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LONG TERM STABILITY AND PREDICTION
OF SOFT TISSUE CHANGES
FOLLOWING LE FORT I SURGERY

Presented by

Gregory A. Hack, DDS

A thesis submitted in partial fulfillment of the requirements
for a Certificate in Orthodontics

Chief Advisor: Dr. Ravindra Nanda
Co-Advisors: Dr. Leon Assael
Dr. Joseph Burleson

Division of Orthodontics
The University of Connecticut
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Review and Approval Page

Certificate in Orthodontics Thesis

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Abstract

Long Term Stability and Prediction of Soft Tissue Changes Following LeFort I Surgery

Gregory A. Hack, DDS

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Numerous evaluations of soft tissue changes following orthognathic surgery have been undertaken and many correlations of soft tissue to hard tissue movements have been established. These studies have not, however, specifically discussed the long term stability or characteristics of the soft tissue changes. The objectives of this study were as follows: (1) To determine the long term stability of soft tissue changes five years after LeFort I osteotomy, (2) to determine reliable correlations, if any, of soft tissue changes to bony movements effected in surgery, and (3) To determine the predictability of soft tissue changes as an aid to orthodontic treatment planning.

Cephalometric data from 25 patients treated with LeFort I osteotomy with or without a concurrent mandibular procedure were analyzed retrospectively. Cases were selected from the patient records of the Department of Oral Surgery of the Vrije Universiteit in Amsterdam, the Netherlands. These patients were followed up at four time points, the last being a mean of 6.1 years post-surgery.

Analysis of stability data revealed that most horizontal and vertical soft tissue change following LeFort I surgery occurred in the first year after surgery. Significant (>10%) change continued to occur for subnasale, labrale inferius, upper lip protrusion, lower lip protrusion, and soft tissue convexity during the subsequent five years.

Hard tissue to soft tissue correlations were calculated and ratios of soft tissue to hard tissue movement were determined for appropriate hard and soft tissue landmarks at four time intervals. Reliable correlations of hard tissue change at surgery to five year soft tissue change could be made for ten variables, which was considerably less frequently than for one year soft tissue change. The relatively low reliability of long term prediction correlations suggests that soft tissue movements may be more independent of hard tissue over time. One year prediction values were similar to five year values and thus could be used for prediction purposes in orthodontic treatment planning. Most short term hard to soft tissue correlations found in the present study were in the range of those established by previous authors. Long term hard tissue to soft tissue correlations gave higher ratios of soft tissue movement secondary to maxillary surgery, approaching ratios of 1.0:1.0 for some variables. This finding as well as the long term stability data suggest that soft tissue settling or equilibrium following surgery may take several years to complete.
INTRODUCTION

The analysis of the soft tissues of the face has been an important part of orthodontic treatment planning since the 1950's, when Riedel\(^1\), Holdaway\(^2\), Burstone\(^3,4\), and Subtelny\(^5\) independently described the salient aspects of the soft tissue profile as well as the relationship of soft tissue landmarks to the underlying skeletal structures. In modern orthodontic practice, orthognathic surgery is quite frequently utilized in order to maximize function and facial esthetics. It is not surprising, then, that the behavior of soft tissue facial structures after these procedures is of great interest.

One of the primary objectives of orthodontic treatment is the attainment of a stable result. When orthognathic surgery is required in order to fulfill treatment objectives, stability of the result is of even greater concern. A great deal of literature has been devoted to quantifying the post-surgical bony changes following orthognathic surgery\(^6,7,8,9\). Similarly, some studies have investigated post-surgical soft tissue changes, usually over a one to two year follow-up period. Soft tissue stability per se, however, has not been as extensively studied. It would appear then that a study of long term stability of soft tissue changes following orthognathic surgery would be a significant contribution to the literature. After the stability of the changes has been quantified, it may be of further use to correlate the soft tissue changes with the bony movements achieved at surgery, with the ultimate goal of gaining the ability to predict the long term soft tissue changes resulting from orthognathic surgery procedures.
REVIEW OF THE LITERATURE

Following the early work of Obwegeser\textsuperscript{10} and others\textsuperscript{11,12,13,14}, initial studies\textsuperscript{15} of soft tissue behavior after orthognathic surgery concentrated mainly on the profile following mandibular procedures. These studies were quite general in scope. In the early 1970's several authors began to quantify the relationships between hard and soft tissues. At this time Robinson et al.\textsuperscript{16} reported on ten patients who had mandibular procedures and found that at surgery sulcus inferius and soft tissue pogonion followed B point and pogonion respectively on almost a 1:1 basis. Bell and Dann\textsuperscript{17} studied 25 patients who were followed a mean of 25.6 months and found a coefficient of 0.6 for soft to hard tissue chin (following genioplasty) and 0.7 +/- 0.1 for upper lip movement relative to incisor movement following anterior maxillary ostectomy. Lines and Steinhauser\textsuperscript{18}, in a preliminary report of 35 patients who had seven various surgical procedures among them, stated values of 1:1 for soft tissue chin to bony chin and 2:3 for lower lip to incisor for eight mandibular setbacks and nine mandibular advancements. Among three maxillary advancements they found soft tissue to hard tissue ratios of 2:3, and among seven maxillary alveolar setbacks a ratio of 1:2 was determined. These results were based upon records taken at least three months after surgery.

In the mid 1970's Dann et al.\textsuperscript{19} reported on eight patients who had total maxillary advancements and were followed at least six months post-surgery. They found correlations for horizontal change in upper lip to upper incisor of 0.5 +/- 0.1
and for vertical change in upper lip to incisor of 0.3 +/- 0.15. They also found a change in nasolabial angle according to horizontal change of upper incisor of 1.2 degrees/mm +/- 0.3 degrees. They further found that lip thickness stabilized after six months. Schendel et al.\textsuperscript{20} reported on 30 patients with maxillary impactions who were followed up a mean of 14 months. They found posterior horizontal movement of upper lip to bone of 0.76:1 and a vertical correlation of lip to incisor of 0.38:1. Further, they noted that soft tissue pogonion followed pogonion in a 1:1 relationship following autorotation. Speidel et al.\textsuperscript{21} followed 12 patients a mean of 25.5 months after mandibular subapical osteotomy and found correlation coefficients for soft tissue changes which were in agreement with those established by previous authors. Kajikawa\textsuperscript{22} also agreed with earlier studies in reporting 1:1 movements of soft tissue structures over B point, pogonion, and menton following correction of skeletal prognathism.

