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LONG TERM SOFT TISSUE LIP CHANGES FOLLOWING ORTHODONTIC TREATMENT

BY: R.M. SATHEKGE

LONG TERM SOFT TISSUE LIP CHANGES FOLLOWING ORTHODONTIC TREATMENT

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

Johannesburg, 2005

DECLARATION

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

RM Sathekge

RM Sathekge

_____ day of, _____, 2005

DEDICATION

To my husband, Mike and my two sons, Machaba and Tshimogo, for the encouragement, love, patience and support throughout this work.

ACKNOWLEDGEMENTS

I wish to express my gratitude to my supervisor, Dr C Lesar, for his valuable assistance and guidance in both the execution and preparation of this research report.

Appreciation is also due to Professor E Stein for his valuable input.

Many thanks to Dr P Becker of the Institute of Biostatistics, Medical Research Council, for his advice and assistance with the statistical interpretation of data.

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ABSTRACT

Evaluating facial profiles and facial balance is a continuous learning process for orthodontists. Hence, the importance of studying the immediate and the long term effects of treatment on the soft tissues cannot be overemphasized.

The objective of this study was to evaluate the lip changes occurring in response to tooth movement, not only immediately post-treatment but also to following the long-term monitoring when cranio-facial growth has ceased. The lip changes were measured relative to the Burstone (B-line) line. The sample was taken from the records of successfully treated orthodontic cases in the Department of Orthodontics at the University of Witwatersrand, Johannesburg. This sample comprised 18 Caucasoid females (14 extraction, 4 non-extraction). Pre-treatment, post-treatment, and long term follow-up lateral cephalometric radiographs were evaluated.

Statistical evaluation of the lips in the long term follow-up records revealed no statistically significant changes. The lips remained, relatively, in a similar position to that which had been attained immediately post-treatment. This was the case for both the extraction and non-extraction groups.

The general lack of consistency in post-treatment correlations between dental variables and the soft tissue form supports the hypothesis that the soft tissues, having their own inherent architecture, respond independently. This varied response to tooth movement makes lip movement difficult to predict on a reliable basis.

The concept that it is better to finish the cases slightly more protrusive because the lips tend to lose elasticity with age and, as a result, become more retrusive, is therefore supported by these observations.

CHAPTER 1

INTRODUCTION

The architecture and topographic relationships of the facial skeleton form a 'foundation' on which the aesthetics of the face are based. Norman Kingsley (1980, cited by Nanda and Gosh, 1995) recognized the infinite variety of human countenance and equally infinite diversity in the form of jaws, but emphasized that the attractiveness of facial features is dependent on a harmonious relationship of the dentition and the facial configuration. Whether viewed dynamically or statically, individual facial harmony and profile balance are determined by the interaction between the soft tissues themselves, the characteristics of the underlying skeletal foundation and the positions of the teeth. All these factors combine to provide the visual impact of the face.

Among the objectives of orthodontic treatment is the achievement of this very balance and harmony between the hard and soft tissues. The ability to predict the final soft tissue drape of the face is of paramount importance to the orthodontist. Studying the immediate and the long term effects of treatment on the soft tissues is of concern in

clinical orthodontics as these factors could be crucial to the public's perception of the acceptability of orthodontics.

CHAPTER 2

2.1 REVIEW OF THE LITERATURE

Angle's philosophy of non-extraction argues that the best balance and proportions of the mouth and its relation to other features require that there will be a full complement of teeth in all cases. Tweed (1944), who was a student of Angle, demonstrated in his cases poor stability after non-extraction treatment, and showed that, in order to achieve good aesthetics and stability, re-treatment with extraction of premolar teeth needed to be carried out in a large proportion of the cases. Begg (1954) argued that the natural decrease in arch length due to abrasive dietary effects and evolutionary factors results in the need to extract teeth as part of orthodontic treatment. Soft tissue changes do occur as a result of orthodontic treatment regardless of the techniques used. Both sides of the extraction debate have claimed similar improvements in facial aesthetics and comparable stability of the treatment, with both sides exhibiting advantages and disadvantages as well as limitations.

