SOFT TISSUE PROFILE CHANGES
DUE TO RETRACTION OF MAXILLARY INCISORS

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ABSTRACT

The response of the soft tissue profile to retraction of the maxillary incisors is still a matter of controversy. The purpose of this study was to improve the clinician's ability to predict the soft tissue profile changes due to retraction of the maxillary incisors by quantifying the profile changes and identifying and quantifying the contribution of the most significant factors responsible for these changes.

The cephalometric records of eighty treated female subjects and fifty three untreated female subjects were digitized and analyzed using a stepwise multiple regression analysis. The statistical assessment of the data suggested the following conclusions:

1. In general, only minimal changes in the soft tissue profile took place due to growth itself.
2. Orthodontic tooth movement seemed to influence the soft tissue profile when change due to growth was eliminated.
3. The three most important soft tissue changes which took place in reaction to orthodontic treatment were the retraction of the upper lip, the increase in the lower lip length and the increase in the nasolabial angle. Other soft tissue changes - of little clinical significance - included the retraction of the lower lip, the reduction of the interlabial gap, the increase in the thickness of both the upper and lower lips, the increase

in the soft tissue lower face height and the lower soft tissue component. The length of the upper lip did not increase with either growth or orthodontic treatment.

4. In general, changes in the lower lip in response to orthodontic tooth movement were more predictable than those of the upper lip. The low degree of predictability associated with the upper lip response to orthodontic tooth movement may be due to the complex anatomy of the upper lip which could not be deleted by using the presently available cephalometric techniques, or to other factors unknown at present.

DEDICATION

Some ten years ago in a refugee camp somewhere in the Arab world, I met a Palestinian child. He had just lost his father, mother and two young sisters in an Israeli air raid on the civilian camp.

I still remember him sitting in the corner of a hospital bed, telling me with a sad smile on his little face: "Someday I will be home. Someday I will go back to Palestine. My father could not make it. I will do it myself".

It is to that child and to four millions of his homeless people, this work is dedicated.

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Chapter I

INTRODUCTION

An orthodontist is often confronted with the problem of prediction of soft tissue profile changes that may result from orthodontic treatment. The problem arises due to the fact that the contribution of many of the factors influencing the soft tissue profile are not fully understood. The complexity of the problem is increased in growing individuals where the post treatment soft tissue profile is the result of both growth and orthodontic treatment.

Prediction of soft tissue profile changes becomes very critical in some cases, including:

1. A patient with bimaxillary protrusion where upper and lower lip retraction is the main treatment objective.
2. A patient with an overcrowded dentition and pleasant soft tissue profile where the treatment objective is to correct the dental problem without compromising the soft tissue profile.
3. A patient with an obtuse nasolabial angle and protruded upper anterior teeth where the treatment objective is to correct the dental problem (by retracting the maxillary incisors) without worsening the profile by increasing the nasolabial angle.

The hypothesis postulated here is that the controversy concerning the soft tissue response to orthodontic tooth movement exists because factors other than those traditionally evaluated in previous studies have an influence on the soft tissue response.

This project was designed primarily to improve the clinician's ability to predict the soft tissue profile changes due to retraction of maxillary incisors in growing and adult Caucasian females by identifying the contribution of the most significant factors responsible for such profile changes.

* * *

Chapter II

REVIEW OF THE LITERATURE

Excluding two studies [RAINS and NANDA[61] and LO and HUNTER[48]], the majority of the studies on soft tissue profile changes due to orthodontic treatment either used small samples which prevented either adequate sample segregation or reliable statistical analysis [40,57,8,39,16,3,38,82,46,49,42,70,47,81,56,1], used superimposition techniques that were sometimes questionable[77,57,14,8,69,9,39,16,41,2,84,35,38,82,46,49,42,70,47,50,81,52,1,26], or paid little or no attention to the vertical dimension thus limiting their findings to changes taking place in the antero- posterior direction.[77,40,57,69,39,41,2,84,35,38,82,46,49,70,81,56,26]

Another major problem was the lack of good control samples of untreated subjects to discriminate between the effect of growth and treatment[77,40,57,14,8,69,9,39,16,2,84,35,38,82,46,49,42,70,47,81,56,26]. Most reported findings were a mixture of both growth and treatment changes and although the sample of one study by HERSHEY[41] was comprised of late adolescent subjects, the effect of any possible growth was not investigated.

A fifth problem was the fact that with the exception of some studies [57,14,8,69,9,16,38,48,61,26] the tension in the lips when the cephalometric records were taken was neither controlled nor evaluated.[77,40,39,3,2,84,35,82,46,49,42,70,47,50,81,56,1,26]

Further details concerning these problems are listed in (Table 1) The various superimposition techniques will be evaluated in the discussion chapter. The North American literature provides the most valuable data available at present. All studies included in this literature review used caucasian subjects, except CHANG's [26] study where American-Chinese were used and GARNER's [38] study where the sample was comprised of black subjects.

This literature review will discuss in detail the contribution of hard tissue changes produced by orthodontic treatment on the following soft tissue profile dependent variables:

1. Upper lip retraction.
2. Lower lip retraction.
3. Change in upper lip thickness.
4. Change in lower lip thickness.
5. Change in upper lip length.
6. Change in lower lip length.
7. Change in nasolabial angle.
8. Change in interlabial gap.

* * *

TABLE 1

Studies on soft tissue change due to orthodontic treatment

AUTHOR/ YEAR	STUDY SAMPLE	CONTROL SAMPLE	SUPERIMPOSITION	LIP POSITION AND/ OR TENSION	COMMENT
STONER et al 1956	- 57 consecutively - treated cases - M/F ? - Age : growers	- None	- Sn at Nasion to eliminate growth changes	- No attempt to standardize lip position	- Edgewise, - Raw data not published
HASSTEDT 1956	- 28 treated cases - M/F ? - Age ?	- None	?	?	- Edgewise
O'RIELLY 1957	- 25 treated cases - 8 M/17 F - Growers and adults (9 to 18.4 years)	- None	- N-Pg plane at N (to eliminate growth changes)	- Relaxed	- Edgewise
BLOOM 1961	- 60 treated American whites - 30 M/30 F - Growers : mean 11:6 to 14:10	- None	- (ANS-PNS) plane - Registration point : the projection of (point (A) on this plane	- Relaxed (photographs used)	
BIRSH, HUGGINS 1963	- not clear whether 38 or 70 cases. - M/F ? - Age ?	- None	- (ANS-PNS) plane - Registration point ?	- Relaxed	
RUDEE 1964	- 85 treated cases - 35 M/50 F - Growers : from 6:11 to 22:6	- None	- SN line at N	- "In repose"	
BIRSH, HUGGINS 1966	- 44 Class II div I - M/F ? -Growers : average age 11 yr. 6 mo.	- None	- (ANS-PNS) plane -Registartion point ?	- Relaxed	- Fixed and removable appliances
GRUSSMARK 1968	- 30 treated cases - M/F ? - Growers : average age 11 yr. 10 mo.	- None	- (ANS-PNS) plane - Registration point ?	?	
BRANOFF 1970	- 30 cases - Class I or II,I - All 4|4 4|4 ext. - 13 M/17 F - Growers: mean age 11 yr. 9 mo.	- None	- (ANS-PNS) plane - Registration point ?	- Individuals with strained lip position were eliminated	
HERSHEY 1972	- 36 females - Age > 16 years	- Not required	- (N-Pg) plane at N (to eliminate growth changes)	?	- Good study
ANGELLE 1973	- 36 treated cases - 21 M/15 F - Mean age for males (11:7) females (10:0)	- 16 cases - 5 M/11 F -Ideal occlusion - Mean age males (13:6) females (13:7)	?	- no particular attention to lip posture	- Raw data not published - Only means were presented with no mention of ranges - Very little U, retraction
ANDERSON et al 1973	- 70 treated cases - 27 M/43 F - Age ?	- None	- (N-Pg) plane as (Y) axis and the most labial U/L lip contact point as an origin for (X) axis - Registration point ?	- Lips must be in contact	- raw data not published
WISTH 1974	- 60 males - Normal O.B. - Growers: mean age 11 yr. 6 mo.	- None	- (ANS-PNS) plane - Registration point ?	- ALL subjects with competent lips (with light contact)	
DE LAAT 1974	- 150 treated cases - Males and females - M/F ? - Growers - 60 class I and 90 class II div.	- None	- (N-Pg) plane - Registration point ?	?	- 50 treated with BEGG technique - 50 with RIEDEL technique - 50 with TWEED technique

GARNER 1974	- 16 treated cases - 6 M/10 F - Growers - Age ?	- None	- (N-Pg) plane at N	- Relaxed	- Negro subjects
WARFIELD 1975	- 25 randomly selected with no regard to age/sex - 7 M/18 F - Growers: mean age 12 yr. 8 mo.	- None	- A line connecting a certain cranial base structure (SE) to (PTM) - Registration point ?	?	- Point (SE): intersection of the shadows of the greater wings of the sphenoid with the floor of the anterior cranial fossa
HUGGINS, McBRIDE 1975	- 33 randomly selected cases - 14 M/19 F - Growers: mean age males (13 : 1) females (13 : 0)	- None	- (N-Pg) plane - Registration point ?	?	- OJ from 3 to 12 mm. pretreatment
MADIGAN 1977	- 40 treated cases - 17 M/23 F - Growers: mean age 12 yr. 9 mo.	- None	- (ANS-PNS) plane at ANS	?	
HILL 1977	- 50 treated cases - M/F ? - Growers: mean age 12 yr. 6 mo.	- None	- A line connecting a certain cranial base structure (SE) to (PTM) - Registration point ?	- Lips should be together	- ANB > 4.5 - See WARFIELD for (SE) definition
ROOS 1977	- 30 treated cases - All class II div I - 10 M/20 F - All 4|4 4|4 ext - Growers: mean age 12 yr. 3 mo.	- None	- SN and a perpendicular line to it at (S) - Registration point ?	?	- Edgewise
JACOBS 1978	- 20 treated cases - 11 M/9 F - All class II div I - All 4|4 4|4 ext - Pre-treatment age 11 to 16 years	- None	- S,N,Ba triangle - Registration point ?	?	
MAMANDRAS 1980	- 74 treated cases - 29 M/45 F - Age: growers - Class I and II,I - Ext and non ext	- 28 cases -14 M/14 F - Growers	- SN at S	?	
WALDMAN 1982	- 41 treated cases - 11 M/30 F - Growers - Age between (8:9) and (29:5) - All class II, I	- None	- "PM" (the posterior margin of the maxilla) - Registration point ?	?	
OLIVER 1982	- 40 treated cases - 20 M/20 F - All class II div I - Growers	- None	- (ANS-PNS) plane - Registration point ?	- "Lightly closed lips"	
LO, HUNTER 1982	- 50 treated cases - 25 M/25 F - Class II div I - OJ > 3 mm. - Growers	- 43 cases -25 M/18 F - II div I - OJ > 4mm - Growers	- Best fit of cranial base structures - Registration point : S	- Relaxed	- Good study
RAINS, Nanda 1982	- 30 adult females - Median age 16 yr. 6 mo. - 9 class I and 21 class II div I - 26 ext/ 4 non ext	- Not required	- Best fit of cranial base structures - Registartion point : S	- Relaxed	- Edgewise - 7 degrees reference line used - Good study
ABDEL KADER 1983	- 22 adult males - All class II div I - All 4|4 4|4 ext	- Not required	- (S-N-Pg) triangle at N	?	
CHANG 1983	- 52 treated cases - 26 M/26 F - Growers - All class I - 26 ext/26 non ext	- None	- (N-Pg) plane - Registration point ?	- "Unstrained closed lips"	- Chinese subjects

1. UPPER LIP RETRACTION

A relationship between the retraction of maxillary incisors during orthodontic treatment and the retraction of the upper lip is a well documented finding in the literature. The only study where such relationship could not be established was done by ANGELLE [3] who used a comparatively small sample and did not publish any of his raw data for further evaluation. The fact that his subjects had a very minimal retraction of the maxillary incisors during orthodontic treatment may explain why such a relationship could not be established.

Most studies found a range of (0.7:1) to (3.8:1) incisor retraction to lip retraction ratios. For simplicity, this review will be divided into two parts: The first includes studies where a strong relationship could be found (0.7:1 to 2:1 incisor to lip retraction ratios), while the second includes studies where a moderate relationship could be found (2.5:1 to 3.8:1 incisor to lip retraction ratios).

A. STRONG RELATIONSHIP (Ratio of 0.7:1 to 2:1)

In 1980, MAMANDRAS [50] found a very close relationship between maxillary incisor retraction and lip retraction with a ratio of (0.7:1). However, one might have a reservation about how the changes taking place in the soft tissue profile due to growth itself were eliminated. In addition MAMANDRAS segregated his sample according to both ANGLE's classification and the extraction pattern performed during orthodontic treatment. These parameters have less influence on the soft tissue reaction than the nature and the amount of retraction of anterior teeth. Furthermore, MAMANDRAS' method of eliminating the growth changes was based on the questionable assumption that growth rate is constant and growth direction is linear.

Both O'RIELLY[57] and RAINS and NANDA[61] found a (1.6:1) incisor to lip retraction ratio. The former used a small sample of 25 growing individuals where the changes due to growth alone were not evaluated, while the latter used a sample of 30 randomly selected adult females and found that the rotation of the mandible due to the orthodontic treatment had a greater influence on both upper and lower lip response than incisor movement.

A (2:1) incisor to lip retraction ratio was found by both WARFIELD [82] and WISTH.[84] No attempt to control the growth effect was made in the first study in which a sample of 25 growing subjects was used. The second study, with a larger sample of 60 growing boys where change due to growth was also ignored, showed that in reduction of both small (3-4 mm.) and large (8-10 mm.) overjets the same ratio existed. This finding suggested that the amount of retraction in the maxillary anterior segment was not a significant factor in establishing the ratio.

OLIVER[56], in another study where change due to growth itself was ignored, emphasized the importance of the initial upper lip thickness. He found a significant correlation of hard and soft tissue changes in both sexes when the upper lip was thin (correlation coefficient of 0.9), while no significant correlation was found where the upper lip was thick.

Both BLOOM[14] and HERSHEY[41] found a high correlation coefficient (0.87 and 0.79 respectively) between the change in the position of the most anterior point of the maxillary incisors and the retraction of the upper lip. BLOOM, who used a sample of 60 growing subjects, did not control the effect of growth in his sample, while HERSHEY eliminated the need to control growth by using adult females in his sample.

B. MODERATE RELATIONSHIP (Ratios of 2.5:1 to 3.8:1)

Using a sample of 30 growing subjects where the change due to growth was not evaluated, ROOS[70] found a (2.5:1) incisor to lip retraction ratio. This ratio was somewhat similar to ratios established by RUDEE [69] (2.9:1), MADIGAN[49] (2.82:1) and HILL[39] (2.8:1). None of these studies used any control sample or made an attempt to assess change due to growth itself.

It was interesting to notice that in 17.5 percent of RUDEE's sample the retraction of the maxillary incisors caused the upper lip to protract. There was no attempt made to explain this unexpected finding. Instead, the author concentrated on the fact that the actual amount of forward lip movement was relatively small. RUDEE's findings suggest that factor(s) other than upper incisor retraction may have a role in determining the way the upper lip responds to orthodontic treatment.

GARNER[38] established a (3.6:1) incisor to lip retraction ratio by using a small sample of growing negro subjects where the growth effect was not assessed. He stated that, in some cases, changes happened in the opposite direction (the same observation made by RUDEE) and that although a ratio of (3.6:1) was reported for the total sample, no meaningful ratio can be established.

HUGGINS and McBRIDE[46], using a sample of 33 randomly selected growing male and female subjects found a relationship between the retraction of the upper incisors and the reduction in the prominence of the upper lip only in the females. The authors did not quantify their observations so that no meaningful interpretation of their findings can be made.

A minimal effect of the maxillary incisor retraction on the upper lip retraction was found by WALDMAN[81] in a study where 41 growing individuals were used. WALDAMN established an incisor retraction to lip retraction ratio of (3.8:1).

2. LOWER LIP RETRACTION

Various studies have tried to establish a relationship between the retraction of the lower lip and the lingual movement of maxillary and mandibular anterior teeth in orthodontically treated cases:

A. THE EFFECT OF LINGUAL MOVEMENT OF MAXILLARY ANTERIORS ON THE RETRACTION OF THE LOWER LIP:

A relationship between the lingual movement of maxillary anterior teeth and the retraction of the lower lip was established in the majority of the studies available in the literature. The range in which such a relationship existed, however, differed sharply.

In 1956, HASSTEDT[40] using a sample of 28 orthodontically treated individuals of unspecified age or sex found that movement of the maxillary incisors had very little effect on lower lip retraction (correlation coefficient of 0.268), while RUDEE[69] who used a sample of 85 subjects where the growth effect was not assessed found a (1:1) ratio which made him believe that the lower lip is supported by the maxillary incisors to a great extent.

Between these extremes were the findings of ROOS[70] who noticed, without introducing any specific ratio, a retraction of the lower lip due to the lingual movement of maxillary incisor. He emphasized that such a relationships was of lesser degree if compared to the upper lip retraction. HERSHEY[41] who also declined to mention any specific ratio, seemed to be in agreement with ROOS' findings.

In 1961, BLOOM[14] found a correlation coefficient of ($r=0.82$) between the lingual movement of maxillary incisor and the retraction of lower lip. MAMANDRAS[50], using a sample of 74 growing individuals where changes due to growth itself were assessed showed that the lower lip was partially affected by the retraction of maxillary incisors. MAMANDRAS established a (3:1) maxillary incisor to lower lip retraction ratio.

ANDERSON et al[2] investigated the effect of the amount of the initial overjet on the relationship between maxillary incisor retraction and lower lip retraction. They found that the sample of small overjet (OJ < 3 mm.) showed a higher correlation between maxillary incisor lingual movement and lower lip retraction by comparison to another sample of subjects with large overjet (OJ > 4mm.).

In a well controlled study where a sample of 30 orthodontically treated adult females was used, RAINS and NANDA[61] stated that the lower lip was influenced to a higher degree both horizontally and vertically by the change of mandible location through rotation of the mandible. The authors did not specify whether this rotation was in the clockwise or in the counterclockwise direction.

B. THE EFFECT OF LINGUAL MOVEMENT OF MANDIBULAR ANTERIORS ON THE RETRACTION OF THE LOWER LIP:

A relationship between the lingual movement of mandibular anterior teeth and the retraction of the lower lip has been well established but again with a wide range of variation.

GARNER[38], using a small sample of negro subjects found a (1:1) mandibular incisor retraction to lower lip retraction ratio. This ratio was in agreement with the findings of HASSTEDT[40] who described the relationship as "strong" without introducing any specific ratio. BLOOM's [14] findings also agreed with those of GARNER and HASSTEDT as he found a correlation coefficient of 0.93.

Both O'RIELLY[57] and RUDEE[69] established an (0.6:1) mandibular incisor retraction to lower lip retraction ratio. On the other hand, MAMANDRAS[50] and RAINS and NANDA[61] found no significant correlation between the lingual movement of the mandibular incisors and the retraction of the lower lip. The fact that O'RIELLY and RUDEE did not control the effect of growth in their sample while MAMANDRAS and RAINS and NANDA did, suggests that what O'RIELLY and RUDEE thought to be a "labial protrusion of the lower lip due to mandibular incisor retraction" was simply a situation where the protrusion of the lower lip due to growth itself was greater than the retraction of the lip due to the lingual movement of the mandibular incisors, or that something more important than retraction of the lower incisors was influencing the retraction of the lower lip.

3. CHANGE IN UPPER LIP THICKNESS

All studies that reported on the change in the upper lip thickness agreed that the thickness of the upper lip increases with incisor retraction[40 2 3 84 82 70 42 50 48] except LO and HUNTER[48] who described the relationship between the lip thickness increase and the incisor retraction as "insignificant". Both ANDERSON et al[2] and HILL[42] established a (1:1.5) upper lip thickness increase to maxillary incisor retraction ratio.

Without providing any specific ranges, HASSTEDT[40] stated that the more the orthodontist retracts the maxillary incisors, the stronger would be the tendency to increase the upper lip thickness. On the other hand, WISTH [84] found that the amount of maxillary incisor retraction was not significant in affecting the increase of the upper lip thickness. The increase of the upper lip thickness in reaction to maxillary incisor retraction was similar in both samples with small (3-4 mm.) and large (8-10 mm) overjets.

4. CHANGE IN LOWER LIP THICKNESS

The literature showed no agreement among researchers concerning this point. ANDERSON et al[2] stated that the lower lip thickness was not affected by mandibular incisor movement in orthodontically treated subjects.

