THE SAGITTAL SOFT TISSUE CHANGES RELATED TO THE SURGICAL CORRECTION OF MAXILLARY DEFICIENT CLASS III MALOCCLUSIONS

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by
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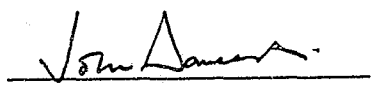
A Research Report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Dentistry in the branch of Orthodontics.

Johannesburg 1999

DECLARATION

I declare that this research report is my own work. It is being submitted for the degree of Master of Dentistry in the branch of Orthodontics in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.



J.T.Dancaster

10TH day of January, 1999

DEDICATION

This research is dedicated to my wife, Rayne, my six year old daughter Julie and my recently born son Ben, for their unselfish support, patience and love, without which none of this would have been possible.

ABSTRACT

This study assessed the sagittal soft tissue changes in relation to hard tissue changes as seen on lateral cephalometric radiographs of twenty six Class III patients who had undergone maxillary advancement surgery. Thirteen of the patients had in addition received mandibular surgery. Radiographs were available at the immediate pre-surgical and at various post-surgical stages ranging between 3 months and 16 months.

Twenty six cephalometric landmarks were identified and six linear and seven angular measurements were taken on each radiograph. X and Y axes were established and coordinates locating each landmark were recorded on a Kontron Videoplan Image Analysis System. The changes in the horizontal and vertical dimensions following surgery were then assessed. No significant differences were found in the data relating to nasal and upper lip changes between those patients who had undergone additional mandibular surgery and those who had not.

For the combined sample a significant correlation was found for the horizontal changes in the measurement between the upper lip (labrale superius) and upper incisal tip with a ratio of 0.55 : 1. The patients were then divided according to whether or not a V-Y surgical closure of the vestibular incision had been performed and into those with thick or thin lips. The V-Y technique of closure of an incision enhances tissue flexibility by an interlocking of the flaps and improves lip aesthetics by increasing the amount of vermilion exposed.

Ratios remained almost the same irrespective of the V-Y surgical procedure. Patients in the thin lip group had a mean soft tissue advancement at labrale superius of nearly three times more than those patients in the thick lip group. Incorporating a measure of lip tissue thickness into a multiple regression analysis improved the correlation in all areas studied. When a V-Y surgical closure procedure had been performed, inclusion of this variable in the regression equation marginally improved the correlation.

As a result, suggestions were made to facilitate and to possibly enhance the accuracy of preparing a visual treatment objective (VTO).

ACKNOWLEDGEMENTS

Grateful thanks are due to :

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CHAPTER 1 INTRODUCTION

The Angle classification, originally used to describe the occlusion, is commonly employed to define the antero-posterior relationship of the upper and lower jaws. The Class III relationship is synonymous with mandibular excess, maxillary hypoplasia or a combination of both discrepancies.

Before the 1970's all severe Class III jaw deformities were primarily treated by mandibular setback osteotomies. Maxillary osteotomies were considered too dangerous due to the possibility of severance of the blood supply during the operation.

The down fracturing technique of the maxillary osteotomy at the Le Fort 1 level was first described by Obwegeser (1969) and Bell (1975), although an earlier description of a similar technique was recorded in 1864 by Cheever and by Wassamund in 1927. Nowadays the maxilla is routinely advanced surgically in the correction of Class III malocclusions caused by maxillary deficiency. According to Proffit and White (1991), half of the Class III deformity cases treated at the University of North Carolina required maxillary surgery either alone or in combination with mandibular setback osteotomies.

Comprehensive multi-disciplinary treatment planning is required to treat these patients in order to satisfy the demands of excellent aesthetics, function and stability. The need for accurate predictions of the soft tissue response to orthognathic surgery is critical if treatment is to be effective in achieving optimum balance and harmony of the face.

A number of studies have examined the relationship between surgical movement of the maxilla and the soft tissue reaction. This has been expressed as a ratio and the results have been remarkably variable. For example, the ratio that the upper lip responds to maxillary advancement varies from 0.4 : 1 (Araujo, Schendel, Wolford, Epker, 1978) to 0.96 : 1 (Carlotti, Aschaffenburg, Schendel, 1986). The studies have not however always been consistent regarding research procedure. Many of them combined the vertical and antero-posterior movements, some included cleft lip and palate patients, and in many instances the sample size was small.

In some investigations variables such as soft tissue thickness, magnitude of movement, removal of the anterior nasal spine and vestibular mucosa closure techniques were incorporated but in others were excluded.

The purpose of this research was to retrospectively study soft tissue changes in the sagittal plane, primarily of the upper lip and of the nasal area as a result of maxillary advancement. It followed the theoretical ideal characteristics for research conducted in this field as defined by Betts and Fonseca (1992). (see page 13)

CHAPTER 2 LITERATURE REVIEW

The first studies on the soft tissue response to maxillary surgery were published by Bell and Dann, (1973) and Willmar (1974). Prior to these reports, horizontal soft to hard tissue response ratios had already been proposed for orthodontic incisor retraction. The ratio of horizontal movements of labrale superius to the upper incisor varied in these reports from 0.34 : 1 to 0.87 : 1 (Bloom, 1961; Rudee, 1964; Hershey, 1972). Although these studies were on orthodontic incisor retraction the range of movement was very similar to current reports on horizontal soft tissue response to maxillary advancement surgery. In 1959 Burstone and Subtelny agreed that not all parts of the soft tissue profile directly follow the underlying skeletal profile. Burstone (1959) suggested that this may be due to variation in the thickness of the soft tissues covering the face.

During the 1970's, rapid progress in maxillary surgery led to the widespread adoption of the Le Fort 1 downfracture technique, which allowed the maxilla to be repositioned in all three planes of space.

Lines and Steinhauser (1974) studied the soft tissue changes of 35 patients who had undergone various surgical procedures. Of these only three had been subjected to maxillary advancements and all had cleft lip and cleft palate deformities. Horizontal hard to soft tissue changes were considered using four hard and four soft tissue cephalometric landmarks on a pre-surgical, and on an at least a 3 month post-surgery radiograph of each patient. In these three patients the ratio of change in soft to hard tissue structures was nearly 0.67 : 1. The ratio described was a generalised conclusion and specific hard and soft tissue points were not compared. There was no indication of the amount of vertical maxillary movement involved in these advancements. Lines and Steinhauser (1974) suggested that the scar bands in the upper lip caused by the surgical lip closure probably influence the soft tissue changes to a greater extent than do retruded maxillae resulting from other etiological factors. They concluded that with such a small number of cases, this may only be a preliminary indication. A valid conclusion could only be drawn if more cases of each etiological group were measured.

Dann, Fonseca and Bell (1976) assessed eight patients (two with cleft lip and cleft palate) upon whom maxillary advancements had been performed. Pre-operative and immediate post-operative records and a minimum period of follow-up at six months post-operatively were requirements for inclusion. Horizontal and vertical positional changes of the most protruding point on the upper lip in relation to movement of the incisal edge of the maxillary incisor were measured in relation to the Frankfort horizontal. Surgically produced changes in the nasolabial angle were also recorded. They found a high positive correlation between horizontal change at the lip and at the incisal edge, the mean ratio being 0.5 : 1. In the vertical dimension they found a low correlation between the horizontal movement of the upper incisor in relation to the vertical movement of the upper lip. The mean ratio was 0.3 : 1. Decrease in the nasolabial angle correlated closely with the horizontal movement of the upper incisor edge. The mean ratio was -1.2 degrees : 1. A relatively uniform decrease in lip thickness was observed six months post-operatively with a mean reduction of -1.9 mm. Thereafter lip thickness tended to remain stable.

Freihofer (1976) studied a sample of 50 patients comprising 25 cases with unilateral cleft of the lip, alveolus and palate with retromaxillism (CLAP), and 25 cases with pure retromaxillism (RM). Seven cephalometric landmarks were plotted and digitized from each film, and the information gained from the pre-surgical and at least 6 months postsurgical radiographs were used to analyse the changes. Freihofer found that the base of the upper lip (subnasale) followed the base of the maxilla (A point) in a mean ratio of 0.57 : 1. The free end of the upper lip (labrale superius) was moved forward by the upper front teeth (upper incisal edge), in a mean ratio of 0.56 : 1. No important differences between CLAP and RM were found. In the CLAP patients, the base of the upper lip followed the base of the maxilla in a ratio of 0.67 : 1, and the free end of the upper lip followed the upper incisal edge at 0.5 : 1. In the RM patients the mean ratio of forward movement of subnasale to A point was 0.5 : 1 and labrale superius to incisal edge was 0.57 : 1. For all cases the thickness of the upper lip was reduced by approximately 3 mm. The length of the upper lip, defined as the distance between subnasale and labrale superius, increased by 2 mm in both groups. Removing the nasal spine resulted in a 0.5 : 1 ratio for horizontal movement of the landmarks studied and an intact nasal spine resulted in a movement ratio of 0.67 : 1 of subnasale to A point; and 0.57 : 1 of labrale superius to upper incisal edge.

The amount of skeletal movement had no influence on the ratio of hard to soft tissue movement. Lip thickness was of importance. Lips thicker than 19 mm produced a ratio of movement of labrale superius to upper incisal edge of 0.5 : 1 while lips thinner than 16 mm recorded a ratio of 0.78 : 1. Freihoffer (1976) believed that Lines and Steinhausers' (1974) findings of 0.67 : 1 were a little too favourable due to the fact that lip profile changes continue to occur measurably between the 4^{th} and 6^{th} postoperative months.

Freihofer (1977) extended his studies of the nasal profile to changes following maxillary advancement in 25 cases of cleft lip, alveolus, and palate and 25 cases with pure retromaxillism. He found that the anterior nasal tip followed subspinale in the ratio of 0.29 : 1. In the CLAP patients the anterior nasal tip moved forward in a mean ratio of 0.33 : 1 and in the RM patients the anterior nasal tip moved forwards in a mean ratio of 0.25 : 1. In order to evaluate whether the nasal spine was essential for support of the soft tissues, the 26 cases in which the nasal spine had not been removed were compared to the 24 cases in which the nasal spine had been removed at operation. In the cases with the nasal spine intact the soft tissues of the nose moved further forwards (0.33 : 1) than after removal of the spine (0.25 : 1).

Araujo, Schendel, Wolford and Epker (1978) studied a sample of 21 patients with a minimum follow up time of six months. Eight cleft lip and palate patients and three edentulous patients were included in the study. In the ten patients with idiopathic maxillary deficiency the average maxillary advancement was 6 mm. The vermilion border of the upper lip (labrale superius) moved forward in a 0.4 : 1 ratio with the maxillary incisor tip. The thickness of the lip changed from 16.6 mm to 14.1 mm, i.e. a decrease of 2.5 mm. For every millimetre of advancement the lip decreased in thickness by 0.6 mm. The upper lip was observed to " fill out ", becoming less concave between the vermilion border and subnasale after maxillary advancement. The nasal tip advanced in a ratio of 0.17 : 1 to the maxilla, and this was not a consistently predictable relationship. In the eight cleft lip and palate patients the average maxillary advancement was 5 mm. Patients in this study underwent anterior nasal spine removal. The ratio of movement of the vermilion border of the upper lip to maxillary incisor tip was 0.3 : 1, and that of the nasal base to A point was 0.53 : 1. The nasal tip to A point ratio measured 0.36 : 1.

Teuscher and Sailer (1982) randomly selected 16 of 65 patients who had undergone anterior repositioning of the maxilla. The patients, who were recalled after a minimum of 1 year for follow up records, had an average advancement of 7.1 mm. The ratio of upper lip (labrale superius) advancement to maxillary (A point) advancement was 0.63 : 1 and the ratio of the tip of the nose (Ant) to A point advancement was 0.22 : 1. No account was taken of the maxillary impactions that occurred simultaneously with advancements.

Mansour, Burstone and Legan (1983) studied the soft tissue to hard tissue change in a group of 21 subjects. Of these 14 had undergone maxillary impaction and seven maxillary advancement. The results demonstrated many statistically significant correlations. The soft-tissue response to maxillary surgery appeared to be predictable, and the changes to be expected following advancement surgical procedures were summarized. Prediction schemes for soft-tissue change evaluation were presented and tested, with a mean error value of approximately 22 percent. The postoperative radiograph was taken not less than 6 months after surgery. This appears to be the first study in which mention is made of taking the cephalograms with the patient's lips in repose. This eliminates potential sources of lip strain which could have an artificial influence on the soft-tissue profile. In addition, the authors claimed that a greater degree of uniformity is achieved by having patients adopt a relaxed lip position. They classified the Le Fort 1 procedures as primarily impaction (greater that 2 mm posterior impaction, resulting in significant mandibular autorotation) or, primarily advancement (less than 2 mm posterior impaction, resulting in minimal mandibular autorotation). Mansour, Burstone and Legan (1983) found a progressive increase in the soft tissue movement from the base of the upper lip (Sn) to the free end of the upper lip (Ls). They suggested that this finding was logical due to the greater extent of soft tissue attachment to the underlying skeletal structures at the nasal tip (ANt) and at the base of the upper lip (Sn), compared with the free end of the upper lip (Ls). All the horizontal alterations in the soft tissue were strongly related to the movement of the underlying skeletal structures. The 0.62 : 1 ratio of horizontal upper lip (Ls) movement to the horizontal change in the maxillary incisor essentially agrees with the findings of Lines and Steinhauser (1974), Dann, Fonseca and Bell (1976) and Freihoffer (1976). In the advancement group a shortening of the upper lip was observed with a mean vertical change of 2 mm. The nasal tip moved in a superior direction in six of the seven patients.

The nasolabial angle decreased in five of the seven subjects following maxillary advancement. The greater the area of the upper lip, the less was the horizontal change in Ls. The authors mention the high standard error values for many of the ratios even when statistically significant differences were reached. This did not imply that the results were not clinically applicable, but merely indicated that the clinician should be aware of individual variation. The use of a stepwise regression equation offered the greatest accuracy in predicting change. However most of the soft tissue alterations in the facial profile could be estimated with closely equal reliability using the simple ratio equations only. A comparison of the stepwise regression with the mean ratio prediction schemes demonstrated almost identical error values.

Carlotti, Aschaffenburg and Schendel (1986) assessed a sample of 25 cases of Le Fort 1 maxillary advancement with nasolabial reconstruction (alar cinch and V-Y closure: Wolford, 1988). They demonstrated a predictable soft tissue-osseous ratio of 0.9 : 1 with the lip moving forward an average of 90% of the movement of the dentition. Lip shortening was not found in this group of patients. All cases were originally diagnosed as having maxillary retrusion without clefting or other head and neck syndromes. The minimum follow up period was four months. The average incisor advancement was 5.5 mm and the lip vermilion advancement was 5.3 mm. Vermilion horizontal change to incisor horizontal change was in the ratio of 0.9 : 1. Mean lip length was 21.9 mm before surgery and 23.7 mm after surgery. In the analysis of soft tissue A point, the horizontal movement of the incisor was determined to be the most significant predictor. The ratio soft tissue A pt : incisor horizontal was 0.78 : 1. The subnasale to incisor horizontal ratio was 0.67 : 1. No mention was made of lip thickness.

Rosen (1988) studied the dimensional changes of the upper lip and nasal lobule occurring in 41 consecutive Le Fort 1 osteotomies for anterior and superior repositioning of the maxilla. The minimum follow up period was 6 months. All patients were non-cleft patients. Thirty patients underwent Le Fort 1 osteotomy which involved an anterior vector of movement. There were thirteen patients in whose operations the sole direction of movement was anterior but these were not observed as an entity. The nasal spine was preserved in all patients. No attempt was made to alter soft tissue morphology by V-Y closure of the incision or attempted cinching of the subcutaneous tissue of the alar bases. Lip changes studied were the horizontal displacements at the vermilion border and subnasale compared

with those at the incisal edge and point A (The mean anterior displacement at the incisor edge was 5.9 mm and the mean anterior displacement of the lip at the vermilion border was 4.6 mm). For every 1 mm of maxillary advancement at the incisal edge the upper lip advanced 0.82 mm, and 0.51 mm of advancement occurred at subnasale for every 1 mm of advancement at pt A. Upper lip thickness ranged from 7 mm to 18 mm with a mean of 13.8 mm. Although it seemed that thinner lips had larger ratios of soft to osseous tissue movement, Rosen stated that no statistically significant correlation could be demonstrated when using this as a variable. The mean increase in inter-alar rim width was 3.4 mm. The mean increase in nasal tip projection was 1.8 mm. According to Rosen (1988), for nasal tip projection to occur there has to be an anterior vector of movement, ie isolated superior movement did not cause elevation of the nasal tip. There was no statistically significant quantitative correlation between increase in tip projection or inter-alar rim width and maxillary advancement. Rosen (1988) suggested that all patients should be clearly informed about the variable increases in alar rim width which accompany maxillary advancement. He stated that the alar cinch technique advocated by Schendel and Williamson (1983) is inaccurate, unpredictable and that it is associated with other soft tissue changes such as lip lengthening which may be undesirable. He believed that this may be a useful procedure to perform secondarily once the final soft-tissue drape has been attained.

Wolford (1988) discussed this opinion and commented on certain problems in the methodology of the project. He stated that it frequently takes at least 12 months before all residual oedema has dissipated and complete animation of the upper lip has returned. Rosen had followed the cases for an average of 9.8 months with a minimum of 6 months. Wolford (1988) commented that in the group of 30 patients evaluated following maxillary advancement surgery, only 13 had maxillary advancement without impaction. 12 patients had superior repositioning as well as advancement and five had inferior repositioning as well as advancement. These three different surgical procedures have different effects on soft tissue changes of the lip in the anteroposterior and vertical dimensions. As far as alar rim width increase is concerned, Wolford was of the opinion that better results could be achieved with the alar cinch procedure. He agreed that with some techniques control is difficult to achieve. However, if the suture is correctly placed through the muscles directly beneath the alar base area and through the fibro-adipose tissue of the alar bases in

a figure of 8 fashion; the alar base width can be controlled and is relatively predictable. Guyman, Crosby and Wolford (1988) have shown that the alar base suture in combination with the V-Y closure procedures to have an average widening of 3.5 % of the inter-alar base width with the suture, as compared with 10.7 % widening without the suture. It also minimises lip shortening, anteroposterior thinning of the lip and loss of visible vermilion.