Interest in soft tissue movements continued into the 1980's, when Mansour et al.\textsuperscript{23} analyzed 14 maxillary impactions and seven advancements followed at least six months and reported numerous correlations, notably mandibular soft to hard tissue correlations of 1.0 and superior movement of upper lip to incisor of 0.4. Quast et al.\textsuperscript{24} discussed the desirability of long term (at least 1.5 years post surgery) patient follow-ups to develop accurate prediction data. They basically agreed with the findings of Lines and Steinhauser but recognized the variability of hard and soft tissue spatial changes, particularly noting the added variability of predicting short to
long term events. Carlotti et al.\textsuperscript{25} investigated 25 cases of LeFort I maxillary advancement and nasolabial reconstruction followed an average of eight months and found a lip to osseous ratio of 0.9:1, a considerably larger number than stated in previous studies. This may have been due in part to the fact that nasolabial reconstruction as well as advancement of the remaining associated facial muscles via V-Y closure was performed in these cases. Davis et al.\textsuperscript{26} evaluated 23 advancement genioplasty patients for bony and soft tissue stability. The patients were followed over three years post-surgery. They reported only generalizations about soft tissue movements and suggested that some soft tissue variation may occur independent of bony remodeling. Fanibunda\textsuperscript{27} discussed 33 patients evaluated nine months to seven years after correction of mandibular prognathism and found coefficients of B' to B point of 1.07:1 and soft tissue pogonion to pogonion of 0.94:1, among others. Stella et al.\textsuperscript{28} followed 21 maxillary advancement patients at least six months and found no reliable correlations between bony advancement and soft tissue position. They did find, however, that tissue change varies with different lip thicknesses and that lip thickness appears to stabilize six months post-surgery.

**OBJECTIVES**

This brief review of the literature includes many but certainly not all of the studies which have examined soft tissue movements following surgery. The review reveals that numerous evaluations of soft tissue changes following orthognathic surgery have been undertaken and that many correlations of soft to
hard tissue movements have been established. None of the studies, however, specifically discusses the long term stability of the soft tissue changes. The specific objectives of this study were as follows:

1. To determine the long term stability of soft tissue changes five years after LeFort I osteotomy,
2. To determine reliable correlations, if any, of soft tissue changes to bony movements effected in surgery, and
3. To determine the predictability of soft tissue changes as an aid to orthodontic treatment planning.

MATERIALS AND METHODS

Cephalometric data from 25 patients treated with LeFort I osteotomy with or without a concurrent mandibular procedure were studied retrospectively. Cases were selected from the patient records of the Department of Oral Surgery of the Vrije Universiteit in Amsterdam, the Netherlands. All patients underwent surgery between the years 1981-85 and were placed in intermaxillary fixation for four weeks post-surgery (IMF is no longer the sole practice of this institution). The mean postoperative follow-up period was 6.1 years.

The criteria for patient inclusion in the study were as follows:

1. All patients were non-growing adults.
2. Patients had deformities of development only. Patients with genetic syndromes or other congenital deformities were excluded from the study.
3. Patients had LeFort I osteotomy performed with or without a concurrent
mandibular procedure (mandibular advancement or genioplasty). At least 2.0 mm of bony movement occurred at surgery, in either a horizontal or a vertical direction (Table I).

Cephalometric Criteria

Lateral cephalometric radiographs were used for this study. All radiographs were taken in centric relation with the lips at rest. Barium paste was applied to the soft tissues to facilitate accurate soft tissue tracing. The radiographs used for the present study were taken at the following intervals:

1. The pre-operative radiograph (T₀) was taken less than one month prior to surgery.
2. The immediate post-operative radiograph (T₁) was taken within one month of surgery (mean = 5.5 days).
3. A third radiograph (T₂) was taken one year post-surgery (mean = 13.2 months).
4. The final radiograph (T₃) was taken at least five years post-surgery (mean = 6.1 years).

Cephalometric Data Analysis

Vertical and horizontal measurements were made of each tracing with a digital caliper on an X-Y coordinate system (Fig. 1). The X coordinate was formed by
a line rotated 7 degrees downward from the SN line (Constructed Frankfort Horizontal (CFH)). A perpendicular vertical reference line through sella was drawn and used as the Y coordinate. The X-Y coordinates were drawn on the pre-operative tracing of each patient. The three subsequent tracings were superimposed on the original tracing and then measured on the X-Y axes in order to maximize the consistency among measurements. Eight hard tissue and six soft tissue landmarks were measured on this grid (Fig. 1). Lip protrusions (measured from the Sn-Pg' line), interlabial gap, and hard and soft tissue convexity were also measured on each tracing.

Patients were placed into two groups, Group 1 being comprised of patients with LeFort I osteotomy alone and Group 2 being comprised of patients with LeFort I osteotomy with a concurrent mandibular procedure. Descriptive statistics for both groups and the total sample are given in Table I.

Measurement Reliability

Great care was taken in this investigation to obtain the maximum possible accuracy of all measurements. As a more objective indicator of accuracy, a study of measurement reliability was performed. This was achieved in two parts. In part I measurement error alone was determined by remeasurement of five randomly selected tracings. These tracings were previously measured and included in the data sample. Five landmarks were selected and the X and Y coordinates of this remeasurement group were compared with the original measurements via Pearson correlations. The average Pearson corelation coefficient for part I was 0.988 with a
statistical significance of \( p < .004 \).

In part II retracing and resuperimposition error was evaluated. Five randomly selected radiographs were retraced, superimposed on the original X-Y coordinate system, and remeasured. Landmarks were selected and Pearson correlation coefficients for this group versus the original measurements were determined as for part I. The average Pearson correlation coefficient for part II was 0.948 with a statistical significance of \( p < .03 \). Not surprisingly, somewhat greater error was seen in the retraced and resuperimposed group, but Pearson coefficients for both groups were extremely high, indicating very high measurement reliability.

