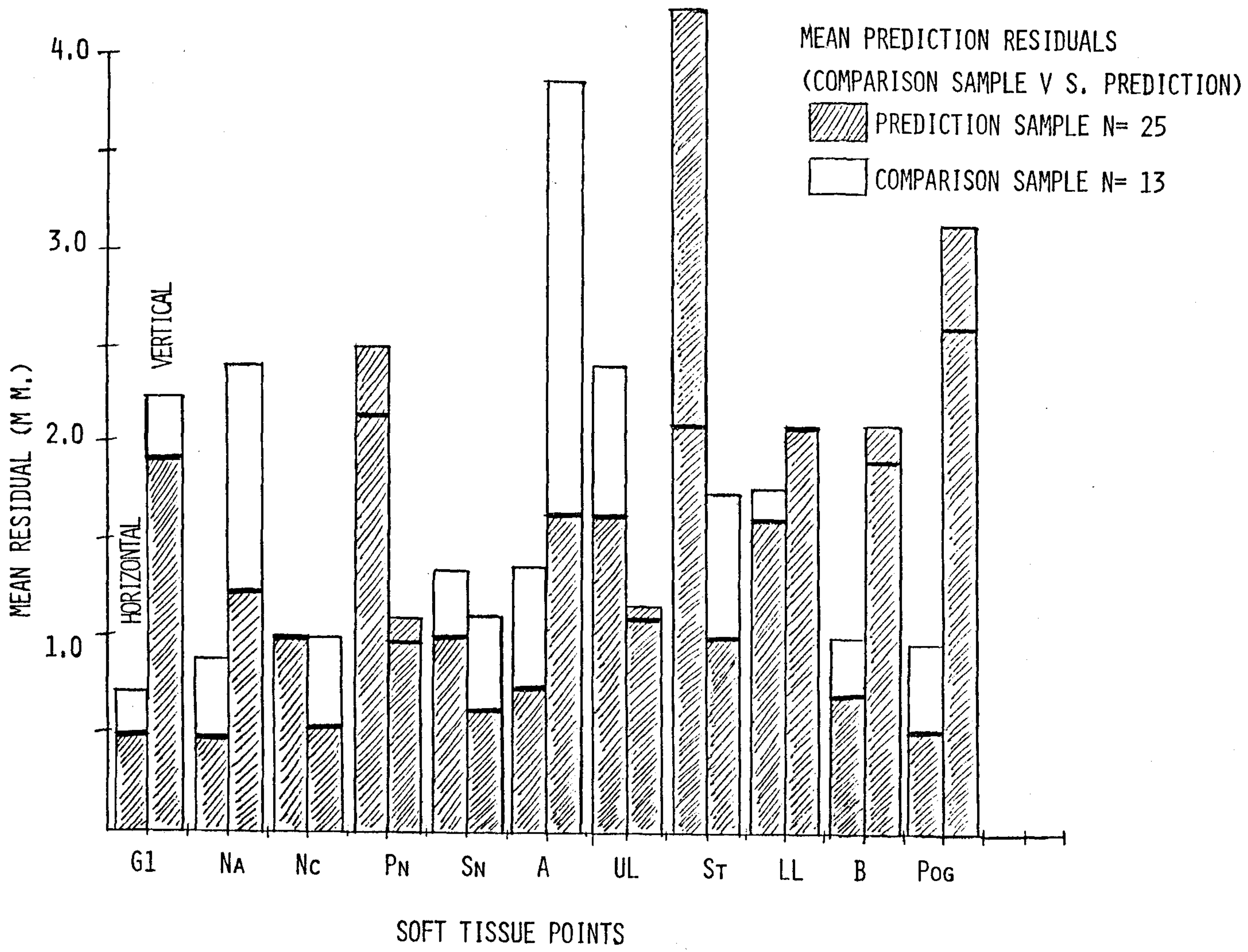

MEAN PREDICTION RESIDUALS
(COMPARISON SAMPLE V S. PREDICTION)
PREDICTION SAMPLE N= 25
COMPARISON SAMPLE N= 13
MEAN RESIDUAL (M M.)
4.0
3.0
2.0
1.0
VERTICAL
HORIZONTAL
Gl
NA
NC
PN
SN
A
UL
ST
LL
B
POG
SOFT TISSUE POINTS

FIGURE 6.

Case #1

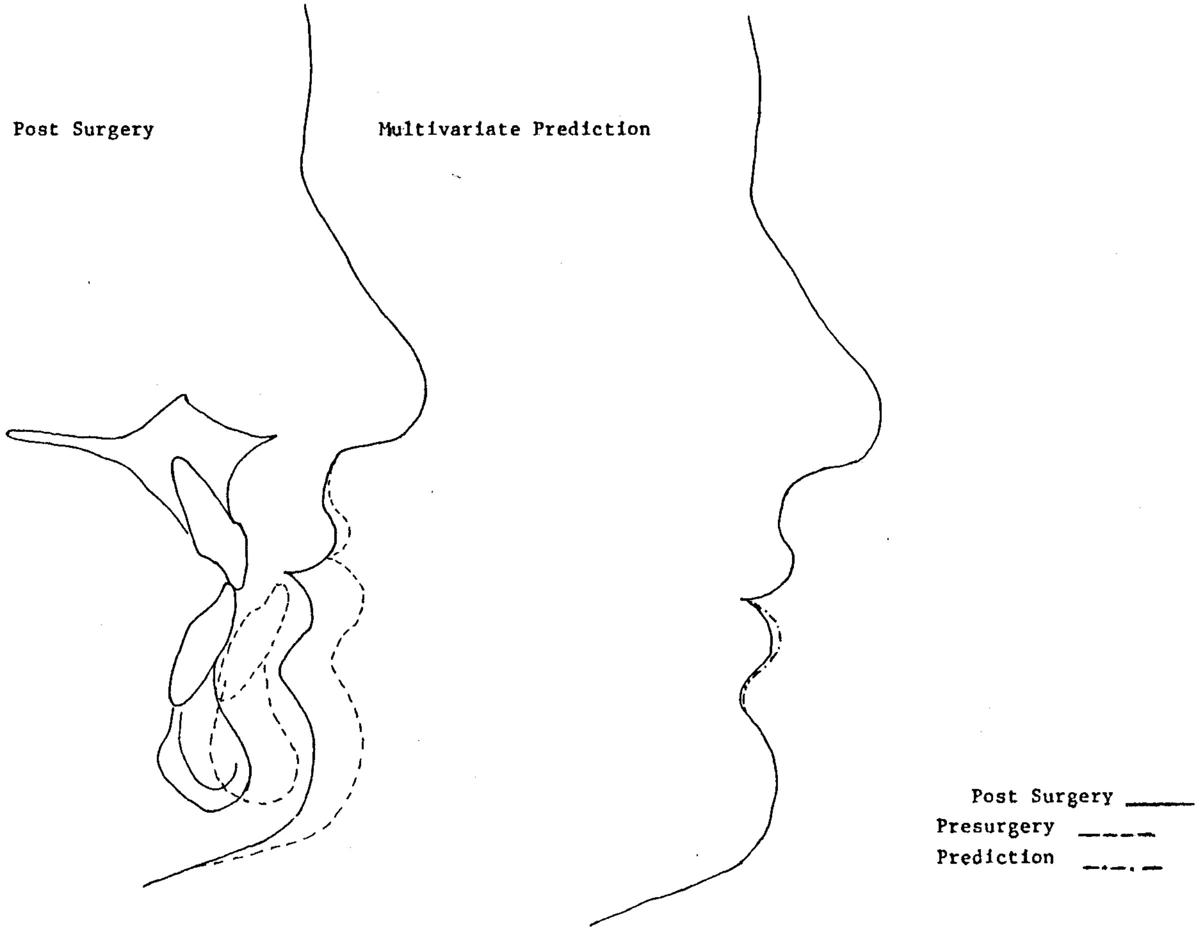


FIGURE 7.