Stella, Streater, Epker, and Sinn (1989) assessed 21 patients who underwent isolated maxillary advancements without adjunctive nasal soft tissue procedures or V-Y closure of the vestibular incision. Homogeneity of the patient population was ensured by selecting cases with less than 2 mm of vertical change. There were no cleft palate patients in the group studied. The only soft tissue point evaluated was subnasale and changes were related to the hard tissue point directly posterior to it (A point). The patients were then divided into 2 groups based on lip thickness, group 1 having lips between 10 and 17 mm thick and group 2 with lips greater than 17 mm thick The authors divided the groups into those that had less than 5 mm of maxillary advancement and those with more than 5 mm of advancement. The correlation coefficients of the ratios of changes in Sn and in other bony references were calculated. In the group with less than 5 mm of maxillary advancement the correlation coefficient was 0.54 indicating a mediocre relationship between magnitude of advancement and change in Sn. In the group with maxillary advancement exceeding 5 mm the correlation coefficient was 0.22 demonstrating an extremely poor relationship between the magnitude of maxillary advancement and changes in Sn. Soft tissue change for a given amount of maxillary advancement appeared to be unpredictable. Postoperative lip thickness stabilised at approximately 6 months. In the thin lip group the ratio of soft tissue change to hard tissue change at Sn was 0.5 : 1 and there was an excellent correlation of 0.72. In the thick lip group the ratio of soft to hard tissue change at Sn was 0.3 : 1 and there was virtually no relationship (correlation coefficient 0.26) between magnitude of maxillary advancement and change at Sn. Fourteen of the 21 patients showed at least a 2 mm reduction of lip thickness postoperatively. The seven remaining patients showed less than 1 mm of lip thinning. No lips thickened. Stella et al (1989) stated that the very bulk of a thick lip may have a tendency to absorb a large amount of maxillary advancement without a perceptible change in soft tissue contour. Dead space was evident in many of these cases and the investigators noted this phenomenon to be most noticeable in the most severely retrognathic cases in whom an actual air pocket

often existed between the maxillary dentoalveolar structures and the upper lip labial mucosa. Patients with this phenomenon were more likely to show soft-to-bony ratios at the lower end of the distribution curve, ie 0.3 : 1.

Proffit and White (1991), discussed the changes that occur following maxillary advancement. They pointed out that the changes in lip position given in their data are at best rough guidelines and stated that slight elevation of the nose tip is usually temporary. The ratio of the base of the upper lip to subspinale movement was 0.2 : 1. Upper lip to upper incisor protraction was 0.6 : 1, with the upper lip shortening 1 to 2 mm. They concluded that producing the predicted soft-tissue outline is more of an art form than a scientific exercise.

McCance, Moss, Fright, James and Linney (1992) studied the ratio of soft tissue to bone movements in 16 Class III patients following orthognathic surgery. Computerised tomogram scans were taken for each patient pre-operatively and one year postoperatively. The scans were superimposed, radial measurements calculated, and the changes illustrated by two separate colour scales. There was commonly a 1 : 1 ratio in the midline which increased to 1.25 : 1 at the alar bases and over the canine regions bilaterally. This increased ratio did not continue into the paranasal areas, where a 1 : 1 ratio was commonly found. There was no attempt to seperate maxillary impactions from maxillary advancements in their study. Problems were encountered in the interpretation of the changes in the bone when a vertical displacement of the jaws was undertaken. In the case of maxillary impaction the bone changes recorded on the colour scale suggested marked anterior displacements of the jaws when little or no advancement actually occurred.

Hack, de Mol van Otterloo and Nanda (1993) assessed 25 patients studied at four time points, the first radiograph being taken 1 month before surgery. The immediate postoperative radiograph was taken within 1 month following surgery. The third radiograph was taken 1 year after surgery and the final radiograph was taken at least 5 years after surgery. Patients were not specifically divided into predominantly horizontal or vertical maxillary movements. The only criterion for inclusion was that at least 2 mm of bony movement occurred at surgery in either a horizontal or a vertical direction. The mean horizontal advancement was 3.05 mm at

the upper incisor tip, and the mean vertical impaction was 2.27 mm at the upper incisor tip. There was no indication of the soft tissue surgical procedure used. After one year the ratio of horizontal change at subnasale to A point was 0.25 : 1 and after 5 years, 0.30 : 1. Horizontally, labrale superius to upper incisor movement was in the ratio of 0.82 : 1 after one year, and 0.91 : 1 after five years. The one year follow up of vertical movement of labrale superius compared with incisor superius was 0.23 : 1. Most horizontal and vertical soft tissue change occurred in the first year after surgery. Significant (>10%) change continued to occur for subnasale and upper lip protrusion during the subsequent 5 years. This suggested that the soft tissues overlying maxillary structures may take several years to reach their final equilibrium.

Hui, Hagg and Tideman (1994) compared the soft tissue changes in 25 cleft lip and palate patients and 25 patients with maxillary hypoplasia who had undergone maxillary osteotomy. The post-surgical cephalograms were taken 6 weeks after surgery and before the commencement of postoperative orthodontic treatment. The reason for this was that the aim of their study was to measure the soft tissue changes due to surgery only and without the influence of orthodontics (furthermore, the authors believed that oedema would usually have subsided clinically 6 weeks after the operation). Another reason was that the upper incisor was considered to be the most reliable structure on the anterior maxilla for image superimposition. Incisor movement was also used to represent the movement of the anterior maxilla because the underlying skeletal structure could not be traced accurately. The findings of the study were that in the cleft group the ratio of movement of pronasale to A point was 0.26 : 1. Subnasale followed A point in the ratio of 0.55 : 1 and labrale superius followed the upper incisor at 0.66 : 1. In the vertical plane the lip followed the upper incisor at 0.43 : 1.

In the non cleft group the ratio of movement of pronasale and subnasale to A point showed no quantitative correlation. Labrale superius followed the upper incisor in the ratio of 0.54 : 1. In the vertical plane the lip followed the upper incisor at 0.29 : 1. In maxillary osteotomy of unilateral cleft lip and palate patients both lip and nose profile changes showed statistically significant correlation with hard tissue movement in the horizontal plane. Only lip changes showed statistically significant correlation with hard tissue movement in the vertical plane. In maxillary osteotomy of non cleft patients only lip changes showed statistically significant correlation with hard tissue movement in both horizontal and vertical planes. For nasal movement in the

non-cleft patients there was no significant correlation between Sn and Pn movement and the underlying structures. This finding was in agreement with Radney and Jacobs, (1981); Mansour, Burstone Legan, (1983); Bundgaard, Melsen and Twerp (1986); and Rosen, (1988). The most interesting observation arising from this work was that in cleft cases the soft tissue and hard tissue movements showed more reliable correlations than in non-cleft cases. This may be due to the firmer scar tissue which therefore responds more directly to the movement of the underlying maxilla. This could result in a more consistent and greater magnitude of movement of the soft tissue.

In summary, the findings of the report studied indicate a wide range of ratios for soft tissue to hard tissue response following maxillary advancement surgery.
A) The horizontal changes occurring at the soft tissue anterior nasal tip was compared with subspinale advancement. The reported ratios varied from 0.17 : 1 to 0.36 : 1 with an average of 0.29 : 1.
B) The horizontal change occurring at the nasal base was evaluated with the movement of soft tissue subnasale being compared with subspinale advancement. The reported ratios varied from 0.2 : 1 to 0.95 : 1 with an average ratio of 0.45 : 1.
C) The horizontal changes occurring at the most anterior point of the upper lip with movement of soft tissue labrale superius being compared with upper incisor advancement. The ratio varied from 0.4 : 1 to 0.96 : 1 with an average of 0.65 : 1.
D) The vertical changes occurring at the lower-most aspect of the upper lip were assessed with movement of stomion superius being compared with changes in position of the upper incisor tip. The reported ratios varied from 0.23 : 1 to 0.30 : 1, with an average of 0.29 : 1.

It is evident that the wide disparity in the findings of the studies reviewed result in diminished accuracy of clinical predictions. Betts and Fonseca (1992), enumerated twenty three criteria that they claim contribute towards the theoretical ideal characteristics of a study investigating the soft tissue changes associated with orthognathic surgery.

These are listed here :

1 The study should be prospective.
2 Adequate sample size.
3 Randomized treatments (if treatments differ within the sample).
4 The subjects should all be non-growing patients.
5 No history of previous trauma to the osseous structures of the face.
6 Exclusion of patients with congenital defects or syndromes (e.g. cleft patients).
7 Elimination of the confounding effects of pre- and post-operative orthodontic tooth movements).
8 Constant presence or absence of orthodontic appliances.
9 The same cephalostat to be used for all cephalograms with identical source-subject and subject-film distances.
10 Soft tissues in repose for all cephalograms.
11 Superimpositions of cephalograms on the nearest osseous structure not affected by surgery or on a stable reference line.
12 The use of a tracing template to assist in landmark identification.
13 Evaluation of both profile and full facial soft tissue change, or 3D analysis.
14 No concomitant or prior soft tissue surgery.
15 Exclusion of segmental surgical procedures.
16 One vector of movement (or grouped in study).
17 No concomitant osseous surgery on another portion of the facial skeleton.
18 Homogeneity of the soft tissue incisions and closure techniques.
19 No hard tissue contouring (e.g. recontouring of the anterior nasal spine).
20 Use of rigid osseous fixation.
21 Uniform follow up intervals.
22 Follow-up time of at least 6 months (one year is preferable).
23 Error analysis of measurement and landmark identification.

The methodology of the current study was aimed at satisfying as many of these criteria as possible.

TABLE 1

Summary of the literature reviewed

Area of measurement H = horizontal V = vertical	Ratio of soft : hard change	Ratio of soft : hard tissue points	Source and summary of findings
Upper lip (H) CLP	0.67 : 1	Ls : Is removed ANS	Lines and Steinhauser (1974) 3 patients - all CLP Amount of horizontal advancement not quantified Amount of vertical impaction not quantified
Upper lip (H) Upper lip (V) Nasolabial angle	0.50 : 1 0.30 : 1 -1.2 deg : 1	Ls : Is Ls : Is NLA : Is	Dann, Fonseca, Bell (1976) 8 patients - 2 CLP Amount of vertical impaction not quantified Mean horizontal advancement at Is = 6.6 mm Upper lip thickness decreased by 1.9 mm
Nasal base (H) CLP Upper lip (H) CLP Nasal base (H) Upper lip (H) Thic . lips >19 mm (H) Thin lips < 16 mm (H)	0.67 : 1 0.50 : 1 0.50 : 1 0.57 : 1 0.50 : 1 0.78 : 1	Sn : A Ls : Ia Sn : A Ls : A Ls : Is Ls : Is	Freihofer (1976) 25 patients without CLP 25 patients with CLP Mean horizontal advancement at Is = 6.3 mm Mean vertical downgraft at pt A of 1 mm Upper lip length increases 2 mm Upper lip thickness decreased 3 mm
Nasal tip (H) CLP Nasal tip (H) Intact nasal spine (H) Removal of nasal spine (H) Intact nasal spine (H) Removal of nasal spine (H) Intact nasal spine (H) Removal of nasal spine (H)	0.33 : 1 0.25 : 1 0.33 : 1 0.25 : 1 0.67 : 1 0.50 : 1 0.57 : 1 0.50 : 1	Pn : A Pn : A Pn : A Pn : A Sn : A Sn : A Ls : Is Ls : Is	Freihofer (1977) 25 patients with CLP 25 patients without CLP Mean horizontal advancement at Is = 6.3 mm Mean vertical downgraft at pt A of 1 mm

Nasal tip (H) CLP Nasal base (H) CLP Upper lip (H) CLP Nasal tip (H) Nasal base (H) Upper lip (H)	0.36 : 1 0.53 : 1 0.30 : 1 - - 0.40 : 1	Pn : A Sn : A Ls : Is Pn : A Sn : A Ls : Is	Araujo et al (1978) 21 patients - 8 CLP, 3 edentulous Removal of nasal spine in all patients Mean vertical (UFH) downgraft < 1.2 mm Mean horizontal advancement at Is = 5.5 mm U lip thickness decreased 0.6 mm for 1 mm of advancement
Nasal tip (H) Nasal base (H) Upper lip (H) Upper lip (V)	0.22 : 1 - 0.63 : 1 -	Pn : A - Ls : Ia Stm-s : Ia	Teuscher and Sailer (1982) 16 patients Horizontal movement of 6.7 mm Vertical movement at ANS 0.2 mm and at PNS 0.3 mm
Nasal tip (H) Nasal base (H) Upper lip (H) Upper lip (V)	0.17 : 1 0.24 : 1 0.62 : 1 2 mm shortening	Pn : Ia Sn : Ia Ls : Ia Stm-s : Ia	Mansour, Burstone, Legan (1983) 7 patients Amount of horizontal or vertical movement not stated. These were primarily advancement with less than 2 mm of posterior impaction and excluded posterior impactions which were considered greater than 2 mm.
Nasal tip (H) Nasal base (H) Upper lip (H)	0.34 : 1 0.95 : 1 0.96 : 1	Pn : A Sn : A Ls : Is	Carlotti, Aschaffenburg, Schendel (1986) 25 patients Mean horizontal advancement at Is = 5.5 mm Mean vertical impaction at Is = 0.1 mm V-Y closure and alar base cinch Lip length increased 1.8 mm
Nasal tip (H) Nasal base (H) Upper lip (H) Upper lip (V)	0.35 : 1 0.51 : 1 0.82 : 1 0.32 : 1	Pn : A Sn : A Ls : Is Stm-s : Is	Rosen (1988) 30 patients with a mean anterior vector of movement at Is of 5.9 mm. This included a group of 12 patients with vertical intrusion averaging 6 mm and advancement averaging 4 mm. Circumvestibular incision from 16 to 26 Nasal spine preserved - no V-Y or alar cinch Mean increase in interalar rim width = 3.4 mm Thin lips displaced greater distances than thick

Nasal tip (H) Nasal base (H : lips 10-17 mm) Nasal base (H : lips > 17 mm) Upper lip (H) Upper lip (V)	- 0.50 : 1 0.30 : 1 - -	- Sn : A Sn : A - -	Stella et al (1989) 21 patients : no alar cinch or V-Y closure Vertical change < 2 mm. ANS intact Lip thickness between 12 - 17 mm cc 0.72 Lip thickness greater that 17 mm cc 0.26 Dead space and bulk absorbs maxillary advancement All lips thinned about 2 mm max adv < 5 mm correlation coefficient 0.54 Max adv > 5 mm correlation coefficient 0.22
Nose (H) Nasal base (H) Upper lip (H) Upper lip (V)	slight elevation of tip 0.2 : 1 0.6 : 1 shortens 1-2 mm	 Sn : A pt. Ls : Is	Proffit and White (1991) Whether these are personal findings or not was not mentioned. No indication of amount of vertical or horizontal mvt was mentioned. Soft tissue surgical procedures were not discussed
midline Canine areas Paranasal areas		1.0 : 1.0 1.25 : 1.0 1.0 : 1.0	McCance et al (1992) CT scans 16 patients : 13 advancements and 3 reductions No average vertical or horizontal movements presented Lateral cephs : landmarks provide no information of shape or change in shape - only profile analysis 30 to 60 1.5 mm thick slices separated by a gap of 3 mm throughout the area of surgical interest Problems in interpretation include radial measurement changes ie impactions could be incorrectly recognised as advancements

Nasal tip (H 1 yr) Nasal base (H 1yr) Upper lip (H 1yr) Upper lip (V 1yr) Nasal tip (H 5yrs) Nasal base (H 5yrs) Upper lip (H 5yrs) Upper lip (V 5yrs)	- 0.25 : 1 0.82 : 1 0.23 : 1 - 0.30 : 1 0.91 : 1 -	Pn : A Sn : A Ls : Is Ls : Is Pn : A Sn : A Ls : Is Ls : Is	Hack, de Molo van Otterloo, Nanda (1993) 25 patients - long term stability of soft tissue changes. Multidirectional movement - no attempt to separate the advancements and impactions. Mean horizontal advancement 3.05 mm at Is. Mean vertical impaction of 2.27 mm at Is Sn followed ANS more closely than A pt and showed significant changes well beyond the 1 yr follow up period. No mention of soft tissue surgical procedure used
Nasal tip (H CLP) Nasal base (H CLP) Upper lip (H CLP) Upper lip (VCLP) Nasal tip (H) Nasal base (H) Upper lip (H) Upper lip (V)	0.26 : 1 0.55 : 1 0.66 : 1 0.43 : 1 - - 0.54 : 1 0.29 : 1	Pn : A Sn : A Ls : Is Ls : Is Pn : A Sn : A Ls : Is Ls : Is	Hui, Hagg and Tideman (1994) 50 patients : 2 groups 25 with CLP and 25 without CLP No reference made to soft tissue procedures nor whether ANS was intact nor not. Mean vertical movement not mentioned Mean horizontal movement not mentioned Cephs taken 6-9 weeks after surgery. For nasal movement in non cleft patients there was no significant correlation of Sn and Pn movement and this is consistent with Radney and Jacobs 81, Mansour, Burstone and Legan 83, Bundgaard, Melsen and Twerp 86, Rosen 88. Clefts more predictable - scarred lip firmer with less lateral displacement.

The key to abbreviations is included in the appendix pages 1 and 2.

CHAPTER 3 METHODS AND MATERIALS

3.1 SAMPLE

The cephalometric records of twenty six Caucasian patients in whom growth had been completed were sequentially selected from amongst the files of a private orthodontic practice. The criterion for subject selection was maxillary advancement involving minimal maxillary impaction. All patients had undergone surgery in an orthognathic treatment programme for the correction of Class III malocclusion. All were medically fit and had not presented with any congenital defects or developmental syndromes. They had each received full fixed appliance orthodontic therapy in which tooth positions had been stabilized for at least six weeks prior to surgery. The incisor teeth had been orthodontically decompensated so that minimal incisor movement was required in the post-operative period. Non-segmental maxillary advancement had been performed using a Le Fort 1 surgical osteotomy by a number of different maxillo-facial and oral surgeons. The sample comprised 16 females with an average age at surgery of 25.0 years, with ages ranging from 16 to 38 years, and 10 males with an average age at surgery of 22.1 years with ages ranging from 18 years to 29 years (TABLE 2). Six of the patients had received in addition, mandibular reduction, four, additional reduction genioplasty, and three, a combination of additional mandibular reduction and reduction genioplasty. All lateral cephalometric radiographs had been taken on the same machine by the same operator; using identical source-subject and subject-film distances. Soft tissues were in repose for all cephalograms and the teeth were in occlusion at the time of exposure. Each radiograph was of a quality sufficient to enable accurate recording of the soft tissue profile and identification of pertinent hard tissue landmarks. For inclusion in the study the records of each case had to include lateral radiographs which had been taken :

i. within a period of four weeks preceding surgery, after which time no further orthodontic tooth movement had been indicated prior to surgery (referred to hereafter as T1 radiographs).
ii. a minimum of three months post-surgically at the time of completion of

active post-surgical orthodontic treatment (referred to hereafter as T2 radiographs). The greatest post-surgical time period to have elapsed was 16 months.