Statistical Analysis

The mean and standard deviation were calculated for each landmark at each time interval (\( T_1 - T_0, T_2 - T_0, T_3 - T_0 \)). Specifically, these are reported as the absolute values of the means of the differences between the measurements obtained at the given time points minus \( T_0 \). That is, the mean of \( T_1 - T_0 \) indicates change at the time of surgery, \( T_2 - T_0 \) indicates change one year after surgery, and \( T_3 - T_0 \) indicates change over five years. Reporting the data as absolute values was necessary because the surgical bony movements were not always in the same direction. Thus, the means reported indicate only the net magnitude of change and do not suggest directionality of that change.

Next, correlations between hard tissue landmarks (independent variables) and soft tissue landmarks (dependent variables) were calculated for both horizontal
and vertical measurements. Correlation coefficients (r) were calculated only for those hard and soft tissue landmarks which were considered likely to have some association. For these chosen landmarks, correlation coefficients were calculated for the following time periods:

1. Hard tissue at T1 to soft tissue at T2,
2. Hard tissue at T1 to soft tissue at T3,
3. Hard tissue at T2 to soft tissue at T2,
4. Hard tissue at T3 to soft tissue at T3.

These coefficients were calculated for the total sample as well as for both Group I (Le Fort I alone) and Group II (Le Fort I with a mandibular procedure). In this way 570 correlation coefficients were calculated. Of these, only those significant at better than a p < .05 level were considered reliable. For some landmarks, significant r values were found for more than one of the groups. When this was the case, the highest r value with the greatest level of significance was selected. Beta values were then calculated from these significant correlations to give a millimeter unit relationship between hard tissue and soft tissue movements.

RESULTS

Stability Data

Stability data are summarized in Tables II and III. Data for hard tissue as well as soft tissue changes are listed, but only soft tissue data will be discussed. This is due to the fact that most modern studies of hard tissue stability evaluate
only very specific procedures, i.e. maxillary intrusions only or advancements only, whereas this sample included multidirectional movements. The hard tissue data were used only to determine subsequent soft tissue correlations. A patient demonstrating considerable soft tissue variation over the five year period is shown in Figure 2(a.,b.,c.). The range of mean horizontal movements achieved at surgery varied from 2.72 mm for A pt and subnasale up to 6.70 mm for soft tissue pogonion. Vertical movements overall were considerably smaller, with a range from 1.28 mm for subnasale up to 3.16 mm for infradentale. Mean changes at surgery for lip protrusions, interlabial gap, hard tissue convexity, and soft tissue convexity are also given in Tables II and III.

Table IV lists the net change in position of soft tissue landmarks for three time intervals: one year post surgery, one to five years post surgery, and five years post-surgery (total change). These are listed as the percent of change which occurred relative to T1 - T0 values. A negative value indicates that the mean absolute value decreased for that time interval, whereas a positive value indicates an increase. A "significant" change was arbitrarily set at 10% of the T1 - T0 value. A smaller change than this may have included considerable measurement variability.

1. One year stability data. A greater than 10% change was seen for all soft tissue landmarks in a horizontal direction. The negative values suggest a tendency to return toward the presurgical condition. Mentolabial sulcus showed the greatest change at -43.7%. All other measurements were at approximately the -30% level. In a vertical direction, only superior labial sulcus showed greater than 10% change. At + 23.8%, superior labial sulcus showed a tendency toward moving inferiorly in the
first year after surgery. Further, upper lip protrusion and soft tissue convexity remained relatively stable during this period, whereas interlabial gap and hard tissue convexity decreased. Lower lip protrusion increased considerably during the first year.

2. Long term stability data. A greater than 10% change was seen for several of the soft tissue landmarks in the one to five year postoperative period. Subnasale was seen to move an additional -16.2% for a total change of -46.7% over the five year period. Labrale inferior measurements increased during this period, bringing net five year change down to -13.7%. Other soft tissue landmarks were found to be relatively stable in a horizontal direction during the one to five year postoperative period. In a vertical direction, subnasale and labrale inferior measurements decreased -19.5% and -24.0%, causing total five year change of -13.3% and -27.5% respectively. Other vertical soft tissue measurements were relatively stable during this period.

Upper lip protrusion increased rather dramatically during this period, perhaps due in part to the large change in subnasale during this time. Lower lip protrusion increased also, giving upper and lower lip protrusions final change values of +40.2% and +38.2%. Soft tissue convexity also decreased further over the long term, as would be expected with the decrease in subnasale measurements.

Hard and soft tissue correlations

Tables V and VI list reliable correlations in horizontal and vertical directions among hard and soft tissue landmarks for the various time intervals. Correlations
were made between the means of the absolute values of the differences for each 
time interval (T1 - T0, T2 - T0, T3 - T0).

1. Horizontal correlations. Many statistically significant and reliable 
correlations were found among hard and soft tissue landmarks. Anterior nasal 
spine had significant correlations with subnasale, superior labial sulcus, and labrale 
superius. The position of subnasale, superior labial sulcus, and labrale superius at 
T2 (one year post-surgery) could be reliably predicted from the position of anterior 
nasal spine at T1 (immediately post-surgery). The range of these determined ratios 
was from 0.2:1.0 for superior labial sulcus to 0.69:1.0 for labrale superius. The ratios 
for these landmarks at other time intervals fell into the range of 0.25:1.0 to 0.60:1.0. 
Long term values of anterior nasal spine to labrale superius gave the highest ratio at 
0.60:1.0. Anterior nasal spine at T1 did not correlate significantly with any of the soft 
tissue variables at T3 (five year prediction).