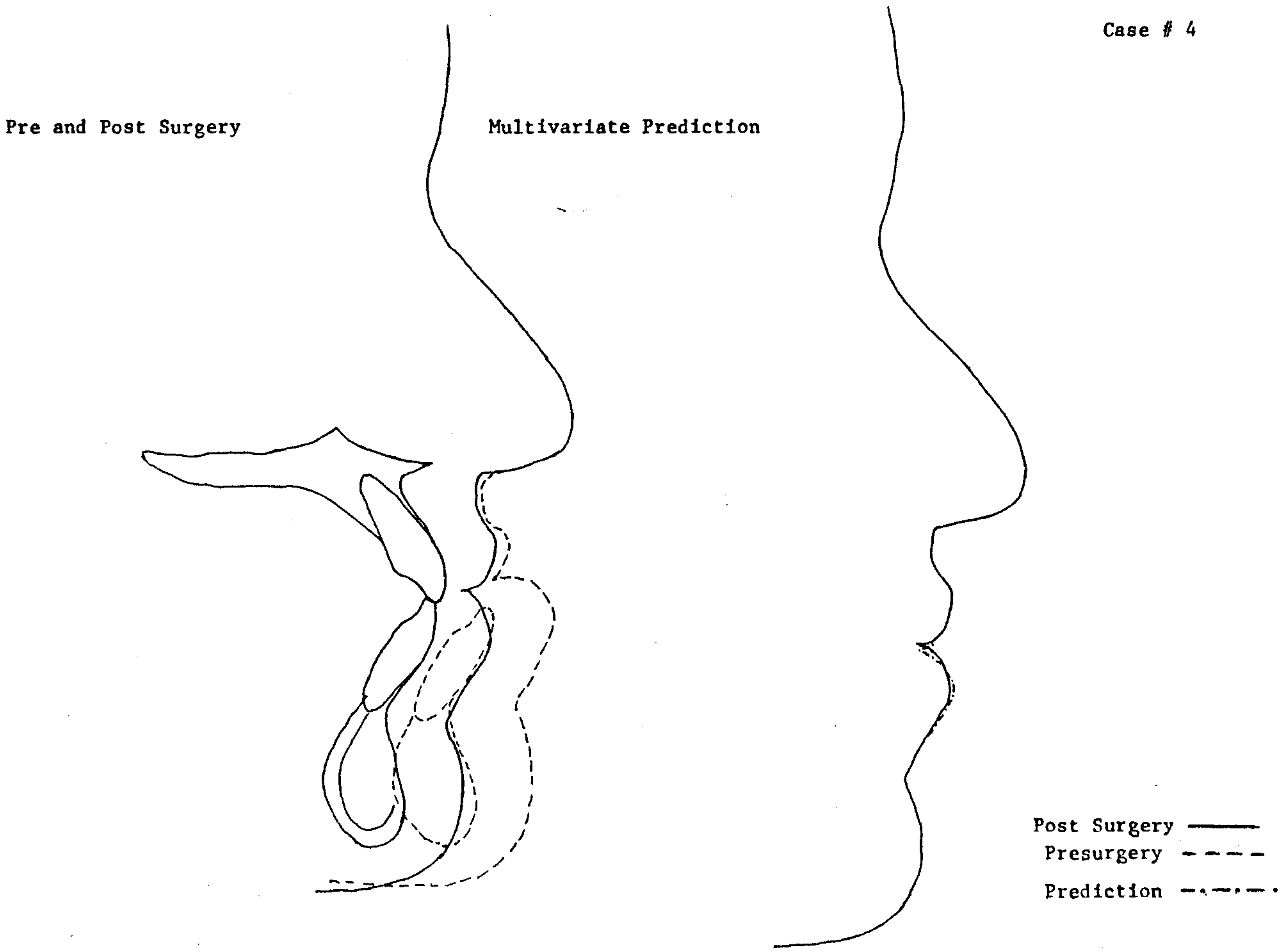

Case # 4
Pre and Post Surgery
Multivariate Prediction
Post Surgery
Presurgery
Prediction

FIGURE 8.

Case # 14

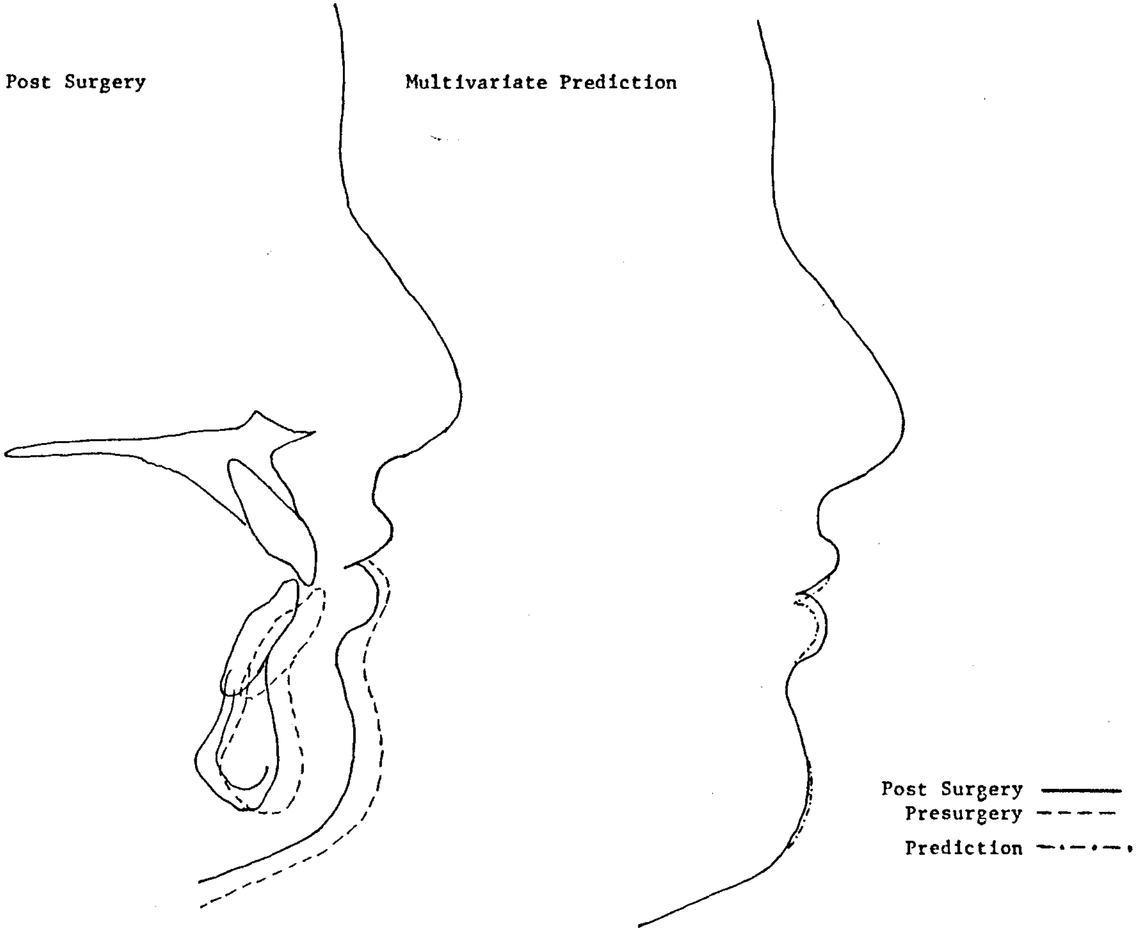


FIGURE 9.