T2 - T1 demarcated the time interval from the date of surgery to the completion of orthodontic treatment. This was an important period to analyse because it represented the changes that had taken place as a result of the orthognathic surgical treatment.

The data was divided into two groups.

i. Patients who had maxillary advancements (figure 3.1).

ii. Patients who had maxillary advancements and mandibular surgery (figure 3.2).

TABLE 2

Details of the sample used in this study

PAT No.	SEX	AGE yrs	MX ADV ONLY	MX ADV/ MD RED	MX ADV/ GENIO	MX ADV/ MD RED/ GENIO	X-RAYS T1	X-RAYS T2-T1
D1	F	38	*				x	4m
D2	F	19			#		x	6m
D3	M	18				+	x	5m
D4	M	19				+	x	6m
D5	M	21	*				x	5m
D6	F	17				+	x	6m
D7	F	21		~			x	6m
D8	M	25	*				x	5m
D9	F	17	*				x	16m
D10	F	35			#		x	6m
D11	F	29	*				x	3m
D12	F	20		~			x	4m
D13	M	24	*				x	6m
D14	F	31			#		x	4m
D15	M	23			#		x	5m
D16	M	25	*				x	6m
D17	F	31	*				x	5m
D18	F	33	*				x	7m
D19	F	17		~			x	8m
D20	M	20		~			x	10m
D21	M	20	*				x	4m
D22	F	26	*				x	6m
D23	F	21		~			x	3m
D24	F	27	*				x	5m
D25	F	18		~			x	4m
D26	M	26	*				x	4m
Total	M 10	22.1	13	6	4	3	26	
	F 16	25.0						

* maxillary advancement only; ~ maxillary advancement with mandibular reduction; # maxillary advancement with genioplasty; + maxillary advancement with both a mandibular reduction and a genioplasty.

Further abbreviations in index.

a)

b)

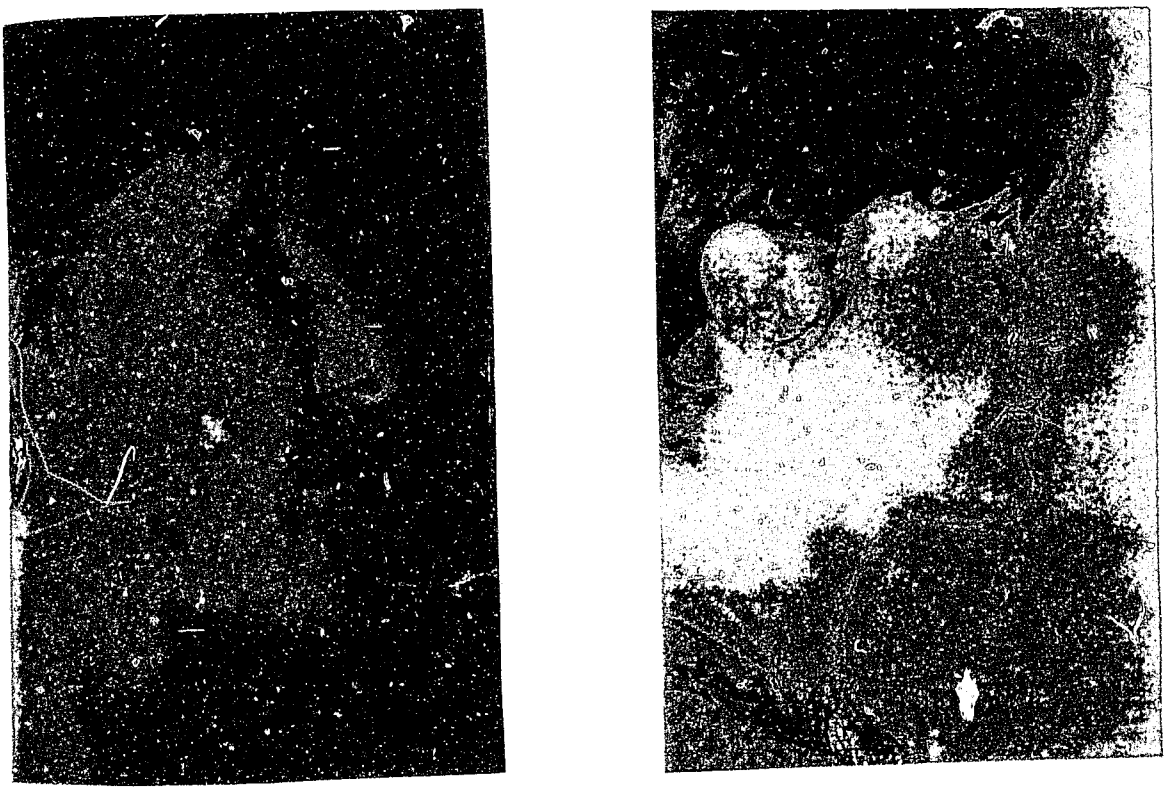


figure 3.1

Patient D18 : Maxillary advancement only a) two weeks prior to surgery and b) five months following surgery.

a)

b)

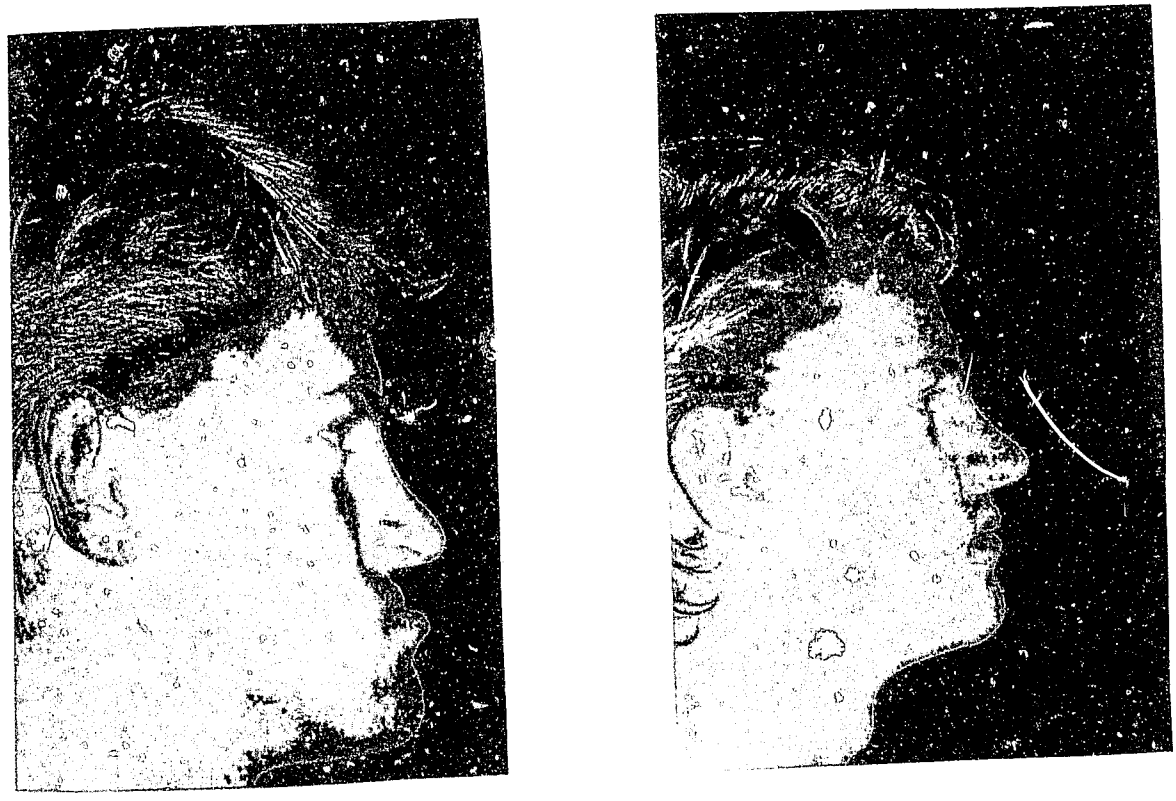


Figure 3.2

Patient D 22 : Maxillary advancement and mandibular reduction a) day before surgery and b) six months following surgery.

TABLE 3

Basic cephalometric analysis of patients prior to surgery (T1)
Descriptive summary of data

	MEAN	RANGE	
		Minimum	Maximum
SNA	79.5	72	84.5
SNB	83	74	94.5
ANB	-3.5	1	-11.5
Md. Plane	26	13.5	39
Overjet	-3 mm	2 mm	-15 mm

The average ANB measurement for the sample was -3.5 degrees, the values ranging from 1 degree to -11.5 degrees and with a mean overjet of -3 mm ranging from 2 mm to -15 mm (measured from the labial of the crown of the upper central incisor to the labial of the crown of the lower incisor as seen in the lateral cephalogram). The mean mandibular plane angle was 26 degrees ranging from 13.5 degrees to 39 degrees. This was measured from constructed Frankfort horizontal to the lower border of the mandible (TABLE 3).

Ten Maxillofacial surgeons performed various operations. In eleven patients the surgical wound was closed using the V-Y technique. Of the twenty six patients only one did not receive contouring of the anterior nasal spine. The sample was subdivided according to lip thickness. Lips greater than fifteen mm were considered to be thick and those less than fifteen mm were classified as thin. Ten patients had thick lips and sixteen patients had thin lips (TABLE 4).

The patients selected for the study had undergone a maxillary advancement with minimal vertical movement. Nineteen patients recorded a superior movement at PNS(mean : 1.76 mm) and sixteen at UIT (mean : 1.7 mm). At UIT, fifteen patients recorded a superior movement (mean : 1.7 mm) and nine, inferior (mean : 1.9 mm). In two patients no vertical change occurred (TABLE 5).

The study was limited to patients on the basis that when the maxilla was superiorly or inferiorly impacted one or both of the measurements taken at the posterior nasal spine or upper incisor tip did not exceed 2 mm (TABLE 5). Mean horizontal advancement at the upper incisor tip was approximately 4.95 mm.

TABLE 4

Descriptive summary of hard and soft tissues

PATIENT REF. No.	SURGEON	ALAR CINCH	V-Y CLOSURE	ANS CONTOUR	THICK LIPS >15 mm	THIN LIPS <15 mm
D1	F	-	-	-		12.5 mm
D2	B	NO	NO	YES		12.9 mm
D3	D	-	-	-		14.8 mm
D4	B	NO	NO	YES	15.7 mm	
D5	A	-	-	-		14.9 mm
D6	B	NO	NO	YES		11.4 mm
D7	A	YES	YES	YES		13.2 mm
D8	A	YES	YES	YES		14.6 mm
D9	A	YES	NO	YES	17.8 mm	
D10	A	YES	YES	YES		10.4 mm
D11	E	NO	YES	YES		12.9 mm
D12	J	NO	YES	YES		11.3 mm
D13	G	-	-	-	17.4 mm	
D14	A	YES	YES	YES	16.4 mm	
D15	B	NO	NO	YES		14.4 mm
D16	I	YES	YES	NO		13.8 mm
D17	C	YES	NO	YES		12.3 mm
D18	C	YES	NO	YES		11.3 mm
D19	A	YES	YES	YES	17.9 mm	
D20	A	YES	YES	YES	24.6 mm	
D21	B	NO	NO	YES	20.0 mm	
D22	A	NO	NO	YES	15.6 mm	
D23	A	YES	YES	YES	19.8 mm	
D24	A	-	-	-		12.9 mm
D25	A	YES	YES	YES		12.9 mm
D26	H	-	-	-	21.1 mm	
A 12	F 1	12 YES	11 YES	19YES	10 thick	16 thin
B 5	G 1	8 NO	9 NO	1 NO		
C 2	H 1					
D 1	I 1					
E 1	J 1					

TABLE 5

The vertical changes at the posterior nasal spine and upper incisal tip

PATIENT REF. No.	ΔPNS	ΔUIT
D1	↑0.9	↓1.1
D2	↓1.6	↑0.8
D3	↑1.4	↑4.6
D4	↑3.9	↑1.6
D5	↑0.6	↑1.4
D6	↑3.3	↑0.7
D7	↑0.6	↓0.8
D8	↑1.8	↓0.3
D9	↓1.9	↑0.1
D10	↑1.4	0.00
D11	↓0.1	0.00
D12	↑1.2	↑4.1
D13	↑2.0	↑1.9
D14	↑2.3	↑0.6
D15	↓0.8	↑3.0
D16	↓0.1	↓5.6
D17	↓0.9	↓1.0
D18	↓0.2	↓3.8
D19	↑2.5	↓2.0
D20	↑0.3	↑0.4
D21	↓0.8	↓1.5
D22	↑0.5	↓0.8
D23	↑0.9	↑3.6
D24	↑1.0	↑1.1
D25	↑2.3	↑1.4
D26	↑2.8	↑0.8
MEANS	↑1.8	↑1.7
	↓0.9	↓1.9

↑ superior movement

↓ inferior movement

3.2 METHOD

The cephalometric radiographs were traced on Ozatex* 0.05 mm D/Matt drafting film paper using a 6 H pencil. Three locating crosses scribed directly onto the radiographic film, were copied onto each tracing paper after these had been secured to the radiographs. The following anatomic structures were traced. Sella turcica, the floor of the anterior cranial fossa, superior orbital roof, the nasal bone, the mandible, the maxilla (including prosthion, anterior nasal spine and the posterior nasal spine), the soft tissue outline from glabella to the junction of the chin and the throat. (Worms, Isaacson and Speidel, 1976). The upper and lower most anteriorly placed incisors were traced using a standard Unitek** tracing template located accurately over the incisal tip and aligned along the long axis of the tooth. The following cephalometric landmarks were identified and traced :

1	Sella	(S)
2	Nasion	(N)
3	Anterior Nasal Spine	(ANS)
4	Subspinale	(A)
5	Prosthion	(Pr)
6	Upper Incisor Anterius	(UIa)
7	Upper Incisor Tip	(UIT)
8	Posterior Nasal Spine	(PNS)
9	Lower Incisor Tip	(LIT)
10	Lower Incisor Anterius	(LIa)
11	Infradentale	(In)
12	Supramentale	(B)
13	Pogonion	(Pog)
14	Anterior Nasal Tip	(ANt)
15	Columellar Point	(Cm)

* Ozalid SA (Pty) Ltd, Drawing Office Material, Spartan, Kempton Park, South Africa

** 3M - Unitek Corporation, Monrovia, California, U.S.A.

16	Subnasale	(Sn)
17	Sulcus Superius	(Ss)
18	Labrale Superius	(Ls)
19	Stomion Superius	(Stm-s)
20	Stomion Inferius	(Stm-i)
21	Labrale Inferius	(Li)
22	Sulcus Inferius	(Si)
23	Soft Tissue Pogonion	(Pog')

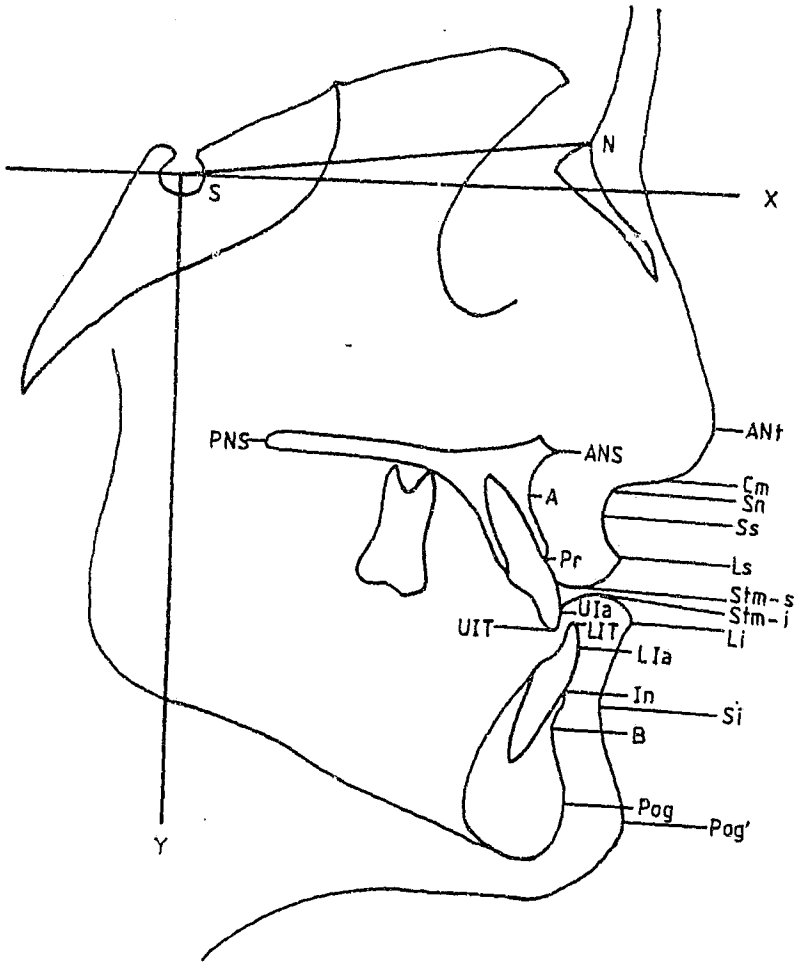


figure 3.3

Cephalometric landmarks and reference planes used in this study.

The landmarks and reference planes were defined as follows :

1) Sella (S) : "The point representing the midpoint of the pituitary fossa (sella turcica) which is a constructed point in the median plane" (Bjork, 1947).
2) Nasion (N) : "The most anterior point of the fronto-nasal suture in the median plane" (Bjork, 1947).

The S-N plane was drawn, connecting these two landmarks. For convenience, an X-axis was constructed through S at 6 degrees below the S-N plane. The "Y" reference axis was drawn at 90 degrees to the X axis through S (Phillips, Turvey and McMillan, 1989). (See figure 3.4).