WISTH[84] found an increase in lower lip thickness in both his groups (small and large overjet), while WARFIELD[82], ROOS[70], and LO and HUNTER[48] found a decrease in lower lip thickness with lower incisor retraction.

5. CHANGE IN UPPER LIP LENGTH

There is agreement that the upper lip increases in length with maxillary incisor retraction[3 61]. ANGELLE[3] stated that he found this tendency in both treated and control groups without elaborating his statement or publishing any raw data for further investigation.

RAINS and NANDA[61] found that Stomion Superius descended by an average of 0.3 mm. in their 30 adult female sample. However, There was no attempt by the authors to explain why Stomion Superius experienced a range of movement from 1.5 mm. superiorly to 0.4 mm. inferiorly.

6. CHANGE IN LOWER LIP LENGTH

An interpretation of RAINS and NANDA's[61] findings showed that the length of the lower lip increased by an average of 0.6 mm. due to lower incisor retraction. Again there was no attempt to explain why Stomion Inferius experienced a wide range of movement from 0.3 mm. inferiorly to 0.5 mm. superiorly.

7. CHANGES IN THE NASOLABIAL ANGLE:

There are only two studies in the literature which investigated the change in the nasolabial angle due to orthodontic treatment. WALDMAN's [81] study showed no significant correlation between the horizontal movement of the incisal edge of maxillary incisor and the change of the angle, or between the lingual movement of "Labrale Superius" and the change of the angle.

LO and HUNTER [48] who used a well controlled sample of 95 growing individuals where the change due to growth was evaluated showed that the nasolabial angle, which did not change as a result of growth itself between 9 and 16 years of age, increased significantly with retraction of maxillary incisal edges (by a ratio of 1.6 degrees for each 1 mm.), increase of lower face height (ANS-Me) (by a ratio of 2.2 degrees for each 1 mm.) and increase in Frankfort Mandibular plane angle (by a 3:1 ratio).

8. CHANGE IN THE INTERLABIAL GAP:

In a study which used a small sample of 20 growing individuals, JACOBS [47] stated that the interlabial gap decreased at a ratio of 1 mm. for every 2 mm. of maxillary incisal edge horizontal retraction when there was no intrusion or extrusion of the maxillary anterior teeth during retraction. He also found that the interlabial gap decreased more quickly when the maxillary incisal edges were intruded and less quickly when they were extruded. Unfortunately, RAINS and NANDA [61] did not evaluate directly this point, but an analysis of their findings seems to be in agreement with JACOBS' findings (Stomion superius descended while Stomion inferius ascended).

ABDEL KADER[1], in a study which used a sample of 22 adult males, stated that the vertical distance between Labrale Superius and Labrale Inferius increased in response to incisor retraction. The author, however, did not postulate as to the reason for this finding but emphasize that this increase was not statistically significant.

*   *   *

Chapter III

MATERIALS AND METHODS

The present investigation was carried out on 133 caucasian females. The study sample comprised 80 subjects who had undergone orthodontic treatment in a private orthodontic office in Winnipeg. The control sample comprised the remaining 53 subjects who had no orthodontic treatment and were obtained from the Burlington Growth Center serial sample. [1]

The subjects of both the study and the control samples were divided into smaller subgroups according to age. Due to difficulties in matching control to experimental subjects, each control subgroup was proportionally smaller than its equivalent study group (maximum of 20 percent). The size and the mean age of the initial radiograph of each subgroup in both samples are listed in (Table 2)

1. The study sample

All 80 subjects used in this sample were caucasian females with class II division I malocclusions treated with multibanded edgewise appliances. The mean for the treatment period was 27 months for growing subjects (a range of 21 to 36 months) and 30.1 months for adult subjects (a range of 21 to 36 months). Ten subjects were treated on a non extraction basis. In the remaining seventy, various teeth were ex-

[1] Courtesy of the Burlington Growth Centre, Clinical Science Division, Faculty of Dentistry, The University of Toronto, Canada.

TABLE 2

The study and control samples

AGE** (YRS.)	THE STUDY SAMPLE		THE CONTROL SAMPLE	
	NUMBER OF SUBJECTS	MEAN AGE	NUMBER OF SUBJECTS	MEAN AGE
10-12	25	10 yr 8 mo	20	11 yr 0 mo
12-14	20	12 yr 4 mo	16	12 yr 5 mo
14-16	13	14 yr 5 mo	11	14 yr 9 mo
16-18	07	16 yr 3 mo	06	16 yr 6 mo
18 and older	15	27 yr 3 mo	00	--
TOTAL	80	--	53	--

** Pre treatment age in the study sample and the age when the first set of records is taken in the control sample.

TABLE 3

Age, treatment procedures and mean treatment period of the study sample

SUB-GROUP	NO. OF SUBJECTS	AGE (YRS.)		MEAN TX. PERIOD (mo)	TREATMENT			
		PRE TREATMENT	POST TREATMENT		4|4 4|4 EXT.	4|4 EXT	OTHER EXT.	NON EXT.
1	25	10-12	12-14	27.0	14	8	0	3
2	20	12-14	14-16	27.0	07	8	2	3
3	13	14-16	16-18	26.5	04	2	3	4
4	07	16-18	18-20	27.0	03	2	2	0
5	15	18-39	20-41	30.1	03	8	4	0

tracted as shown in (Table 3). Both extraction and non extraction subjects had a minimum amount of 3 mm. maxillary incisal edge retraction at treatment completion.

The cephalometric records of each experimental subject were taken with a MOSS CORPORATION cephalometer in which the focal spot - midsagittal plane distance was 152.4 cm. and the midsagittal plane - film distance was 15 cm. The enlargement of the cephalometric radiographs was 9.84 percent (Appendix 1). An appropriate correction for this magnification was performed during the process of analysis by incorporating this percentage into each linear measurement using a computer program.

Pre treatment and post treatment lateral cephalographs used in this study were taken with natural head position and relaxed lip posture. The operators attempted to carefully place the subjects with the Frankfort plane as horizontally oriented as possible. The lip posture was carefully evaluated by the author who compared the lateral cephalographs to photographic records. Any subject who appeared to have an abnormal head posture or tension in the lip area was discarded. None of the subjects had any appliance in the mouth at the time the lateral cephalographs were taken.

The growth pattern of each subject in the study sample was evaluated by using the following formula:

$$\boxed{\frac{\text{Vertical change of landmark (Menton) during treatment}}{\text{Horizontal change of landmark (Pogonion) during treatment}}}$$

The growth pattern was considered "VERTICAL" when the above ratio was equal to or greater than 1.5, "HORIZONTAL" when it was equal to or less than 0.5 and "NORMAL" when it was less than 1.5 and greater than 0.5.

2. The control sample

In order to evaluate changes due to growth itself, an untreated sample of 53 caucasin females was selected from the files of the Burlington Growth Centre on the basis of age and skeletal pattern using the upper face height (N-ANS), the lower face height (ANS-Me) and the anteroposterior locations of landmarks "Subspinale" (A) and "supramentale" (B) as parameters.

Although only 18 subjects in the control sample had class II division I malocclusion while the remaining 35 had class I occlusion, each one of these subjects was carefully matched to a subject of a similar age in the study group using all four parameters with a range not exceeding (± 1.5 mm.) for each parameter.

None of the adult subjects in the study sample was matched by an untreated subject since it is accepted that changes due to growth itself in females aged 18 years and older are minimal, and therefore any alteration in the soft tissue proofile of these adult females is due to orthodontic treatment.

With the exception of three subjects who had lingual arch space maintainers for a short period of time during their childhood, none of the control subjects had any orthodontic treatment.

The cephlometric radiographs of each control subject were taken with a WHEMER cephalometer of the same focal spot - midsagittal plane and midsagittal plane - film distances as used in the study group. Therefore, the enlargement of the control cephalometric radiographs was also 9.84 percent. An appropriate correction for this magnification was performed using the same computer program mentioned earlier.

The two lateral cephalographs used for every control subject were taken with relaxed lip posture. The author compared these cephalographs to photographic records. Any subject who appeared to have an abnormal head posture or tension in the lip area was discarded. None of the subjects had any appliance in the mouth at the time the lateral cephalographs were taken.

3. Cephalometric assessment

The first and second lateral cephalographs were traced for each one of the 133 subjects on one piece of 0.003 acetate paper (8X10 inches) with 0.5 mm. black and red mechanical pencil leads respectively. Both cephalographs were traced at the same sitting in a dark room in order to minimize tracing errors. The tracing sequence was as follow:

1. The facial and cranial base structures and the two reference lines of the first cephalograph were traced in black.
2. The tracing of the first cephalograph was superimposed on the second cephalograph using the best fit of the cranial base, and registered at landmark Sella (S).
3. The facial structures of the second cephalograph were then traced on the same sheet of tracing paper in red.

The two reference lines that were used were as follows (Figure 1):

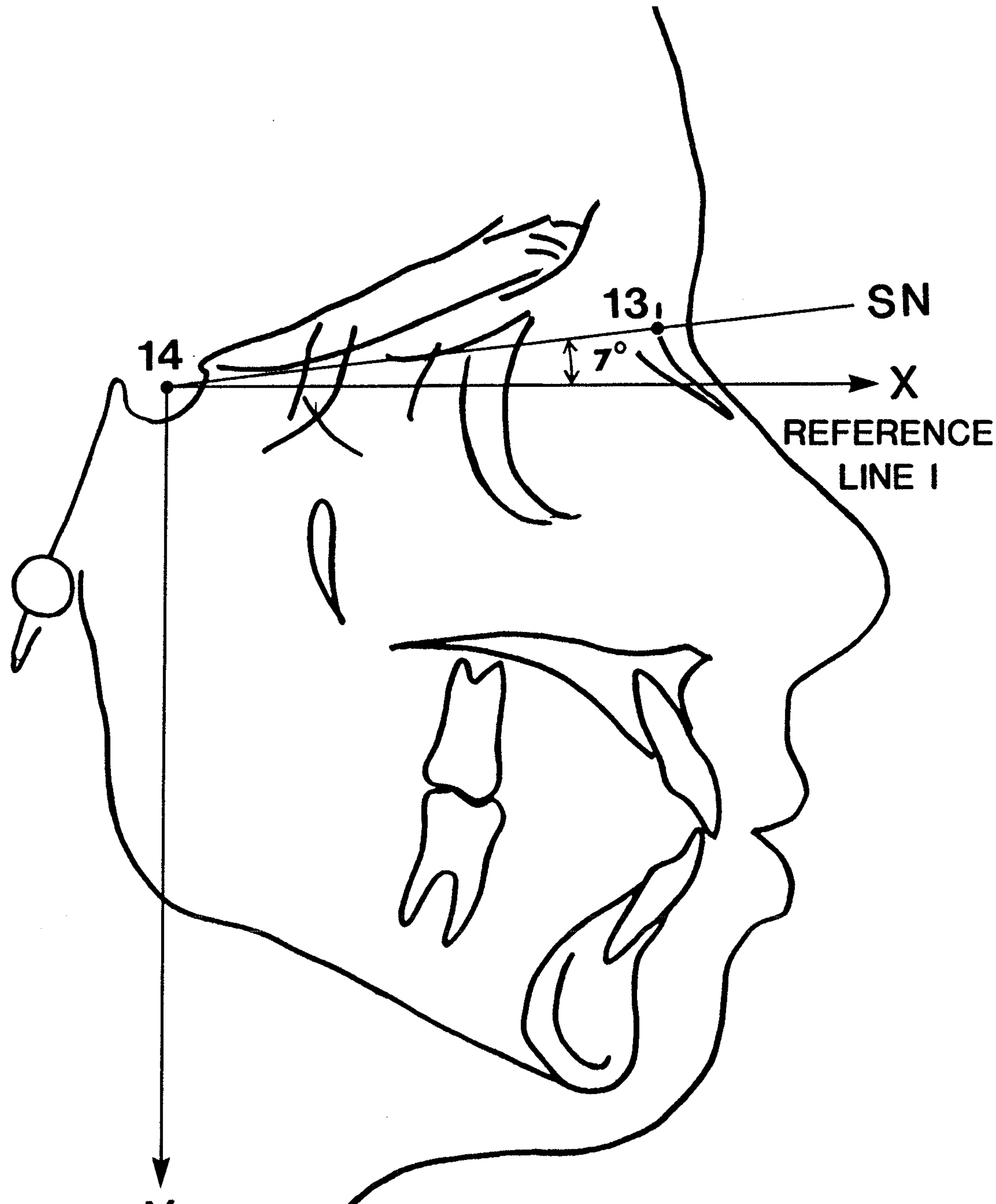


Figure-1: THE TWO REFERENCE LINES

<u>Reference line I (X axis):</u>

A line drawn from landmark "Sella" on the pre treatment cephalograph at 7 degrees inferior to the original Sella-Nasion line. Superior-inferior locations of skeletal, dental and soft tissue landmarks and vertical measurements are all done perpendicular to this reference line.

<u>Reference line II (Y axis):</u>

A line drawn from landmark "Sella" on the pre treatment cephalograph at 90 degrees to reference line I. Antero-posterior and labio-lingual locations of skeletal, dental and soft tissue landmarks and horizontal measurements are all done perpendicular to this reference line.

"Reference line I" was used so that all measurements are made in relation to Frankfort horizontal plane since it has been previously shown that an average angle of 7 degrees exists between SN and FH planes([25]).

Thirty dental, skeletal and soft tissue landmarks were used in this study. All midsagittal plane landmarks were defined according to their appearance on the lateral cephalograph and relative to the reference line I or II. All bilateral landmarks were mid-planed and defined according to their apparent location on the lateral cephalograph and relative to the reference line I or II.(Figures 2, 3, appendix 2)

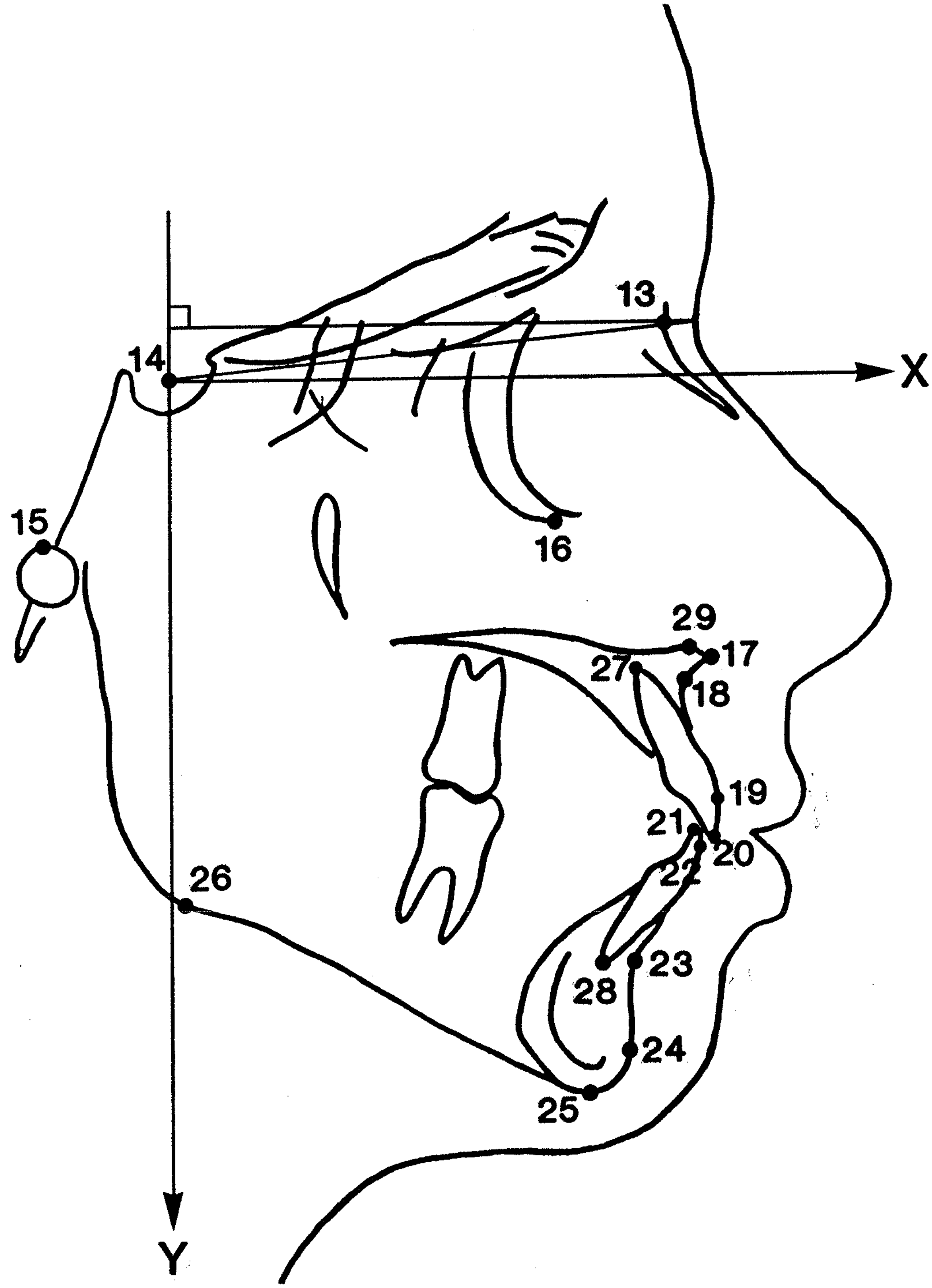
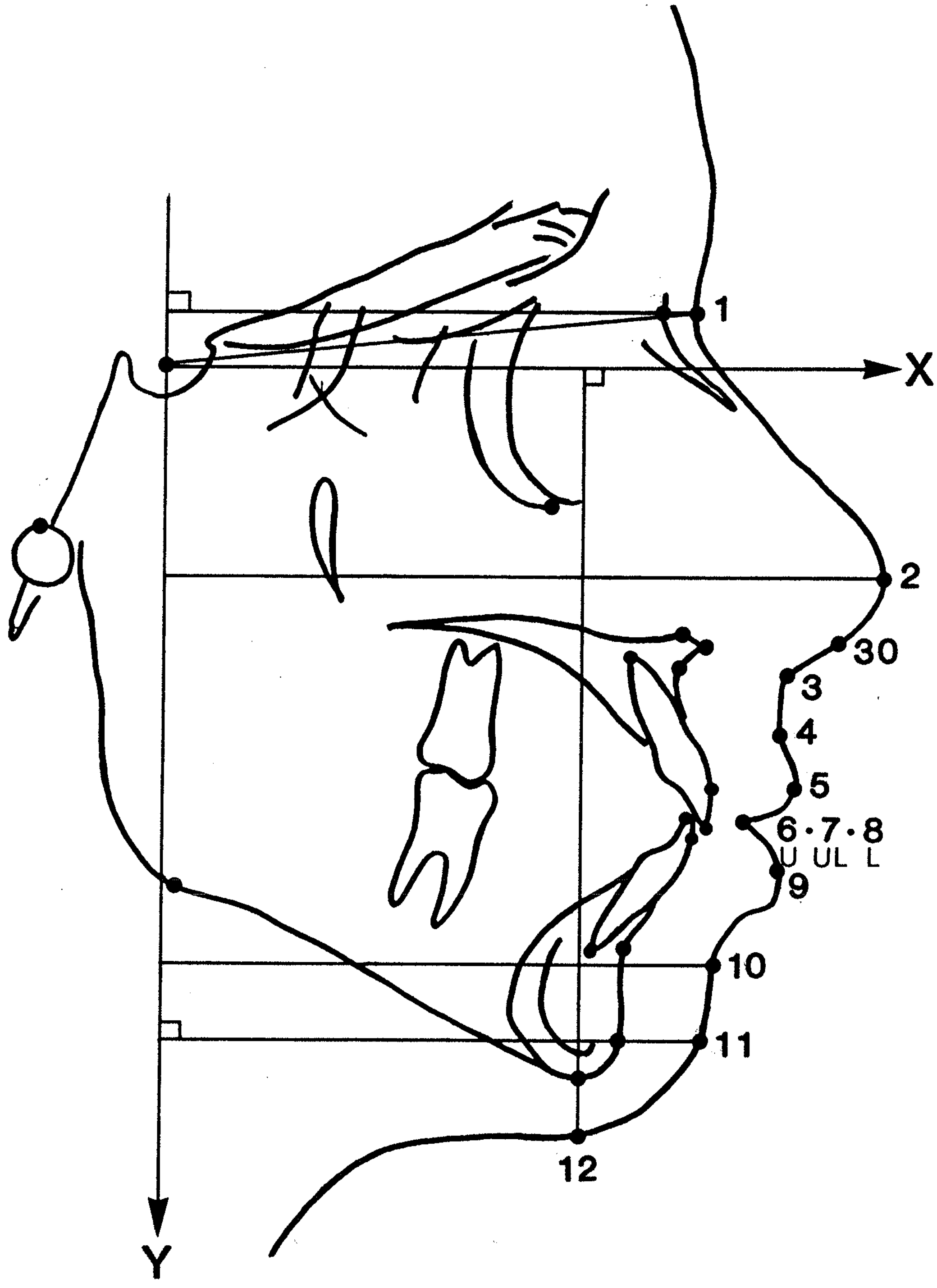


Figure-2: THE HARD TISSUE LANDMARKS



Figure–3: THE SOFT TISSUE LANDMARKS

NOTICE/AVIS

PAGE(~~S~~) 26 IS/~~ARE~~ EST/~~SONT~~ Colour photo

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4. The computer work

An "Apple Graphics Tablets" digitizer was used to digitize all landmarks (Fig -4). The numerical data was stored on floppy disks and then transfered by ASC11 EXPRESS into the University of Manitoba main-frame computer (AMDAHL) where the linear and angular measurements (all demonstrated in Figure -5) were computed, analyzed and stored using a coordinate analysis computer program. [2]

Figure 4: THE COMPUTER EQUIPEMENT

---

[2] General coordinate analysis program by F. CHEBIB, Dept. of Biostatistics, Faculty of Dentistry, The University of Manitoba, Canada.