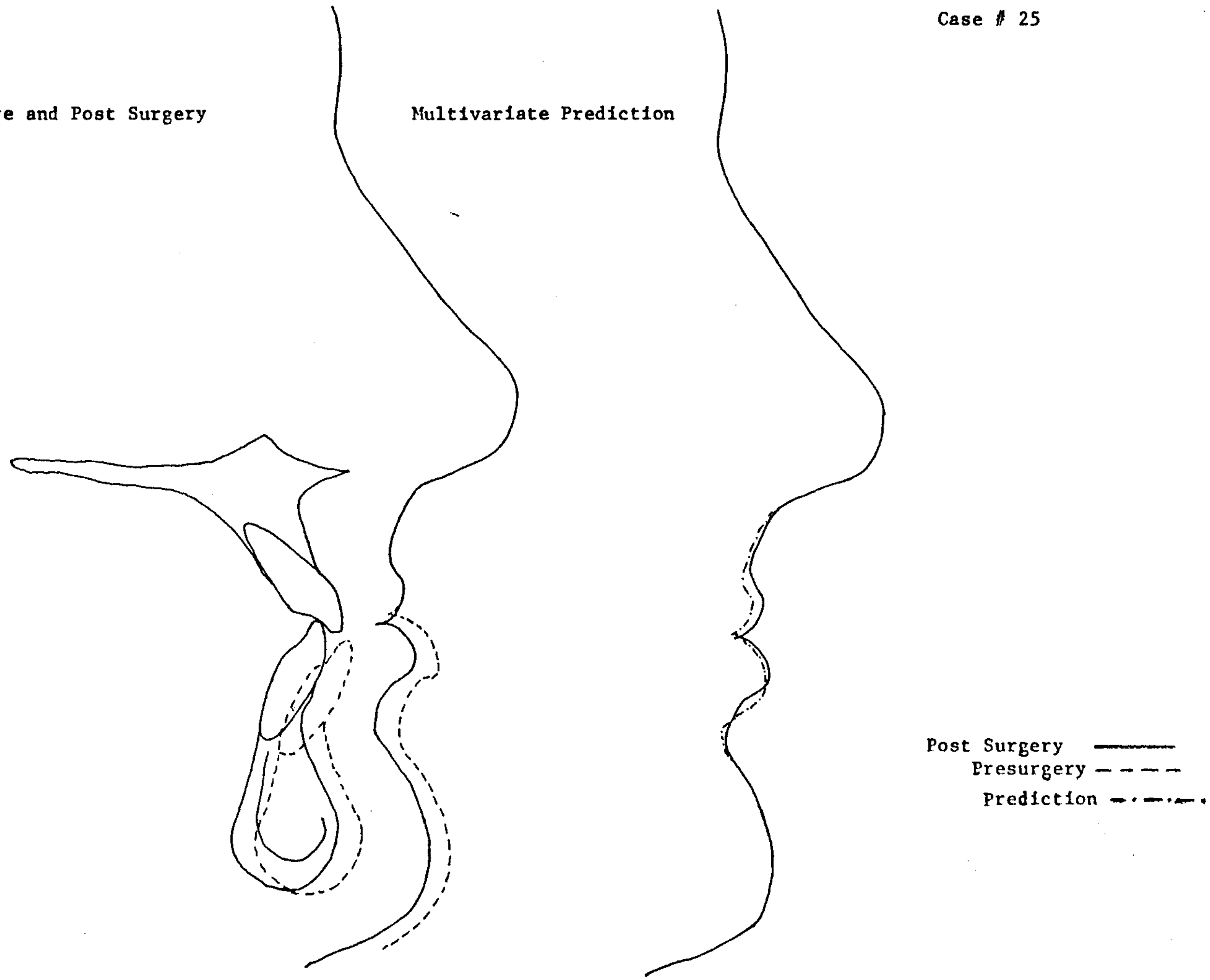

Case # 25
Pre and Post Surgery
Multivariate Prediction
Post Surgery
Presurgery
Prediction

FIGURE 10.