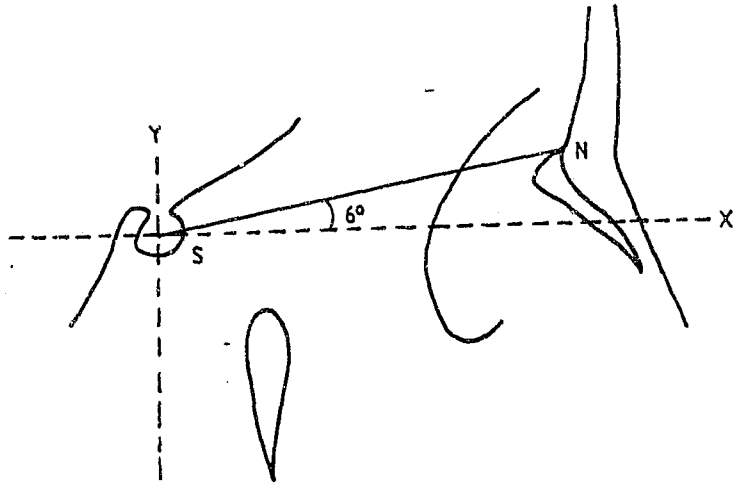


Figure 3.4

The X axis was constructed at 6 degrees below the S-N plane through S. The Y axis was then constructed at 90 degrees to the X-axis through S.

Thus a coordinate reference system with the origin at point S was established. In order to locate those landmarks defined as "most anterior" or most "posterior" on curved segments of the tracing, a perpendicular from the X-axis was dropped to the most anterior or most posterior part of the curvature in question. In some cases this perpendicular would effect a one point contact with the tracing, automatically identifying that particular landmark. In other instances, the perpendicular met the curved tracing outline as an area contact rather than at a single point. In these cases, the midpoint of this linear contact area was established by measuring the distance of this linear contact and bisecting it, thereby identifying the particular landmark (Figure 3.5)

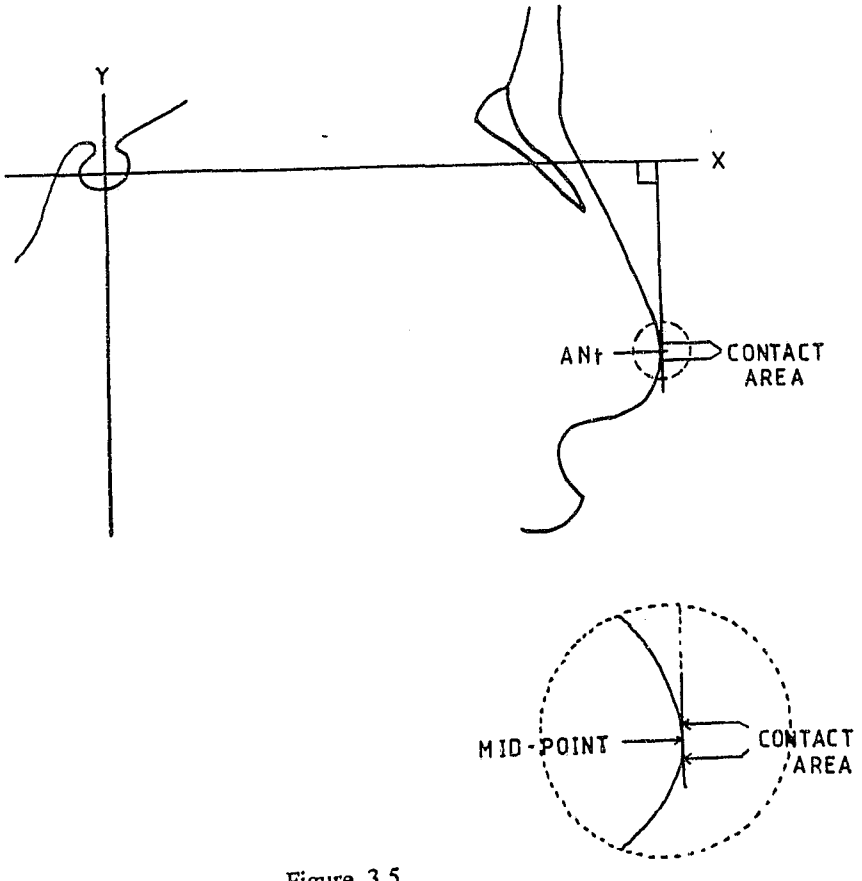


Figure 3.5

Definition of a point on a curved segment. A perpendicular line was dropped from the X axis, tangent to the relevant cephalometric landmark e.g. nose tip. The contact zone was then bisected to define the precise location of the point.

This method of location was intended to allow for a more precise and repeatable measurement of the cephalometric landmarks in both the horizontal and vertical planes, by use of simple geometric principles. However it was only used for those landmarks in which it was difficult to locate the point on a curved hard or soft tissue outline. Landmarks numbered three to eleven in the list below required the use of this method of location.

3) Anterior Nasal Tip (ANt) :

"The most anterior point of the soft tissue nasal outline" (Wisth and Boe, 1975).

4) Hard Tissue Subspinale - Point A (A) :

"The deepest point on the contour of the alveolar projection between the anterior nasal spine and prosthion"
(Van der Linden, 1971).

5) Upper Incisor Anterius (UIa) :

"The most anterior point on the outline of the crown of the upper central incisor outline"
(Mansour Burstone and Legan, 1983)

6) Lower Incisor Anterius (LIa) :

"The most anterior point on the crown of the lower central incisor outline" (Mansour Burstone and Legan, 1983).

7) Sulcus Inferius (Si) :

"The point of greatest concavity in the midline of the lower lip between labrale inferius and soft tissue pogonion"
(Van der Linden, 1971).

8) Hard Tissue Supramentale - Point B (B) :

"The most posterior point in the concavity between infradentale and pogonion" (Van der Linden, 1971).

9) Soft Tissue Pogonion (Pog') :

"The most prominent or anterior point on the soft tissue chin, in the midsagittal plane" (Burstone, 1958).

10) Hard Tissue Pogonion (Pog) :

"The most prominent or most anterior point on the bony chin" (Van der Linden, 1971).

11) Superior Superius (Ss) :

"The point of greatest concavity in the midline of the upper lip between subnasale and labrale superius" (Burstone, 1958).

In approximately 30 % of cases this area of the upper lip was very flat, making it impossible to construct a tangent perpendicular to the horizontal axis. In these cases superior labial sulcus was located as the midpoint between subnasale and labrale superius (Figure 3.6)

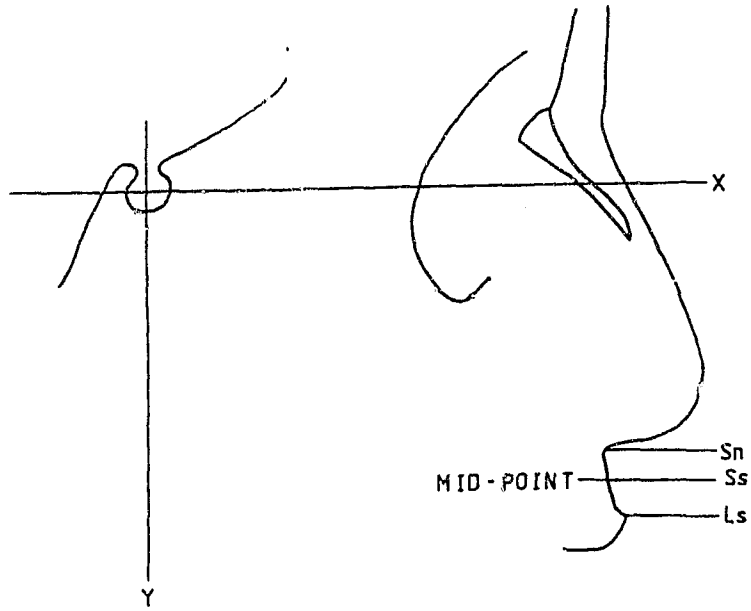


Fig 3.6

Alternative construction to identify point Ss when the upper lip contour was straight. This point was located midway between Sn and Ls on the contour line.

12) Prosthion (Pr) :

"The transition point between the crown of the most prominent medial maxillary incisor and the alveolar projection" (Bjork, 1947).

13) Maxillary Incisor Tip (UIT) :

"The midpoint of the incisal edge of the most anterior maxillary central incisor in the sagittal plane." (Bjork, 1950).

14) Infradental (In) :

"The point of transition from the crown of the most prominent medial mandibular incisor to the alveolar projection" (Bjork, 1947).

15) Soft Tissue Subnasale (Sn) :

"The point at which the columella merges with the upper cutaneous lip" (Worms, Isaacson and Speidel, 1976).

This was located along a line drawn tangential to the nasal base area and at an angle of 45 degrees to the palatal plane (ANS - PNS). Practically this was achieved by the use of a set square with a 45 degree line marked on it. The base of the set square was orientated along the ANS - PNS plane and then moved along this palatal plane until the 45 degree line was tangential to the nasolabial contour. This 45 degree line was then drawn on the tracing and the area of contact bisected for location of Sn (Fig 3.7).

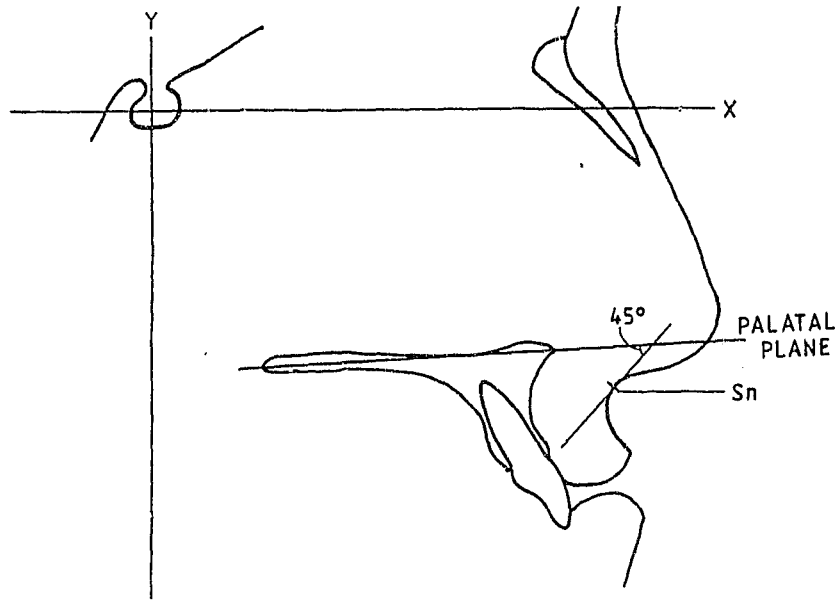


Fig 3.7

Sn was located using a tangent to the nasolabial contour line at 45 degrees to the palatal plane.

16) Columella Point (Cm) :

" The most anterior point on the columella of the nose" (Legan and Burstone, 1980).

This was identified by passing a line beginning at subnasale tangent to the inferior border of the soft tissue columella. The columella point lies precisely where the curvature of the nose leaves the columella.

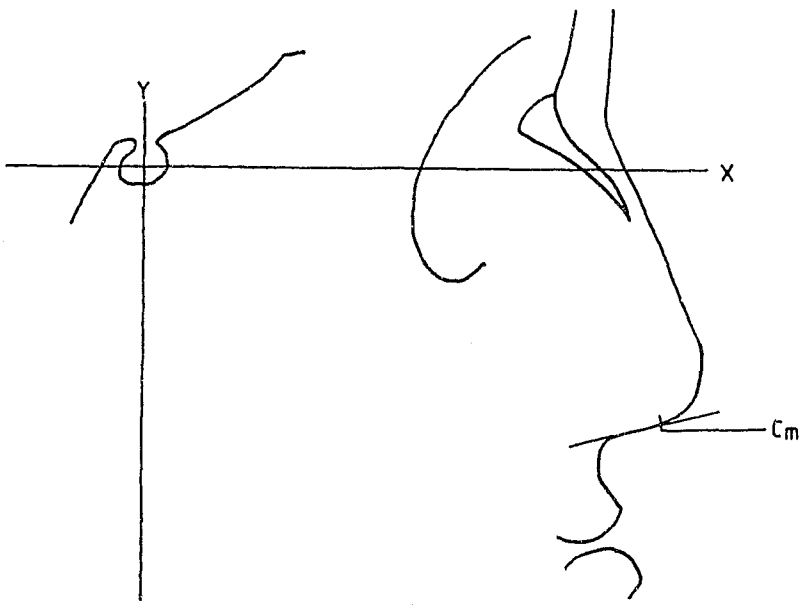


Fig 3.8

Cm was located using a tangent beginning at subnasale on the inferior border of the nose. The columella point lies precisely where the curvature of the nose leaves the tangent

The remainder of the landmarks were located directly according to the following definitions :

17) Labrale Superius (Ls) :

"The median point in the upper margin of the upper membranous lip" (Burstone, 1958).

This was identified at the point where the upper lip contour changes from anteriorly concave to anteriorly convex.

18) Labrale Inferius (Li) :

"The median point in the lower margin of the lower membranous lip" (Burstone, 1958).

This was identified as the point where the lower lip contour changes from anterior convex to anteriorly concave.

19) Stomion (St) :

"The junction of the upper and lower membranous lips" (Worms, Isaacson and Speidel, 1976).

In every case the principle that the lips be in complete repose was adhered to. This was checked by the radiographer and the orthodontist. In those patients where the lips were apart in repose, stomion superius was constructed at the most inferior level of the upper membranous lip because in this study the point was utilised as a vertical indicator of the position of the upper lip (fig 3.9) and stomion inferius as the most superior level of the lower membranous lip.

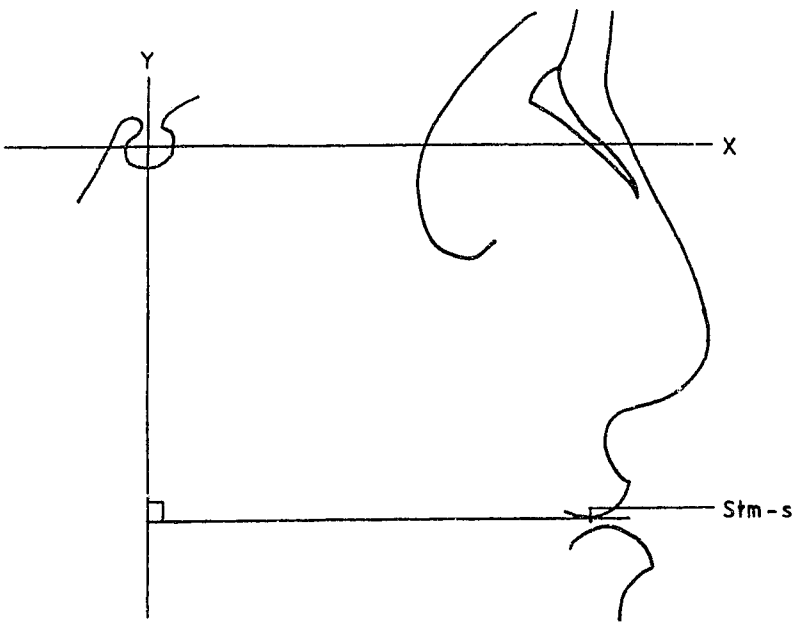


Figure 3.9

Wth the lips apart Stm-s was located at the inferior margin of the upper lip

20) Anterior Nasal Spine (ANS) :

"The apex of the anterior nasal spine." (Bjork, 1947).

21) Posterior Nasal Spine (PNS) :

"The tip of the posterior nasal spine." (Bibby and Preston, 1981).

22) Maxillary Incisal Tip (UIT) :

"The midpoint of the incisal edge of the most anterior maxillary central incisor in the sagittal plane." (Bjork, 1960).

23) Mandibular Incisal Tip (LIT) :

"The midpoint of the incisal edge of the most anterior mandibular central incisor in the sagittal plane." (Solow and Tallgren, 1976).

THE LINEAR MEASUREMENT USED

An extension of the soft tissue point labrale superius parallel to the constructed Frankfort horizontal to the intersection of the hard tissue tissue directly posterior to it. Upper lip thickness at labrale superius (figure 4.0)

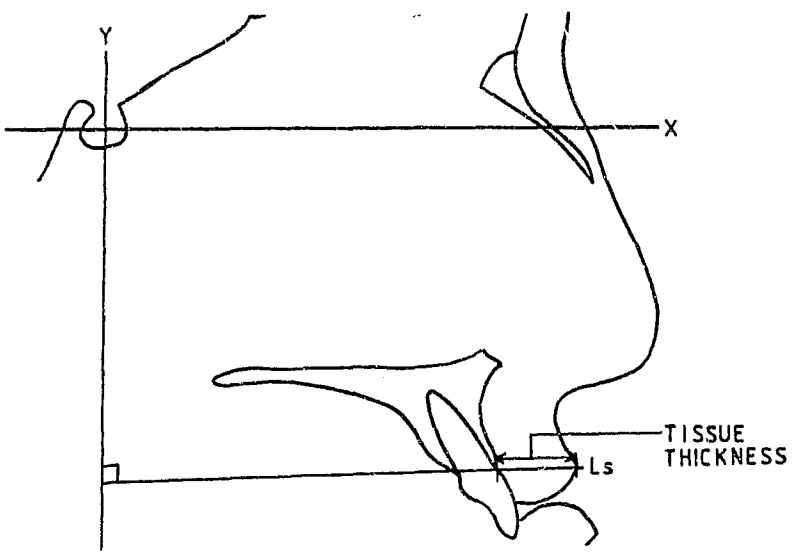


figure 4.0

Tissue thickness at the upper lip was measured as an extension of labrale superius parallel to the constructed Frankfort horizontal to the intersection of the hard tissue tissue directly posterior to it.

3.2.1 THE CEPHALOMETRIC MEASURING SEQUENCE

The reference axes were constructed for each subject on the pre-surgical tracing and were then transferred to each of the post-surgical tracings after superimposition over the cranial base areas. This was achieved by finding the closest correspondence between the two tracings using sella turcica, De Costa's line (the line representing the sphenoid plane and the cribiform plate - Quast, Biggerstaff and Haley, 1983), superior orbital roof, orbit and the frontonasal area as reference structures.

The T1 radiographs of fifteen patients were traced twice. The reference axes were transferred from the first pre-surgical tracing to the second pre-surgical tracing after superimposing the two tracings over the locating crosses which had been traced directly from the film. This standardized the reference system for each set of tracings for each patient. Then in each set of tracings the reference axes were transferred from the pre-surgical tracings to the post-surgical tracings by using the method of superimposition over the cranial base area.