Figure -5: Demonstration of all dependent and independent variables

INDEPENDENT VARIABLES: SKELETAL

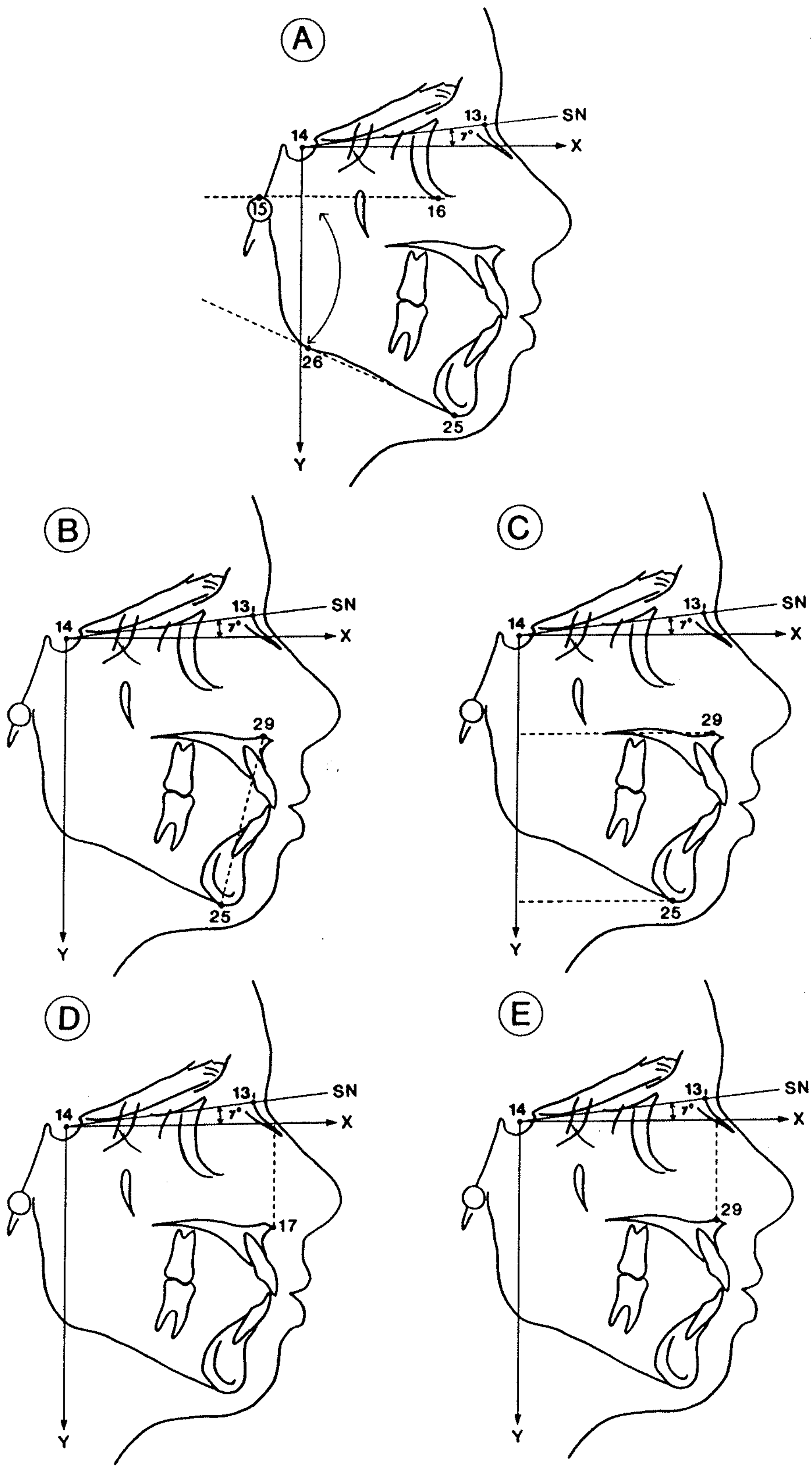
A. Initial size of FMA angle: (Angle 16-15-26-25)

B. Initial size of anterior LFH (direct): (direct measurement between 29 and 25)

C. Initial size of anterior LFH (indirect): (Y25)-(Y29)

D. ANS antero-posterior location (anatomical): (X17)

E. ANS antero-posterior location (structural): (X29)


A
14
13
SN
7°
X
15
16
26
25
Y
B
14
13
SN
7°
X
29
25
Y
C
14
13
SN
7°
X
29
25
Y
D
14
13
SN
7°
X
17
Y
E
14
13
SN
7°
X
29
Y

INDEPENDENT VARIABLES: DENTAL

A. Initial overbite:
(Y20)-(Y21)

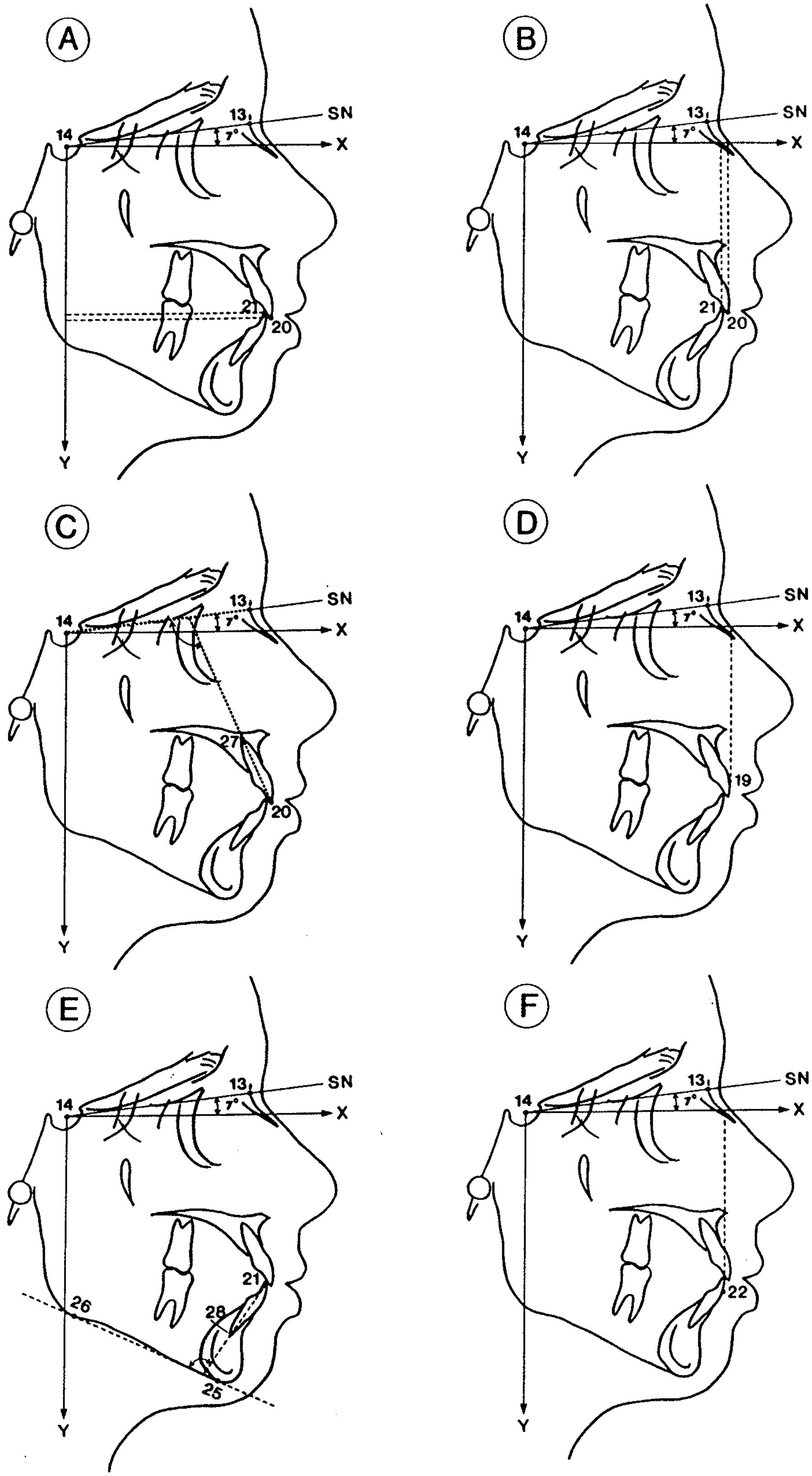
B. Initial overjet:
(X20)-(X21)

C. Initial Ul inclination:
(Angle 20-27-13-14)

D. Initial location of Ul (A-P)
(X19)

E. Initial Ll inclination:
(Angle 21-28-25-26)

F. Initial location of Ll (A-P):
(X22)


A
14
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SN
7°
X
Y
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B
14
13
SN
7°
X
Y
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C
14
13
SN
7°
X
Y
27
20
D
14
13
SN
7°
X
Y
19
E
14
13
SN
7°
X
Y
21
26
28
25
F
14
13
SN
7°
X
Y
22

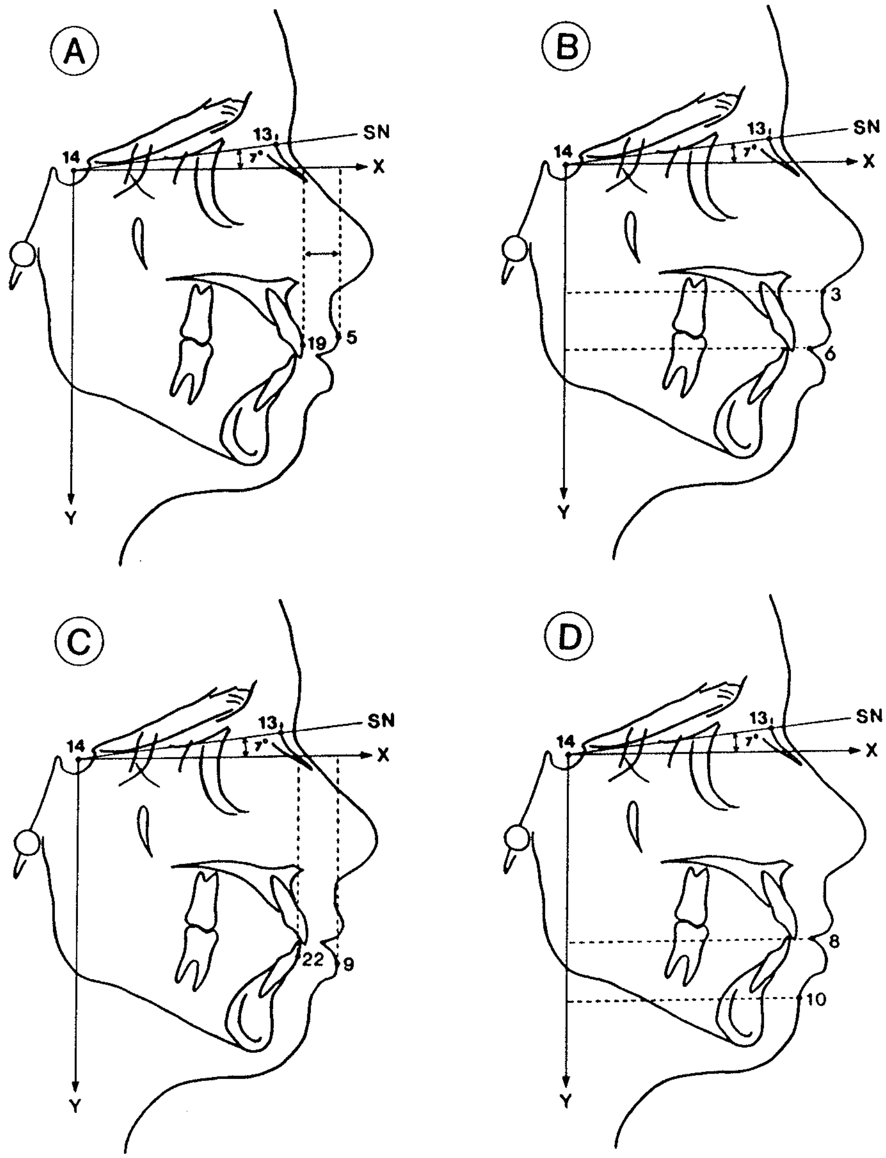
INDEPENDENT VARIABLES: SOFT-TISSUE

A. Initial U/lip thickness:
(X5)-(X19)

B. Initial U/lip length:
(Y6)-(Y3)

C. Initial L/lip thickness:
(X9)-(x22)

D. Initial L/lip length:
(Y10)-(Y8)


A
14
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SN
7°
X
Y
19
5
B
14
13
SN
7°
X
Y
3
6
C
14
13
SN
7°
X
Y
22
9
D
14
13
SN
7°
X
Y
8
10

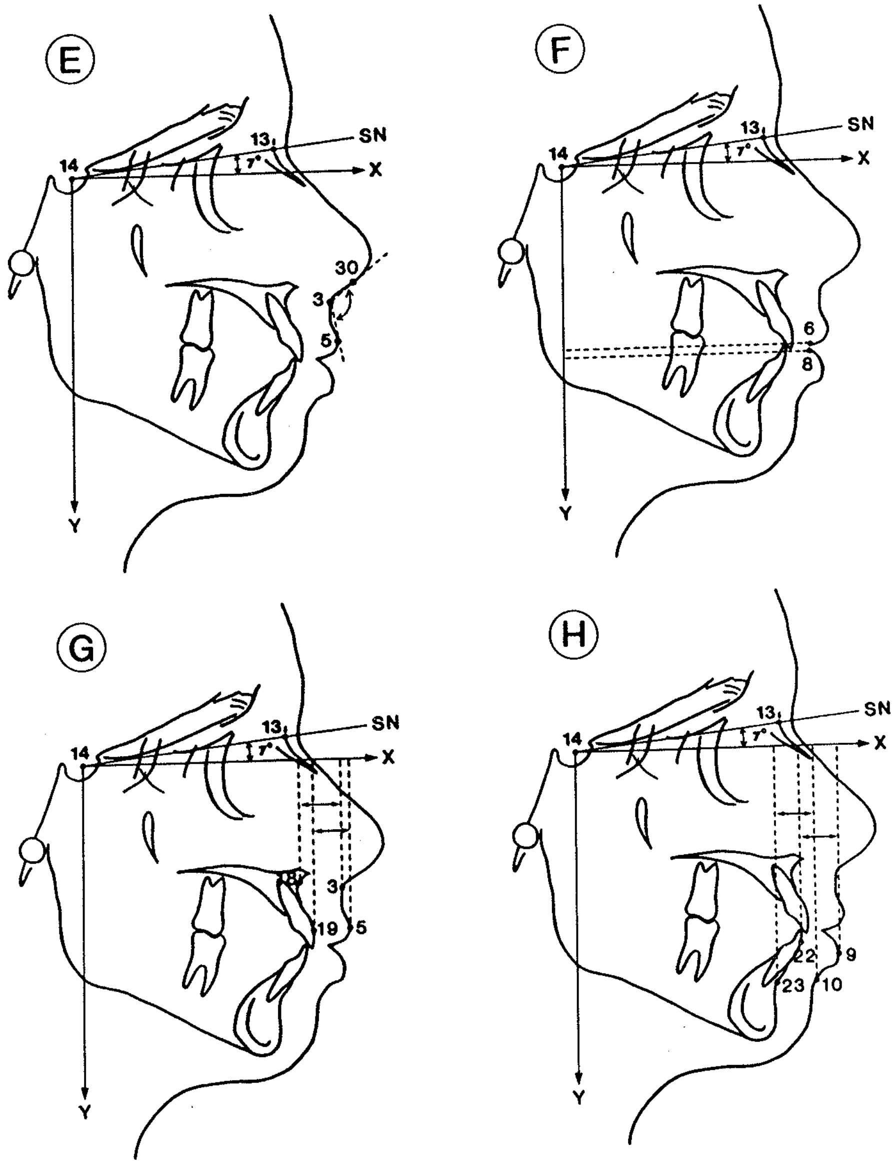
INDEPENDENT VARIABLES: SOFT-TISSUE (Contd.)

E. Initial nasolabial angle:
(Angle 30-3-5)

F. Initial interlabial gap:
(Y8)-(Y6)

G. Initial U/lip taper:
[(X3)-(X18)]/[(X5)-(X19)]

H. Initial L/lip taper:
[(X9)-(X22)]/[(X10)-(X23)]


E
13
SN
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7°
X
30
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5
Y
F
13
SN
14
7°
X
6
8
Y
G
13
SN
14
7°
X
3
19
5
Y
H
13
SN
14
7°
X
22
9
23
10
Y