Soft tissue landmarks superior labial sulcus and labrale superius appeared to 
follow A pt and prosthion more closely than anterior nasal spine. Subnasale, 
however, followed anterior nasal spine more closely than prosthion or A pt. A 
surgical movement of A pt and prosthion (T1) could predict long term movement 
of superior labial sulcus (T3) with ratios of 0.38:1.0 and 0.49:1.0 respectively. That is, 
a 1.0 mm hard tissue movement would predict a 0.38 mm and a 0.49 mm soft tissue 
movement for each. T3 to T3 values were considerably higher for both. A pt and 
prosthion to labrale superius had the highest ratios among anterior nasal spine, A 
pt, and prosthion measurements. Surgical movement of A pt and prosthion (T1) 
predicted long term position of labrale superius (T3) with ratios of 0.52:1.0 and
0.68:1.0 respectively. Labrale superius at T3 followed prosthion at T3 on almost a 1.0:1.0 basis.

Incision superius correlated quite highly with superior labial sulcus and labrale superius at all time intervals. Superior labial sulcus followed incision superius with ratios of 0.33:1.0 from T1 to T2 (one year change) and 0.55:1.0 from T3 to T3. Labrale superius followed incision superius more closely, again approaching a 1.0:1.0 relationship (0.91:1.0) for the T3 to T3 comparison. Figure 3 shows a patient for whom labrale superius followed incision superius posteriorly at nearly a 1.0:1.0 ratio over the five year period.

Labrale inferius had relatively weak associations with infradentale and incision inferius (r =0.34) and no significant correlations at all with B point. Mentolabial sulcus, however, had clear associations with infradentale, incision inferius, and B point. The correlations and ratios tended to become stronger at the later time intervals. Mentolabial sulcus showed the strongest relationship with incision inferius, with ratios ranging from 0.44:1.0 for T1 to T2 (one year soft tissue change) up to 0.91:1.0 for T3 to T3. Not surprisingly, soft tissue pogonion had very high correlations with B point and pogonion. Five year to five year ratios (T3 toT3) for both pogonion and B point were close to 1.0:1.0, but long term predictors were far less uniform. A 1.0 mm movement of B point at surgery predicted a 0.51 mm movement of soft tissue pogonion after one year, and a 1.0 mm movement of pogonion (T1) predicted only a 0.27 mm movement of soft tissue pogonion by T3 (five year change). Figure 4 illustrates a patient for whom soft tissue pogonion followed pogonion posteriorly at nearly a 1.0:1.0 ratio over the five year time period.
2. **Vertical correlations.** A number of reliable correlations for vertical movements could be found, but far less than for horizontal movements. Anterior nasal spine at T1 was the only hard tissue landmark reliably correlated to a soft tissue landmark after five years. Subnasale followed anterior nasal spine at a ratio of 0.29:1 over this time period. Superior labial sulcus at T3 followed anterior nasal spine at T3 in a vertical direction at a ratio of 0.43:1.0. Only superior labial sulcus (at T3) followed A point (at T3) reliably, with a vertical ratio of 0.54:1.0.

Superior labial sulcus followed prosthion and incision superius at the most time intervals of any vertical measurements, getting correlations as high as \( r = .64 \) with a beta of 0.72 for the incision superius at T3 to superior labial sulcus at T3 interval. That is, the five year to five year ratio of superior labial sulcus to incision superius in a vertical direction is 0.72:1.0. Labrale superius was moderately correlated with prosthion and incision superius only at the T2 to T2 interval.

Regarding mandibular measurements, labrale inferius was moderately related to infradentale and incision inferius. Mentolabial sulcus was similarly related to incision inferius only. Soft tissue pogonion followed pogonion in a vertical direction with a ratio of 0.70:1.0 for the T2 to T2 time period, among the highest seen for vertical variables.

**DISCUSSION**

1. **Stability of soft tissue structures following surgery.** One of the main purposes of this investigation was to determine the long term stability of soft tissue changes following LeFort I procedures. Proper sample selection was very important
in order to achieve the most reliable and meaningful results. All patients selected had deformities of development only and were non-growing adults. Almost all of the patients were treated with the same surgeon and orthodontist in order to keep operator variability to a minimum. Record collection was very consistent among those patients selected, although the data was collected retrospectively.

Dann et al.\textsuperscript{19} and Stella et al.\textsuperscript{28} have reported that lip thickness stabilizes approximately six months after orthognathic surgery. Singh\textsuperscript{33} has reported that soft tissue chin thickness may continue to change five years after orthodontic treatment.

In the dental literature, Anderson et al.\textsuperscript{34} reported that soft tissues of the facial profile were closely related and dependent on the underlying dentoskeletal framework. They found that soft tissue profile had changed ten years post-retention, but they did not specify when the change occurred. The short term nature of most of these studies, however, leaves doubt as to whether soft tissue equilibrium for all structures is reached within this time period. The data reported here show that although most postoperative change occurs in the first year after surgery, labrale inferius and subnasale show a significant (> 10%) change occurring in horizontal and vertical directions over the next five years. Part of the change occurring in the first year must be attributed to a reduction of swelling following the surgical procedures. The subsequent change occurring after the first year cannot, however, have a great relationship to reduction in postoperative swelling. R. Behrents\textsuperscript{35} has reported that significant "growth" or adult enlargement continues in the craniofacial complex throughout life. These natural adult changes are probably not
of sufficient magnitude to account for the relatively large changes seen for subnasale and labrale inferius in both horizontal and vertical dimensions.

Genecov et al.\textsuperscript{36} and Nanda et al.\textsuperscript{37} would further support the notion that the changes seen here were not related to facial growth. Genecov et al.\textsuperscript{36} found that facial growth in females was largely completed by age 12, while males showed some further growth until age 17. Nanda et al.\textsuperscript{37} also found that females completed growth before males but that in males growth of the nose and thickness of the upper lip was still not completed by age 18. Bishara et al.\textsuperscript{38} have found that in males facial changes may continue to occur for some parameters after age 17, but they were not able to determine when facial growth effectively "stops". Since the present sample contained mostly females and the mean age was considerably greater than age 18, growth contributions were probably not relevant to the present study. It should be noted in addition that weight changes following surgery may have had an effect on some of the patients. These possible effects were not evaluated in the present study.