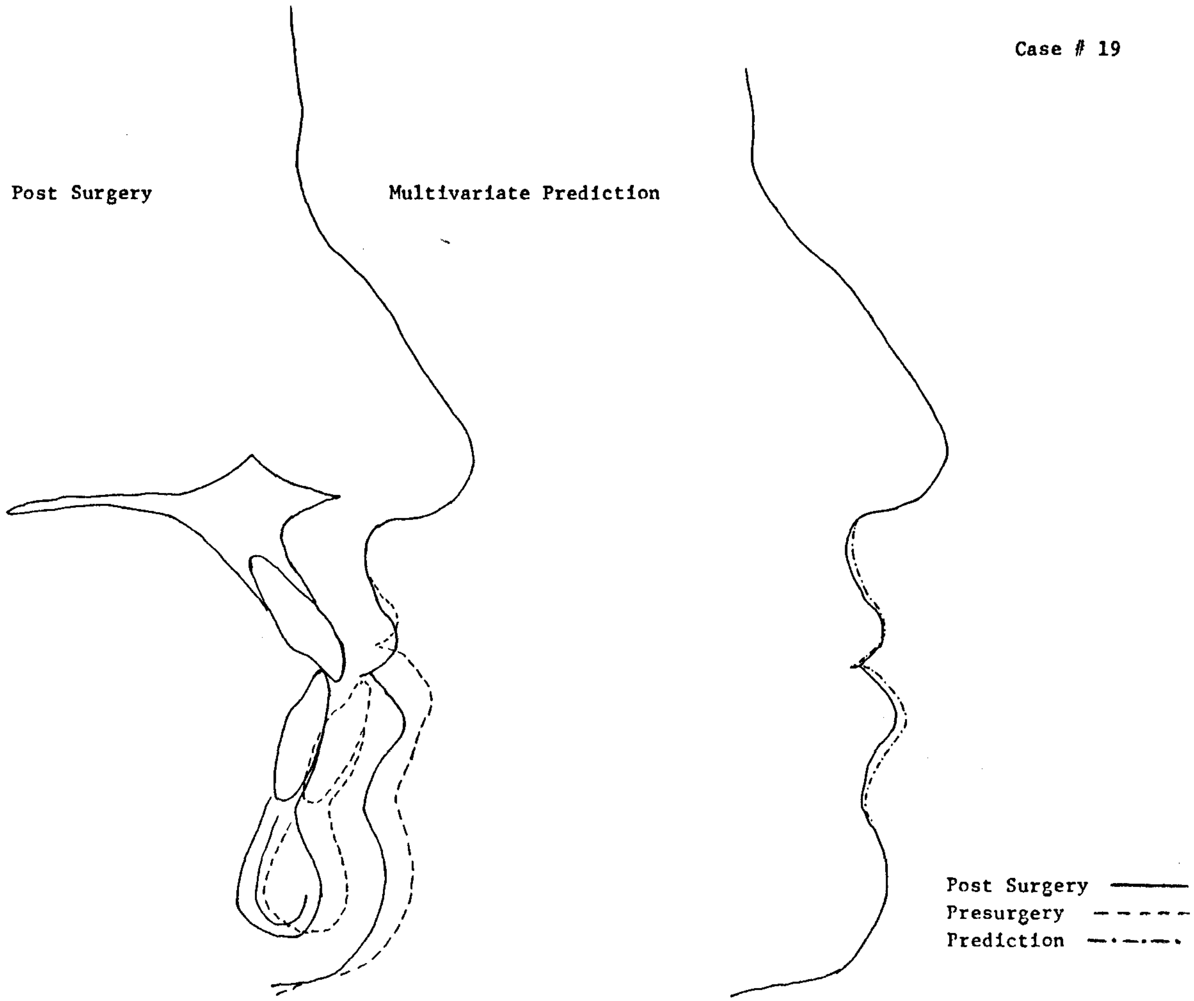

Case # 19
Pre and Post Surgery
Multivariate Prediction
Post Surgery
Presurgery
Prediction

FIGURE 11.

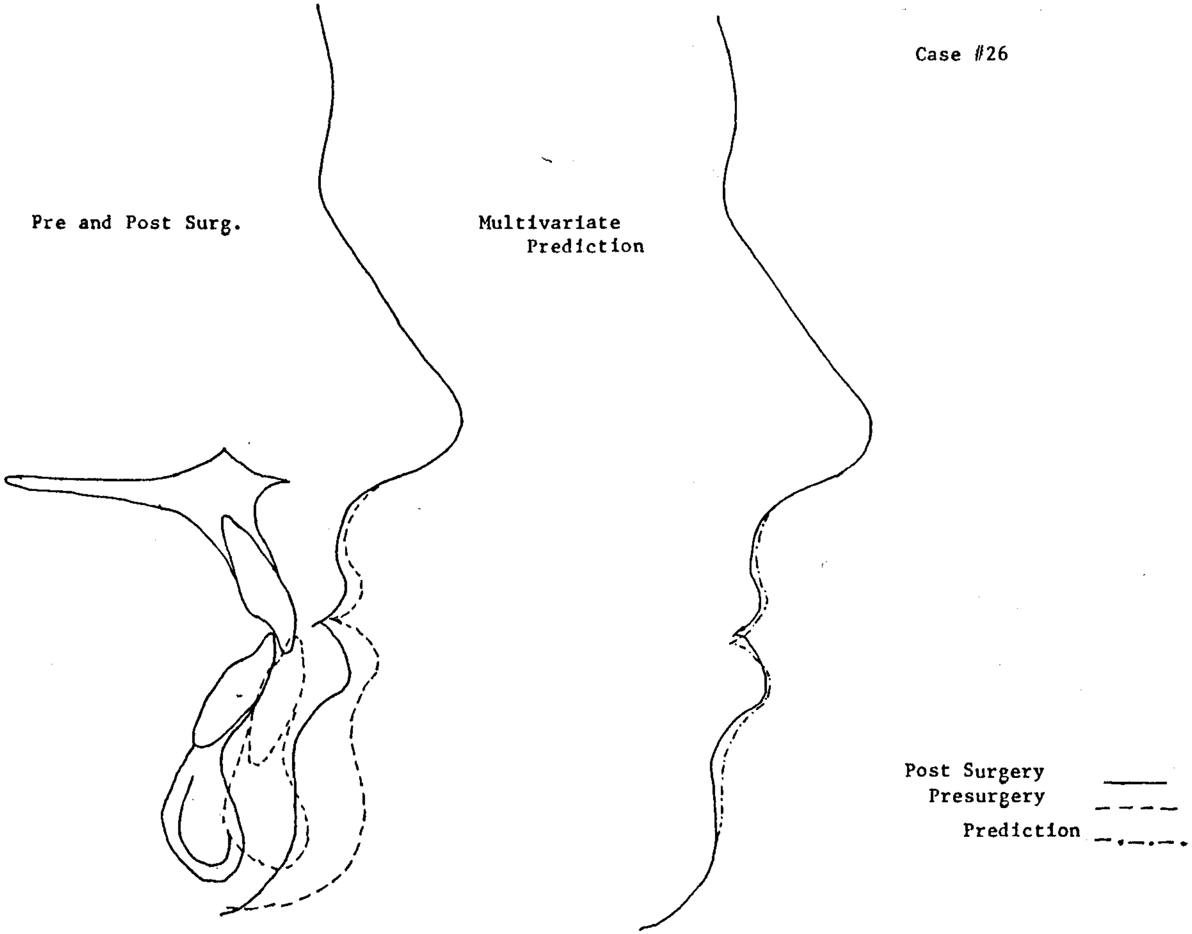

Case #26
Pre and Post Surg.
Multivariate Prediction
Post Surgery
Presurgery
Prediction

FIGURE 12.