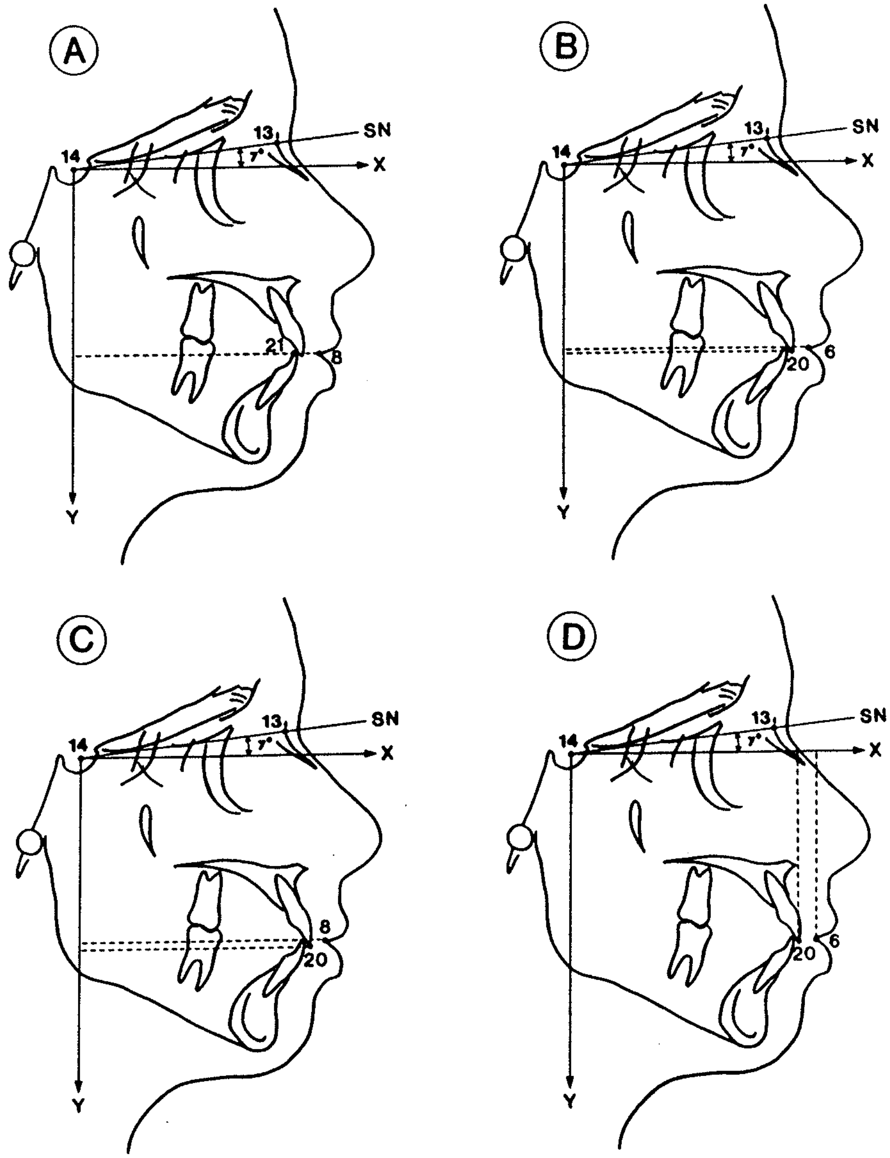
INDEPENDENT VARIABLES: DENTAL-SOFT TISSUE

A. Initial L1-lower lip relationship (Vertical): (Y8)-(Y21)

B. Initial U1-upper lip relationship (Vertical): (Y20)-(Y6)

C. Initial U1-lower lip relationship (Vertical): (Y8)-(Y20)

D. Initial U1-upper lip relationship (A-P): (X6)-(X20)


A
B
C
D
14
13
SN
X
Y
7°
21
8
20
6

INDEPENDENT VARIABLES: MECHANO THERAPY

A. U1 incisal edge movement (A-P):
(X20)-(X50)

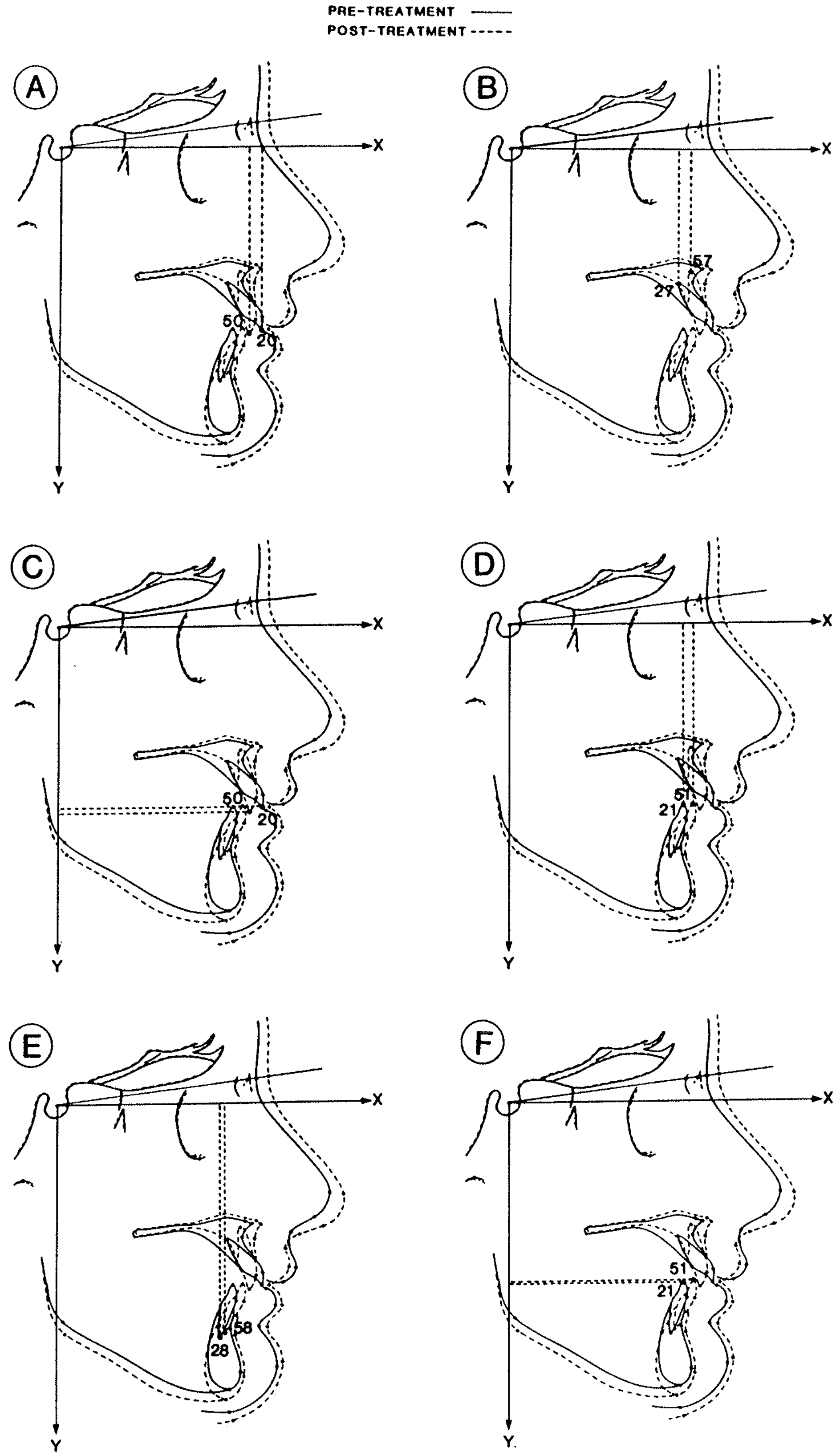
B. U1 root apex movement (A-P):
(X27)-(X57)

C. U1 incisal edge movement (Vertical):
(Y20)-(Y50)

D. L1 incisal edge movement (A-P):
(X21)-(X51)

E. L1 root apex movement (A-P):
(X28)-(X58)

F. L1 incisal edge movement (Vertical):
(Y21)-(Y51)



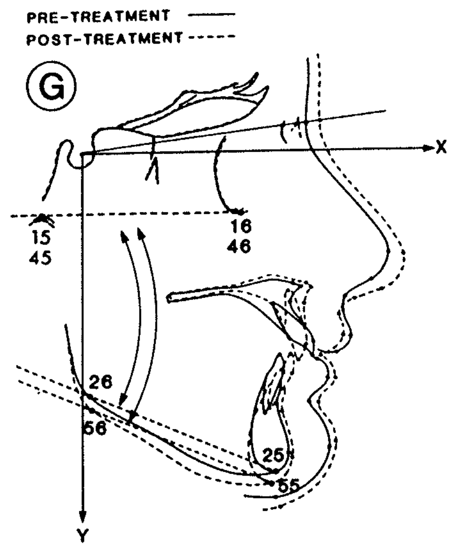
PRE-TREATMENT
POST-TREATMENT
A
X
Y
50
20
B
X
Y
57
27
C
X
Y
50
20
D
X
Y
51
21
E
X
Y
58
28
F
X
Y
51
21

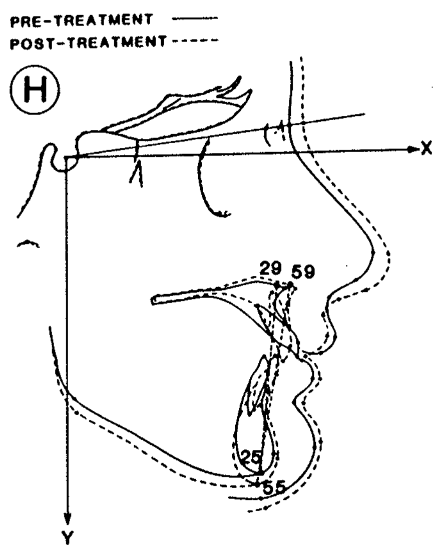
INDEPENDENT VARIABLES: MECHANO THERAPY (Contd.)

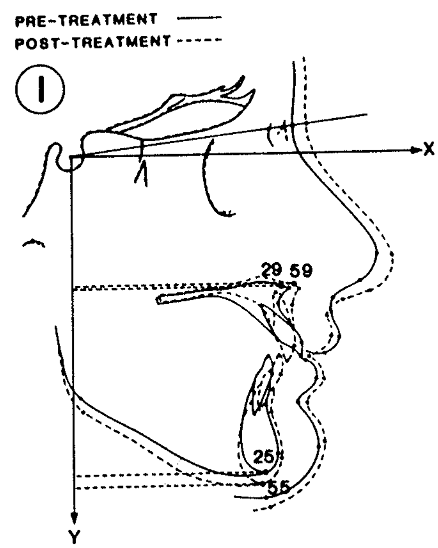
G. Change in FMA angle:
(Angle 16-15-26-25)-(Angle 46-45-56-55)

H. Change in anterior LFH (direct):
(Distance 29,25)-(distance 59,55)

I. Change in anterior LFH (indirect):
[(Y55)-(Y59)]-[(Y25)-(Y29)]


PRE-TREATMENT
POST-TREATMENT
G
X
Y
15
45
16
46
26
56
25
55


PRE-TREATMENT
POST-TREATMENT
H
X
Y
29 59
25
55


PRE-TREATMENT
POST-TREATMENT
I
X
Y
29 59
25
55

INDEPENDENT VARIABLES: NASAL

A. Initial nasal component (direct):
(direct measurement between 1 and 3)

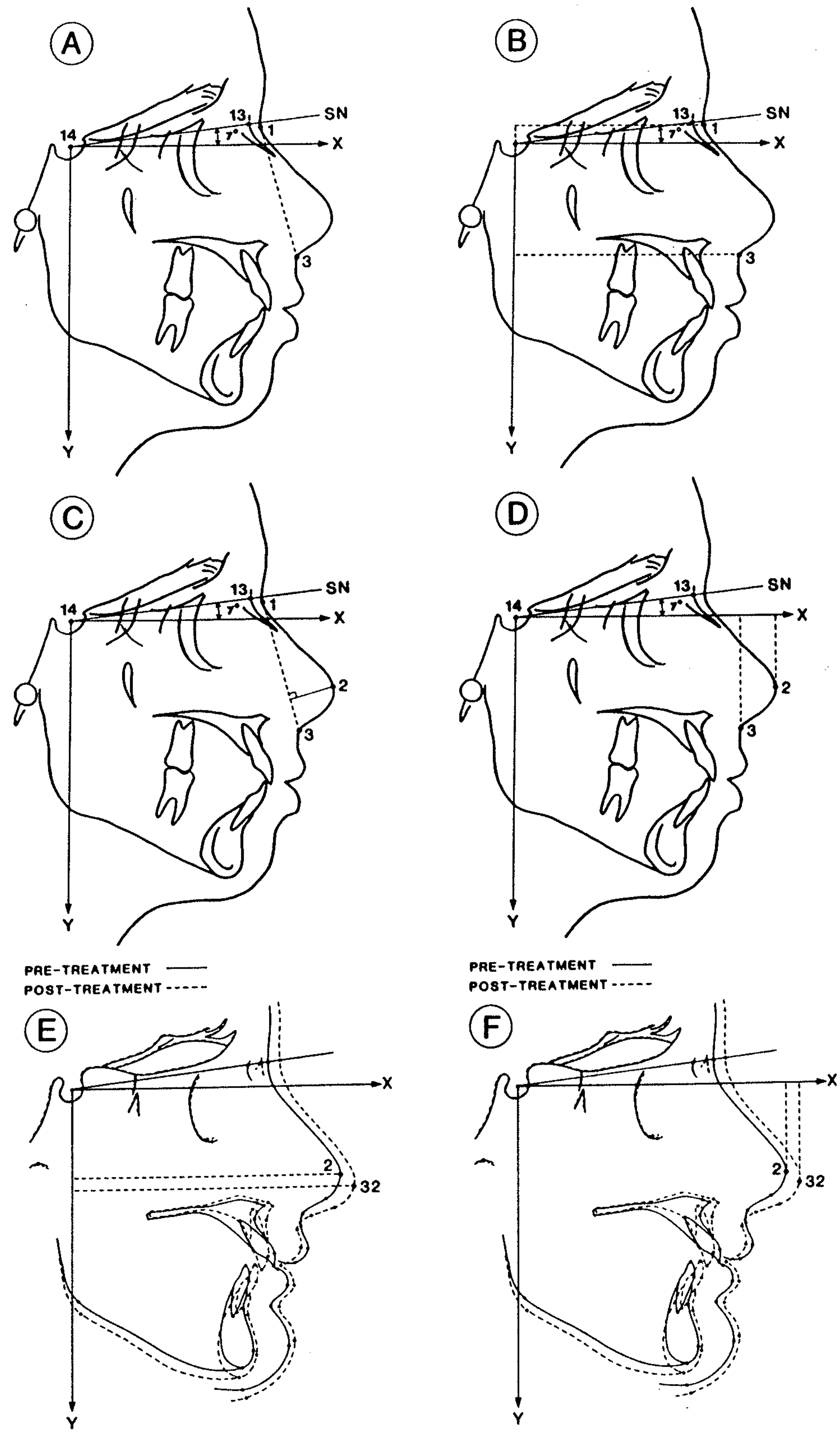
B. Initial nasal component (indirect):
(Y3)-(Y1)

C. Initial nasal depth (direct):
The perpendicular distance between point (2) and a line connecting (1) and (3)

D. Initial nasal depth (indirect):
(X2)-(X3)

E. Vertical nasal growth during treatment:
(Y32)-(Y2)

F. Horizontal nasal growth during treatment:
(X32)-(X2)


A
B
C
D
E
F
SN
X
Y
13
14
1
7°
2
3
32
PRE-TREATMENT
POST-TREATMENT

DEPENDENT VARIABLES

A. Upper lip retraction:
(X5)-(X35)

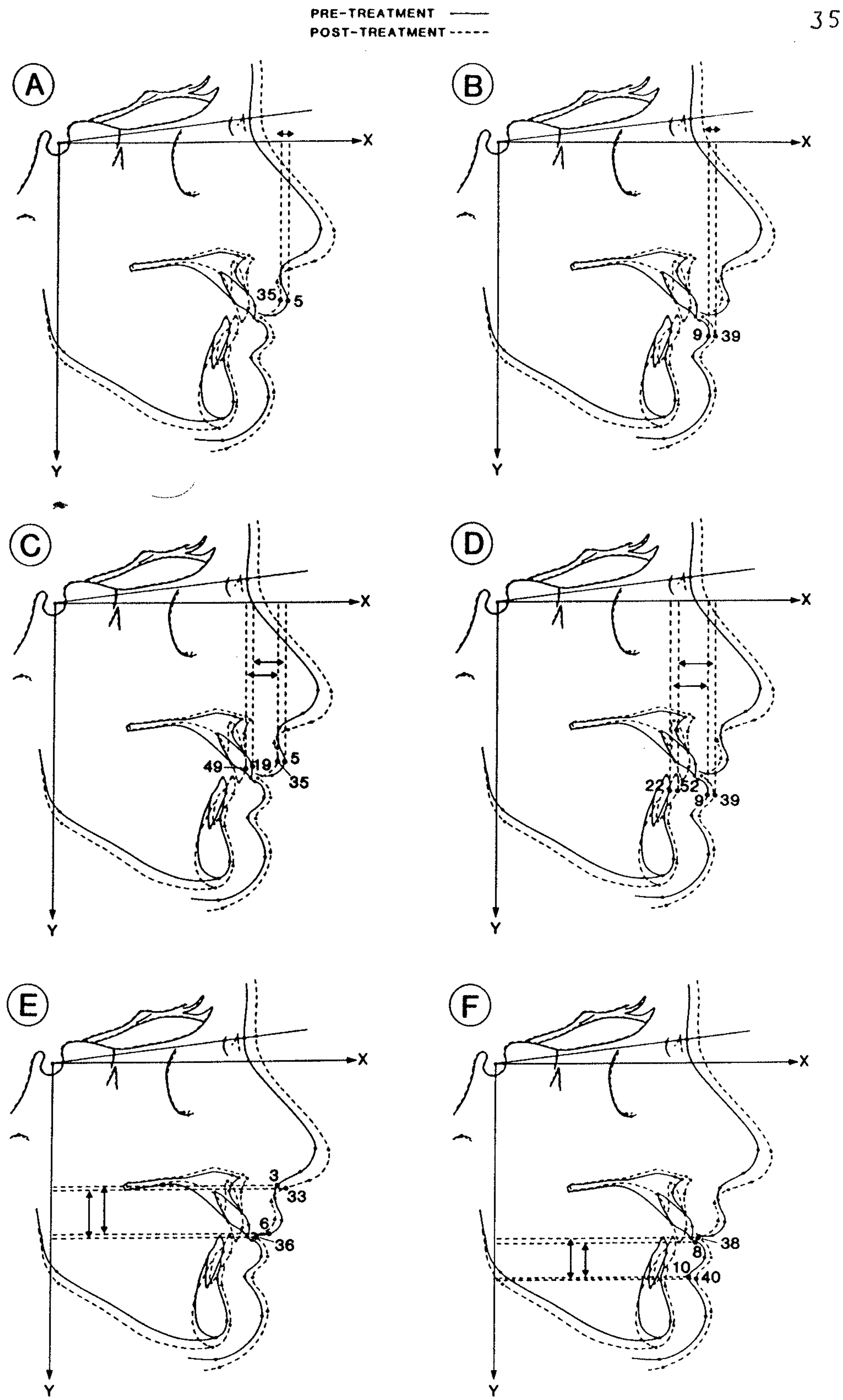
B. Lower lip retraction:
(X9)-(X39)

C. The change in upper lip thickness:
[(X5)-(X19)]-[(X35)-(X49)]

D. The change in lower lip thickness:
[(X9)-(X22)]-[(X39)-(X52)]

E. The change in upper lip length:
[(Y6)-(Y3)]-[(Y36)-(Y33)]

F. The change in lower lip length:
[(Y10)-(Y8)]-[(Y40)-(Y38)]


PRE-TREATMENT
POST-TREATMENT
A
X
Y
35
5
B
9
39
C
49
19
5
35
D
22
52
9
39
E
3
33
6
36
F
38
8
10
40

DEPENDENT VARIABLES (Cont.)

G. The change in nasolabial angle:
[(Angle 60-33-35)-(Angle 30-3-5)]

H. The change in interlabial gap:
[(Y8)-(Y6)]-[(Y38)-(Y36)]

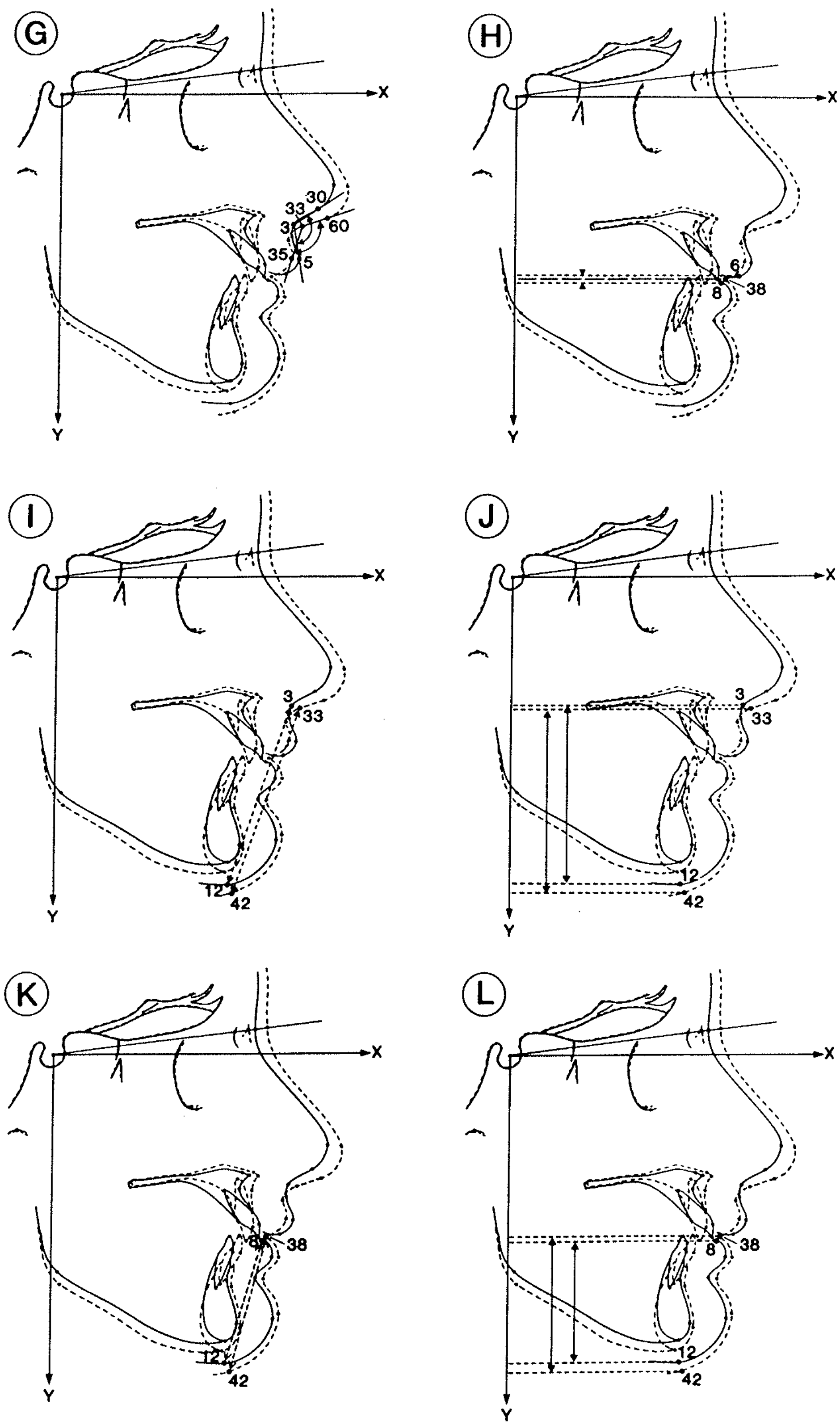
I. The change in soft tissue LFH (direct):
(distance 3,12)-(distance 33,42)

J. The change in soft tissue LFH (indirect):
[(Y12)-(Y3)]-[(Y42)-(Y33)]

K. The change in lower soft tissue component (direct):
(distance 8,12)-(distance 38,42)

L. The change in lower soft tissue component (indirect):
[(Y12)-(Y8)]-[(Y42)-(Y38)]

PRE-TREATMENT ——
POST-TREATMENT - - - - -



5. Test of cephalometric assessment technique

The reliability of all angular, linear and perpendicular measurements used in this study was examined in a pilot study where cephalographs of 10 randomly selected adult subjects were traced 4 times (one per day for four consecutive days) by the same operator. All dental, skeletal and soft tissue landmarks were identified and digitized by another operator.