Changes seen in lip protrusions may be significant in themselves in light of movements of labrale inferius over the one to five year period, but the large increase in upper lip protrusion is difficult to explain by upper lip movement alone. Certainly concurrent movement of subnasale has an influence in this regard. It is possible that the lips were not at rest for all radiographs, since this was a retrospective study and lip posture was not evaluated by the investigator when the radiographs were taken. The long term stability of interlabial gap seen here suggests that lip posture may have been relatively constant. Hard tissue convexity and soft
tissue convexity appeared to move in similar directions over the five year period, but the contributing factors are obscured by the several landmarks involved in convexity measurements.

In summary, subnasale and labrale inferius showed significant changes well beyond the one year follow-up period, while other soft tissue landmarks remained relatively stable after one year. This suggests that in some cases soft tissues may take much longer to reach equilibrium with the underlying bony structures than has been commonly cited in the literature\textsuperscript{19,28}. Precisely how this "equilibrium" is achieved remains an enigma. Weinstein et al.\textsuperscript{39} and Proffit\textsuperscript{40} have elaborated on the primary and theoretical factors involved in dentofacial equilibrium, but how these apply to post-surgical changes is difficult to characterize. Proffit and Phillips\textsuperscript{41} have shown that resting pressures of the lips decrease following surgical advancement of the maxilla or mandible. This unexpected finding is probably just one of many which contribute to the establishment of equilibrium following orthognathic surgery procedures.

2. *Hard tissue and soft tissue correlations and soft tissue prediction.*

Numerous significant and reliable correlations and beta values were found for horizontal and vertical measurements. In the literature, horizontal changes of soft tissue structures in the midface seem to follow maxillary hard tissue structures in the range of 0.5 - 0.7:1.0 (upper lip to incisor is most commonly reported).

Specifically, Bell and Dann\textsuperscript{17} found a coefficient of 0.7 +/- 0.1 for upper lip movement relative to incisor movement following anterior maxillary ostectomy.
Lines and Steinhauser\textsuperscript{18} found soft to hard tissue ratios of 2:3 for maxillary advancements and 1:2 for maxillary alveolar setbacks. Dann et al.\textsuperscript{19} established horizontal correlations of upper lip to incisor of 0.5 +/- 0.1 and vertical change in upper lip to incisor of 0.3 +/- 0.15. Schendel et al.\textsuperscript{20} agreed with these numbers, reporting horizontal change of upper lip to bone of 0.76:1 and vertical correlation of lip to incisor of 0.38:1. These ratios were based upon follow-up periods between 3-25.6 months.

In general the data of the present study tend to fall within this range (0.50-0.70:1), although direct comparison of long term and short term data is difficult. The present study found that labrale superius follows incision superius in a horizontal direction over the short term (one year) at a ratio of 0.60:1.0 and over the long term (five years) at 0.50:1.0. Vertical ratios were not significant for these intervals, but the ratio of soft tissue position at one year to hard tissue at one year is 0.23:1.0. Similar ratios were established for other midfacial points for these intervals as noted in the Results section.

Prediction ratios for lower facial landmarks were also somewhat similar to those established in the literature. Robinson et al.\textsuperscript{16}, Lines and Steinhauser\textsuperscript{18}, Kajikawa\textsuperscript{22}, Fanibunda\textsuperscript{27}, and others have reported that sulcus inferius and soft tissue pogonion follow B point and pogonion on approximately a 1:1 basis. While this was true for the T2 - T2 (0.93:1.0) and T3 - T3 (0.96:1.0) values for pogonion to soft tissue pogonion, the short term and long term predictor ratios (T1 - T2 and T1 - T3) were much less uniform. A 1.0 mm surgical movement of pogonion (T1) predicted
a long term movement of soft tissue pogonion of only 0.27 mm.

The ultimate goal of the present study was to gain the ability to predict the long term (five year) soft tissue changes resulting from a given surgical movement. In many cases this could be achieved, but the correlations of surgical hard tissue movement (T1) to one year soft tissue position (T2) were more frequently reliable. Davis et al.\textsuperscript{26} have suggested that minor long term soft tissue variation may occur without obvious correlation to bony remodeling. The relatively low reliability of long term prediction correlations found here support the notion that soft tissue movements may become more independent of hard tissue over time. Reliable hard to soft tissue ratios derived from the T1 to T3 intervals were similar to those of the T1 to T2 intervals, indicating that one year change may be a reliable predictor of long term change for those landmarks.

As a general rule beta values increased at the later time points, i.e., the beta values for five year hard tissue position to five year soft tissue position were higher than for T2 hard tissue to T2 soft tissue. In fact, for several landmarks, namely A pt to superior labial sulcus, A point to labrale superius, prosthion to labrale superius, and incision superius to labrale superius, the long term (T3 to T3) ratios approached a 1.0:1.0 relationship. This suggests that the soft tissues overlying maxillary structures may take several years to reach their final equilibrium rather than six months as reported by some authors\textsuperscript{19,28}. A description of the processes involved in the long term soft tissue changes is purely speculative. As Quast et al.\textsuperscript{24} have summarized, factors responsible for long term "relapse or remodeling" are not well
characterized. Muscle tissue adaptation has been described to some extent, but little is known about remodeling changes of blood vessels, connective tissue, epithelium, fatty tissues, and glandular tissues.

Vertical correlations of hard tissue to soft tissue found in the literature (following maxillary procedures) are in the range of 0.3:1 - 0.4:1\(^\text{19,20,23}\). The data here suggest similar ratios, although again at the T3 to T3 interval ratios of 0.4 - 0.7:1.0 were found. This would support the notion that soft tissue may take several years to reach vertical equilibrium as well. It should be noted, however, that many fewer significant vertical correlations were found, perhaps due in part to the relatively small mean vertical movements at surgery in this study.

The results of this investigation suggest possibilities for future study. Long term data are valuable for analysis of soft tissue behavior, but longitudinal data in the framework of a prospective study with a large sample size would be most beneficial. This would ensure proper lip posture when radiographs were taken. Further, a more procedure specific sample would be desirable. Such a study of soft tissue could easily be incorporated into a long term bony stability study currently in progress at several institutions.