The co-ordinates of every reference landmark on each tracing were sequentially computed using a digitizing programme on a Kontron MOP - Videoplan computer* (Figure 4.1). This entailed orientating the tracing on the computer tracing board so that the reference axes superimposed upon the 'X' and 'Y' co-ordinate axes set by the computer on the digitizing tablet (Figure 4.2 and 4.3). Each landmark was then digitized and the computer recorded the specific co-ordinates related to the reference axes. The 'X' co-ordinate represented the horizontal distance from the vertical axis and the 'Y' co-ordinate the vertical distance from the horizontal axis, measured in millimetres to an accuracy of one decimal place.

In this way the parameters on the fifteen radiographs were measured twice (i.e. two tracings per radiograph), the values being averaged to give the mean, thereby decreasing the error of variability. (Houston, 1983). This error variance in location of the landmarks was further minimized by completing both sets of tracings for an individual patient at the same session (Houston, 1983).

*Kontron Messgerate GMBH, Image-analysis-systems 8057 Eching/Munchen, Breslauer Street 2, West Germany.

All the data was recorded on the Kontron computer and backed up on a stiffy disc. The data was then organised and tabulated using Statistix version 4.1 software. The data was statistically analysed by Dr Piet Becker of the Medical Research Council, Centre for Epidemiological Research in Southern Africa, Pretoria.

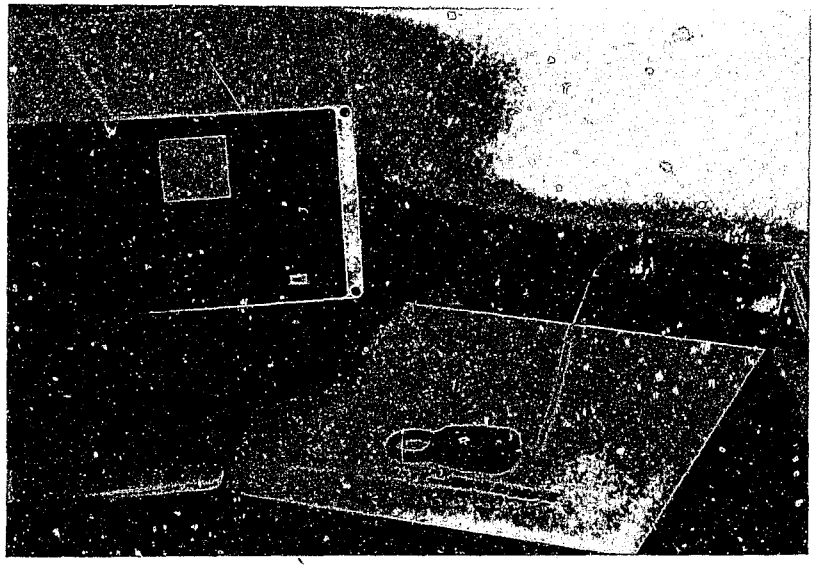


Figure 4.1

Kontron Videoplan Digitizing System.

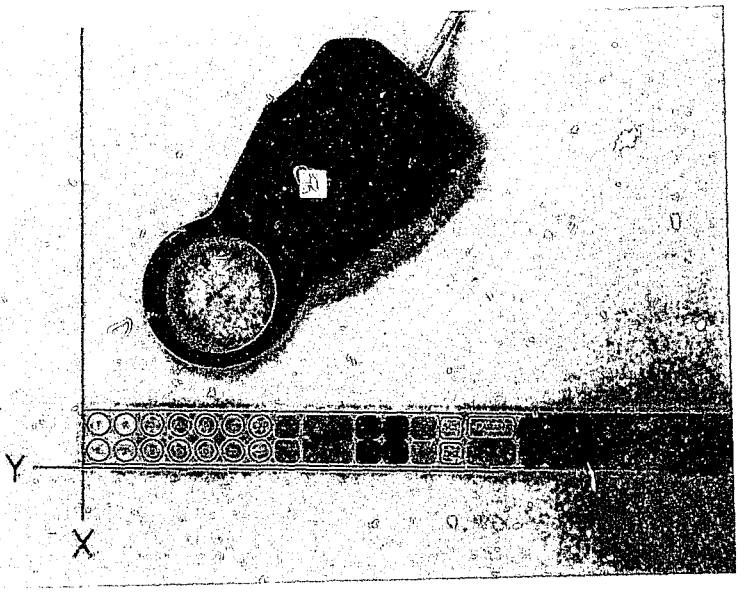


Figure 4.2

Digitizing tablet showing position of X and Y axes

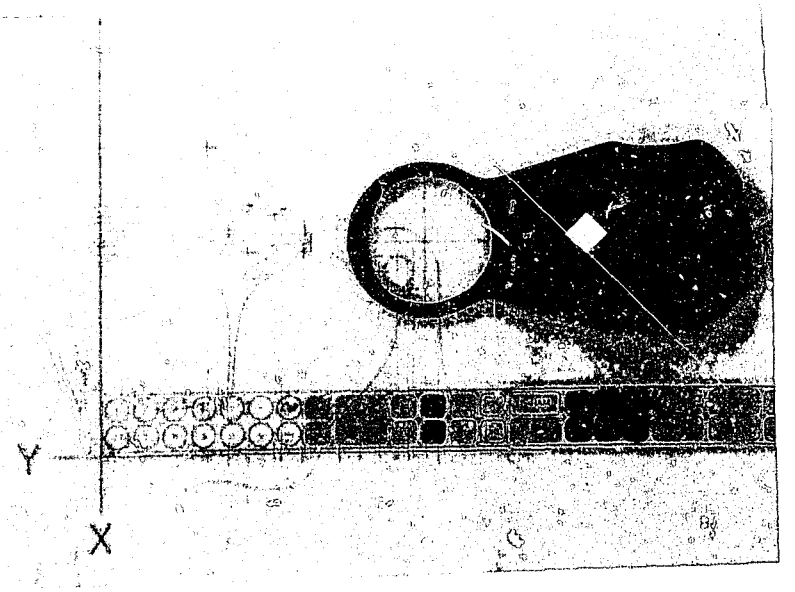


Figure 4.3

Orientation of tracing on X and Y axes.

3.3 STATISTICS

A series of statistical analyses were performed including descriptive and correlative procedures. A summary flowchart of the statistics used can be found in the Appendix pages three to four.

3.3.1 Error of method

3.3.1.1. Accuracy of digitizing

To test the proficiency of the operator in using the Kontron Videoplan digitizing system, one randomly chosen tracing was redigitized on nine separate occasions, each at least twenty four hours apart. The coefficient of variation between the nine measurements of each landmark was used to assess the accuracy of digitizing. A 5% or lower variation was chosen as a clinically acceptable level of accuracy.

3.3.1.2. Intra-examiner repeatability of accuracy of landmark identification.

The duplicate set of data from the first fifteen pre-surgical tracings for each patient was used to assess the accuracy of repeatability of landmark identification. A coefficient of repeatability, as utilized by the British Standards Institution (Bland and Altman, 1986) was calculated for each landmark.

Under the hypothesis that the difference between the observations is zero, the 95% confidence limits around zero are -1.96s and +1.96s where s is the standard deviation of the differences (di) calculated with the mean of the differences (d) set equal to zero. The differences can then be assessed and the value 1.96s referred to as the repeatability coefficient as adopted by the British Standards Institution. (1979). If more than two repeated measurements are made then s is found as the square root of the mean square error when the subjects are compared in a one-way analysis of variance.

Mitgard, Bjork and Linder-Aaronson (1974) reported the accuracy of repeatability of hard tissue landmarks to range from 0.42 mm (for S) to 2.08 mm (orbitale). They found the majority of the landmarks to be reproducible at an accuracy level of between 1 mm and 1.5 mm. Hillesund, Field and Zachrisson (1978) reported the accuracy in the horizontal plane of soft tissue reproducibility on cephalometric radiographs to be within 1 mm to 1.5 mm. Wisth and Boe (1975) found no significant difference between the reliability of the location of hard and soft tissue landmarks. Therefore a level of

repeatability of less than 1.5 mm was chosen as acceptable for this study.

3.3.1.3. Inter-examiner accuracy of landmark location

A randomly chosen radiograph was traced on separate occasions by ten orthodontists familiar with cephalometric techniques. Each, using the described method, located the following six landmarks

1) Ss
2) Li
3) Pog'
4) LIT
5) Pog
6) A

These were chosen as being representative of the diversity of landmarks used in this study.

Each landmark on each of the ten tracings was digitized and the data subjected to statistical analysis. A coefficient of variation was derived to assess the inter-operator accuracy of the described method.

3.3.2 Statistics for the change from the T1 to T2 time interval

Firstly it was necessary to determine whether proportional changes between various hard and soft tissue landmarks in the thirteen patients who had only maxillary advancement surgery differed from those patients who had an additional surgical procedure (i.e. either a mandibular reduction or a genioplasty, or a combination mandibular reduction genioplasty). Simple proportional equations were calculated for the same hard to soft tissue changes in all of the patients. A Student's t test was used, and when applicable, adjusted for non-equal variances established from Levene's test for equal variance (Levene, 1960). The t test evaluated whether a significant difference occurred between the maxillary advancement group and the other groups with respect to the mean proportion between the change occurring at the chosen hard tissue point with that at the chosen soft tissue point. A finding of no significant difference would allow the groups to be joined for the study, thereby increasing the sample size. The detection of significant differences from any one of the groups that was not in the maxillary advancement only group would exclude that group from the sample. A level

of $P \leq 0.05$ was chosen to represent significance.

Descriptive and comparative statistics were then calculated for the data from the T1 to T2 time interval for the chosen sample. A paired Student's t-test was used to evaluate the significance of the mean of the differences between T1 and T2 values for each landmark, as measured in millimetres along both the horizontal and vertical reference planes. A level of $P \leq 0.05$ was chosen to represent significance. The significant changes were then further evaluated for their clinical relevance. A clinically relevant change was chosen to represent any change of greater than 1.5 mm (Baumrind and Frantz, 1971; Mitgard, Bjork and Linder-Aronson, 1974; Hillesund, Fjeld and Zachrisson, 1978).

Those hard and soft tissue landmarks for which statistically significant and clinically relevant changes were recorded were then subjected to analysis to assess the relationship between those changes. Correlation and regression analyses were used in the statistical evaluation. (refer to the appendix pages three and four for a summary flowchart of the statistics used).

The Pearson correlation coefficients were calculated, and from these the coefficients of determination (c of d) were subsequently calculated for each set of landmarks using the formula :

$$c \text{ of } d = (R^2 \times 100)\%$$

where $R = r$ = Pearson correlation coefficient for simple linear regressions. The coefficient of determination assesses the amount of variation of the response variable (i.e. soft tissue change) that may be explained by the variation of the independent variable (i.e. hard tissue change) expressed as a percentage. eg. a 60% coefficient of determination for a specific hard to soft tissue change implies that 60% of the change occurring at the soft tissue point would be explained by the change occurring at the hard tissue point. A coefficient of determination of greater than 50% indicates a good correlation i.e. $r \geq 0.7$.

The correlation analyses were performed to evaluate the strength of the relationship of the changes between the corresponding hard and soft tissue landmarks in the horizontal and vertical dimensions :

Horizontal dimensions

1) UIa and ANt
2) UIa and Sn
3) UIa and Ss
4) UIa and Ls
5) UIa and Li
6) A and ANt
7) A and Sn
8) LIT and Li
9) Pr and Ls
10) UIT and Ls
11) Pog and Pog'
12) ANS and Ant

The vertical response to horizontal movement
1) UIT (h) and Stm-s (v)
The angular response to horizontal movement
1) UIa (h) and Cm.Sn.Ls. (Nasolabial angle)

The multiple regression analysis was performed to assess the influence of various factors upon the relationship between the hard and soft tissue changes in the horizontal and vertical dimension. These factors included the pre-surgical tissue thickness and whether or not a V-Y closure had been performed.

Tissue thickness was measured along a perpendicular to the Y axis from labrale superius to the first encountered hard tissue intersection. Again the coefficient of determination was calculated where R is equal to the multiple correlation coefficient found from the multiple regression calculations. Changes recorded at the following landmarks were assessed :

1) Ls - h and UIT - h
2) Li - h and LIT - h
3) Stm-s - v and UIT - h

Tissue thickness was incorporated into the multiple regression model because it can vary depending upon the type of soft tissue. Furthermore, it is relatively easy to measure. Freihofer (1976) discussed the variability of the thickness of the soft tissue covering the

dentition and bone, and drew attention to the possible importance of evaluating this factor during the treatment planning process. Other variables that could influence the soft tissue changes include wound closure techniques. Carlotti, Aschaffenburg, Schendel, (1986) and Jensen, Sinclair and Wolford (1992) believe a more pronounced movement of the upper lip will be observed following the V-Y closure technique.

From the results of these statistical analyses, it was possible to identify the best hard tissue predictors upon which to base a forecast of the new positions of soft tissue landmarks.

CHAPTER 4

RESULTS

4.1 ERROR OF METHOD

4.1.1 Accuracy of digitizing

Table 6 presents the coefficients of variation for each landmark between the nine readings recorded by the operator on separate occasions.

TABLE 6

Coefficients of variation. Each landmark was digitized on nine separate occasions

Hard tissue landmark		C.V. %	Soft tissue landmark		C.V. %
S	h	0.00	ANt	h	0.05
	v	0.00		v	0.13
N	h	0.06	Cm	h	0.08
	v	0.80		v	0.11
ANS	h	0.07	Sn	h	0.09
	v	0.00		v	0.10
A	h	0.05	Ss	h	0.08
	v	0.09		v	0.00
Pr	h	0.11	Ls	h	0.08
	v	0.07		v	0.10
UIa	h	0.07	Stm-s	h	0.07
	v	0.04		v	0.00
UIT	h	0.05	Stm-i	h	0.07
	v	0.07		v	0.00
PNS	h	0.24	Li	h	0.42
	v	0.12		v	0.09
LIT	h	0.07	Si	h	0.09
	v	0.07		v	0.04
LIa	h	0.10	Pog'	h	0.06
	v	0.04		v	0.03
In	h	0.07			
	v	0.06			
B	h	0.09			
	v	0.00			
Pog	h	0.00			
	v	0.08			

TABLE 7

Coefficient of variation for the measurement of lip thickness. The line was digitized on nine separate occasions

Soft tissue landmark to hard tissue landmark	C.V. %
Upper lip thickness was measured along a perpendicular to the Y axis from labrale superius to the first encountered hard tissue intersection	0.48

TABLE 8

Coefficient of variation for the nasolabial angle. The angle was digitized on nine separate occasions

Soft tissue landmarks	C.V. %
Cm to Sn to Ls	0.43

For the 23 individual landmarks measured the coefficient of variation ranged from 0.00 % to 0.42 % in the horizontal dimension and 0.00 % to 0.8 % in the vertical dimension. The measurement for lip thickness had a coefficient of 0.48 % and the measurement for the nasolabial angle had a coefficient of variation of 0.43 %. This was well within the 5 % level chosen and with the Kontron Videoplan digitizing system set at an accuracy level of 0.01 mm. The variability between repeat measurements for any particular landmark would be well below 1.5 mm, the accuracy level set for this study.

4.1.2. Intra-examiner repeatability of accuracy of landmark identification.

Table 9 presents the coefficients of repeatability for the pre-surgical hard and soft tissue landmarks using the first fifteen patients whose T1 radiographs were traced on two separate occasions twenty four hours apart.

The coefficient of repeatability for the landmarks measured in the horizontal dimension ranged from 0.47 to 3.10 mm. In the vertical dimension the mean coefficient of repeatability for the landmarks ranged from 0.38 mm to 2.88 mm.

The coefficient of repeatability for lip thickness measured 0.63 mm. The coefficient of repeatability for the nasolabial angle measured 3.64 degrees (Tables 10 and 11).

TABLE 9

Coefficients of repeatability for each landmark measured on fifteen T1 radiographs which had been traced on two separate occasions 24 hours apart

Hard tissue landmark		C.R. (mm)	Soft tissue landmark		C.R. (mm)
S	h	0.00	ANt	h	0.66
	v	0.00		v	1.06
N	h	0.64	Cm	h	3.10
	v	0.64		v	1.28
ANS	h	1.82	Sn	h	0.81
	v	0.90		v	0.87
A	h	0.49	Ss	h	0.61
	v	2.52		v	1.09
Pr	h	0.57	Ls	h	0.63
	v	0.73		v	1.13
UIa	h	0.51	Stm-s	h	2.40
	v	1.05		v	0.83
UIT	h	1.28	Stm-i	h	2.38
	v	0.51		v	1.00
PNS	h	2.54	Li	h	0.68
	v	0.68		v	1.49
LIT	h	0.47	Si	h	0.65
	v	0.38		v	2.88
LIa	h	0.67	Pog'	h	0.48
	v	0.99		v	2.27
In	h	1.07			
	v	1.44			
B	h	0.78			
	v	2.08			
Pog	h	0.70			
	v	2.00			

TABLE 10

Coefficient of repeatability for the measurement of lip thickness

Soft tissue landmark to hard tissue landmark	C.R .(mm)
Ls to distal hard tissue intersection parallel to constructed Frankfort	0.63

TABLE 11

Coefficient of repeatability for the measurement of the nasolabial angle

Soft tissue landmarks	C.R .(degrees)
Cm to Sn to Ls	3.64

The following landmark measurements were considered reliable points for further analysis because their coefficients of repeatability were within the 1.5 mm limit (Baumrind and Frantz 1971; Mitgard, Bjork and Linder-Aronson 1974; Hillesund, Fjeld and Zachrison 1978) :

1	A	horizontal
2	Pr	horizontal
3	UIa	horizontal
4	UIT	horizontal
5	LIT	horizontal
6	LIa	horizontal
7	In	horizontal
8	B	horizontal
9	Pog	horizontal
10	ANt	horizontal
11	Sn	horizontal
12	Ss	horizontal
13	Ls	horizontal
14	Li	horizontal
15	Si	horizontal
16	Pog'	horizontal
17	Ls (lip thickness)	
18	ANS	vertical
19	Pr	vertical
20	UIa	vertical
21	UIT	vertical
22	PNS	vertical
23	LIT	vertical
24	LIa	vertical
25	In	vertical
26	ANt	vertical
27	Cm	vertical
28	Ss	vertical
29	Ls	vertical
30	Stm-s	vertical
31	Stm-I	vertical
32	Li	vertical

The coefficient of repeatability for the horizontal dimension ranged from 0.48 mm to 1.28 mm, and for the vertical dimension ranged from 0.38 mm to 1.49 mm, all below the recommended 1.5 mm level (Baumrind, Frantz, 1971; Mitgard, Bjork, Linder-Aronson, 1974; Hillesund, Fjeld, Zachrison, 1978). The horizontal measurements were more variable than the vertical measurements particularly for the soft tissue landmarks.