The total error involved in this study may be attributed to six sources:

1. Error of cephalometric tracing technique.
2. Error of superimposition technique.
3. Error of constructing the coordinate system.
4. Error of landmark identification.
5. Error of landmark digitizing.
6. Error of the digitizing instrument.

The total error was calculated for each one of the six angular and fifty seven linear "variables" using the ten sets of four replicated measurements.

The pooled standard deviation of the measurement error within each set of 4 measurements, of each cephalometric film, was calaulated as suggested by CHEBIB and BURDICK[27] using the following formula:

$$sd = \sqrt{\frac{\sum_{j=1}^{m} \sum_{i=1}^{n} \left(X_{ij} - \bar{X}_j\right)^2}{m\,(n-1)}}$$

Where (m) is the number of subjects and (n) is the number of repeated measurement per subject. The maximum error was evaluated by multiplying (Sd) by the t value for the respective degrees of freedom [df=m(n-1)] at 95% and 99% probability level, i.e. 95% and 99% of the measurements will have an error not exceeding the maximum error.

6. Statistical analysis:

Fourty eight selected angles and distances were calculated for each subject from the coordinates. The 12 soft tissue parameters were identified as "dependent" variables and the remaining 36 parameters as "independent" variables (Table 4). The data was then processed through a series of computer programs including the following steps:

1. The mean and standard error for each of the dependent variables for each of the four age groups were calculated for the control sample. These means are considered to measure the growth effect for each of the four age groups.
2. The growth effects as calculated in step 1 were subtracted from the observed values of each of the dependent variables for each of the growing subjects in the study sample. The growth effects subtracted were those corresponding to the age group of that subject. The resultant differences are considered to be the pure effects of the treatment on each of these variables.
3. The corrected data resulting in step 2 was subjected to a correlation analysis where the correlation coefficient between each pair of the variables used in this study was calculated.
4. For each of the 12 dependent variables, a stepwise multiple regression was performed in order to study the effect of the in-

dependent variables. The multiple regression technique yields an equation of the type:

$$Y = bo + b1(X1) + b2(X2) \ldots\ldots bk(xk)$$

Where (bo) is a constant, b1, b2, ... bk are the partial regression coefficients measuring the effects of each of the independent varaibles on the amount of changes in the dependent variable (here the changes in the soft tissues due to orthodontic treatment). Each "partial" regression coefficient measures the effect of the corresponding independent variable on the soft tissue variable studied had all other independent variables included in the equation been held constant.

Only independent variables which showed a correlation coeficient exceeding 0.09 with the studied dependent variables were included in the analysis. It was felt that independent variables with correlation coefficients smaller than 0.09 have no significant effect on the soft tissue profile response to orthodontic tooth movement.

TABLE 4

Dependent and independent variables in the stepwise multiple regression analysis

DEPENDENT VARIABLES	INDEPENDENT VARIABLES	
1- U/lip retraction 2- L/lip retraction 3- Change in U/lip thickness 4- Change in L/lip thickness	SKELETAL	1- Initial size of FMA angle 2- Initial size of anterior LFH 3- Initial location of ANS (antero-posterior)
5- Change in naso-labial angle 6- Change in inter-labial gap 7- Change in U/lip length	DENTAL	4- Initial OB 5- Initial OJ 6- Initial U_1 inclination (U_1-SN) 7- Initial location of U_1 incisal edge (antero-posterior) 8- Initial L_1 inclination (L_1-MP) 9- Initial location of L_1 incisal edge (antero-posterior)
8- Change in L/lip length 9- Change in soft tissue (LFH) (direct measure-ment) 10- Change in soft tissue (LFH) (indirect measure-ment)	SOFT TISSUE	10- Initial U lip thickness 11- Initial U lip length 12- Initial L lip thickness 13- Initial L lip length 14- Initial size of nasolabial angle 15- Initial size of interlabial gap 16- Initial U lip taper 17- Initial L lip taper
11- Change in lower soft tissue component (LSTC) (direct measure-ment)	DENT.-S.T.	18- Initial U_1-U lip relationship (vertical) 19- Initial U_1-L lip relationship (vertical) 20- Initial L_1-L lip relationship (vertical) 21- Initial U_1-U lip relationship (antero-posterior)
12- Change in lower soft tissue component (LSTC) (indirect measure-ment)	MECHANO THERAPY	22- U_1 incisal edge movement (antero-posterior) 23- U_1 root apex movement (antero-posterior) 24- U_1 incisal edge movement (vertical) 25- L_1 incisal edge movement (antero-posterior) 26- L_1 root apex movement (antero-posterior) 27- L_1 incisal edge movement (vertical) 28- Change in FMA angle 29- Change in anterior LFH
	GROWTH	30- Vertical pattern 31- Horizontal pattern 32- "Normal" pattern
	NASAL	33- Initial size of the nasal component 34- Initial nasal depth 35- Vertical growth during orthodontic treatment 36- Horizontal growth during orthodontic treatment

Chapter IV

RESULTS

1) The error assessment:

As shown in (Appendix 3) where the mean error, the standard deviation and the maximum error associated with 95% and 99% of the measurements for each of the linear variables are listed, the error did not exceed ± 1 mm. in any case.

The angular measurements, also listed in (Appendix 3), seem to be less reliable than the linear measurements. The nasolabial angle in particular was not a very reliable angle pre treatment or post treatment. The maximum error associated with 99% of its measurements was ± 3.412 degrees pre treatment and ± 3.368 degrees post treatment.

The four other angular measurements where somewhat more reliable. The maximum error associated with 99% of the measurements of the pre treatment Frankfort mandibular plane angle, the post treatment Frankfort mandibular plane angle, the angle between the upper incisors and the SN line and the angle between the lower incisors and the mandibular plane were ± 0.816, ± 1.581, ± 1.094 and ± 1.419 degrees respectively.

2) Comparison of the control and study samples:

The means and standard deviations of all linear and angular distances used for both the control and the study samples are listed in (Appendix 4). A comparison between the changes taking place in the soft tissue variables in both samples is shown in (Table 5) where changes in the control sample are due to growth only while changes in the study sample are due to both growth and orthodontic treatment. The interpretation of (Table 5) led to the following conclusions:

A. In general, only minimal changes (less than 2 mm. for linear measurements and 5 degrees for angular measurements) took place due to growth itself in the soft tissue variables listed in (Table 5).

B. The changes in the antero-posterior position of the upper lip due to growth itself was minimal. On the other hand, a significant retraction of the upper lip took place when orthodontic treatment was performed (by a mean of 3.7 mm.).

C. The antero-posterior position of the lower lip seemed to remain almost unchanged in both samples.

D. While the nasolabial angle remained almost unchanged in the control sample, it increased substantially (by a mean of 10.5 degrees) in the study sample.

E. The interlabial gap decreased by a small amount (mean of 1.2 mm.) with growth. The amount of this decrease almost doubled with orthodontic treatment.

F. The length of the upper lip increased marginally in both samples. The lower lip length showed a marginal increase in the control sample while it increased substantially in the study sample (by a mean of 3.4 mm.).

G. The thickness of the lower lip remained almost unchanged in both samples. The upper lip thickness which also remained unchanged in the control sample, increased by a mean of 2.3 mm. in the study sample.

H. Whether measured directly or indirectly, the soft tissue lower face height increased marginally in the control sample, and slightly more in the study sample.

I. The lower soft tissue component, measured directly and indirectly, increased moderately (by a mean of 1.7 mm.) in the control sample and by double the amount in the study sample.

J. It was interesting to notice that among all measurements listed in (Table 5), only three measurements had a change that is clinically significant. These measurements are the upper lip retraction, the increase in the nasolabial angle and the increase in the lower lip length.

All previous observations were equally applicable to all age groups in both the control and the study samples. The few exceptions underlined in (Tables 6 and 7) were small and therefore, clinically irrelevant.

TABLE 5

Mean changes taking place in the soft tissue variables in both control and study samples

SOFT-TISSUE VARIABLES	CONTROL SAMPLE (T2-T1)		STUDY SAMPLE POSTtx - PREtx	
Upper lip retraction	-0.633 mm.	NS	+3.702 mm.	*+
Lower lip retraction	-1.096 mm.	NS	+1.604 mm.	NS
Change in the nasolabial angle	+0.197 deg	NS	+10.467 deg	*+
Change in the interlabial gap	-1.189 mm.	NS	-2.554 mm.	*-
Change in upper lip length	+0.065 mm.	NS	+0.165 mm.	NS
Change in lower lip length	+0.173 mm.	NS	+3.390 mm.	*+
Change in upper lip thickness	-0.004 mm.	NS	+2.293 mm.	*+
Change in lower lip thickness	-0.536 mm.	NS	-1.359 mm.	NS
Change in soft tissue LFH (direct measurement)	+0.386 mm.	NS	+1.763 mm.	NS
Change in soft tissue LFH (indirect measurement)	+0.371 mm.	NS	+1.481 mm.	NS
Change in lower soft tissue component (direct measurement)	+1.792 mm.	NS	+3.267 mm.	*+
Change in lower soft tissue component (indirect measurement)	+1.624 mm.	NS	+3.869 mm.	*+

- (*+) represents an increase exceeding 2 mm. or 5 degrees.
- (*-) represents a decrease exceeding 2 mm. or 5 degrees.
- (NS) represents a change which is smaller than 2 mm. or 5 degrees.

TABLE 6

Mean changes taking place in the soft tissue variables in the control sample

SOFT TISSUE VARIABLES	10:0 to 11:11 YR SUBGROUP	12:0 to 13:11 YR SUBGROUP	14:0 to 15:11 YR SUBGROUP	16:0 to 17:11 YR SUBGROUP
Upper lip retraction	-1.350 (NS)	-0.330 (NS)	-0.036 (NS)	-0.146 (NS)
Lower lip retraction	-2.050 (*-)	-1.122 (NS)	-0.127 (NS)	-0.083 (NS)
Change in the nasolabial angle	-0.577 (NS)	+1.655 (NS)	+1.119 (NS)	-1.869 (NS)
Change in the interlabial gap	-1.904 (NS)	-1.429 (NS)	-0.035 (NS)	-0.279 (NS)
Change in upper lip length	+0.305 (NS)	-0.195 (NS)	-0.475 (NS)	-0.195 (NS)
Change in lower lip length	-0.523 (NS)	-0.368 (NS)	+0.529 (NS)	+0.230 (NS)
Change in upper lip thickness	+0.334 (NS)	-0.637 (NS)	+0.271 (NS)	+0.117 (NS)
Change in lower lip thickness	+1.310 (NS)	+0.022 (NS)	+0.259 (NS)	-0.163 (NS)
Change in soft tissue LFH (direct measurement)	+0.336 (NS)	+0.129 (NS)	+0.995 (NS)	+0.123 (NS)
Change in soft tissue LFH (indirect measurement)	+0.087 (NS)	+0.634 (NS)	+0.626 (NS)	+0.149 (NS)
Change in LSTC (direct measurement)	+2.273 (*+)	+1.797 (NS)	+1.547 (NS)	+0.626 (NS)
Change in LSTC (indirect measurement)	+1.685 (NS)	+2.259 (*+)	+1.135 (NS)	+0.623 (NS)

- (*+) represents an increase exceeding 2 mm. or 5 degrees.
- (*-) represents a decrease exceeding 2 mm. or 5 degrees .
- (NS) represents a change which is smaller than 2 mm. or 5 degrees.

TABLE 7

Mean changes taking place in the soft tissue variables in the study sample

SOFT TISSUE VARIABLES	10:0 to 11:11 YR SUBGROUP	12:0 to 13:11 YR SUBGROUP	14:0 to 15:11 YR SUBGROUP	16:0 to 17:11 YR SUBGROUP	18 YR AND OLDER SUBGROUP
Upper lip retraction	+4.142 (*+)	+3.455 (*+)	+4.071 (*+)	+3.386 (*+)	+3.124 (*+)
Lower lip retraction	+2.056 (*+)	+2.405 (*+)	+2.069 (*+)	+1.912 (NS)	+1.032 (NS)
Change in the nasolabial angle	+13.022 (*+)	+9.035 (*+)	+9.497 (*+)	+9.735 (*+)	+9.303 (*+)
Change in interlabial gap	-2.707 (*+)	-3.067 (*+)	-2.324 (*+)	-1.970 (NS)	-2.002 (*+)
Change in upper lip length	+0.089 (NS)	+0.382 (NS)	-0.213 (NS)	-0.165 (NS)	+0.017 (NS)
Change in lower lip length	+4.114 (*+)	+3.347 (*+)	+3.744 (*+)	+2.289 (*+)	+2.444 (*+)
Change in upper lip thickness	+2.205 (*+)	+2.331 (*+)	+2.746 (*+)	+1.925 (NS)	+2.169 (*+)
Change in lower lip thickness	-1.512 (NS)	-1.206 (NS)	-1.389 (NS)	-1.393 (NS)	-1.266 (NS)
Change in s.t. LFH (direct m.)	+2.336 (*+)	+1.916 (*+)	+1.976 (*+)	+0.049 (NS)	-0.445 (NS)
Change in s.t. LFH (indirect m.)	+1.745 (NS)	+1.831 (NS)	+1.214 (NS)	+0.057 (NS)	-0.199 (NS)
Change in LSTC (direct m.)	+4.630 (*+)	+4.125 (*+)	+2.877 (*+)	+1.344 (NS)	+1.552 (NS)
Change in LSTC (indirect m.)	+5.363 (*+)	+4.516 (*+)	+3.752 (*+)	+1.613 (NS)	+1.871 (NS)

- (*+) represents an increase exceeding 2 mm. or 5 degrees.
- (*-) represents a decrease exceeding 2 mm. or 5 degrees .
- (NS) represent a change which is smaller than 2 mm. or 5 degrees.

3) Changes in the soft tissue profile due to orthodontic treatment:

The results of this study showed that due to orthodontic treatment both upper and lower lips were retracted, their length was increased, the upper lip thickness was increased, the lower lip thickness was decreased, both the soft tissue lower face height and the lower soft tissue component were increased, the interlabial gap was increased and the nasolabial angle was increased. Among these changes, three were the most important at the clinical level. They included the retraction of the upper lip, the increase in the nasolabial angle and the increase in the lower lip length.

A. The upper lip retraction: As shown in (Table 5), the orthodontic treatment caused the upper lip to retract. Four independent variables seemed to be related to this retraction to some extent. However, these variables explained only 48.5% of its variability; (Table 8)

- The retraction of maxillary incisal edge, a significant factor at the 1% level, was directly related to the retraction by a ratio of (0.2:1) upper lip retraction to maxillary incisal edge retraction.
- The pre treatment soft tissue thickness at "Subnasale", another significant factor at the 1 % level, was inversely related to the upper lip retraction. Subjects with thinner pre treatment soft tissue at "Subnasale" had a greater amount of upper lip retraction. For every 1 mm. decrease in the pre treatment soft tissue thickness at "Subnasale", there was an 0.1 mm. increase in the upper lip retraction.

- The pre treatment upper lip thickness, a third significant factor at the 1% level, was directly related to the upper lip retraction. Subjects with thicker upper lips pre treatment had a greater amount of upper lip retraction. For every 1 mm. increase in this distance, there was an 0.3 mm. increase in the upper lip retraction.
- The vertical growth of the nose, a significant factor at the 5% level, was directly related to the retraction by a ratio of (0.3:1) upper lip retraction to vertical growth of the nose.

TABLE 8

The important factors influencing the retraction of the upper lip

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
UPPER LIP RETRACTION	Retraction of U1 incisal edge	+0.240 (**)	(+0.2 : 1)	48.5%
	Pre treatment soft tissue thickness at Subnasale	-0.111 (**)	(-0.1 : 1)	
	Pre treatment upper lip thickness	+0.307 (**)	(+0.3 : 1)	
	Vertical growth of the nose	+0.297 (*)	(+0.3 : 1)	

- (**) significant at 1% level.
- (*) significant at 5% level.

<u>B. The lower lip retraction:</u> As shown in (Table 5), orthodontic treatment also caused the lower lip to retract. Three independent variables seemed to be related to the lower lip retraction to a great extent explaining 78.6% of its variability. These variables are: (Appendix 5/ Table 1)

- The retraction of the mandibular incisal edge.
- The intrusion of the mandibular incisal edge.
- The pre treatment lower lip thickness.

<u>C. The increase in the upper lip length:</u> As shown in (Table 5), the length of the upper lip increased with orthodontic treatment. Six independent variables seemed to affect it to some extent. All six variables explained only 50.2% of its variability. These variables are: (Appendix 5/ Table 2)

- The pre treatment interlabial gap.
- The pre treatment upper lip length.
- The pre treatment depth of the nose.
- The pre treatment overjet.
- The amount of maxillary incisor crown appearing when the upper lip is at rest (pre treatment).
- The pre treatment nasal component.

<u>D. The increase in the lower lip length:</u> As shown in (Table 5), the length of the lower lip increased with orthodontic treatment. Three independent variables seemed to affect it to a great extent explanining 75.8% of its variability. These variables are: (Table 9)

- The pre treatment lower lip length, a significant factor at the 1% level, was directly related to the increase in the lower lip length. Subjects with longer pre treatment lower lips had a greater amount of increase in the lower lip length. For every 1 mm. increase in the pre treatment length of the lower lip, there was an 0.4 mm. increase in the lower lip length.
- The amount of maxillary incisor crown covered by the lower lip at rest, a significant factor at the 5% level, was directly related to the increase in the lower lip length. Subjects with a greater amount of maxillary incisor crowns covered by the relaxed lower lip pre treatment had a greater amount of increase in the lower lip length. For every 1 mm. increase in the amount of maxillary incisors covered by the relaxed lower lips, there was an 0.3 mm. increase in the lower lip length.
- The increase in the hard tissue lower face height (direct measurement), another significant factor at the 5% level, was directly related to the increase by a ratio of (0.2:1) increase in the lower lip length to increase in the LFH.

TABLE 9

The important factors influencing the increase in the lower lip length

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
INCREASE IN THE LOWER LIP LENGTH	Pre treatment lower lip length	+0.423 (**)	(+0.4 : 1)	75.8%
	The amount of U1 crown covered by the lower lip (pre treatment)	+0.286 (*)	(+0.3 : 1)	
	Increase in the hard tissue LFH due to treatment (direct m.)	+0.195 (*)	(+0.2 : 1)	

- (**) significant at 1% level.
- (*) significant at 5% level.

<u>E. The increase in the upper lip thickness:</u> As shown in (Table 5), the thickness of the upper lip increased with orthodontic treatment. Four independent variables seemed to affect it to some extent. In this case the four variables explained only 52.7% of its variability. These variables are: (Appendix 5/ Table 3)

- The pre treatment interlabial gap.
- The pre treatment overbite.
- The pre treatment depth of the nose.
- The pre treatment length of the upper lip.

<u>F. The decrease in the lower lip thickness:</u> As shown in (Table 5), the thickness of the lower lip decreased with orthodontic treatment. Four independent variables seemed to affect it to a great extent explaining 74.9% of its variability. The four variables are: (Appendix 5/ Table 4)

- The pre treatment thickness of the lower lip.
- The retraction of the mandibular incisal edge.
- The intrusion of the mandibular incisal edge.
- The pre treatment hard tissue lower face height (indirect measurement).