**SUMMARY AND CONCLUSIONS**

Cephalometric data of 25 patients treated with LeFort I osteotomy with or without a concurrent mandibular procedure were analyzed retrospectively. These patients were followed up at four time points, the last being a mean of 6.1 years post-
surgery. Analysis of stability data revealed that most horizontal and vertical soft
tissue change following LeFort I surgery occurred in the first year after surgery.
Significant (> 10%) change continued to occur for subnasale, labrale inferius, upper
lip protrusion, lower lip protrusion, and soft tissue convexity during the subsequent
five years.

Hard tissue to soft tissue correlations were calculated and ratios of soft tissue
to hard tissue movement were determined for appropriate hard and soft tissue
landmarks at four time intervals. Reliable correlations of hard tissue change at
surgery to five year soft tissue change could be made for ten variables, which was
considerably less frequently than for one year soft tissue change. The relatively low
reliability of long term prediction correlations suggests that soft tissue movements
may be more independent of hard tissue over time. One year prediction values
were similar to five year values and thus could be used for prediction purposes in
orthodontic treatment planning. Most long term hard tissue to soft tissue
correlations (T3 - T3) gave higher ratios of soft tissue movement secondary to
maxillary surgery, approaching ratios of 1.0:1.0 for some variables. This finding as
well as the long term stability data suggest that soft tissue settling or equilibrium
following surgery may take several years to complete.
FIGURES
Fig. 1. The X-Y coordinate system used for measurement and the hard and soft tissue landmarks included in this study. Included points are: anterior nasal spine (ANS), A point (A pt), prosthion (Pr), incision superius (IS), incision inferius (II), infradentale (In), B point (B pt), pogonion (Pg), subnasale (Sn), superior labial sulcus (SLS), labrale superius (LS), labrale inferius (LI), mentolabial sulcus or sulcus inferius (SI), and soft tissue pogonion (Pg').
Fig. 2a. Patient #11, showing the bony movements achieved at surgery. Note the soft tissue swelling present at T₁.
Fig. 2b. Patient #11 from surgery to one year follow-up. Posterior movement of both the lips and subnasale is seen as the soft tissue swelling subsides.
Fig. 2c. Patient #11—long term follow-up. The soft tissues continue to move posteriorly in this patient from one to five years after surgery.
Fig. 3. Patient #8. In this patient labrale superius followed incision superius posteriorly at nearly a 1.0:1.0 ratio over the five year follow-up period.
Fig. 4. Patient #12. In this patient soft tissue pogonion followed pogonion posteriorly at nearly a 1.0:1.0 ratio over the five year time period.
TABLES
<table>
<thead>
<tr>
<th></th>
<th>Total sample</th>
<th>Group I (Le Fort I only)</th>
<th>Group II (Le Fort I with mand. procedure)</th>
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<td></td>
<td>N</td>
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<td>SD</td>
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<td>6</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>19</td>
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Table II: Stability data. Mean movements for all landmarks in a horizontal direction, in mm, listed as the absolute values of the differences for all time intervals. All values are reliably different from zero at the $p < .01$ level.

<table>
<thead>
<tr>
<th>Landmark</th>
<th>$T_1 - T_0$ Mean</th>
<th>$T_1 - T_0$ SD</th>
<th>$T_2 - T_0$ Mean</th>
<th>$T_2 - T_0$ SD</th>
<th>$T_3 - T_0$ Mean</th>
<th>$T_3 - T_0$ SD</th>
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<td>2.82</td>
<td>1.72</td>
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<td>1.57</td>
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<td>2.11</td>
<td>2.86</td>
<td>1.86</td>
<td>2.56</td>
<td>1.86</td>
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<td>3.13</td>
<td>2.18</td>
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<td>4.44</td>
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<td>1.89</td>
<td>1.12</td>
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<td>2.27</td>
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Upper lip protrusion
(from Sn-Pg' line)

2.14 1.53 1.98 1.29 3.00 3.26

Lower lip protrusion
(from Sn-Pg' line)

2.51 2.30 3.13 1.91 3.47 2.18
Table III: Stability data: Mean movements for all landmarks in a vertical direction, in mm, listed as the absolute values of the differences for all time intervals (All values are reliably different from zero at the $p < .01$ level.).

**Vertical Measurements**

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<th>$T_1 - T_0$</th>
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<th>$T_3 - T_0$</th>
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<td>Mean  SD</td>
<td>Mean  SD</td>
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<td>2.65 1.73</td>
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<tr>
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<td>2.81 1.96</td>
<td>2.25 1.98</td>
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<td>2.66 1.71</td>
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<td>B point</td>
<td>3.27 2.15</td>
<td>2.64 1.89</td>
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<td>1.11 0.95</td>
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<tr>
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<td>2.23 2.03</td>
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<td>1.54 1.05</td>
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**Angular Measurements**

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<td>Mean  SD</td>
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<td>6.44' 3.75</td>
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<td>5.00' 3.23</td>
<td>4.36' 3.43</td>
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Table IV: Net change (in percent) of soft tissue landmarks

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<th>(T3 - T2)</th>
<th>(T3 - T1)</th>
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<tr>
<td></td>
<td>(One year post-surgical) change</td>
<td>(1-5 year post-surgical) change</td>
<td>(5 year post surgical) change</td>
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<td>Subnasale</td>
<td>-30.5</td>
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<td>-46.7</td>
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<td>-33.9</td>
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<td>-13.7</td>
</tr>
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<td>+5.1</td>
<td>-38.6</td>
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<td>Lower lip protrusion</td>
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<thead>
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<th>Landmark</th>
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<tr>
<td>Subnasale</td>
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<td>-2.0</td>
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<tr>
<td>Labrale inferius</td>
<td>-3.5</td>
<td>-24.0</td>
<td>-27.5</td>
</tr>
<tr>
<td>Mentolabial sulcus</td>
<td>-3.0</td>
<td>-6.1</td>
<td>-9.1</td>
</tr>
<tr>
<td>Soft tissue pogonion</td>
<td>+1.0</td>
<td>+4.8</td>
<td>+5.8</td>
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<tr>
<td>Interlabial gap</td>
<td>-36.3</td>
<td>+5.0</td>
<td>-31.3</td>
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</table>