4.1.3. Inter-examiner accuracy of landmark location

Table 12 presents the coefficients of variation for the means of the values obtained by the ten orthodontists and compares these means with the researcher's mean measurements of the same six landmarks.

TABLE 12

Means and standard deviations of the measurements recorded by the ten orthodontists, and the coefficients of variation for each parameter. The means are compared with the means of the data recorded by the researcher.

L/MARK		ORTHODONTISTS Mean	S.D.	C.V. %	RESEARCHER'S MEAN RESULTS	DIFFERENCE BETWEEN THE MEANS
A	h	68.9	1.16	1.69	68.8	0.10
	v	58.5	2.14	3.66	58.3	0.20
LIT	h	68.6	1.36	1.98	68.5	0.10
	v	77.9	0.90	1.16	77.5	0.40
Pog	h	66.2	1.80	2.72	65.7	0.50
	v	113.3	1.52	1.34	112.9	0.40
A'	h	84.0	1.27	1.51	84.0	0.00
	v	66.5	1.25	1.89	65.7	0.20
LI	h	85.0	1.47	1.73	84.6	0.40
	v	80.6	1.15	1.43	80.2	0.40
Pog'	h	81.9	1.87	2.29	81.7	0.20
	v	108.1	1.46	1.35	107.1	1.00

The coefficients of variation obtained by the ten orthodontists in the horizontal dimension ranged from 1.51 % to 2.72 % and in the vertical dimension the coefficients of variation ranged from 1.16 % to 3.66 %. This indicates a high degree of accuracy for the method of location used.

Bland and Altman's limits of agreement (1986) indicate a bias of 0.380 mm in the researcher's mean measurement compared with the orthodontists' mean. i.e. on average the researcher's measurements were 0.380 mm less than the mean of the measurements of the orthodontists. The upper and lower limits of agreement show that the researcher's measurements lay within 0.9588 mm to -0.1988 mm of the orthodontists mean (this being ± 1.96 standard deviations from the researcher's mean). These figures are within the accepted 1.5 mm accuracy for cephalometrics (Hillesund, Fjeld and Zachrisson, 1978).

4.2 RESULTS FROM THE TIME PERIOD T1 to T2

Firstly, changes occurring at the following hard and soft tissue landmarks were expressed as simple proportional relationships. These proportions were calculated for the thirteen maxillary advancement only patients and for the thirteen patients who had undergone maxillary advancement with additional mandibular surgery (TABLE 13).

i. Δ LIT -h to Δ Li -h
ii. Δ UIT -h to Δ Ls -h
iii. Δ UIT -h to Δ Stm-s -v

These combinations were chosen as representative of the statistically significant and clinically relevant changes and their statistical relationships were assessed in various ways (TABLES 13, 14, 15, 16, 18, 19, 20, 21, 22)

The proportions representing the relative changes were subjected to t test analysis, adjusted for non-equal variance using Levene's test. The results demonstrated no significant differences between the means at a P value of ≤ 0.05 (TABLE 13). The two groups could therefore be combined into one group for the purpose of the study.

TABLE 13

Testing for significant differences between data derived from thirteen maxillary advancement cases, and thirteen cases having maxillary advancements with additional mandibular surgery, using the Student's t test

Hard to Soft Tissue Ratios	Max adv only Beta	S.D.	Max adv+md surgery Beta	S.D.	P value
Δ LIT-h = β [Δ Li -h]	0.47	1.53	1.11	1.72	0.327
Δ UIT -h = β [Δ Ls -h]	0.65	0.41	0.55	0.42	0.567
Δ UIT -h = β [Δ Stm-s-v]	0.03	0.36	0.18	0.52	0.395

β = mean ratio

TABLE 14

Descriptive statistics and P values for the changes during the time interval T1 to T2

Landmark		Mean Change	S.D.	S.E.M.	Range Min	Range Max
A	h	3.87	1.85	0.36	-0.60	9.00
Pr	h	4.46	1.75	0.34	1.80	8.50
UIa	h	4.68	1.73	0.34	1.60	8.20
UIT	h	4.95	1.72	0.34	1.70	8.20
	v	0.25	0.26	0.05	5.60	-4.60
PNS	h	3.30	2.57	0.50	-1.90	8.00
	v	-0.99	1.55	0.30	1.90	-3.90
LIT	h	0.93	3.81	0.75	-10.9	6.80
Pog	h	0.90	4.21	0.83	-15.2	3.60
Ant	h	1.21	0.94	0.19	-0.70	3.40
	v	1.06	1.51	0.23	1.20	-5.20
Sn	h	2.30	1.65	0.32	-1.40	5.80
Ss	h	3.18	1.86	0.37	0.30	7.60
Ls	h	2.67	2.24	0.44	-1.20	7.00
	v	0.10	1.46	0.29	3.40	-2.20
Stm-s	v	0.20	1.90	0.37	4.10	-3.80
Li	h	-1.10	3.42	0.67	-11.90	4.00
Pog'	h	-0.51	4.00	0.78	-13.90	4.3

A negative value indicates either posterior movement in the horizontal direction or superior movement in the vertical direction.

TABLE 14

Descriptive statistics and P values for the changes during the time interval T1 to T2

Landmark		Mean Change	S.D.	S.E.M.	Range Min	Range Max
A	h	3.87	1.85	0.36	-0.60	9.00
Pr	h	4.46	1.75	0.34	1.80	8.50
UIa	h	4.68	1.73	0.34	1.60	8.20
UIT	h	4.95	1.72	0.34	1.70	8.20
	v	0.25	0.26	0.05	5.60	-4.60
PNS	h	3.30	2.57	0.50	-1.90	8.00
	v	-0.99	1.55	0.30	1.90	-3.90
LIT	h	0.93	3.81	0.75	-10.9	6.80
Pog	h	0.90	4.21	0.83	-15.2	3.60
Ant	h	1.21	0.94	0.19	-0.70	3.40
	v	1.06	1.51	0.23	1.20	-5.20
Sn	h	2.30	1.65	0.32	-1.40	5.80
Ss	h	3.18	1.86	0.37	0.30	7.60
Ls	h	2.67	2.24	0.44	-1.20	7.00
	v	0.10	1.46	0.29	3.40	-2.20
Stm-s	v	0.20	1.90	0.37	4.10	-3.80
Li	h	-1.10	3.42	0.67	-11.90	4.00
Pog'	h	-0.51	4.00	0.78	-13.90	4.3

A negative value indicates either posterior movement in the horizontal direction or superior movement in the vertical direction.

4.2.2 Correlation analyses

4.2.2.1 Correlation analyses relating horizontal soft tissue changes to horizontal hard tissue changes.

Table 15 summarizes the results obtained :

TABLE 15

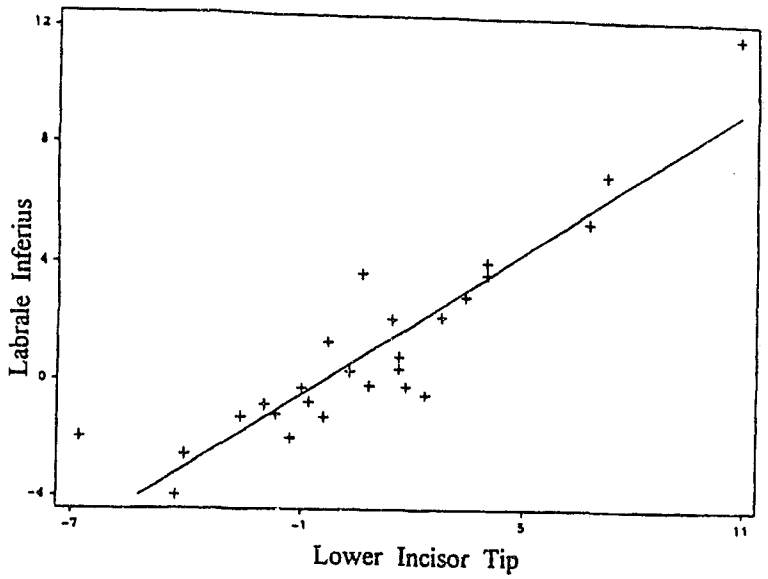
Pearson correlation coefficients and coefficients of determination for horizontal changes between corresponding hard and soft tissue landmarks for the time period T1 to T2, with the entire sample (n = 26)

Soft to Hard tissue Relation	Mean Ratio	Pearson correlation (r)	Coeff. of Determination (R^2 X 100)%	P-value
Δ ANt / ΔUIA	0.2553	0.5965	35.58	0.0013**
Δ Sn / ΔUIA	0.5212	0.4176	17.43	0.0338**
Δ Ss / ΔUIA	0.6937	0.6625	43.89	0.0002***
Δ Ls / ΔUIA	0.5749	0.5434	29.52	0.0041**
Δ ANt / ΔANS	0.3383	0.3879	15.0	0.0502**
Δ ANt / ΔA	0.1742	0.3359	11.28	0.0934
Δ Sn / ΔA	0.5638	0.4457	19.86	0.0255**
Δ Ls / ΔPr	0.6162	0.3787	14.34	0.0564
Δ Ls / ΔUIT	0.5490	0.5117	26.18	0.0067**
Δ Stm-s /ΔUIT	0.5680	0.7063	49.9	0.0001***
Δ Li / ΔLIT	0.7917	0.9128	83.32	0.0000***
Δ Pog' / ΔPog	1.0024	0.9684	93.77	0.0000***

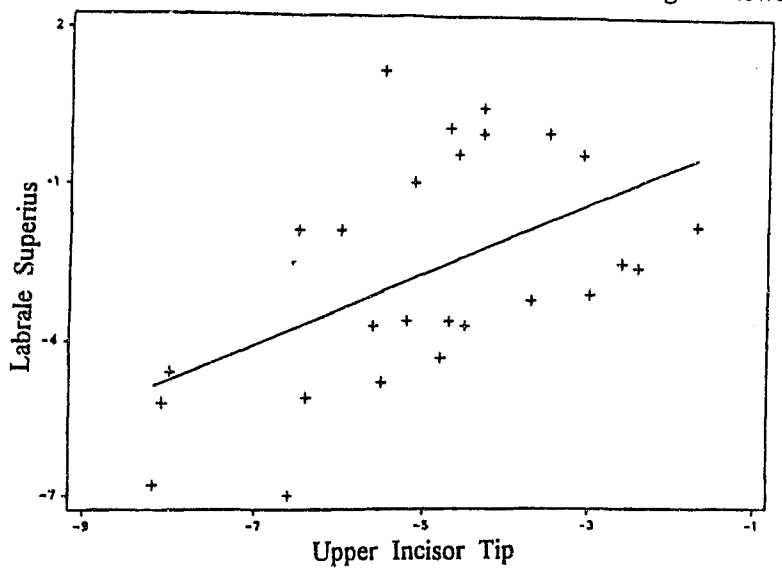
** $P \leq 0.05$
*** $P \leq 0.001$
In the case of simple linear regression r = R

All but two correlations were significant at a level of $P \leq 0.05$ and the coefficient of determination for these ratios ranged from 15 % to 93.77 %.

Simple scattergram and regression graphs enable visual comparison of ratios having differing levels of significance (Fig 4.4).



a) Horizontal change at labrale inferius compared to horizontal change at lower incisor tip



b)Horizontal change at upper incisor tip compared to horizontal change at labrale superius

Fig 4.4

Comparison of the simple regression graphs plotting the relative changes :

a) Labrale inferius horizontal against lower incisor tip horizontal ($r = 0.9128$; $P \leq 0.001$)

b) Labrale superius horizontal against upper incisor tip horizontal ($r = 0.5117$; $P \leq 0.05$)

Derived from data in Table 15.

TABLE 16

Pearson correlation coefficients and coefficients of determination for changes between a hard tissue point in the horizontal dimension and a corresponding soft tissue point in the vertical dimension for the time period T1 to T2.

Soft to. Hard tiss. Relation	Mean Ratio	Pearson correlation (r)	Coeff. of Determination (R^2 X 100)%	P-value
∆ Stm-s-v / ∆UIT-h	0.1034	0.3925	15.4	0.0473**

* n = 26

** P ≤ 0.05 df 24

In the case of simple linear regression r = R.

A statistically significant correlation at a P value of ≤ 0.05 existed between changes at Stm-s in the vertical direction and UIT in the horizontal direction. The coefficient of determination measured 15.4%.

TABLE 17

Pearson correlation coefficients and coefficients of determination for changes between a hard tissue point in the horizontal dimension and an associated angular change for the time period T1 to T2.*

Nasolabial angle to hard tissue relation	Mean Ratio	Pearson correlation (r)	Coeff. of Determination (R^2 X 100)%	P-value
∆ CmSnLs∆ /∆ UIT -h	0.2260	0.1814	3.29	0.375

* n = 26

In the case of simple linear regression r = R.

There was no statistically significant correlation at a P value of ≤ 0.05 between changes at UIT in the horizontal direction and nasolabial angle change.

TABLE 18

Simple regression equations, Pearson correlation coefficients and coefficients of determination for the time period T1 to T2; following the division of the groups into cases having tissue thickness greater than 15 mm (10 patients) or having less than 15 mm (16 patients).

Soft to hard tissue ratios for thin lips (i.e. < 15 mm)

Soft to. Hard tiss. Relation	Mean Ratio	Pearson correlation (r)	Coeff. of Determination (R^2 X 100)%	P-value
Δ Sn -h /Δ A - h	0.7947	0.5781	33.42	0.0240**
Δ Ls -h /Δ UIT - h	0.7572	0.6940	48.16	0.0029**
Δ Stm-s -h /Δ UIT - h	0.7245	0.8005	64.08	0.0002***

simple regression equation : Δ Stm-s -h = 0.72876 + 0.88664(Δ UIT - h)

n = 16

** P ≤ 0.05

*** P ≤ 0.001

Soft to hard tissue ratios for thick lips (i.e. > 15 mm)

Soft to. Hard tiss. Relation	Mean Ratio	Pearson correlation (r)	Coeff. of Determination (R^2 X 100)%	P-value
Δ Sn -h /Δ A - h	0.2174	0.6228	38.79	0.0544
Δ Ls -h /Δ UIT - h	0.2698	0.5830	33.99	0.0769
Δ Stm-s -h /Δ UIT - h	0.3176	0.7718	59.57	0.0089**

simple regression equation : Δ Stm-s -h = 6.19468 + 1.6023(Δ UIT - h)

n = 10

** P ≤ 0.05

Summary : The ratio of advancement of labrale superius to upper incisor tip is 2.8 times greater in thin lips compared to thick lips. By dividing the patients into groups, those having thick and those having thin lips, there is an increase in the accuracy of prediction of the variation in the soft tissue landmark in thin lips.

TABLE 19

Simple regression equations, Pearson correlation coefficients and coefficients of determination for the time period T1 to T2; following the division of the sample into groups depending on whether or not a V-Y surgical procedure had been performed.

Soft to hard tissue ratios with a V-Y procedure (n = 11)

Soft to. Hard tiss. Relation	Mean Ratio	Pearson correlation (r)	Coeff. of Determination (R^2 x 100)%	P-value
Δ Ls-h /Δ UIT - h	0.5593	0.4446	19.77	0.0737
Δ Stm-s-h /Δ UIT - h	0.6261	0.7572	57.33	0.0004***
Δ Stm-s -v /Δ UIT - h	0.1161	0.5115	26.16	0.0359**

** P ≤ 0.05

*** P ≤ 0.001

Soft to hard tissue ratios without a V-Y procedure (n = 9)

Soft to. Hard tiss. Relation	Mean Ratio	Pearson correlation (r)	Coeff. of Determination (R^2 x 100)%	P-value
Δ Ls-h /Δ UIT - h	0.5756	0.6406	41.04	0.0101**
Δ Stm-s-h /Δ UIT - h	0.3863	0.7244	52.48	0.0023**
Δ Stm-s -v /Δ UIT - h	0.2640	0.4302	18.51	0.1095

** P ≤ 0.05

Summary : Whether or not a V-Y closure technique was used appears to exert little influence on the ratio of movement of labrale superius to that of upper incisor tip in the horizontal plane.

When a V -Y procedure is used the vertical movement of stomion superius to upper incisor tip decreases from 0.2640 to 0.1161.

4.2.3. Multiple regression analyses

4.2.3.1. Multiple regression analyses : changes at soft tissue landmarks versus changes at corresponding hard tissue landmarks when pre-surgical tissue thicknesses and surgical closure (V-Y) technique are taken into account.

Table 20 lists results obtained for the multiple regression analyses and compares these results with those obtained for the correlation analyses, the latter being equivalent to a simple regression.

TABLE 20

Coefficients of determination obtained from multiple regression analysis and correlation analyses for corresponding soft and hard tissue points for the time period T1 to T2.

Hard to soft tiss. relation	Multiple Regression (R^2)	(adjusted R^2)%	Simple Regression Analysis (R^2)	(adjusted R^2)%
ΔUIT -h / ΔLs -h	0.8319	80.03	0.2681	23.76
ΔUIT -h / ΔStm-s -v	0.2896	15.64	0.1541	11.88
ΔLIT -h / ΔLi -h	0.9296	91.64	0.8332	82.62

In the case of simple linear regression r = R.
Multiple regression analysis permits the consideration of several factors in the evaluation of a relationship. The inclusion of tissue thickness and method of surgical closure as additional factors in determining the relationships of changes at corresponding hard and soft tissue points did result in improved levels of relationships. For example, the coefficient of determination for the horizontal changes at UIT and at Ls was substantially enhanced from 23.76% to 80.03 % when tissue thickness was included in the multiple regression analysis. The data for the other two landmarks (although not as significantly enhanced) were also improved. For example ΔUIT-h : ΔStm-s -v improved from 11.88 % to 15.64 % and ΔLIT-h : ΔLi - h improved from 82.62 % to 91.64%.

4.2.3.2. Multiple regression analyses : changes at soft tissue landmarks versus changes at corresponding hard tissue landmarks, including pre-surgical tissue thicknesses and soft tissue surgical procedures (V-Y closure).

TABLE 21

Relative contributions for each variable obtained from multiple regression analysis for corresponding soft and hard tissue points when tissue thickness and surgical procedure (V-Y closure) are taken into account (T1 to T2).