<u>G. The increase in the soft tissue lower face height:</u> As shown in (Table 5), the soft tissue lower face height, whether measured directly or indirectly, increased in dimension with orthodontic treatment. Three independent variables seemed to affect it to a great extent.

When measured directly, these three independent variables seemed to explain 78.3% of its variability: (Appendix 5/ Table 5)

- The increase in the hard tissue lower face height.
- The increase in the Frankfort mandibular plane angle.
- The pre treatment nasal component.

When measured indirectly, the same three previous variables along with another variable seemed to explain 70.0% of its variability. The added variable is the pre treatment interlabial gap. (Appendix 5/ Table 6)

<u>H. The increase in the lower soft tissue component:</u> As shown in (Table 5), the lower soft tissue component, whether measured directly or indirectly, increased in dimension with orthodontic treatment. Three independent variables seemed to affect it to a great extent.

When measured directly, the three independent variables (significant at the 1% level) along with two other variables significant at the 5% level, seemed to explain 66.7% of its variability. These variables are: (Appendix 5/ Table 7)

- The pre treatment interlabial gap.
- the increase in the hard tissue lower face height (direct measurement)
- The horizontal growth of the nose.
- The increase in the Frankfort mandibular plane angle.
- The pre treatment lower lip thickness.

When measured indirectly, the same independent variables (significant at the 1% level and listed earlier) along with two other variables one of them significant at the 1% level and the other at the 5% level, seemed to explain 71.7% of its variability. The two new variables are: (Appendix 5/ Table 8)

- The amount of downward movement of hard tissue "Menton" during orthodintic treatment.
- The pre treatment lower lip length.

<u>I. The decrease in the interlabial gap:</u> As shown in (Table 5), the interlabial gap decreased with orthodontic treatment. Three

independent variables seemed to affect it to a great extent explaining 83.3% of its variability. They are: (Appendix 5/ Table 9)

- The pre treatment interlabial gap.
- The amount of downward movement of hard tissue "Menton" during orthodontic treatment.
- The pre treatment soft tissue thickness at "Subnasale".

<u>J. The increase in the nasolabial angle:</u> As shown in (Table 5), the nasolabial angle increased with orthodontic treatment. Six independent variables seemed to affect it to some extent. However, all these variables explained only 41.6% of its variability; (Table 10)

- The increase in the hard tissue lower face height (indirect measurement), a significant factor at the 1% level, was directly related to the increase by a ratio of (+3.5:1) increase in the angle to increase in LFH.
- The pre treatment soft tissue thickness at "Subnasale", another significant factor at the 1% level, was directly related to the increase in the nasolabial angle. Subjects with thicker soft tissue at "subnasale" pre treatment had a greater amount of increase in the nasolabial angle. For every 1 mm. increase in soft tissue thickness at "Subnasale", there was an 0.9 mm. increase in the nasolabial angle.
- The retraction of the maxillary incisal edge, a third significant factor at the 1% level, was directly related to the in-

crease by a ratio of (0.8:1) increase in the angle to incisal edge retraction.

- The increase in hard tissue lower face height (direct measurement), a fourth significant factor at the 1% level, was directly related to the increase by a ratio of (+3:1) increase in the angle to increase in LFH.
- The pre treatment upper lip thickness, a significant factor at the 5% level, was inversely related to the increase in the nasolabial angle. Subjects with thinner upper lips pre treatment had a greater increase in the nasolabial angle. For each 1 mm. decrease in the thickness of the upper lip pre treatment, there was a 1.3 degrees increase in the nasolabial angle.
- The pre treatment overjet, another significant factor at the 5% level, was inversely related to the increase in the nasolabial angle. Subjects with smaller overjet had a greater amount of increase in the nasolabial angle. For each 1 mm. decrease in the overjet pre treatment, there was an 0.9 degrees increase in the nasolabial angle.

TABLE 10

The important factors influencing the increase in the nasolabial angle

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
INCREASE IN THE NASOLABIAL ANGLE	Increase in hard tissue LFH (indirect)	+3.513 (**)	(-3.5 : 1)	41.6%
	Pre treatment soft tissue thickness at subnasale	+0.911 (**)	(+0.9 : 1)	
	Retraction of U1 incisal edge	+0.752 (**)	(+0.8 : 1)	
	Increase in hard tissue LFH (direct)	+3.047 (**)	(-3 : 1)	
	Pre treatment upper lip thickness	-1.288 (*)	(-1.3 : 1)	
	Pre treatment overjet	-0.894 (*)	(-0.9 : 1)	

- (**) significant at 1% level.
- (*) significant at 5% level.

Chapter V

DISCUSSION

Recognizing the various shortcomings existing in the literature, the extreme variabilities previously reported concerning the soft tissue reaction to orthodontic tooth movement, and the complexity of the problem itself, a substantial effort was made by this author to avoid any possible sources of error in this study.

- <u>The superimposition technique:</u>

Special attention was given to the method by which the cephalometric radiographs were superimposed. Various techniques have been previously used for cephalometric superimpositioning. The most widely used technique is the one where tracings are superimposed on <u>the Sella-Nasion line registered at (S).</u> This technique - which was first introduced by BRODIE[19, 20] in the 1940's - remains accurate as long as the growth change at Nasion follows an extension of the original SN line, which is unfortunately not the case all the time. SCOTT[72, 73] using dried skull material, and BERGRSEN[7] using the cephalometric radiographs of 40 individuals between 3 months and 20 years of age, both found that, without exception, Nasion migrated in an antero-superior direction from the original SN line. It becomes obvious that due to the antero-superior movement of Nasion, superimposition using the SN line registered at (S) may create an artificial clockwise rotation of the second tracing, increasing the vertical dimension of the face and making the profile more retrognathic.

Some authors superimposed their tracings also using the SN line but registered at (N). This method improves the ability of assessing changes taking place due to orthodontic treatment in the antero-posterior direction. It does not, however, solve the possible problem of creating the artificial clockwise rotation of the second tracing due to vertical changes in landmark (N) itself.

The palatal plane (ANS-PNS) is another reference plane used for cephalometric superimposition. The accuracy of this technique is also questionable. BERGERSEN[7] showed that in 90% of his untreated sample, growth itself caused the palatal plane to descend more rapidly at the PNS than at the ANS. Only 2.5% of the subjects exhibited a parallel descent of the palatal plane due to growth. This finding suggests first that the palatal plane is not a "stable" structure as some authors would like to believe, and second that using it to superimpose cephalometric tracings may create in the great majority of the cases an artificial clockwise rotation of the second tracing similar to the one discussed earlier, which will also make the profile more retrognathic but without increasing the vertical dimension of the face. One should also keep in mind that both ANS and PNS are difficult landmarks to identify in a cephalometric radiograph, so that registration on either of these landmarks is risky. The palatal plane may also be altered when certain orthopedic appliances are used as part of the orthodontic strategy to correct an antero-posterior skeletal discrepancy. Here again it becomes obvious that the palatal plane is a very unreliable plane for accurate superimposition.

Other, less common methods have also been used. Superimposition using the N-Pg line registered at (N) was advocated as a good method to eliminate changes due to growth. One should keep in mind that both landmarks (N) and (Pg) remodel vertically and antero-posteriorly during orthodontic treatment. This technique may be acceptable if the changes in these landmarks are of a similar magnitude vertically and also antero-posteriorly, which may not be the case.

Superimposition using the posterior margin of the maxilla "PM" alone or in conjunction with landmark "SE" on the cranial base is acceptable as a concept but seems to be difficult to perform clinically with enough accuracy since both landmarks "PM" and "SE" are not easily identified on a radiograph.

In this study, superimposition using the best fit of cranial base strutures was used since it was considered superior to any other technique. This method, which is based on the well documented fact that the cranial base stuctures are the most stable of any other structures in the cranio-facial complex following the age of 6 years, was first introduced in 1937 by BROADBENT[18] who noticed that the cranial base showed a relatively small amount of size increase with growth and, therefore, used it as a basis for "orientation". Similar remarks were later made by McDOWELL[52] who mentioned that the most desirable method for "orientation" was that of using succesive calvarial outlines as a mean of reference since approximately 90% of calvarial growth is completed by the age of 6 years. In 1967, SCOTT[73] stated that the middle segment of the cranial base (which extends from the hypophyseal fossa to the foramen caecum anteriorly) reaches 62% of the adult size at birth, 94% between the ages of 4 and 7 years, and 98% between the ages of 8 and 13 yeasr. SICHER[74] in 1970 also stated that the cranial base furnishes the most convenient reference point for growth studies, as the annual increments of cranial growth are negligible after the seventh year of life.

The best study that proved the relative stability of the cranial base was done by STEUER[76] who examined the cephalographs of 54 cases varied in age from 5 to 11 years at the first examination. STEUER stated that while no cranial base structure was perfectly constant during growth period, superimposition on the midline outlines of the sphenoidal portion of the middle cranial base is an acceptable procedure during the usual orthodontic age range since 90 to 95% of cranial base growth was completed by the age of 6 years.

- Changes in the soft tissue profile due to orthodontic treatment:

While the great majority of earlier studies tried to explain the complex nature of soft tissue profile change in response to orthodontic tooth movement by establishing numerical ratios between changes in some soft tissue measurements and changes taking place in some dental and skeletal parameters as a result of the orthodontic treatment, the present study used a different approach keeping in mind that although such ratios could be established, they can explain only parts of a greater picture. A certain ratio, for instance, could exist between the amount of maxillary incisor retraction and the upper lip retraction. The retraction of the maxillary incisors, however, may or may not be the most important factor influencing the retraction of the upper lip. Other factors may have a greater influence on the upper lip response than that of the maxillary incisor retraction. Such factors may include the complex anatomy of the upper lip which could not be analysed by using the cephalometric radiographs for soft tissue evaluation. Another possible source of variability may be the difficulty involved in assessing the tension in the lips when the cephalometric radiographs are taken. No electromyographic recordings were made to investigate whether the lips were in total relaxation since this study was retrospective in nature.

By using the stepwise multiple regression analysis, the strategy in this study was not only to identify the most important "independent" variables (listed in Table 4) influencing each one of the 12 soft tissue "dependent" variables, but also to investigate how much variability in each one of the 12 soft tissue variables is explained by the group of independent variables influencing it the most, and therefore giving an estimation of how well a clinician could predict the kind and amount of soft tissue changes due to orthodontic tooth movement in his patients.

In all five treated subgroups, the retraction of the lower lip in response to orthodontic tooth movement seemed to be more predictable than that of the upper lip. The decrease in the interlabial gap was much more predictable than the increase in the nasolabial angle. The increase in both the soft tissue lower face height and the lower soft tissue component was also predictable to a good extent. Clinically, it was interesting to notice that the three major changes which took place in reaction to orthodontic treatment were the retraction of the upper lip, the increase in the lower lip length and the increase in the nasolabial angle.

<u>A. The upper lip retraction:</u> In agreement with all previous studies, this study showed that orthodontic treatnment including an average retraction of the maxillary incisors of 6.7 mm. caused the upper lip to retract by an average of 4.3 mm. when changes due to growth were eliminated. The results indicated that a greater amount of upper lip retraction seemed to take place with:

1. Greater amount of maxillary incisal edge retraction.
2. Thinner soft tissue at "Subnasale" pre treatment.
3. Thicker upper lip pre treatment.
4. Greater amount of vertical nasal growth during the treatment period.

All these factors, however, explained only 48.5% of the variability in the upper lip response, which means that prediction of upper lip retraction is not an easy task to do. It is important here and in the following sections to remember that only factors which contributed to the variability of the corresponding soft tissue variable by a minimum of 1% were reported. The influence of other factors, each with a very little contribution by itself, could be as important as the listed factors.

Other possible factors not included in this study may also have a great influence on the way the upper lip respods to orthodontic tooth movement. These factors, may, for example, include the anatomical interrelations between the various upper lip muscles, and the anatomy of the "nose - upper lip" complex.

The traditional way of looking at the upper lip retraction was to relate it directly to the amount of maxillary incisor edge retraction which took place during orthodontic treatment. Various ratios have been reported in earlier studies with a very wide range. And while this study reported yet another ratio (a 1:5 upper lip retraction to maxillary incisal edge retraction), it is of great importance to emphasize that this ratio may not be valuable in every patient since other factors - some of them still unknown - can modify it in a manner which is still not well understood.

The results of this study agreed with those of WISTH[84] who found that the initial overjet is not an important factor in the upper lip retraction. This study did not agree, however, with OLIVER[56] who found that a greater amount of upper lip retraction took place with thinner upper lips pre treatment. The results also could not confirm RAINS and NANDA's(61) finding that the mandibular rotation had a great influence on the upper lip retraction, possibly because such rotation was minimal in this sample (the mean increase in the Frankfort mandibular plane angle was 0.5 degrees).

B. The lower lip retraction: The results showed that orthodontic treatment caused the lower lip to retract by an average of 2.7 mm. when changes due to growth were eliminated. The results indicated that a greater amount of lower lip retraction seemed to take place with:

1. Greater amount of mandibular incisal edge retraction.
2. Greater amount of mandibular incisal edge intrusion.
3. Thicker lower lip pre treatment.

These three factors explained 78.6% of the variability in the lower lip response, which means that the clinician's ability to predict the retraction of the lower lip is far better than that of the upper lip.

Traditionally, previous studies tended to associate the lower lip retraction with the amount of retraction in both the maxillary and the mandibular incisal edges that took place during orthodontic treatment. No such relationship could be established in this study between the lower lip retraction and the maxillary incisal edge retraction. This finding is in agreement with those reported earlier by HASSTEDT(40), ROOS(70) and HERSHEY(41). Here again this study could not confirm RAINS and NANDA's(61) finding that the mandibular rotation had a great influence on the lower lip retraction, possibly because such rotation was minimal in the sample used in this study.

When the lower lip retraction was compared to the retraction of the mandibular incisal edge retraction, this study could establish a ratio of (1:2 lower lip retraction to mandibular incisal edge retraction) which was the smallest ever reported in the literature, possibly due to the fact that all our cephalometric radiographs were taken with relaxed lips, and also to the fact that changes due to growth itself were eliminated before this ratio was established.

The ratio established in this study did not agree with the ratios previously reported by GARNER[38], O'RIELLY[57] and RUDEE[69] who did not correct for growth changes. One reason why RAINS and NANDA[61] could not establish any ratio between the lower lip retraction and the lower incisal edge retraction was probably the relatively small magnitude of the changes taking place in the position of both the lower anterior teeth and the lower lip.

<u>C. The increase in the upper lip length:</u> In agreement with two previous studies, this study showed that the length of the upper lip increased with orthodontic treatment. It was interesting, however, to notice that this increase was very insignificant at the clinical level (0.1 mm. on average). This means that the decrease in the interlabial gap - which will be discussed later - is due mostly to the increase in the length of the lower lip.

The results indicated that a greater increase in the upper lip length seemed to take place with:

1. Smaller pre treatment interlabial gap.
2. Longer pre treatment upper lip length.
3. Smaller depth of the nose pre treatment.
4. Smaller pre treatment overjet.
5. Lesser amount of maxillary incisor crowns appearing under the relaxed upper lip pre treatment.
6. Larger nasal component pre treatment.

Here again, all these factors explained only 50.2% of the variability in the upper lip length increase, suggesting that other factors or combination of factors have also a role to play in determining the increase in the upper lip length.

Unfortunately, ANGELLE(3) did not publish any data for further investigation only stating that the length of the upper lip increased with orthodontic treatment. The findings of this study agreed with those of RAINS and NANDA(61) who reported a slightly greater increase in the upper lip length which still remains clinically very insignificant.

Finally, it was interesting to notice that the amount of maxillary incisor retraction did not seem to affect the increase in the upper lip length, a finding which may surprise some clinicians.

<u>D. The increase in the lower lip length:</u> In agreement with RAINS ans NANDA(61), this study showed that the length of the lower lip increased with orthodontic treatment. Contrary to the situation in the upper lip, the increase in the lower lip length was significant at the clinical level (3.4 mm. on average), which means that the lower lip is

the major contributor in the interlabial gap reduction with orthodontic treatment. It is important to mention here that the 0.6 mm. average increase in the lower lip length reported by RAINS and NANDA was much smaller than that reported in this study.

The results indicated that a greater increase in the lower lip length seemed to take place with:

1. Longer pre treatment lower lip.
2. Greater amount of maxillary incisor crowns covered by the relaxed lower lip.
3. Greater increase in the hard tissue lower face height due to orthodontic treatment.

These three factors explained 75.8% of the variability in the lower lip length increase, suggesting again that it is highly predictable.

Here again, the amount of mandibular incisor retraction did not seem to affect the increase in the lower lip length.

<u>E. The increase in the upper lip thickness:</u> In agreement with all previous studies, this study showed that while the thickness of the upper lip remained unchanged due to growth itself, it increased by an average of 2.3 mm. with orthodontic treatment. Our results indicated that a greater increase seemed to take place with:

1. Smaller pre treatment interlabial gap.
2. Larger pre treatment overjet.

3. Smaller pre treatment depth of the nose.
4. Shorter pre treatment upper lip.

All these four factors explained only 52.7% of the variability in the upper lip thickness increase, suggesting that the situation is a very difficult one to predict.

The traditional way of looking at the increase in the upper lip thickness was to relate it to the amount of maxillary incisal edge retraction which took place during orthodontic treatment. Interestingly enough, along with LO and HUNTER[48] whose work seemed to be highly reliable we were the only two studies which stated that no such correlation did exist. This study disagreed with ANDERSON et al[2], and HILL[42] and WISTH[84] whose studies failed to control changes taking place due to growth itself.

<u>F. The decrease in the lower lip thickness:</u> In disagreement with ANDERSON et al[2] and WISTH[84] who stated that the lower lip thickness increased or remained unchanged, this study agreed with WARFIELD[82], ROOS[70] and LO and HUNTER[61] who stated that the thickness of the lower lip decreased with orthodontic treatment. Unfortunately, none of these studies could identify the factors influencing this decrease. In this study, however, a greater decrease seemed to take place with:

1. Thicker pre treatment lower lip.
2. Smaller amount of mandibular incisal edge retraction with orthodontic treatment.

3. Smaller amount of mandibular incisal edge intrusion with orthodontic treatment.
4. Smaller pre treatment lower face height.

These four factors explained 74.9% of the variability in the lower lip thickness decrease, suggesting that it is highly predictable.

One should, however, mention - for clinical considerations - that the thickness of the lower lip which did not change due to growth itself, decreased by a very small amount which did not exceed 1.4 mm. on average, making this decrease clinically insignificant.

<u>G. The increase in the soft tissue lower face height:</u> Unfortunately, none of the previous studies evaluated the change in this measurement due to orthodontic treatment. This study showed that while this measurement increased marginally due to growth itself (by a mean of 0.4 mm.), it increased with orthodontic treatment by an average of 1.5 mm. when measured directly and 1.8 mm. when measured indirectly in relation to the (Y) axis. The increase in both measurements was predictable to a good extent and the following three factors seemed to cause a greater increase in the soft tissue lower face height:

1. Greater increase in the hard tissue lower face height with orthodontic treatment.
2. Greater increase in the Frankfort mandibular plane angle with orthodotic treatment.
3. Smaller pre treatment nasal component.

Two clinical observations seem to be important to report here:

- The increase in the soft tissue lower face height was smaller than the increase in the hard tissue lower face height in all treated cases, which means that the former does not interact with the latter on a one to one basis when orthodontic treatment is performed.

- Using the direct method for measuring the soft tissue lower face height is almost as reliable as the indirect method since both measurements were related to the same three factors listed earlier when evaluated on a short term basis.

<u>H. The increase in the lower soft tissue component:</u> This measurement, introduced in the orthodontic literature for the first time in this study, may have a special importance in the field of clinical orthodontics. It was postulated earlier that the length of the upper lip might be - at least partially - anatomically determined and remains unchanged with both growth and orthodontic treatment. It is the impression of the author that the balance of the facial profile can be maintained as long as the lower soft tissue component is equal in size to the nasal component, an assumption yet to be scientifically evaluated.

This study showed that the lower soft tissue component increased moderately (by an average of slightly less than 2 mm.) due to growth itself, and by almost double that amount with orthodontic treatment. The increase in both its direct and indirect methods of measurement was predictable to a good extent, and the following three factors were those which seemed to cause a greater increase in the lower soft tissue component:

1. Smaller pre treatment interlabial gap.
2. Greater increase in the hard tissue lower face height with orthodontic treatment.
3. Smaller vertical growth of the nose during treatment period.