Case # 33

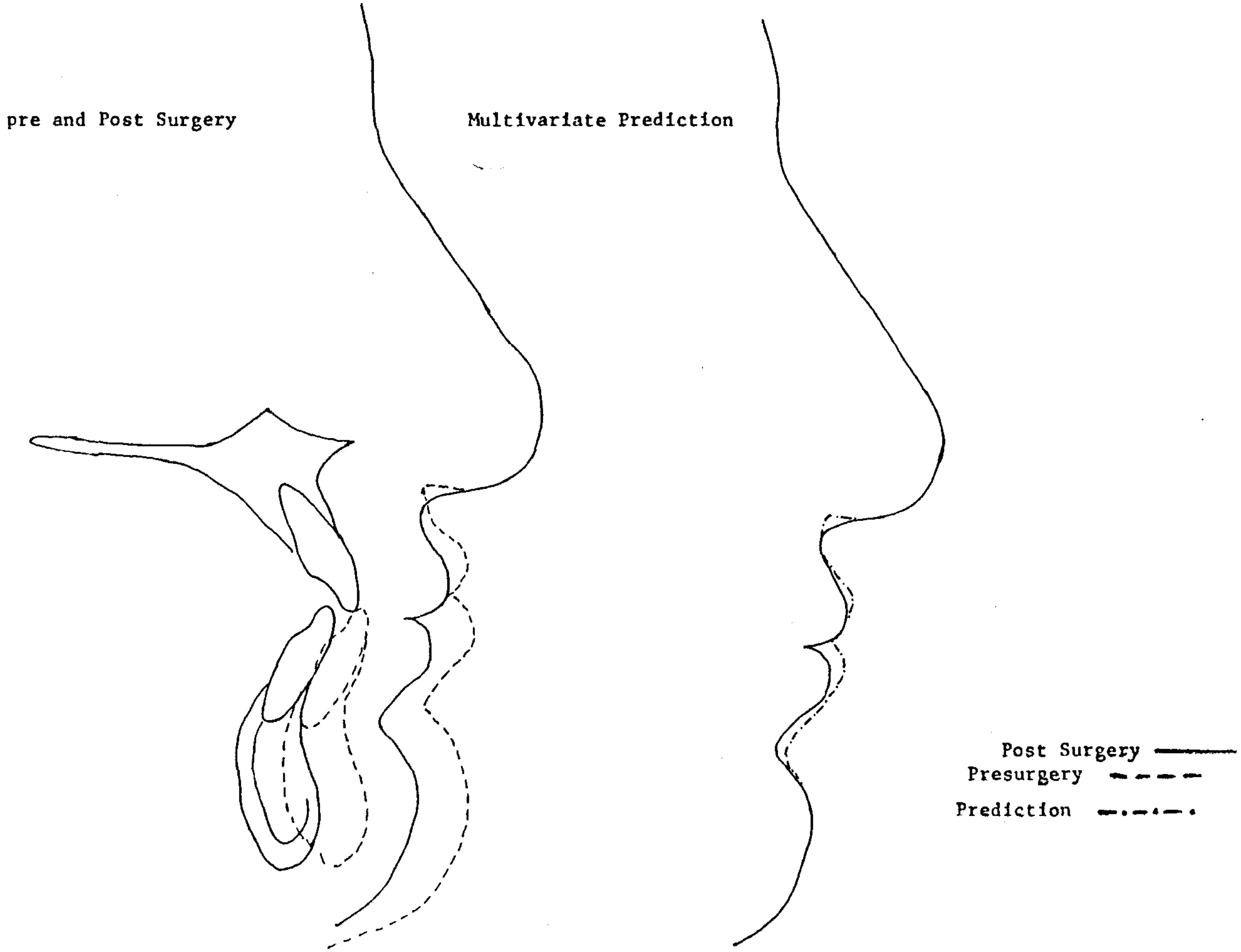


FIGURE 13.

Case # 34

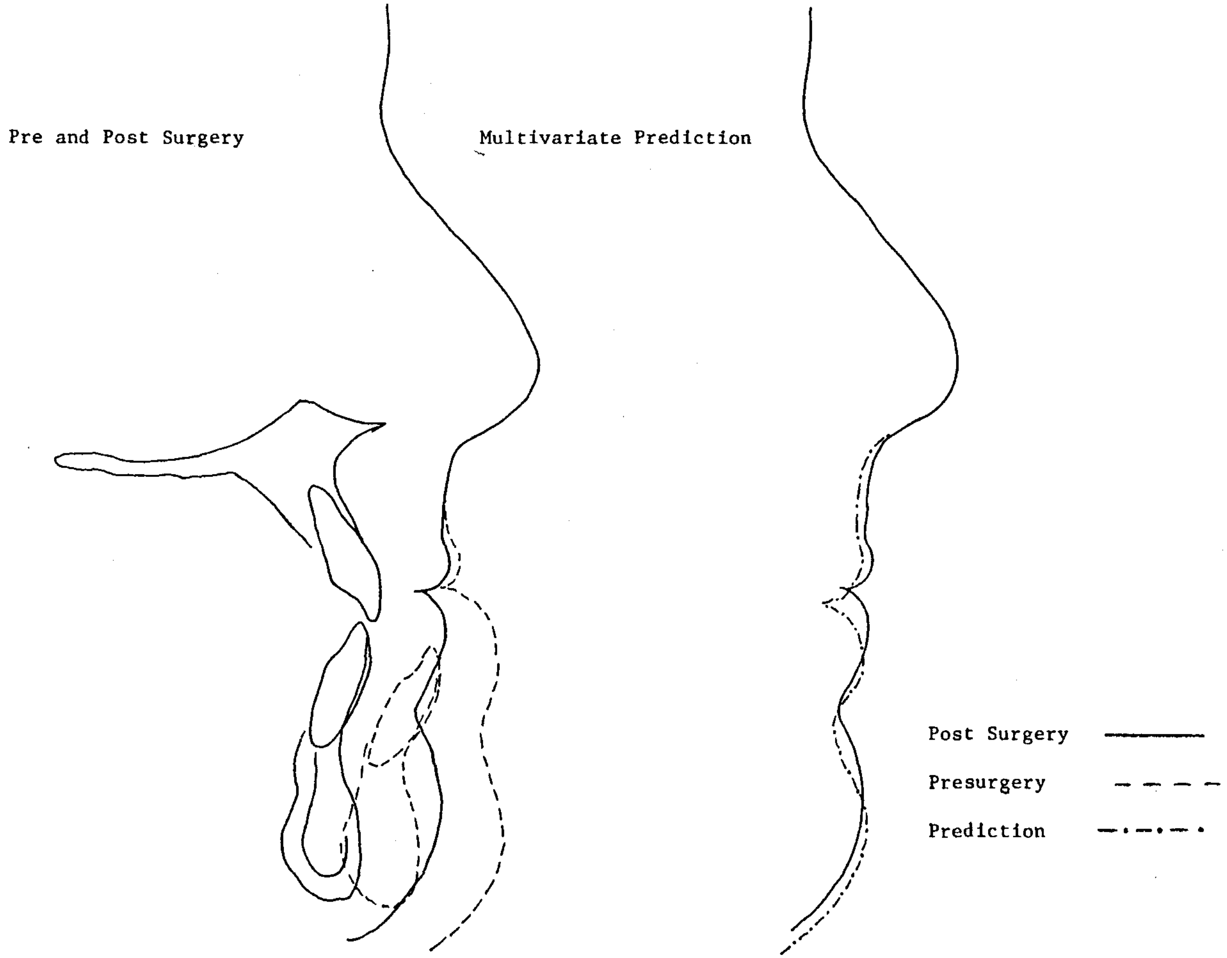


FIGURE 14.