Δ Ls -h vrs Δ UIT -h

Predictor variables	coefficient	P value
Constant	-1.22606	0.1454
UIT - h	0.64550	0.0002***
V-Y	0.60645	0.1799
TT	3.2428	0.0000***

Adjusted R^2 X 100 80.00 %

*** $P \leq 0.001$

Δ Stm-s-v vrs Δ UIT -h

Predictor variables	coefficient	P value
Constant	-3.79847	0.0151
UIT - h	-0.42614	0.0859
V-Y	1.14823	0.1469
TT	0.96552	0.2119

Adjusted R^2 X 100 15.64 %

No variable is significant at $P \leq 0.05$

Δ Li -h vrs Δ LIT -h

Predictor variables	coefficient	P value
Constant	-1.04954	0.0278
LIT - h	0.69005	0.0000***
V-Y	1.07448	0.0566
TT	2.11058	0.0014**

Adjusted R^2 X 100 91.64 %

** $P \leq 0.05$

*** $P \leq 0.001$

The hard tissue landmark variables are significant to $P \leq 0.001$, and tissue thickness at a $P \leq 0.05$. The V-Y closure is only marginally not statistically significant. Leaving out the V-Y variable decreases the accuracy of variation by 7.9 %.

4.2.4 Regression equations and proportional relationships

Table 22 summarizes the simple and multiple regression equations for the relationship between the changes in soft and hard tissue points which had been identified as being statistically significant. The simple proportional relationships were derived directly from the mean changes occurring between T1 and T2 at the landmarks. These simple proportions reflect only the mean changes observed in this sample. It is the regression equations which more appropriately define the relationships between the changes at the landmarks, and it is these equations which may be extrapolated to orthognathic surgery in general.

TABLE 22

Summary of simple and multiple regression equations and the mean proportional relationships of the significant soft and hard tissue changes.

SIMPLE REGRESSION EQUATIONS	PROPORTIONAL RELATIONSHIPS
$\Delta Ls - h = 0.67 + 0.67\ (\Delta UIT - h)$	$\Delta Ls - h = 0.5534\ (\Delta UIT - h)$
$\Delta Stm\text{-}s\text{-}v = -2.33 + -0.43\ (\Delta UIT\text{-}h)$	$\Delta Stms - v = 0.1034\ (\Delta UIT - h)$
$\Delta Li - h = 0.34 + 0.82\ (\Delta LIT - h)$	$\Delta Li - h = 0.7917\ (\Delta LIT - h)$

MULTIPLE REGRESSION EQUATIONS

MULTIPLE REGRESSION EQUATIONS

$\Delta Ls - h = -1.23 + 0.65\ (\Delta UIT - h) + 0.61(V-Y) + 3.24\ (TT)$

$\Delta Stms - v = -3.80 + -0.43\ (\Delta UIT - h) + 1.15\ (V-Y) + 0.97\ (TT)$

$\Delta Li - h = -1.05 + 0.69\ (\Delta LIT - h) + 1.07\ (V-Y) + 2.11\ (TT)$

CHAPTER 5 DISCUSSION

Upper jaw antero-posterior deficiency is commonly corrected in the adult non-growing patient by surgically advancing the maxilla, utilising an osteotomy at the Le Fort 1 level. Thus the mid-face profile can be altered significantly. In the literature the data relating the soft tissue to hard tissue change varies considerably. Such variation may tempt surgeons to use personal artistic expectation rather than to employ scientific data when predicting facial changes.

The present study followed the majority of the twenty three criteria advocated by Betts and Fonseca 1992 in order to improve the accuracy of predicting the ratios of soft to hard tissue changes which may occur in response to maxillary advancement surgery.

Every effort was made to standardize the technique of landmark identification. Houston (1983) presented practical advice on how to minimize the effect of these problems in research, and his suggestions were incorporated in this study. Cephalometric variability was minimised as far as possible by using records which had been taken on the same machine by the same operator using well established radiographic techniques. Gardner's (1991) method of identification of a landmark on a gently curving contour was followed. Acceptable limits of intra- and inter-observer accuracy were achieved for the method of landmark identification. The accuracy of repeatability in landmark identification was shown in previous studies to represent an acceptable level of precision when variation was below 1.5 mm (Baumrind and Frantz, 1971; Mitgard, Bjork and Linder-Aronson, 1974; Hillesund; Fjeld and Zachrison, 1978). In ew of the fact that variation in the measurement of two landmarks (ANS horizontal and Stm-s horizontal) in this study were greater than 1.5 mm, caution is advocated in accepting these points as being reliable in predicting soft to hard tissue ratios.

No significant differences were found between the means of the ratios of soft to hard tissue response when comparing those patients having mandibular and maxillary surgery with those who had maxillary surgery alone.

Betts and Fonseca (1992) advocated that the sample should not include any cases having had any osseous recontouring. Freihofer (1976) found that the removal of the anterior nasal spine resulted in slightly less forward movement of the nose tip. In the majority of maxillary advancements in this study the anterior nasal spine was removed

to reduce untoward nasal tip movement. In a retrospective study it is not always possible to control every variable and in this study only one patient did not have recontouring of the anterior nasal spine. Consequently there are no comparisons of the amount of soft tissue movement following surgical or non-surgical procedures to the anterior nasal spine.

The data in this study tends to confirm the feasibility of predicting changes in the soft tissue profile and may clarify why previous studies have reported different values for soft tissue reactions to hard tissue movements.

The soft tissue contours of the face responded in the following manner :

The anterior nasal tip followed the horizontal movement of the anterior nasal spine at a ratio of 0.34 : 1, subspinale at 0.17 : 1 and upper incisor anterius at 0.26 : 1. The relationships of the movement of the anterior nasal tip to the upper incisor and anterior nasal spine were both statistically significant at $P \leq 0.05$. These results confirm those of Freihofer (1977), Teuscher and Sailer (1982), Mansour, Burstone, Legan (1983) and Hui, Hagg, Tideman (1994) who showed the ratio of Ant : A point to vary from 0.17 : 1 to 0.36 : 1. Freihofer (1977) indicated that removal of the anterior nasal spine reduced the ratio of ANt : A point from 0.33 : 1 to 0.25 : 1.

Subnasale (Sn) followed subspinale (A point) at a ratio of 0.56 : 1 and upper incisor anterius at 0.52 : 1. Both relationships were statistically significant at $P \leq 0.05$. When the sample was divided into thick and thin lips there was a notable difference between the two groups. Thin lips advanced at a ratio of 0.79 : 1 and thick lips at 0.22 : 1. The correlation coefficients were similar in the two groups. A point was marginally more accurate as a predictor when compared to the upper incisor when assessing the soft tissue response. Previous investigations showed the ratio to vary from 0.2 : 1 to 0.95 : 1 with an average value of 0.46 : 1. Carlotti, Aschaffenburg, Schendel (1986) found the highest ratio for Sn : A of 0.95 : 1. They showed that the upper incisor was a more significant predictor than A point. Using Sn : UIa their ratio decreased to 0.67 : 1. Stella, Streater, Epker, Sinn (1989) reported a ratio at Sn : A of 0.5 : 1 in a thin lip group and 0.3 : 1 in a thick lip group.

The correlation in the thin lip group was excellent and in the thick lip group it was poor. Jensen, Sinclair, Wolford (1992) reported that the base of the nose and the subnasale area have historically been quite unpredictable and they did not show any strong correlations to the hard tissue changes in their study. They believe that this may be due in part to variations in amount of occlusal plane rotation and alar base manipulation or surgical handling of the anterior nasal spine. This finding of the ratio of subnasale to subspinale movement was very close to that described by Freihofer (1976), Araujo, Schendell, Wolford, Epker (1978), Rosen (1988), and Hui, Hagg, Tideman (1994). It was greater than the value found by Proffit and White (1991) of 0.2 : 1 and Mansour, Burstone, Legan (1983) of 0.24 : 1, Hack, de Mol van Otterloo, Nanda (1993) of 0.3 : 1 and well below that of Carlotti, Aschaffenburg, Schendel (1986) of 0.95 : 1.

The superior sulcus followed the upper incisor anterius in the horizontal dimension at a ratio of 0.69 : 1. This was statistically significant at $P \leq 0.0002$. This ratio had the highest coefficient of determination of all the maxillary soft tissue measurements. The ratio was 12 percent greater than at labrale superius which would indicate that the upper lip would become less concave on advancement. The only other authors to have included this measurement in pure maxillary advancement were Mansour, Burstone, Legan (1983). They recorded a ratio of 0.52 : 1. Jensen, Sinclair, Wolford (1992) also showed the greatest amount of movement in the maxillary soft tissue at this point.

Labrale superius followed the upper incisor tip and upper incisor anterius at a ratio of 0.55 : 1 and 0.57 : 1 respectively. Both relationships were statistically significant at $P \leq 0.0067$ and $P \leq 0.0041$ respectively. Previous studies report the ratio to vary from 0.4 to 0.96 : 1. Higher ratios of 1 : 1 have been reported by McCance, Moss, Fright, James, Linney (1992) using computerised scanning tomography. Although advancement surgery was included in their report, no indication of the amount of impaction was stated. There were problems in the interpretation of osseous change when a vertical displacement of the jaws was undertaken. In the cases of maxillary impaction, the osseous change recorded on the colour scale may have suggested marked anterior displacements of the jaws, when little or no advancement actually occurred. Due to these possible inaccuracies, those data were not included in this study.

This large variation in lip response to surgery led Jensen, Sinclair, Wolford (1992) to suggest that soft tissue studies be divided into two groups, a) those using soft tissue manipulation (ie alar base cinch suture and V-Y closure) where a 70 to 90 percent

upper lip response might be anticipated and b) those without any soft tissue manipulation where an upper lip response of 40 to 60 percent could be expected. They believed that the difference between the two groups demonstrated the importance of determining the precise surgical technique that would be used by the surgeon in order to produce an accurate prediction tracing. The subjects in their study were divided into two groups, a thin lip group of 9.5 to 11 mm and a thick lip group of 11.6 to 13.0 mm. Insignificant changes were noted between the two groups with respect to thinning of the lips.

In 1976 Freihofer showed that patients with lips thicker than 19 mm recorded a ratio of movement of labrale superius to upper incisor tip of 0.5 : 1 and in lips thinner than 16 mm a ratio of 0.78 : 1.

Mansour, Burstone and Legan (1983) divided their sample into maxillary advancement without impaction and maxillary advancement with impaction. In the group with maxillary advancement only, the upper lip moved horizontally at a ratio of 0.62 : 1 and in the impaction with advancement group that ratio increased to 0.89 : 1. Although the authors did not divide the groups according to the thickness of lips, they did acknowledge that the greater the area of the upper lip the less would be the horizontal change in the upper lip. There was no alar cinch or V-Y closure used. Rosen (1988) included 12 patients with an average intrusion of six mm in his total sample of thirty advancement cases. There was no V-Y closure or alar cinch surgical procedure. The ratio of upper lip to incisor movement was 0.82 : 1. Upper lip thickness ranged from 7-18 mm with a mean of 13.8 mm. He noted that although it seemed thinner lips had a larger ratio of movement, no statistically significant correlation could be demonstrated using this variable. Stella, Streater, Epker, Sinn (1989), divided their patients into those having thin lips (between 10 and 17 mm thick) and thick lips (greater than 17 mm). Although they did not measure the ratio of movement at labrale superius their measurements at subnasale (as reported above), showed significant differences with regard to the amount of movement between the two groups.

The important question that needed clarification was the relative importance of the surgical V-Y closure and thickness of the lips. In this study the patients were divided into two groups - thick lips greater than 15 mm (ten patients), and thin lips less than 15 mm (sixteen patients). The mean ratio of labrale superius to upper incisor tip was 0.76 : 1 at $P \leq 0.0029$ for thin lips and 0.27 : 1 at $P \leq 0.079$ for thick lips (see TABLE 18). Thin lips advanced 2.8 times that of the thick lip group.

The patients were divided into those who had a V-Y closure procedure (eleven patients) and those who did not (nine patients). The ratio of advancement at labrale superius in the patients who had a V-Y procedure was almost identical to those who did not. With a V-Y procedure the advancement was 0.56 : 1 ($P \leq 0.0737$), and without a V-Y procedure 0.58 : 1 ($P \leq 0.0101$).

In their investigation, Upton, Sadowsky, Sarver and Heaven (1997), found no statistically significant differences in the ratio of movement of soft to hard tissue in the horizontal or vertical plane when comparing a group of subjects who had a V-Y closure of the Le Fort 1 incision with a group who did not have a V-Y closure.

Jensen, Sinclair, Wolford (1992) divided their sample into two groups according to tissue thickness. The thick lip group comprised lips measuring 11.6 to 13 mm and the thin lip group 9.5 to 11 mm. These groupings may have been considered to be part of a single thin lip entity in the present study as the lip thickness was less than 15 mm. The patients in their study underwent predominantly impaction surgery. Rather than nasolabial reconstruction, perhaps tissue thickness and amount of impaction may have had a greater role to play in determining the amount of movement.

In this study, when a V-Y closure was performed the horizontal movement at stomion superius did not behave in exactly the same manner as at labrale superius when compared with the horizontal movement of the upper incisor tip. It moved forward almost 24 percent more when a V-Y closure had been performed. This might indicate that the amount of vermilion exposed was greater with a V-Y closure technique due to the rolling out of the lips.

The ratio of vertical movement of stomion superius to the horizontal movement at the upper incisor tip was 0.10 : 1. It was statistically significant at $P \leq 0.0473$. It measured 0.12 : 1 when a V-Y closure was performed and increased to 0.26 : 1 when no V-Y surgical closure technique was used.

The lower lip (labrale inferius) followed the lower incisor tip in a soft to hard tissue ratio of 0.79 : 1. ($P \leq 0.0000$ and coefficient of determination of 83.32%). This finding was very similar to that of Gardner (1991) who found a ratio of 0.77 : 1. In Gardner's study the P value was ≤ 0.001 and the coefficient of determination 46.92 %.

Syliangco, Sameshima, Kaminishi, Sinclair (1997), stated that despite numerous reported investigations, there are still no acceptable soft to hard tissue ratios for lower lip changes. They recommended that future research should concentrate on understanding the lower lip movements as they relate to hard tissue changes. Upton, Sadowsky, Sarver and Heaven (1997), compared the actual post treatment cephalometric soft tissue profiles with computer predicted soft tissue profiles. The most statistically significant differences were in the horizontal and vertical landmarks associated with the lower lip. The ratio of 0.79 : 1 in this study lies between Talbott's (1975) findings of a proportion of 0.85 : 1 and those of Jensen, Sinclair and Wolford (1992) of 0.72 : 1. It is substantially higher than the observations of Quast, Biggerstaff , Haley, (1983) who found a ratio of 0.38 : 1 and to those of Hernandez-Orsini, Jacobsen, Sarver, Bartolucci (1989) who reported a ratio of 0.43 :1.
The variability in the reported proportional changes at labrale superius and labrale inferius could therefore be due to a number of reasons, among these being :

1 Different thicknesses of the soft tissues.
2 The relaxed, reposed lip position may be difficult to achieve when the cephalometric radiograph is taken (Burstone 1967).
3 Differing musculature patterns and tonicity.
4 Varying facial types.
5 Age related factors.
6 Different cephalostats with different source-subject and subject-film distance.
7 Inadequate sample size.
8 Hard tissue recontouring.
9 Occlusal plane rotation or more than one vector of movement.
10 Patients with cleft lip and palate or congenital syndromes in the sample.
11 Differing soft tissue incisions and closure techniques.
12 Insufficient time (less than four months) to allow the soft tissue oedema to subside (Perhaps a twelve month follow-up radiograph would be more advisable. Wolford 1988).

Soft tissue pogonion followed hard tissue pogonion on a 1 : 1 relationship at a $P \leq 0.000$ and a coefficient of determination of 93.77%. This observation supports the findings of, Lines, Steinhauser (1974), Talbott (1975), Quast, Biggerstaff, Haley (1983), Hernandez-Orsini, Jacobson, Sarver, Bartulucci (1989), Gardener (1991) and Jensen, Sinclair, Wolford (1992).

By including tissue thickness and the method of surgical closure as additional factors in determining the relationships of changes at soft tissue points, levels of predictability were improved. For example the coefficient of determination for the horizontal changes at labrale superius as a result of upper incisor tip movement, improved from 23.76 % to 80.03 %.

This study may have contributed to an improved understanding of the soft to hard tissue ratios following maxillary advancement surgery and thus could be useful in enhancing the accuracy of the prediction techniques. A thorough understanding of the complex correlations between soft and hard tissue responses may enable the clinician to place greater emphasis upon priority planning for the most desirable soft tissue objectives. Further refinement in the concept and practice of VTO planning could depend on more extensive research, particularly taking into account the desirability of a prospective study wherein all appropriate criteria of standardisation could be met. The use of a larger sample would also be appropriate, and may also accommodate age, racial, sexual and other variables.
Prospective studies comparing the effects of a recontoured and unaltered anterior nasal spine on subnasale and anterior nasal tip are required. In addition there is a need to compare the response of the soft tissue to hard tissue ratio when a V-Y closure technique is performed by different surgeons. Long term soft tissue to hard tissue ratios taking into account various factors such as stability of the surgery and orthodontics, ageing, health and weight loss need to be considered.

In the final assessment, soft tissue changes related to maxillary advancements would appear to be fairly predictable. The superior sulcus, lower lip and soft tissue chin reaction to hard tissue movement is highly predictable. The incorporation of a multiple regression equation into the response of upper lip change improves the predictability significantly.

The dramatic changes in facial appearance that may follow certain orthognathic surgical procedures make it essential that clinicians are able to anticipate the changes that will occur in the soft tissues. Predicting the soft and hard tissue changes for patients prior to orthognathic surgery is an essential component of the treatment planning process.

CHAPTER 6 CONCLUSIONS

The findings of this study were :

1 The additional procedure of mandibular surgery did not appear to have a significant influence on the proportional changes between hard and soft tissue movements in patients undergoing surgical maxillary advancements.

2 Changes in the corresponding hard and soft tissue landmarks for the nose, upper lip, lower lip and chin area showed significant correlations for horizontal response. Correlations were also strong in the vertical direction.