<u>I. The increase in the nasolabial angle:</u> The findings of this study agreed in general with those of the two other studies which evaluated the change in the nasolabial angle due to orthodontic tooth movement. The size of the angle which remained almost unchanged due to growth itself, increased substantially (by an average of 10.5 degrees) with orthodontic treatment including an average maxillary incisal edge retraction of 6.7 mm. A greater increase seemed to take place with:

1. Greater increase of hard tissue lower face height.
2. Thicker soft tissue at "Subnasale" pre treatment.
3. Greater amount of maxillary incisal edge retraction.
4. Thinner upper lip pre treatment.
5. Smaller overjet pre treatment.

All these factors, however, explained only 41.6% of the variability in the nasolabial response, which means that prediction of the increase in the angle is another difficult task to do.

This study did not agree with WALDMAN[81] who did not find any significant correlation between the horizontal retraction of the maxillary incisors and the increase in the angle. It also did not agree with the ratios LO and HUNTER[48] established between the increase in the nasolabial angle and retraction of the maxillary incisal edge (1.6 degrees for each 1 mm. in their study and only 0.8 degrees for each 1 mm. in this study) in one hand, and the increase in the angle and the increase in the size of the lower face height (2.2 degrees for each 1 mm. in their study and 3 degrees for each 1 mm. in this study) in the other hand.

LO and HUNTER also reported that for every one degree increase in the Frankfort mandibular plane angle the nasolabial angle increased by 3 degrees on average. That finding was not supported by this study, again possibly duee to the small increase in the Frankfort mandibular plane angle.

J. The decrease in the interlabial gap: Here again the findings of this study agreed in general with those of previous studies, but differed somewhat in explaining why the gap decreased by an average of 2.6 mm. due to orthodontic treatment, and what factors were responsible for this decrease. A greater decrease in the interlabial gap, according to this study, seemed to take place with:

1. Larger pre treatment interlabial gap.
2. Smaller amount of downward movement of landmark hard tissue "Menton" due to orthodontic treatment.
3. Thinner soft tissue at "Subnasale" pre treatment.

These three factors explained 83.3% of the variability in the decrease in the gap, suggesting that interlabial gap reduction with orthodontic treatment is highly predictable.

It was interesting that while JACOBS(47) found that the retraction of the maxillary incisal edge was an important factor influencing the decrease in the interlabial gap, this study could not demonstrate that retraction, intrusion or extrusion of the maxillary incisors had any influence on the interlabial gap.

As mentioned earlier, the results of this study suggests that the interlabial gap reduction is a phenomenon caused mainly by the elongation of the lower lip.

* * *

Chapter VI

SUMMARY AND CONCLUSIONS

In order to improve the clinician's ability to predict the soft tissue profile changes due to retraction of the maxillary incisors, an attempt has been made in this study to identify and quantify the contribution of the most significant factors responsible for these profile changes. This study supports the hypothesis that the controversy concerning the soft tissue response to orthodontic tooth movement exists because factors other than those traditionally evaluated using cephalometric radiographs, where the complex nature of the soft tissue could not be detected, have an influence on the soft tissue response.

The cephalometric radiographs of eighty treated female subjects all of them had a minimum of 3 mm. maxillary incisal edge retraction at treatment completion, and fifty three untreated subjects were digitized and analyzed using a stepwise multiple regression analysis. The statistical assessment of the data led to the following conclusions:

1. In general, only minimal changes in the soft tissue profile took place due to growth itself.
2. Orthodontic toth movement seemed to influence the soft tissue profile when change due to growth was eliminated.
3. The three most important soft tissue changes which took place in response to orthodontic treatment were the retraction of the upper lip, the increase in the lower lip length and the in-

crease in the nasolabial angle. Other soft tissue changes - of little clinical significance - included the retraction of the lower lip, the reduction of the interlabial gap, the increase in the thickness of both the upper and the lower lips, the increase in the soft tissue lower face height and the lower soft tissue component. The length of the upper lip did not increase with either growth or orthodontic treatment.

4. In general, changes in the lower lip in response to orthodontic tooth movement were more predictable than those of the upper lip. The low degree of predictability associated with the upper lip response to orthodontic tooth movement may be due to the complex anatomy of the upper lip which could not be detected by using the presently available cephalometric techniques, or to other factors unknown at present.

These conclusions led us to suggest the following:

- The possible variation in soft tissue response to orthodontic treatment in some patients, especially the ones listed in the introduction, should be carefully evaluated and discussed with the patient prior to the initiation of any orthodontic procedure.
- When it is anticipated that necessary tooth movements might cause undesirable changes in the soft tissue profile, non orthodontic measures (i.e. RHINOPLASTY and/or GENIOPLASTY) should be discussed with the patient prior to the start of the orthodontic treatment.

- Further research projects are recommended to investigate the following:

  A. Whether the low degree of predictability concerning the upper lip response to orthodontic treatment is partially due to the complex anatomical relationships between the upper lip and the nose.

  B. Whether the factors influencing the changes in the soft tissue profile in this study are the same factors influencing the changes in subjects of different racial background (Mongolians and Blacks).

  C. Whether the initial selection of the sample should have been based on subjects who had a minimum upper lip retraction of 3 mm. instead of a minimum of 3 mm. retraction of the maxillary incisors.

- Clinicians should question whether the cephalometric analyses presently available are good enough to evaluate the soft tissue. It is the feeling of this author that dealing with the soft tissue as a homogenious bulk of tissue is very inaccurate since it ignores not only the anatomical aspect of the muscles composing the soft tissue but also its functional aspect which could not be evaluated unless electromyographic recordings are available in conjunction with the cephalometric radiographs.

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Appendix 1

THE MAGNIFICATION FORMULA

The magnification factor is given in the following formula:

$$\underset{(\%)}{\text{Magnification}} = \frac{d}{D - d} \times 100$$

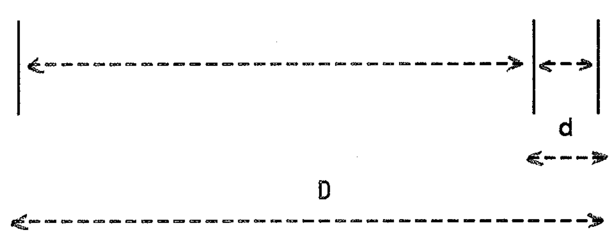
Where (d) is the subject midsagittal plane to film distance

and (D) is the focal spot to film distance

In both study and control samples (d) was equal to 15 cm. and (D) was equal to 167.4 cm.

The magnification factor for both samples is given as follow:

$$\frac{15.0}{152.4} \cdot 100 = 9.84\ \%$$



Appendix 2

DENTAL SKELETAL AND SOFT TISSUE LANDMARKS

1. Dental landmarks

- Upper incisor labial crown point (19):

  The most labial point on the crown of the most labial upper central incisor

- Upper incisor incisal edge (20):

  The point on the incisal edge of the most labial upper central incisor at the greatest distance from reference line I.

- Upper incisor apex (27):

  The point on the end of the upper incisor root (of the most labial upper central incisor) at the maximum distance from the incisal edge.

- Lower incisor labial crown point (22):

  The most labial point on the crown of the most labial lower incisor.

- Lower incisor incisal edge (21):

  The point on the incisal edge of the most labial lower incisor at the shortest distance from reference line I.

- Lower incisor apex (28):

  The point on the end of the lower incisor root (of the most labial lower incisor) at the maximum distance from the incisal edge.

2. Skeletal landmarks:

- Sella (14):

The geometric centre of Sella Turcica, located by inspection.

- Nasion (13):

The anterior limit of the naso-frontal suture.

- Anatomical Porion (15):

The most superior point on the opening of the bony external auditory meatus.

- Orbitale (16):

The most inferior point on the curvature of the lower margin of the bony orbit.

- Anterior nasal spine (anatomical) (17):

The tip of the median sharp bony process of the maxilla at the lower margin of the anterior nasal opening.

- Anterior nasal spine (structural) (29):

The point on the nasal floor where the radiographic outline of the anterior nasal spine is 3 mm. thick (superior-inferiorly).

- Subspinale (A point) (18):

The most posterior point on the curvature of the anterior aspect of the maxilla between the anterior nasal spine and the alveolar crest.

- Supramentale (B point) (23):

The most posterior point on the curvature of the anterior aspect of the mandible between the alveolar crest and the chin.

- Pogonion (24):

The most anterior point on the contour of the bony chin.

- <u>Menton (25):</u>

  The most inferior point on the symphysis of the mandible.

- <u>Gonion (26):</u>

  The most posterior point on the inferior border of the mandible through which a line to menton will best discribe the inferior surface of the mandible.

3. Soft tissue landmarks:

- <u>Soft tissue Nasion (1):</u>

  The outermost point on the soft tissue profile produced by an extension of Nasion anteriorly and perpendicular to Reference line II.

- <u>Nasal tip point (2):</u>

  The most anterior point on the nasal tip.

- <u>Columella Tangent point (30):</u>

  A point on the inferior surface of the columella through which a line to subnasale will best describe the angle of the columella relative to the upper lip.

- <u>Subnasale (3):</u>

  The most posterior-superior point on the soft tissue profile between columella tangent point and upper labial sulcus.

- <u>Upper labial sulcus (4):</u>

  The most posterior point on the profile contour of the upper lip between labrale superius and subnasale.

- <u>Labrale superius (5):</u>

  The most anterior point of the contour of the upper lip.

- <u>Upper Stomion (6):</u>

  The most inferior point of the contour of the upper lip when the lips are apart in the relaxed position.

- <u>Stomion (7):</u>

  The most anterior point of junction between the upper and lower lips.

- <u>Lower Stomion (8):</u>

  The most superior point of the contour of the lower lip when the lips are apart in the relaxed position.

- <u>Labrale inferius (9):</u>

  The most anterior point of the contour of the lower lip.

- <u>Lower labial sulcus (2):</u>

  The most posterior point on the profile contour of the lower lip between labrale inferius and the soft tissue chin.

- <u>Soft tissue Pogonion (11):</u>

  The outermost point on the soft tissue chin produced by an extension of skeletal Pogonion anteriorly and perpendicular to Reference line II.

- <u>Soft tissue Menton (12):</u>

  The most inferior point on the soft tissue chin produced by an extension of skeletal menton inferiorly and perpendicular to Reference line I.

Appendix 3

THE RELIABILITY OF ALL LINEAR, PERPENDICULAR AND ANGULAR MEASUREMENTS

DISTANCE	STANDARD DEVIATION OF THE MEASUREMENT ERROR (Sd)	MEAN ERROR	MAXIMUM ERROR ASSOCIATED WITH 95% OF THE MEASUREMENTS	MAXIMUM ERROR ASSOCIATED WITH 99% OF THE MEASUREMENTS
Anterior LFH (pre treatment)	0.332	0.262	0.677	0.913
Anterior LFH (post treatment)	0.243	0.191	0.496	0.668
The nasal component (a line connecting landmarks 1 and 3)	0.295	0.233	0.602	0.811
The soft tissue LFH (pre treatment)	0.330	0.260	0.673	0.907
The soft tissue LFH (post treatment)	0.286	0.225	0.584	0.786
The "lower soft tissue component" pre treatment (a line connecting landmarks 8 and 12)	0.297	0.234	0.606	0.816
The "lower soft tissue component" post treatment (a line connecting landmarks 38 and 42)	0.273	0.215	0.557	0.750

Appendix (3)/ Table (I)
Error in determining direct distances between two landmarks (in mm.)

DISTANCE	STANDARD DEVIATION OF THE MEASUREMENT (Sd)	MEAN ERRRO	MAXIMUM ERROR ASSOCIATED WITH 95% OF THE MEASUREMENTS	MAXIMUM ERROR ASSOCIATED WITH 99% OF THE MEASUREMENTS
Nasal depth (pre treatment)	0.260	0.205	0.530	0.715
Nasal depth (post treatment)	0.305	0.240	0.622	0.838

Appendix (3)/ Table (II)
Error in determining perpendicular distances
(in mm.)

DISTANCE (ON THE 'X' AXIS)	STANDARD DEVIATION MEASUREMENT ERROR (Sd)	MEAN ERROR	MAXIMUM ERROR ASSOCIATED WITH 95% OF THE MEASUREMENTS	MAXIMUM ERROR ASSOCIATED WITH 99% OF THE MEASUREMENTS
20-21	0.214	0.169	0.436	0.588
05-19	0.180	0.142	0.367	0.495
09-22	0.139	0.109	0.283	0.382
03-18	0.318	0.251	0.649	0.874
10-23	0.242	0.191	0.494	0.665
06-20	0.397	0.313	0.810	1.019
07-20	0.350	0.276	0.714	0.962
20-50	0.208	0.164	0.424	0.572
27-57	0.159	0.125	0.324	0.437
21-51	0.144	0.113	0.942	0.396
28-58	0.164	0.129	0.334	0.451
54-24	0.120	0.094	0.245	0.330
02-03	0.314	0.248	0.641	0.863
32-02	0.185	0.146	0.377	0.508
14-17	0.208	0.164	0.424	0.572
14-29	0.284	0.224	0.579	0.781
14-19	0.245	0.193	0.500	0.673
14-22	0.263	0.207	0.537	0.723
05-35	0.156	0.123	0.318	0.429
09-39	0.160	0.126	0.326	0.440
35-49	0.146	0.115	0.298	0.401
39-52	0.146	0.115	0.298	0.401

Appendix (3)/ Table (III)
Error in determining distances between two landmarks
in relation to the (X) axis antero-posteriorly

DISTANCE (ON THE 'Y' AXIS)	STANDARD DEVIATION MEASUREMENT ERROR (Sd)	MEAN ERROR	MAXIMUM ERROR ASSOCIATED WITH 95% OF THE MEASUREMENTS	MAXIMUM ERROR ASSOCIATED WITH 99% OF THE MEASUREMENTS
25-29	0.349	0.275	0.712	0.959
20-21	0.283	0.223	0.577	0.778
06-03	0.258	0.203	0.526	0.709
07-03	0.215	0.169	0.439	0.591
10-08	0.348	0.274	0.710	0.957
10-07	0.320	0.252	0.653	0.880
08-06	0.132	0.104	0.269	0.363
20-06	0.221	0.174	0.451	0.607
20-07	0.178	0.140	0.363	0.489
08-20	0.239	0.188	0.488	0.657
07-20	0.178	0.140	0.363	0.489
08-21	0.170	0.134	0.347	0.467
07-21	0.168	0.132	0.343	0.462
20-50	0.250	0.197	0.510	0.687
21-51	0.062	0.048	0.126	0.170
55-59	0.266	0.210	0.543	0.731
55-25	0.272	0.214	0.555	0.748
03-01	0.320	0.252	0.653	0.880
32-02	0.371	0.293	0.757	1.002
38-36	0.072	0.056	0.147	0.198
36-33	0.183	0.144	0.373	0.503
40-38	0.183	0.144	0.373	0.503
12-03	0.336	0.265	0.686	0.924
42-33	0.304	0.240	0.620	0.836
12-08	0.299	0.236	0.610	0.822
42-38	0.291	0.229	0.594	0.800

Appendix (3) / Table (IV)
Error in determining distances between two landmarks in relation to the (Y) axis vertically

ANGLE	STANDARD DEVIATION MEASUREMENT ERROR (Sd)	MEAN ERROR	MAXIMUM ERROR ASSOCIATED WITH 95% OF THE MEASUREMENTS	MAXIMUM ERROR ASSOCIATED WITH 99% OF THE MEASUREMENTS
Nasolabial angle (pre treatment)	1.241	0.980	2.534	3.412
Nasolabial angle (post treatment)	1.225	0.967	2.501	3.368
Frankfurt mandibular plane angle (pre treatment)	0.297	0.234	0.606	0.816
Frankfurt mandibular plane angle (post treatment)	0.575	0.454	1.174	1.581
U1-SN (pre treatment)	0.398	0.314	0.812	1.094
L1-MP (pre treatment)	0.516	0.407	1.053	1.419

Appendix (3)/ Table (V)
Error in determining angular values
(in degrees)

Appendix 4

THE CONTROL AND STUDY SAMPLES

DISTANCES	CONTROL SAMPLE		STUDY SAMPLE	
	MEAN	SD	MEAN	SD
- Pre treatment Nasal component (direct measurement)	55.415	3.700	54.879	3.820
- Pre treatment: Nasal depth	14.661	1.946	15.404	2.000
- Post treatment: Nasal depth	15.429	1.824	16.566	1.848
- Pre treatment: Hard tissue LFH (direct measurement)	63.740	4.556	65.308	5.187
- Post treatment: Hard tissue LFH (direct measurement)	65.205	4.409	68.073	4.783
- Pre treatment: Soft tissue LFH (direct measurement)	74.649	5.365	73.745	5.417
- Post treatment: Soft tissue LFH (direct measurement)	75.035	4.970	75.508	5.036
- Pre treatment: Lower soft tissue component (direct measurement)	48.577	4.370	47.671	3.883
- Post treatment: Lower soft tissue component (direct measurement)	50.369	4.323	50.938	3.719

Appendix (4)/ Table (I)
Means and standard deviations of the linear measurements in both samples (in mm.)

DISTANCES ON THE "X" AXIS	CONTROL SAMPLE		STUDY SAMPLE	
	MEAN	SD	MEAN	SD
- Upper lip retraction	-0.633	1.906	3.702	1.678
- Lower lip retraction	-1.096	2.212	1.604	2.325
- Pre treatment: U lip thickness	12.193	2.557	10.248	1.935
- Post treatment: U lip thickness	12.197	2.562	12.541	2.001
- Pre treatment: L lip thickness	12.022	2.866	13.488	2.115
- Post treatment: L lip thickness	12.558	2.895	12.129	1.379
- Pre treatment ST thickness at Subnasale	17.686	2.505	16.125	2.303
- Pre treatment ST thickness at inferior labial sulcus	11.042	1.683	11.271	1.447
- Pre treatment overjet	3.123	1.257	8.773	2.246
- Pre treatment nasal depth (indirect measurement)	13.096	2.040	13.925	2.120
- Nasal tip forward movement during treatment period (or T2-T1)	1.581	1.885	1.063	1.495
- Forward movement of (Pogonion) during treatment period (or T2-T1)	0.807	1.724	-1.125	2.476
- The pre treatment position of U1 most labial point	73.963	4.797	77.101	4.564
- The pre treatment position of L1 most labial point	69.511	4.725	67.690	4.799
- Horizontal distance between the U lip and U1 incisal edge (pre-treament)	6.216	2.409	4.014	1.859
- Pre treatment: location of ANS (anatomical)	69.786	4.399	72.779	3.752
- Pre treatment: location of ANS (structural)	68.894	4.314	70.938	3.828
- U1 incisal edge retraction	-0.656	1.354	6.713	2.158
- U1 root apex retraction	-0.226	1.202	1.803	2.111
- L1 incisal edge retraction	-0.531	1.341	0.110	2.522
- L1 root apex retraction	-0.755	1.741	0.921	2.602

Appendix (4)/ Table (II)
Means and standard deviations of the linear measurements on the "X" axis in both samples (in mm.)

DISTANCES ON THE "Y" AXIS	CONTROL SAMPLE		STUDY SAMPLE	
	MEAN	SD	MEAN	SD
- Pre treatment interlabial gap	3.055	3.198	3.017	2.516
- Post treatment interlabial gap	1.866	2.697	0.463	1.013
- Pre treatment U lip length	20.931	2.528	21.249	1.715
- Post treatment U lip length	20.866	2.434	21.414	1.806
- Pre treatment L lip length	18.202	2.290	15.519	2.562
- Post treatment l lip length	18.029	2.188	18.909	2.520
- Pre treatment soft tissue LFH (indirect measurement)	68.339	5.099	66.529	4.787
- Post treatment soft tissue LFH (indirect measurement)	68.710	4.848	68.010	4.310
- Pre treatment soft tissue component (indirect measurement)	44.354	4.015	42.264	3.751
- Post treatment soft tissue component (indirect measurement)	45.978	3.963	46.133	3.453
- Pre treatment: hard tissue LFH (indirect measurement)	62.406	4.584	62.988	4.800
- Post treatment: hard tissue LFH (indirect measurement)	63.987	4.515	65.635	4.356
- Pre treatment: overbite	3.041	10622	4.931	2.293
- Pre treatment: nasal component (indirect measurement)	54.724	3.780	54.281	3.949
- Nasal tip downward movement during treatment period (or T2-T1)	1.450	1.961	2.166	2.176
- Downward movement of (Menton) during treatment period (or T2-T1)	2.730	2.257	4.090	3.306
- U1 incisal edge extrusion during treatment period (or T2-T1)	1.815	1.796	2.677	2.267
- L1 incisal edge intrusion during treatment period (or T2-T1)	1.672	1.692	5.883	3.070
- Pre treatment how much of the crown appears when the upper lip is at rest	3.676	1.887	3.625	2.222
- Pre treatment how much of U1 crown is covered by the lower lip at rest	-0.621	2.844	-0.609	1.378
- Pre treatment how much of L1 crown appears when the lower lip is at rest	2.420	2.546	4.323	2.318

Appendix (4)/ Table (III)
Means and standard deviations of the linear measurements on the "X" axis in both samples (in mm.)