<table>
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<th>Landmark</th>
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<tr>
<td>Hard tissue convexity</td>
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Table V: Reliable (p < .05) correlations and B values for horizontal measurements

<table>
<thead>
<tr>
<th>Independent variable (Hard tissue)</th>
<th>Dependent variable (Soft tissue)</th>
<th>r</th>
<th>B</th>
<th>SE of B</th>
<th>p</th>
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<tbody>
<tr>
<td>ANS at T1</td>
<td>Sn at T2</td>
<td>.52</td>
<td>.36</td>
<td>.19</td>
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<td>Sn at T2</td>
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<td>.25</td>
<td>.12</td>
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<td>ANS at T1</td>
<td>SLS at T2</td>
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<td>SLS at T2</td>
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<td>.08</td>
<td>&lt;.001</td>
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<tr>
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<td>SLS at T3</td>
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<td>Pr at T1</td>
<td>SLS at T2</td>
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<td>.37</td>
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<td>SLS at T3</td>
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<td>.49</td>
<td>.20</td>
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<td>SLS at T2</td>
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Table VI: Reliable (p < .05) correlations and B values for vertical measurements

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<td>.32</td>
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References

10. Obwegeser, H., Tranner, R.: The surgical correction of mandibular prognathism and retrognathia with consideration of genioplasty. Surgical procedures to correct


APPENDIX

Patient List
1. LUITJES, Marianne  DOB: 10/22/67  SEX: Female
   DX: Lateral open bite
   Orthodontist: VU
   Surgery: LeFort I with 4 weeks IMF
   Surgery Date: 12/14/82
   T0: 12/13/82
   T1: 12/17/82
   T2: 11/8/83
   T3: 11/17/88

2. GROEN-FINTELMAN, Ursula  DOB: 1/13/61  SEX: Female
   DX: Maxillary Hyperplasia and high smile line
   Orthodontist: None
   Surgery: LeFort I 6mm cranial with 4 weeks IMF
   Surgery Date: 2/17/83
   T0: 3/6/80
   T1: 2/21/83
   T2: 1/13/84
   T3: 11/17/88

3. BOSMAN, Ingrid  DOB: 11/18/56  SEX: Female
   DX: Skeletal anterior openbite
   Orthodontist: Dorenbos
   Surgery: LeFort I with genioplasty with 4 weeks IMF.
   Surgery Date: 11/4/82
   T0: 9/2/82
   T1: 11/25/82
   T2: 11/11/83
   T3: 11/17/88

4. KNOOP, E.  DOB: 5/5/60  SEX: Male
   DX: Sagittal overbite and deep bite
   Orthodontist: Dorenbos
   Surgery: LeFort I with genioplasty and 4 weeks IMF
   Surgery Date: 5/10/83
   T0: 3/22/83
   T1: 5/13/83
   T2: 7/24/84
   T3: 1/14/89

5. GRAEVE, Ben  DOB: 7/3/55  SEX: Male
   DX: Mandibular retrognathism
   Orthodontist: Dorenbos
   Surgery: LeFort I with 4 weeks IMF
6. KASPERS, B.  DOB: 7/2/62  SEX: Male
   DX: Sagittal and vertical openbite
   Orthodontist: Dorenbos
   Surgery: LeFort I (4-5 mm) and genioplasty with four weeks IMF
   Surgery Date: 12/3/81

   T0: 9/2/81
   T1: 12/7/81
   T2: 12/15/82
   T3: 11/7/88

7. JANSEN, M.  DOB: 6/15/65  SEX: Female
   DX: Skeletal open bite
   Orthodontist: Dorenbos
   Surgery: LeFort I (3 piece) with genioplasty with 3.5 weeks IMF
   Surgery Date: 6/20/83

   T0: 6/14/83
   T1: 7/14/83
   T2: 7/27/84
   T3: 11/7/88

8. DOPPENBURG, Erwina  DOB: 9/1/61  SEX: Female
   DX: Maxillary Prognathism
   Orthodontist: Dorenbos
   Surgery: LeFort I (2 piece-impaction and setback) with 4 weeks IMF
   Surgery Date: 2/25/82

   T0: 4/11/81
   T1: 2/26/82
   T2: 4/15/83
   T3: 11/7/88

9. BOUWMAN-KOOY, Anna  DOB: 5/2/64  SEX: Female
   DX: Maxillary Prognathism
   Orthodontist: Dorenbos
   Surgery: LeFort I (Dorsal) with 4 weeks IMF
   Surgery Date: 9/16/82

   T0: 2/24/82
   T1: 9/20/82
   T2: 9/30/83
   T3: 1/14/89
10. GRETER-KOPER, Claudia  
   DOB: 1/17/53  
   SEX: Female  
   DX: Mandibular Retrognathism, High Smile Line  
   Orthodontist: Dorenbos  
   Surgery: LeFort I 4mm cranial with genioplasty with 4 weeks (?) IMF  
   Surgery Date: 3/25/82  
   T0: 8/25/81  
   T1: 3/29/82  
   T2: 10/7/83  
   T3: 11/17/88  

11. VITTING, A.  
   DOB: 7/6/60  
   SEX: Female  
   DX: Maxillary Prognathism  
   Orthodontist: None  
   Surgery: LeFort I with 4 weeks IMF  
   Surgery Date: 8/6/81  
   T0: 3/20/81  
   T1: 8/10/81  
   T2: 11/10/82  
   T3: 1/14/89  

12. MOOY-van WONDEREN, Margaretha  
   DOB: 6/5/60  
   SEX: Female  
   DX: Maxillary Retrognathism  
   Orthodontist: None  
   Surgery: LeFort I (5-6mm) and rhinoplasty with 6 weeks IMF  
   Surgery Date: 8/13/81  
   T0: 3/17/81  
   T1: 8/17/81  
   T2: 8/10/82  
   T3: 11/17/88  