Case # 30

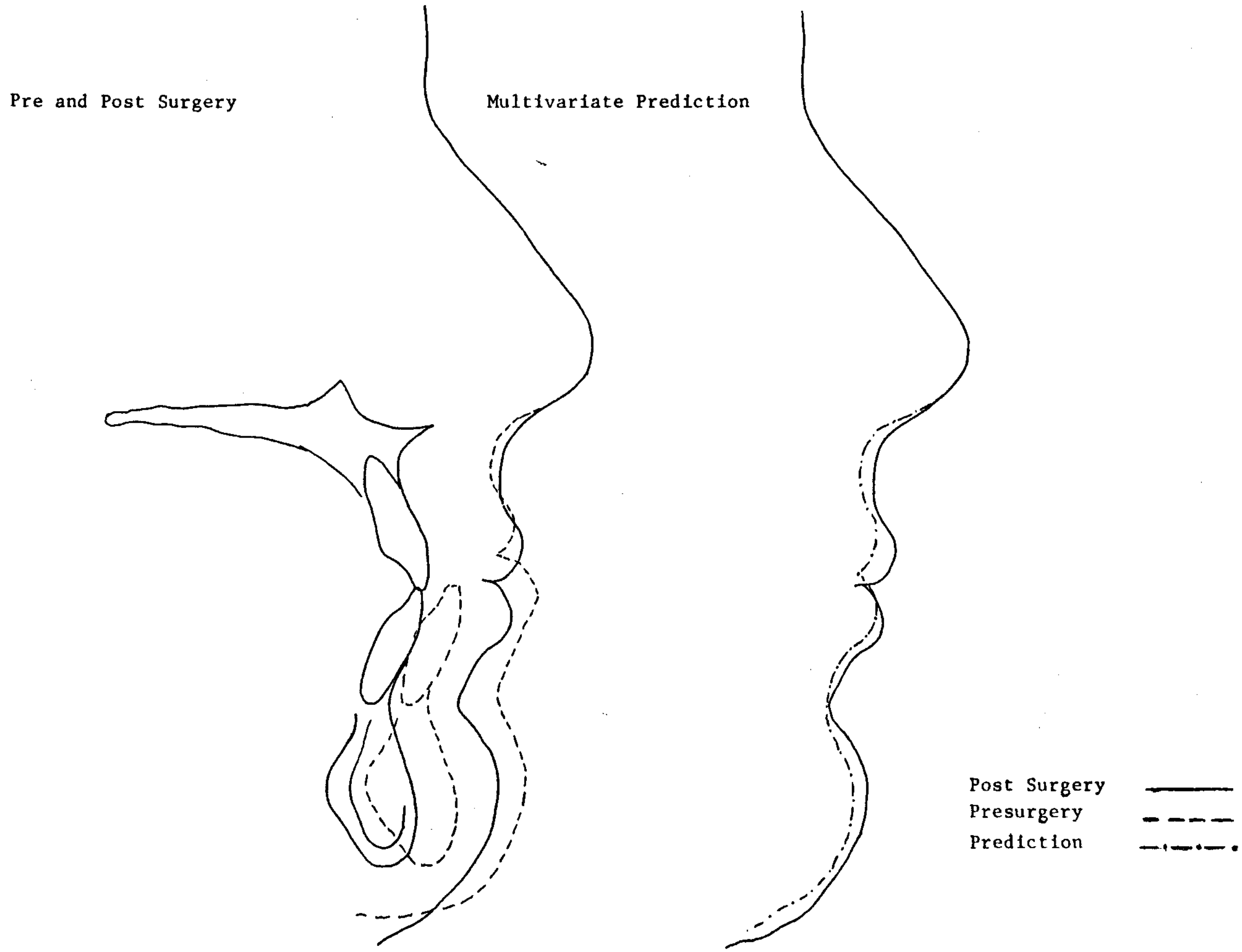


FIGURE 15.

Case # 31

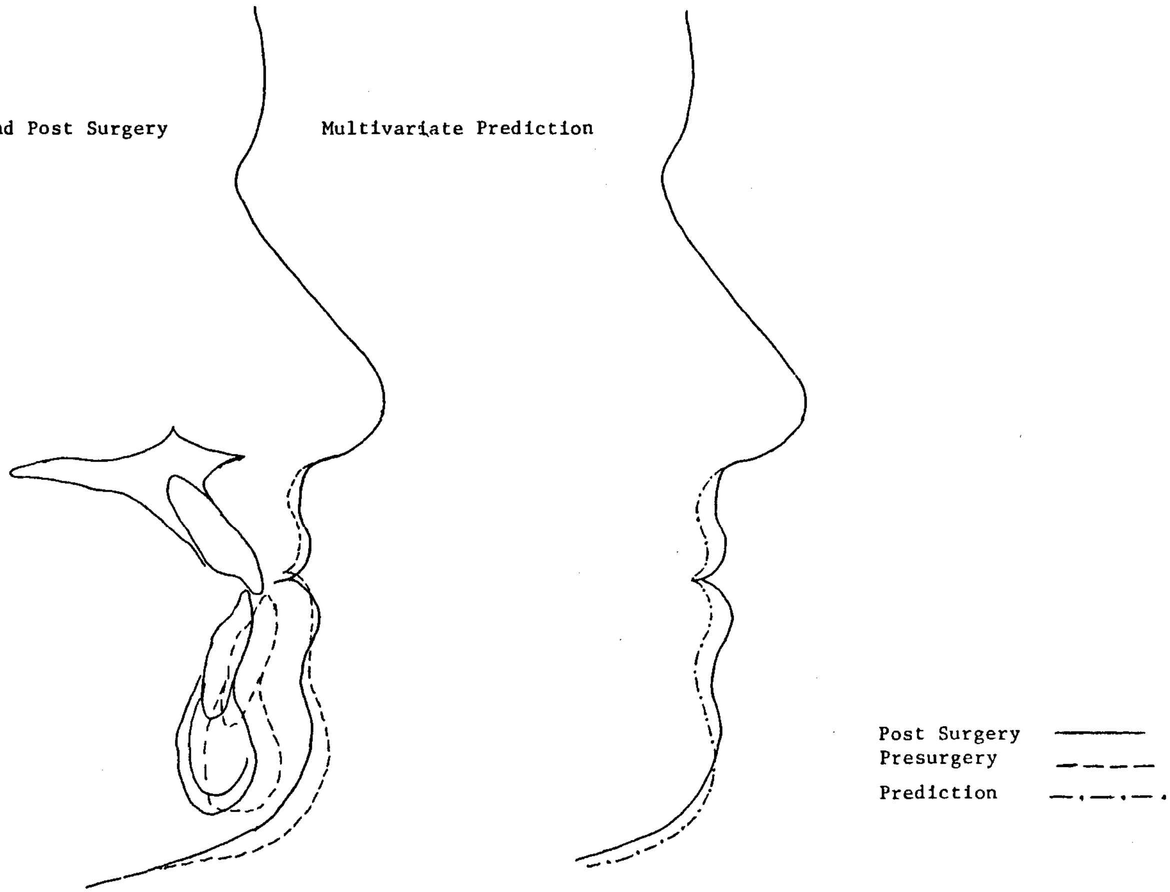


FIGURE 16.