3 Anterior nasal tip moved horizontally in a 0.26 : 1 ratio with upper incisor anterius and 0.17 : 1 with subspinale.

4 Subnasale moved horizontally in a 0.52 : 1 ratio with upper incisor anterius and 0.56 : 1 ratio with subspinale.

5 Superior sulcus moved horizontally in a 0.69 : 1 ratio with the upper incisor anterius.

6 Labrale superius moved horizontally in a 0.55 : 1 ratio with upper incisor tip.

7 Labrale inferius moved horizontally in a 0.79 : 1 ratio with lower incisor tip.

8 Soft tissue pogonion moved horizontally in a 1 : 1 ratio with hard tissue pogonion.

9 Stomion superius moved vertically in a 0.1 : 1 ratio when the upper incisor tip was advanced horizontally.

10 Thin lips advanced 2.8 times further than thick lips when measured as a ratio of labrale superius to upper incisor tip in a horizontal direction.

11 Using a V-Y closure technique had very little effect on forecasting horizontal soft tissue changes in the upper lip at labrale superius. However it did allow the lip to roll out by allowing stomion superius to advance by approximately 25 % more than when no V-Y closure was used.

12 Using a V-Y closure technique decreased the amount of lip shortening from 0.26 : 1 to 0.1 : 1.

13 Multiple regression analysis was significantly more accurate than simple regression analysis in defining relationships between changes at certain landmarks.

REFERENCES

Aaronson, S.A. (1967) A cephalometric investigation of the surgical correction of mandibular prognathism. Angle Orthodontics, 37, 251-256.

Araujo, A.; Schendel, S.A.; Wolford, L.M.; Epker, B.N. (1978) Total maxillary advancement with and without bone grafting. Journal of Oral Surgery, 36, 849-858.

Baumrind, S.; Frantz, R.C. (1978) The reliability of head film measurements; 1. Landmark identification. American Journal of Orthodontics, 60, 111-127.

Bell, W.H.; Dann, J.J. (1973) Correction of dentofacial deformities by surgery in the anterior part of the jaws. A study of stability and soft-tissue changes. American Journal of Orthodontics, 64, 162-187.

Bell, W.H. (1975) Le Fort I osteotomy for correction of maxillary deformities. Journal of Oral Surgery, 33, 412-426.

Betts, N.J.; Fonseca, R.J. (1992) Soft tissue changes associated with orthognathic surgery. Modern Practice in Orthognathic and Reconstructive Surgery. Edited by W.H. Bell. W.B. Saunders Company. Volume 3, 2170-2209.

Bibby, R.E.; Preston, C.B. (1981) The hyoid triangle. American Journal of Orthodontics, 80, 92-97.

Bjork, A. (1947) The face in profile. Svenska Tandlak Tid, 40 (supplement 5 B), 32-33.

Bjork, A. (1960) The relationship of the jaws to the cranium. In : Lundstrom A (ed) Introduction to Orthodontics. McGraw - Hill : London. 104-140.

Bland, J.M.; Altman, D.G. (1986) Statistical methods for assessing agreement between two methods of clinical measurement. The Lancet, 307-310.

Bloom, L.A. (1961) Perioral profile changes in orthodontic treatment. American Journal of Orthodontics, 47, 371-379.

Brown, J.B.; McDowell, F. (1951) Plastic Surgery of the Nose. Charles C Thomas : St Louis, 30-38.

Bungaard, M.; Melsen, B.; Terp, S. (1986) Changes during and following total maxillary osteotomy (le Fort I procedure) : a cephalometric study. European Journal of Orthodontics, 8, 21-29.

Burstone, C.J. (1958) The integumental profile. American Journal of Orthodontics, 44, 1-25.

Burstone, C.J. (1959) Integumental contour and extension patterns. Angle Orthodontics, 29, 93-104.

Burstone, C.J. (1967) Lip posture and its significance in treatment planning. American Journal of Orthodontics, 53, 262-284.

Carlotti, A.E. Jr.; Aschaffenburg, P.H.; Schendel, S.A. (1986) Facial Changes Associated with Surgical Advancement of the Lip and Maxilla. Journal of Oral and Maxillo-Facial Surgery, 44, 593-596.

Cheever. (1864). Cited in Maloney, F.; Worthington, P. (1981) The origin of the Le Fort I maxillary osteotomy : Cheever's operation. Journal of Oral Surgery, 39, 731-734.

Dann, J.J.; Fonseca, R.J.; Bell, W. H. (1976) Soft tissue changes associated with total maxillary advancement : a preliminary study. Journal of Oral Surgery, 34, 19-23.

Freihofer, H.P.M. Jr. (1976) The Lip Profile after Correction of Retromaxillism in Cleft and Non-Cleft Patients. Journal of Maxillo-Facial Surgery, 4, 136-141.

Freihofer, H.P.M. Jr. (1977) Changes in Nasal Profile after Maxillary Advancement in Cleft and Non-Cleft Patients. Journal of Maxillo-Facial Surgery, 5, 20-27.

Gardner, G.J.M. (1991) Soft Tissue Changes Related To Mandibular Advancement Surgery. A research report submitted in partial fulfilment of the requirements for the degree of Master of Dentistry in the branch of orthodontics, University of the Witwatersrand, Johannesburg.

Guyman, M; Crosby, D.R; Wolford, L.M. (1988) The alar cinch suture to control nasal width in maxillary osteotomies. International Journal of Adult Orthodontics and Orthognathic Surgery, 3, 89-96.

Houston, W.J.B. (1983) The analysis of errors in orthodontic measurements. American Journal of Orthodontics, 83, 382-390.

Hack, G.A.; de Mol van Otterloo, J.J.; Nanda, R. (1993) Long-term stability and prediction of soft tissue changes after LeFort I surgery. American Journal of Orthodontics and Dentofacial Orthopedics, 104, 544-555.

Hershey, H.G. (1972) Incisor tooth retraction and subsequent profile change in postadolescent female patients. American Journal of Orthodontics, 61, 45-54.

Hillesund, E.; Fjeld, D.; Zachrison, B.U. (1978) Reliability of soft-tissue profile in cephalometrics. American Journal of Orthodontics, 74, 537-550.

Houston, W.J.B. (1983) The analysis of errors in orthodontic measurements. American Journal of Orthodontics, 83, 382-390.

Hui, E.; Hagg, E.U.O.; Tideman, H. (1994) Soft tissue changes following maxillary osteotomies in cleft lip and palate and non-cleft patients. Journal of Cranio-Maxillo-Facial Surgery, 22, 182-186.

Jensen, A.C.; Sinclair, P.M.; Wolford, L.M. (1992) Soft tissue changes associated with double jaw surgery. American Journal of Orthodontics and Dentofacial Orthopaedics, 101, 266-275.

Knowles, C.C. (1965) Changes in the profile following surgical reduction of mandibular prognathism. British Journal of Plastic Surgery, 18, 432-434.

Levene, H. (1960) Robust tests for equality of variance. Contributions to Probability and Statistics, ed 1, Olkin, Palo Alto: Stanford University Press.

Lines, P.A.; Steinhauser, E.W. (1974) Soft tissue changes in relationship to movement of hard structures in orthognathic surgery : a preliminary report. Journal of Oral Surgery, 32, 891-896.

Legan, H.; Burstone, C.J. (1980) Soft tissue cephalometric analysis for orthognathic surgery. Journal of Oral Surgery, 38, 744-751.

Mansour, S.; Burstone, C.; Legan, H. (1983) An evaluation of soft-tissue changes resulting from Le Fort I maxillary surgery. American Journal of Orthodontics, 84, 37-47.

McCance, A.M.; Moss, J.P; Fright W.R.; James, D.R.; Linney, A.D. (1992) A three dimensional analysis of soft and hard tissue changes following bimaxillary orthognathic surgery in skeletal III patients. British Journal Of Oral and Maxillofacial Surgery, 30, 305-312.

Mitgard, J.; Bjork, G.; Linder-Aronson, S. (1974) Reproducibility of cephalometric landmarks and errors of measurements of cephalometric cranial distance. The Angle Orthodontist, 44, 56-62.

Obwegeser, H. (1969) Surgical correction of small or retro-displaced maxillae. Plastic Reconstructive Surgery, 44, 351-356.

Proffit, W.R.; White, R.P. (1991) Surgical - Orthodontic treatment. Mosby Year Book. 170-171.

Proffit, W.R.; Prewitt, J.W.; Turvey, T.A. (1991) Stability after Surgical - Orthodontic correction of skeletal Class III malocclusion. II. Maxillary advancement. International Journal of Adult Orthodontics and Orthognathic surgery, 6, 71-80.

Phillips, C.; Turvey, A.; McMillian, A. (1989) Surgical orthodontic correction of mandibular deficiency by sagittal osteotomy : Clinical and cephalometric analysis of 10 year data. American Journal of Orthodontics and Dentofacial Orthopaedics, 96, 501-506.

Quast, D.C.; Biggerstaff, R.H.; Haley, J.V. (1983) The short term and long term soft-tissue profile changes accompanying mandibular advancement surgery. American Journal of Orthodontics, 84, 29-36.

Radney, L.J.; Jacobs, J.D. (1981) Soft tissue changes and maxillary intrusion. American Journal of Orthodontics, 80, 191-211.

Rosen, H.M. (1988) Lip-nasal aesthetics following Le Fort I osteotomy. Plastic and Reconstructive Surgery, 81, 171-179.

Rudee, D.A. (1964) Proportional profile changes concurrent with orthodontic therapy. American Journal of Orthodontics, 50, 421-434.

Schendel, S.A.; Williamson, L.W. (1983) Muscle reorientation following superior repositioning of the maxilla. Journal of Oral Maxillofacial Surgery, 41, 235-240.

Solow, B.; Tallgren, A. (1976) Head posture and craniofacial morphology. American Journal of Physiology and Anthropology, 44, 417-436.

Stella, J.P.; Streater, M.R.; Epker, B.N.; Sinn, D.P. (1989) Predictability of upper lip soft tissue changes with maxillary advancement. Journal of Oral Maxillofacial Surgery, 47, 697-703.

Syliangco, S.T.; Sameshima, G.T.; Kaminishi, R.M.; Sarver, P.M. (1997) Predicting soft tissue changes in mandibular advancement surgery : A comparison of two video imaging systems. Angle Orthodontics, 67, 337-346.

Subtelny, J.D. (1959) A longitudinal study of the soft tissue facial structures and their profile characteristics, defined in relation to underlying skeletal structures. American Journal of Orthodontics, 45, 481.

Teuscher, U.; Sailer, H.F. (1982) Stability of Le Fort I osteotomy in Class III cases with retropositioned maxillae. Journal of Maxillo-Facial Surgery, 10, 80-83.

Talbott, J.P. (1975) Cited by Quast, D.C.; Biggerstaff, R.H.; Haley, J.V. (1983) The short-term and long-term soft-tissue profile changes accompanying mandibular advancement surgery. American Journal of Orthodontics, 84, 29-36.

Upton, P.M.; Sadowsky, P.L.; Sarver, D.M.; Heaven, T.J. (1997) Evaluation of video imaging prediction in combined maxillary and mandibular orthognathic surgery. American Journal of Orthodontics and Dentofacial Orthopedics, 112, 656-665.

Van der Linden, F.P.G.M. (1971) A study of roentgen-cephalometric bone landmarks. American Journal of Orthodontics, 2, 111-125.

Wassamund, J. (1935) Herbuch der Practischen Chirurgie des Mundes und der Kiefer. Leipsig, Herman Muesser, Volume 1.

Willmar, K. (1974) On Le Fort 1 Osteotomy. Scandinavian Journal of Plastic and Reconstructive Surgery, Supplement 12, 1-68.

Wisth, P.J.; Boe, O.E. (1975) The reliability of cephalometric soft tissue measurements. Archives of Oral Biology, 20, 595-599.

Wolford, L.M.; Hilliard, F.W.; Dugan, D.J. (1985) Surgical treatment objective : a systemic approach to the prediction tracing. St. Louis. CV Mosby.

Wolford, L.M. (1988) Lip-Nasal Aesthetics following Le Fort I Osteotomy - Discussion by Larry M. Wolford. Plastic and Reconstructive Surgery, 81, 180-182.

Worms, F.W.; Isaacson, R.J.; Speidel, T.M. (1976) Surgical orthodontic treatment planning : Profile analysis and mandibular surgery. The Angle Orthodontist, 46, 1-25.

APPENDICES

Appendix A :

Index of abbreviations used in text and tables

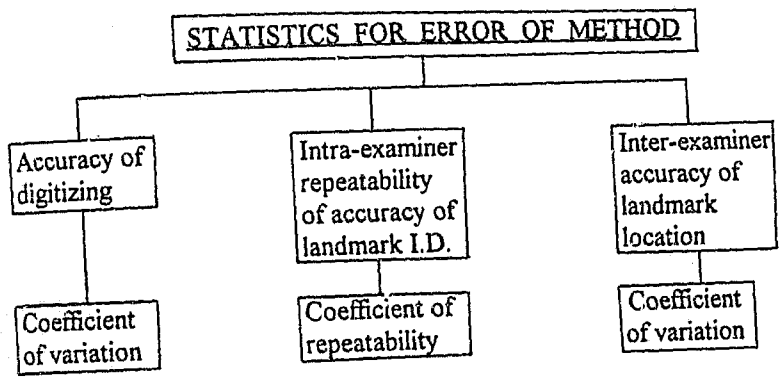
≤	Equal to or less than
Δ	Change
A	Hard tissue subspinale (hard tissue A point)
ANB	Angle between hard tissue A point, Nasion and hard tissue B point
ANS	Anterior nasal spine
ANt	Anterior nasal tip
B	Hard tissue supramentale (hard tissue B point)
CLP	Cleft lip and palate
cm	centimetre
Cm	Columella
C of D	Coefficient of determination
C.V.	Coefficient of variation
df	Degrees of freedom
F	Female
Genio	Genioplasty
Go	Hard tissue gonion
h	Horizontal
HRD	Hard
I.D.	Identification
In	Infradentale
Li	Labrale inferius
LIa	Lower incisor anterior (labial) aspect of crown
LIT	Lower incisor tip
Ls	Labrale superius
M	Male
Max	Maximum
Md. Plane	Mandibular plane
Me	Hard tissue menton
Me'	Soft tissue menton
Min	Minimum

mm	Millimetres
N	Nasion
n	Number
Preop	Pre-surgical
Pog	Hard tissue pogonion
Pog'	Soft tissue pogonion
Postop	Post-surgical
PNS	Posterior nasal spine
r	Pearson correlation coefficient
R	Multiple regression correlation coefficient
Ref	Reference
Rig.F	Rigid fixation
RM	Retro-maxillary
S	Sella
S.D.	Standard deviation
S.E.M.	Standard error of the mean
SFT	Soft
Si	Sulcus inferius
Sn	Subnasale
SNA	Angle between Sella, Nasion and hard tissue A point
SNB	Angle between Sella, Nasion and hard tissue B point
Ss	Superior sulcus
Stm-i	Stomion inferius
Stm-s	Stomion superius
TT	Tissue thickness
UIT	Upper incisor tip
v	Vertical
yrs	Years

Appendix B:

Summary flowchart of statistics used.

1.



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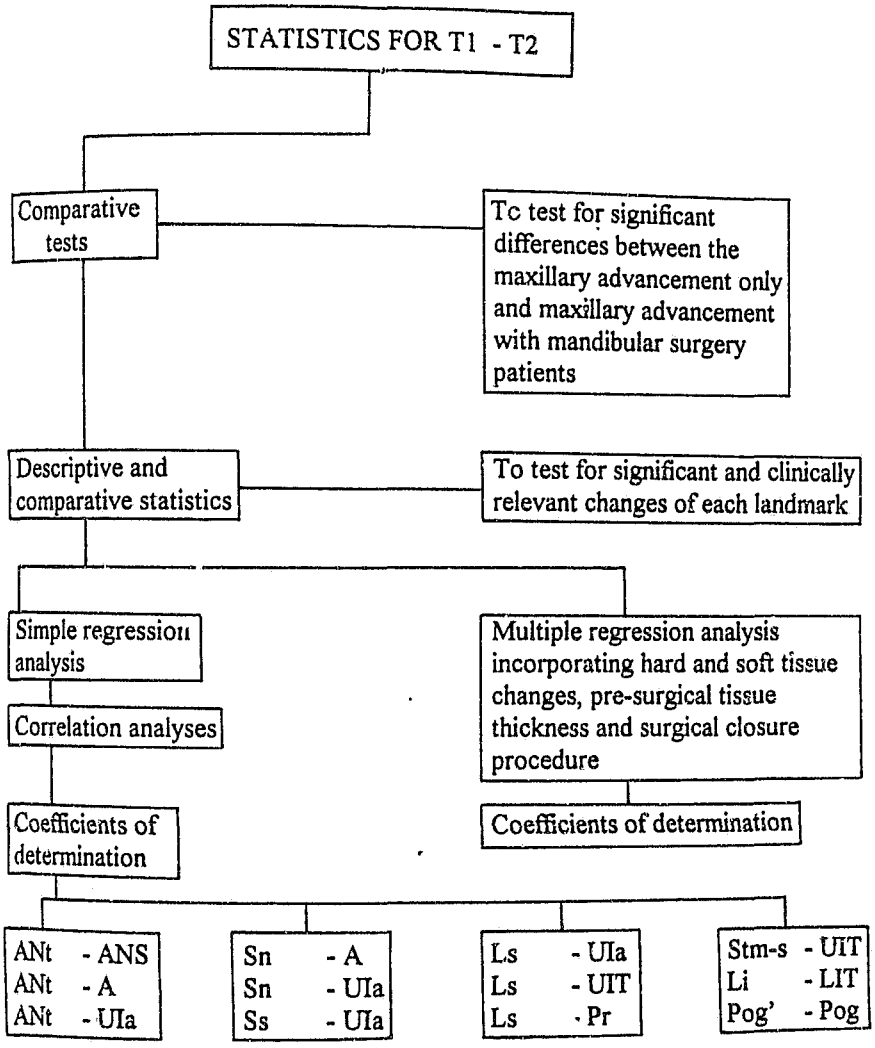
STATISTICS FOR T1 - T2
Comparative tests
Tc test for significant differences between the maxillary advancement only and maxillary advancement with mandibular surgery patients
Descriptive and comparative statistics
To test for significant and clinically relevant changes of each landmark
Simple regression analysis
Correlation analyses
Coefficients of determination
Multiple regression analysis incorporating hard and soft tissue changes, pre-surgical tissue thickness and surgical closure procedure
Coefficients of determination
ANt - ANS
ANt - A
ANt - UIa
Sn - A
Sn - UIa
Ss - UIa
Ls - UIa
Ls - UIT
Ls - Pr
Stm-s - UIT
Li - LIT
Pog' - Pog