13. HOLENAAR-SCHRADER, Alberdina C.  
   DOB: 6/1/60  
   SEX: Female  
   DX: Vertical Openbite  
   Orthodontist: None?  
   Surgery: LeFort I with 4 weeks IMF  
   Surgery Date: 10/29/81  
   T0: 10/13/81  
   T1: 11/2/81  
   T2: 11/6/82  
   T3: 1/14/89  

14. DELGADO, L.  
   DOB: 3/23/60  
   SEX: Female  
   DX: Maxillary Prognathism  
   Orthodontist: Dorenbos  
   Surgery: LeFort I and genioplasty  
   Surgery Date: 11/19/81
15. BONT-PLAT, C. C.  DOB: 5/25/60  SEX: Female
   DX: Maxillary Hyperplasia
   Orthodontist: Dorenbos
   Surgery: LeFort I (cranial)
   Surgery Date: 2/3/83

   T0: 11/16/82
   T1: 2/7/83
   T2: 1/27/84
   T3: 11/17/88

16. SMEELS, M.  DOB: 7/23/58  SEX: Female
   DX: Maxillary Hyperplasia
   Orthodontist: None
   Surgery: LeFort I with genioplasty with 4 weeks IMF
   Surgery Date: 10/15/81

   T0: 1/19/81
   T1: 10/20/81
   T2: 10/28/82
   T3: 1/14/89

17. KAMPS, P.  DOB: 8/12/64  SEX: Female
   DX: Mandibular Retrognathism and Open Bite
   Orthodontist: VU
   Surgery: LeFort I with 4 weeks IMF
   Surgery Date: 1/13/83

   T0: 1/12/83
   T1: 1/17/83
   T2: 7/13/84
   T3: 11/17/88

18. ESCH-BORST, T.  DOB: 4/5/57  SEX: Female
   DX: Class II Skeletal Malocclusion (Maxillary Hyperplasia and Mandibular Deficiency)
   Orthodontist: Dorenbos
   Surgery: LeFort I (4mm impaction) with medial splitting with 4 weeks IMF
   Surgery Date: 1/6/83

   T0: 1/5/83
   T1: 1/10/83
   T2: 1/13/84
   T3: 11/17/88
19. JONGEN, Johannes
   DOB: 8/9/55       SEX: Male
   DX: Mandibular Prognathism (Maxillary Hypoplasia)
   Orthodontist: Oubeherd??
   Surgery: LeFort I with maxillary split (7mm advancement) and genioplasty
   Surgery Date: 12/15/83

   T0: 11/24/83
   T1: 12/16/83
   T2: 12/17/84
   T3: 1/14/89

20. SIEMERINK, Wilhelmus
    DOB: 2/2/51       SEX: Male
    DX: Sagittal Overbite
    Orthodontist: Dorenbos
    Surgery: LeFort I with 4 weeks IMF (impaction)
    Surgery Date: 11/30/81

    T0: 11/4/81
    T1: 12/ /81
    T2: 1/18/83
    T3: 3/21/85

21. MIDDAG, Rudi
    DOB: 7/3/64       SEX: Male
    DX: Skeletal Open Bite (Lip)
    Orthodontist: Prahl
    Surgery: LeFort I and lower segment with 4 weeks IMF (genioplasty 9/87)
    Surgery Date: 9/6/83

    T0: 9/5/83
    T1: 9/7/83
    T2: 9/28/84
    T3: 9/8/87

22. deGRUYTER, Ricardo
    DOB: 4/29/65       SEX: Male
    DX: Mandibular Prognathism
    Orthodontist: VU
    Surgery: LeFort I and Vertical Ramus Osteotomy with 6 weeks IMF
    Surgery Date: 6/21/83

    T0: 5/17/83
    T1: 6/23/83
    T2: 7/27/84
    T3: 10/31/86

23. HAAK, Jan
    DOB: 4/2/50       SEX: Male
    DX: Mandibular Prognathism, Open Bite
    Orthodontist: Dorenbos
    Surgery: LeFort I, Vertical Ramus Osteotomy, Chin Reduction
    Surgery Date: 3/22/84
24. VASTENHOUDT, Gerard
   DOB: 4/26/63
   SEX: Male
   DX: Mandibular Deficiency
   Orthodontist: Gaalman
   Surgery: LeFort I and sagittal split and genioplasty
   Surgery Date: 10/15/84

   TO: 10/9/84
   TI: 10/19/84
   T2: 3/4/86
   T3: 4/14/87

25. DEKKER, Paulina
   DOB: 3/13/62
   SEX: Female
   DX: Mandibular Deficiency, Open Bite
   Orthodontist: Valk
   Surgery: Le Fort I (impaction and setback) with genioplasty
   Surgery date: 9/19/85

   TO: 5/2/85
   TI: 9/23/85
   T2: 11/21/86
   T3: 9/7/88

26. GEITZ-NOPPENEY, Petronella
    DOB: 8/25/53
    SEX: Female
    DX: Mandibular Deficiency, Open Bite
    Orthodontist: None
    Surgery: LeFort I and sagittal split with genioplasty
    Surgery Date: 4/26/84

    TO: 2/1/84
    TI: 5/9/84
    T2: 6/6/85
    T3: 5/8/87

27. NIPSHAGEN, Maria
    DOB: 8/6/68
    SEX: Female
    DX: Mandibular Deficiency, Open Bite
    Orthodontist: Gaalman
    Surgery: LeFort I and sagittal split of mandible
    Surgery Date: 6/13/85

    TO: 5/28/85
    TI: 6/17/85
    T2: 6/10/86
    T3: 9/26/90

28. deJONG, Nelly
    DOB: 1/5/59
    SEX: Female
DX: Mandibular Deficiency
Orthodontist: Berhout??
Surgery: LeFort I and Sagittal Split of Mandible
Surgery Date: 12/5/83

T0: 11/24/83
T1: 12/7/83
T2: 12/12/84
T3: 11/21/89

NOTE: Patients # 21, 23, and 24 were not used in this study.