Case # 22

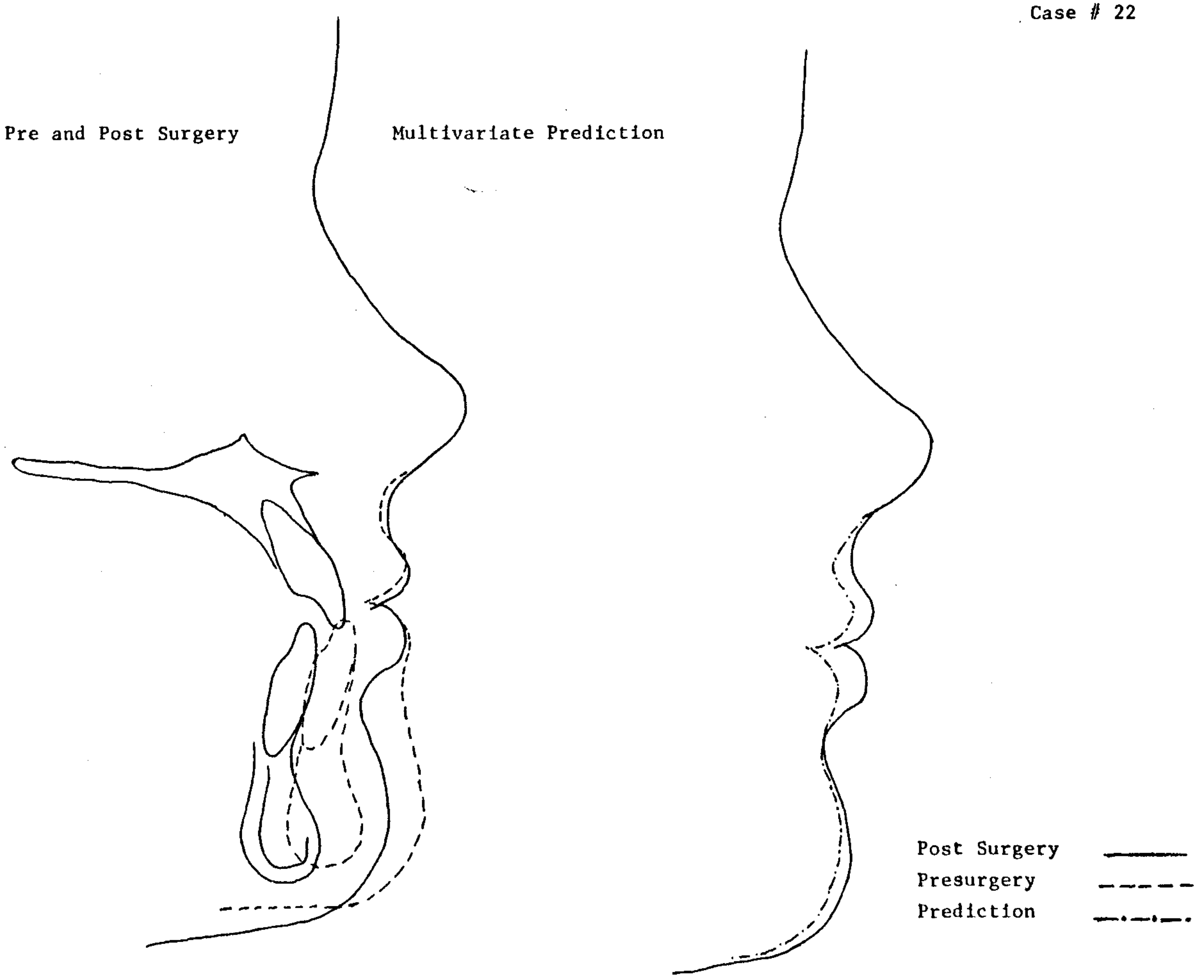


FIGURE 17.

Case # 29

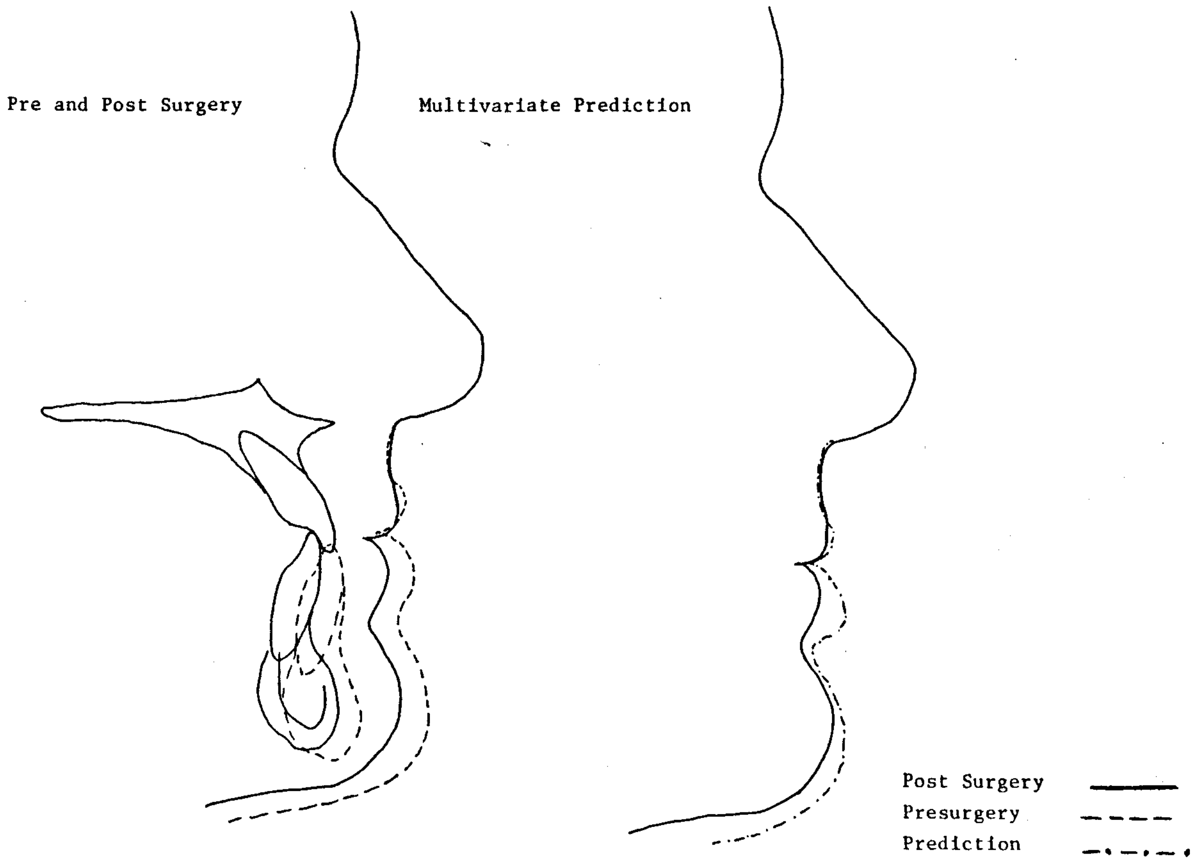


FIGURE 18.