ANGLES	CONTROL SAMPLE		STUDY SAMPLE	
	MEAN	SD	MEAN	SD
Pre treatment nasolabial angle	116.472	8.927	107.888	9.948
Post treatment nasolabial angle	116.669	9.496	118.355	9.628
Pre treatment: FMA angle	23.955	4.381	25.831	5.692
Post treatment: FMA angle	23.421	4.308	26.325	5.846
Pre treatment: U1-SN angle	103.084	6.348	111.578	7.849
Pre treatment: L1-MP angle	82.020	6.468	82.661	6.728

Appendix (4) / Table (IV)
Means and standard deviations of the angular measurements on the "X" axis in both samples (in degrees)

Appendix 5

CHANGES IN MEASUREMENTS OF LIMITED CLINICAL SIGNIFICANCE

<u>The lower lip retraction:</u> 78.6% of the variability in the lower lip retraction in reaction to orthodontic treatment is explained by the following factors: (Appendix 5/ Table 1)

- The retraction of the mandibular incisal edge, a significant factor at the 1% level, was directly related to the retraction by a ratio of (0.5:1) lower lip retraction to mandibular incisal edge retraction.
- The intrusion of the mandibular incisal edge, another significant factor at the 1% level, was directly related to the retraction by a ratio of (0.2:1) lower lip retraction to mandibular incisal intrusion.
- The pre treatment lower lip thickness, a third significant factor at the 1% level, was dierctly related to the lower lip retraction. Subjects with thicker lower lips pre treatment had a greater amount of lower lip retraction. For every 1 mm. increase in the pre treatment lower lip thickness, there was an 0.7 mm. increase in the lower lip retraction.

Appendix 5/ Table 1

The important factors influencing the retraction of the lower lip

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
LOWER LIP RETRACTION	Retraction of L1 incisal edge	+0.538 (**)	(+0.5 : 1)	78.6%
	Intrusion of L1 incisal edge during treatment	+0.236 (**)	(+0.2 : 1)	
	Pre treatment lower lip thickness	+0.723 (**)	(+0.7 : 1)	

- (**) significant at 1% level.
- (*) significant at 5% level.

The increase in the upper lip length: 50.2% of the variability in the increase in the upper lip length in reaction to orthodontic treatment is explained by the following factors: (Appendix 5/ Table 2)

- The pre treatment interlabial gap, a significant factor at the 1% level, was inversely related to the increase in the upper lip length. Subjects with smaller pre treatment interlabial gaps had a greater amount of increase in the upper lip length. For every 1 mm. decrease in the pre treatment interlabial gap, there was an 0.2 mm. increase in the upper lip length.
- The pre treatment upper lip length, a second significant factor at the 1% level, was directly related to the increase in the upper lip length. Subjects with longer upper lips pre treatment had a greater amount of increase in the upper lip length. For every 1 mm. increase in the pre treatment upper lip length, there was an 0.2 mm. increase in the upper lip length.
- The pre treatment depth of the nose, a third significant factor at the 1% level, was inversly related to the increase in the upper lip length. Subjects with smaller nasal depths had a greater amount of increase in the upper lip length. For every 1 mm. decrease in the pre treatment nasal depth, there was an 0.2 mm. increase in the upper lip length.
- The pre treatment overjet, a significant factor at the 5% level, was inversely related to the increase in the upper lip length. Subjects with smaller overjets had a greater amount of increase in the upper lip length. For every 1 mm. decrease in the pre treatment overjet, there was 0.1 mm. increase in the upper lip length.

- The amount of maxillary incisor crown appearing when the upper lip is at rest, another significant factor at the 5% level, was inversely related to the increase in the upper lip length. Subjects with a lesser amount of maxillary incisors appearing under the relaxed upper lip pre treatment had a greater amount of increase in the upper lip length. For every 1 mm. decrease in the amount of maxillary incisors appearing under the relaxed upper lip, there was an 0.1 mm. increase in the upper lip length.
- The pre treament nasal component, a third significant factor at the 5% level, was directly related to the increase in the upper lip length. Subjects with larger nasal components had a greater amount of increase in the upper lip length. For every 1 mm. increase in the nasal component, there was an 0.1 mm. increase in the upper lip length.

Appendix 5/ Table 2

The important factors influencing the increase in the upper lip length

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
	Pre treatment interlabial gap	-0.158 (**)	(-0.2 : 1)	
	Pre treatment upper lip length	+0.238 (**)	(+0.2 : 1)	
	Nasal depth (indirect)	-0.243 (**)	(-0.2 : 1)	
INCREASE IN THE UPPER LIP LENGTH	Pre treatment overjet	-0.086 (*)	(-0.1 : 1)	50.2%
	The amount of U1 crown appearing when the upper lip is at rest	-0.141 (*)	(-0.1 : 1)	
	Nasal component (direct)	+0.050 (*)	(+0.1 1)	

- (**) significant at 1% level.
- (*) significant at 5% level.

<u>The increase in the upper lip thickness:</u> 52.7% of the variability in the increase in the thickness of the upper lip thickness in reaction to orthodontic treatment is explained by the following factors: (Appendix 5/ Table 3)

- The pre treatment interlabial gap, a significant factor at the 1% level, was inversely related to the increase in the upper lip thickness. Subjects with smaller pre treatment interlabial gaps had a greater amount of increase in the upper lip thickness. For every 1 mm. decrease in the pre treatment interlabial gap, there was a 0.4 mm. increase in the upper lip thickness.
- The pre treatment overbite, another significant factor at the 1% level, was directly related to the increase in the upper lip thickness. Subjects with larger pre treatment overbites had a greater amount of increase in the upper lip thickness. For every 1 mm. increase in the pre treatment overbite, there was an 0.3 mm. increase in the upper lip thickness.
- The pre treatment depth of the nose, a third significant factor at the 1% level, was inversely related to the increase in the upper lip thickness. Subjects with smaller nasal depths had a greater amount of increase in the upper lip thickness. For every 1 mm. decrease in the depth of the nose, there was an 0.3 mm. increase in the upper lip thickness.
- The pre treament length of the upper lip, a significant factor at the 5% level, was inversely related to the increase in the upper lip thickness. Subjects with shorter upper lips pre treatment had a greater amount of increase in the upper lip

thickness. For every 1 mm. decrease in the length of the upper lip, there was an 0.2 mm. increase in the upper lip thickness.

Appendix 5/ Table 3

The important factors influencing the increase in the upper lip thickness

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
INCREASE IN THE UPPER LIP THICKNESS	Pre treatment interlabial gap	-0.410 (**)	(-0.4 : 1)	52.7%
	Pre treatment overbite	+0.348 (**)	(+0.3 : 1)	
	Nasal depth (direct)	-0.254 (**)	(-0.3 : 1)	
	Pre treatment upper lip length	-0.159 (*)	(-0.2 : 1)	

- (**) significant at 1% level.
- (*) significant at 5% level.

<u>The decrease in the lower lip thickness:</u> 74.9% of the variability in the decrease in the lower lip thickness in reaction to orthodontic treatment is explained by the following factors: (Appendix 5/ Table 4)

- The pre treatment thickness of the lower lip, a significant factor at the 1% level, was directly related to the decrease in the lower lip thickness. Subjects with thicker lower lips pre treatment had a greater decrease in the lower lip thickness. For every 1 mm. increase in the pre treatment thickness of the lower lip, there was an additional 0.7 mm. decrease in the lower lip thickness.
- The retraction of the mandibular incisal edge, another significant factor at the 1% level, was inversely related to the decrease in the lower lip thickness. Subjects with less mandibular incisal edge retraction had a greater amount of decrease in the lower lip thickness. For every 1 mm. decrease in the mandibular incisal edge retraction, there was an additional 0.3 mm. decrease in the lower lip thickness.
- The intrusion of the mandibular incisal edge, a third significant factor at the 1% level, was inversely related to the decrease in the lower lip thickness. Subjects with a smaller amount of mandibular incisal edge intrusion had a greater amount of decrease in the lower lip thickness. For every 1 mm. decrease in the mandibular incisal edge intrusion, there was an additional 0.2 mm. decrease in the lower lip thickness.
- The pre treatment hard tissue lower face height (indirect measurement), a fourth significant factor at the 1% level, was in-

versely related to the decrease in the lower lip thickness. Subjects with smaller pre treatment lower face heights had a greater amount of decrease in the lower lip thickness. For every 1 mm. decrease in the pre treatment lower face height, there was an extra 0.1 mm. decrease in the lower lip thickness.

Appendix 5/ Table 4

The important factors influencing the decrease in the lower lip thickness

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
DECREASE IN THE LOWER LIP THICKNESS	Pre treatment lower lip thickness	+0.679 (**)	(+0.7 : 1)	74.9%
	Retraction of L1 incisal edge	-0.326 (**)	(-0.3 : 1)	
	Intrusion of L1 incisal edge	-0.231 (**)	(-0.2 : 1)	
	Pre treatment hard tissue LFH (indirect m.)	-0.122 (**)	(-0.1 : 1)	

- (**) significant at 1% level.
- (*) significant at 5% level.

<u>The increase in the soft tissue lower face height:</u> When measured directly, the following three independent variables seemed to explain 78.3% of the variability in the increase in the soft tissue lower face height. These variables are: (Appendix 5/ Table 5)

- The increase in the hard tissue lower face height, a significant factor at the 1% level, was directly related to the increase by a ratio of (0.7:1) increase in the soft tissue lower face height to increase in the hard tissue lower face height.
- The increase in the Frankfort mandibular plane angle, another significant factor at the 1% level, was directly related to the increase by a ratio of (0.5:1) increase in the soft tissue lower face height to increase the FMA angle.
- The pre treatment nasal component, a third significant factor at the 1% level, was inversely related to the increase in the soft tissue lower face height. Subjects with smaller pre treatment nasal component had a greater amount of increase in the soft tissue lower face height. For every 1 mm. decrease in the size of the pre treatment nasal component, there was an 0.1 mm. increase in the soft tissue lower face height.

Appendix 5/ Table 5

The important factors influencing the increase in the direct method of measuring the soft tissue lower face height

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
INCREASE IN THE SOFT TISSUE LFH (DIRECT)	Increase in the hard tissue LFH (direct)	+0.694 (**)	(+0.7 : 1)	78.3%
	Increase in the FMA angle	+0.479 (**)	(+0.5 : 1)	
	Pre treatment nasal component (indirect)	-0.095 (**)	(-0.1 : 1)	

- (**) significant at 5% level.
- (*) significant at 1% level.

When measured indirectly, four independent variables - among them the three previously listed - seemed to explain 70.0% of the variability in the increasse in the soft tissue lower face height. The new variable is: (Appendix 5/ Table 6)

- The pre treatment interlabial gap, a significant factor at the 1% level, was directly related to the increase in the soft tissue lower face height. Subjects with larger pre treatment gaps had a greater amount of increase in the soft tissue lower face height. For every 1 mm. increase pre treatment in the interlabial gap, there was a 0.5 mm. increase in the soft tissue lower face height.

Appendix 5/ Table 6

The important factors influencing the increase in the indirect method of measuring the soft tissue lower face height

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
INCREASE IN THE SOFT TISSUE LFH (INDIRECT)	Increase in the hard tissue LFH (direct)	+0.747 (**)	(+0.7 : 1)	70.0%
	Increase in the FMA angle	+0.501 (**)	(+0.5 : 1)	
	Pre treatment nasal component (indirect)	-0.103 (**)	(-0.1 : 1)	
	Pre treatment interlabial gap	+0.107 (**)	(+0.1 : 1)	

- (**) significant at 1% level.
- (*) significant at 5% level.

<u>The increase in the lower soft tissue component:</u> When measured directly, the following five independent variables seemed to explain 66.7% of the variability in the increase in the lower soft tissue component. These variables are: (Appendix 5/ Table 7)

- The pre treatment interlabial gap, a significant factor at the 1% level, was inversely related to the increase in the lower soft tissue component. Subjects with smaller pre treatment interlabial gaps had a greater amount of increase in the lower soft tissue component. For every 1 mm. decrease in the pre treatment interlabial gap, there was an 0.6 mm. increase in the lower soft tissue component.
- The increase in the hard tissue lower face height (direct measurement), another significant factor at the 1% level, was directly related to the increase by a ratio of (0.5:1) increase in the lower soft tissue component to increase in the hard tissue LFH.
- The horizontal growth of the nose, a third significant factor at the 1% level, was inversely related to the increase by a ratio of (-0.2:1) increase in the lower soft tissue component compared to horizontal growth of the nose.
- The increase in the Frankfort mandibular plane angle, a significant factor at the 5% level, was directly related to the increase by a ratio of (0.2:1) increase in the lower soft tissue component to increase in the FMA.
- The pre treatment lower lip thickness, another significant factor at the 5% level, was directly related to the increase in

the lower soft tissue component. Subjects with thicker lower lips pre treatment had a greater increase in the lower soft tissue component. For every 1 mm. increase in the pre treatment lower lip thickness there was an 0.3 mm. increase in the lower soft tissue component.

When measured indirectly, the same independent variables (significant

Appendix 5/ Table 7

the important factors influencing the increase in the direct method of measuring the lower soft tissue component

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
INCREASE IN THE LOWER SOFT TISSUE COMPONENT (DIRECT)	Pre treatment interlabial gap	-0.567 (**)	(-0.6 : 1)	66.7%
	Increase in the hard tissue LFH (direct)	+0.461 (**)	(+0.5 : 1)	
	Horizontal growth of the nose	-0.253 (**)	(-0.2 : 1)	
	Increase in the FMA angle	+0.166 (*)	(+0.2 : 1)	
	Pre treatment L lip thickness	+0.252 (*)	(+0.3 : 1)	

- (**) significant at 1% level.
- (*) significant at 5% level.

When measured indirectly, the same independent variables (significant at the 1% level and listed earlier) along with two other variables one of them significant at the 1% level and the other at the 5% level, seemed to explain 71.7% of its variability. The two variables are: (Appendix 5/ Table 8) - The amount of downward movement of hard tissue "Menton" during orthodontic treatment, a significant factor at the 1 % level, was inversely related to the increase by a ratio of (-0.4:1) increase in the lower soft tisssue component to "Menton" downward movement.

- The pre treatment lower lip length, a significant factor at the 5% level, was directly related to the increase in the lower soft tissue component. Subjects with longer lips pre treatment had a greater amount of increase in the lower soft tissue component. For every 1 mm. increase in the lower lip length pre treatment, there was an 0.1 mm. increase in the lower soft tissue component.

Appendix 5/ Table 8

The important factors influencing the increase in the method of measuring the lower soft tissue component

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
INCREASE IN THE LOWER SOFT TISSUE COMPONENT (INDIRECT)	Pre treatment interlabial gap	-0.699 (**)	(-0.7 : 1)	71.7%
	Increase in the hard tissue LFH (indirect)	+0.410 (**)	(+0.4 : 1)	
	Horizontal growth of the nose	-0.196 (**)	(-0.2 : 1)	
	The amount of downward movement of hard tissue (Menton) during treatment	-0.350 (**)	(-0.4 : 1)	
	Pre treatment lower lip length	+0.145 (*)	(+0.1 : 1)	

- (**) significant at 1% level.
- (*) significant at 5% level.

<u>The decrease in the interlabial gap:</u> 83.3% of the variability in the decrease in the interlabial gap in reaction to orthodontic treatment is explained by the following factors: (Appendix 5/ Table 9)

- The pre treatment interlabial gap, a significant factor at the 1% level, was directly related to the decrease in the interlabial gap. Subjects with larger pre treatment interlabial gaps had a greater amount of interlabial gap reduction. For every 1 mm. increase in the pre treament interlabial gap, there was an extra 0.8 mm. increase in the gap as a result of orthodontic treatment.
- The amount of downward movement of hard tissue "Menton" during orthodontic treatment, another significant factor at the 1% level, was inversely related to the decrease by a ratio of (-0.1:1) decrease in the gap to "Menton" downward movement.
- The pre treatment soft tissue thickness at "Subnasale", a significant factor at the 5% level, was directly related to the decrease in the interlabial gap. Subjects with smaller soft tissue thickness at "Subnasale" pre treatment had a greater amount of interlabial gap reduction. For every 1 mm. increase in the soft tissue thickness at "Subnasale" pre treatment, there was an extra 0.1 mm.increase in the interlabial gap reduction due to orthodontic treatment.

Appendix 5/ Table 9

The important factors influencing the decrease in the interlabial gap

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	RATIO	COEFFICIENT DETERMINATION (R^2)
DECREASE IN THE INTERLABIAL GAP (see N.B.)	Pre treatment interlabial gap	+0.814 (**)	(+0.8 : 1)	83.3%
	The amount of downward movement of hard tissue (Menton) during treatment	-0.132 (**)	(-0.1 : 1)	
	Pre treatment soft tissue thickness at subnasale	+0.121 (*)	(+0.1 : 1)	

- (**) significant at 1% level.
- (*) significant at 5% level.

NB:- Out of the 80 subjects in the study sample, the interlabial gap existed in 68 cases, the remaining 12 had their lips in contact before treatment.

- None of the 12 subjects who had no interlabial gap pre treatment developed a gap post treatment.

- Out of the 68 subjects who had an interlabial gap pre treatment, 39 had the gap totally eliminated by the end of the treatment. In the remaining 29 cases the gap was reduced but not eliminated.

Appendix 6

SUGGESTED FUTURE APPROACHES

The traditional cephalometric approach, as used in this study, continues to be of value in the clinical assessment of the craniofacial soft and hard tissues. This author, however, shares the views of MOYERS and BOOKSTEIN's [12] concerning the inappropriateness of such conventional cephalometric techniques. For instance, the present cephalometric techniques have little scientific basis in either biology or biometrics; there is no theoretical basis for traditional cephalometrics, only conventional methodologies. Thus such techniques provide scant data regarding the curvilinear form of the craniofacial skeleton and the changes arising from orthodontic therapy. Traditional cephalometry also combines the parameters of size and shape together. Nevertheless, this technique was adopted in the present study, since the form of lateral cephalometric evaluation is still the predominent method used clinically.

Various other methods have been proposed, however, to provide more geometrically accurate description of cephalometric form. Such methods include:

1. STEREOPHOTOGRAMMETRY [4 5]: Wich consists of a 3-D measurement of surfaces, photographed by two cameras, with subsequent restitution of a visual method stereoscopically.

2. SHADOW PROFILE PHOTOGRAPHS [2 6 7 9]: Which consists of 2-D simple silhouette profiles.

3. PHOTOCEPHALOMETRY [8]: Which is a 2-D technique to facilitate the superimposition of cephelographs and photographs so that photographic images of the face may be accurately superimposed on the corresponding images on the cephalograph.

The first two techniques are limited to soft tissues only, and therefore provide limited potential for the assessment of the soft and hard tissue interrelationship in orthodontic patients. PHILIPS et al [13] have also shown that photocephalomerty is of limited potential, since the enlargement factors between the cephalographic and the radiographic images may be of such magnitude that image superimposition may not be feasable for quantitative comparisons of soft and hard tissue morphology.

Recent publications [1 10 14], however, have presented other methods which seem very promising, among these methods are the Nuclear Magnetic Resonance (NMR), the X-ray Computerized Axial Tomography (CAT Scan) and the Fanned Laser Beam Projection.

NMR images are cross-sectional pictures of thin slices through the body obtained by using radio waves to interrogate susceptible atomic nuclei that have been precisely oriented in a magnetic field. 3-D soft and hard tissue structures can be easily identified by the proper choice of frequency in this technique. The soft tissue contrast is inherently superior to that of the cephalometric technique.

The "CAT Scan" can also provide informartion locating both hard and soft tissue contours in three dimensions with great accuracy and precision. The use of two fanned Laser beams projected vertically onto the face from an oblique angle and observed from the front with a video camera have also proved successful in acquiring 3-D coordinates of the soft and hard tissue stuctures.

Based on these 3-D "static" techniques, There is a need to develop new technologies to evaluate the "dynamic" aspects of the soft tissues. This author considers that a combination of such functional approach is required to evaluate the low degree of predictibility in the soft tissue reaction to orthodontic treatment.

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