Case # 37

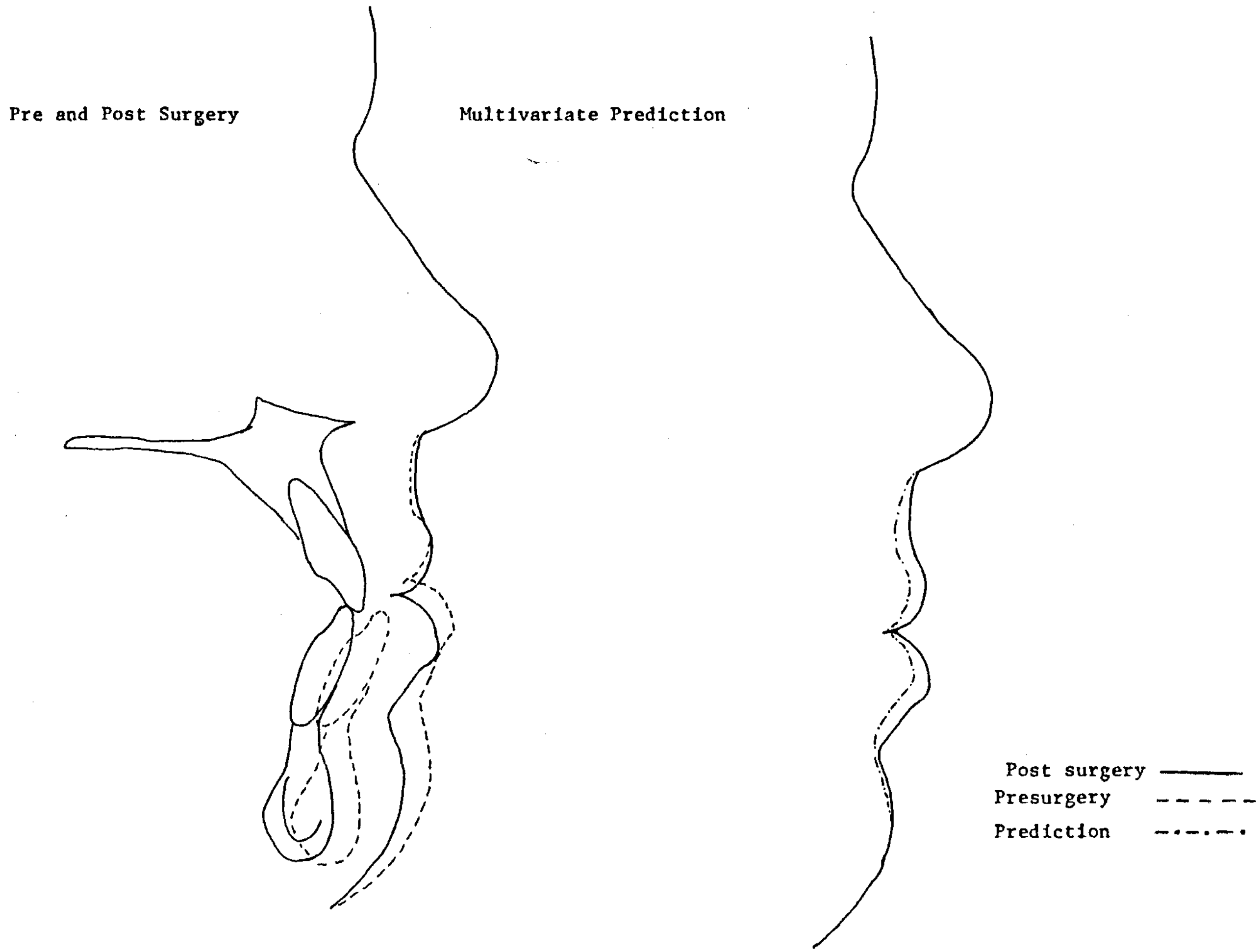
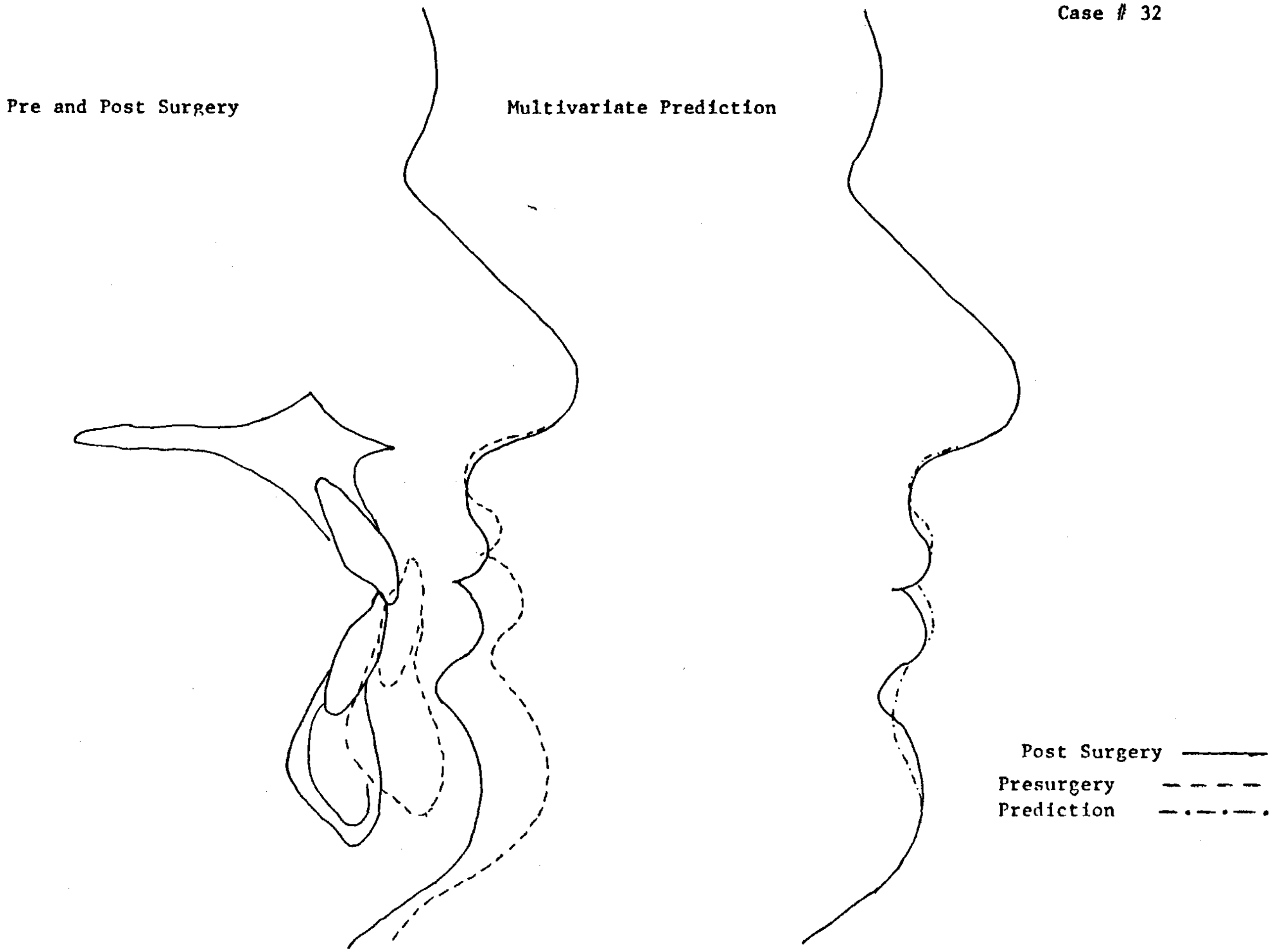


FIGURE 19.


Case # 32
Pre and Post Surgery
Multivariate Prediction
Post Surgery
Presurgery
Prediction

APPROVAL SHEET

The thesis submitted by P. Jack Feller, D.D.S., has been read and approved by the following committee:

Doctor Michael L. Kiely, Director
Associate Professor, Anatomy, Loyola

Doctor Milton L. Braun
Professor, Orthodontics, Loyola

Doctor James Young
Assistant Professor, Orthodontics, Loyola

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the Committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

5-25-79 Michael L. Kiely

Date Director's Signature