Bishara, Cummins and Zacher (1997) found that patients who undergo extractions tend to have straighter faces and slightly more upright maxillary and mandibular incisors, while those treated non-extraction have the opposite tendencies. The study showed that these differences between the two groups were maintained for two years following treatment. Similar results were found over time by Paquette, Beattie and Johnson (1989) in their study of "borderline" extraction/non extraction cases fourteen and half years out of treatment. Luppanapornlarp and Johnson's (1993) findings also indicated that the extraction of first premolars tended to flatten the profile by two - three mm when compared with non-extraction treatment results.

Finnoy, Wisth and Boe (1987) found significant differences in the soft tissue profiles of extraction and non-extraction Class II malocclusion groups immediately after treatment. However, over a three to five year post-treatment period there were very few soft tissue profile differences between the two groups.

More recently, however, a preliminary study of the three-dimensional effects of orthodontic treatment on the facial soft tissues by Ismail and Moss (2001) found no evidence that the extraction of teeth resulted in a flattening of the facial soft tissue profile.

Zierhut, Joondeph, Artun and Little (2000) in a study of 63 Caucasian adolescents evaluated pre-treatment, post-treatment, and long-term post-treatment soft-tissue profiles from lateral cephalometric radiographs. The soft tissue facial profiles of the extraction and non-extraction samples were similar following active treatment and a long-term post-treatment period of fourteen years. Long-term lip positions were more retrusive than the ideals suggested by Ricketts (1960) and Steiner (1953), but were close to the reported normal values for untreated adults of similar age. Zierhut et al (2000) further stated that much of the negative commentary on extraction has centered on the claim that the extraction of four premolars produces an unaesthetic soft tissue profile by a "flattening" or "dishing-in" of the lips relative to chin and nose. This supposition appears to be based in a large part on opinion and anecdotal case reports and lacks well-documented support in the literature. Furthermore, inherent to this conclusion is the unproven assumption that changes in the hard tissue directly and equally affect the overlying soft tissue profile, and that normal maturation does not play a significant role in post-treatment and long-term profile outcomes.

Drobocky and Smith (1989) and Young and Smith (1993) found that in spite of significantly greater lip retraction in their extraction group, the individual variations in facial change were similar between the two groups.

The concept that extraction therapy flattens the profile assumes that a marked amount of incisor retraction takes place secondary to tooth removal and that the soft tissues act as a passive drape, following the underlying dental changes by a corresponding and predictable amount. Most studies have described the relationship of maxillary and/or mandibular incisor retraction to the changes in upper and lower lips. However, the nature of correlation between incisor retraction and lip adaptation remains controversial. Rains and Nanda (1982) found the upper lip at labrale superius to show greater variability with increased retraction of the upper incisors and that the upper lip response was related to both upper and lower incisor movement, mandibular rotation, and to the lower lip. Bloom (1961) reported a high correlation of the relationship of maxillary central incisor changes to the superior sulcus and upper and lower lips. He also noted that it was possible to predict the perioral soft tissue profile changes in relation to the expected amount of anterior tooth movement. Rudee (1964) in a similar study, reported that the average ratio of upper incisor retraction to upper lip retraction was 2.9:1, with a standard deviation of 2.2 mm. The upper incisor to lower lip ratio was 1:1, with a standard deviation of 4.2 mm. Similarly, the lower incisor to lower lip retraction ratio was 0.59:1 with a standard deviation of 7.6 mm. This sample was selected without regard to age and sex, and no attempt was made to isolate the effect of growth from the changes due to treatment.

Conversely, Hershey (1972) examined the effect of incisor retraction on soft tissue profile changes in 30 post-adolescent female patients. He concluded that neither the simple nor the multiple correlation coefficients obtained were clinically significant in the prediction of soft tissue response to incisor retraction. Wisth (1973)reported similar findings and concluded that prediction of soft tissue changes in an individual case is impossible, particularly if the overjet is large.

In order to improve the clinician's ability to predict the soft tissue profile changes relative to the retraction of maxillary incisors, Talass, Talass and Baker (1987) studied the cephalometric records of 80 treated growing female patients with Class II Div 1 malocclusion and 53 untreated growing female subjects and quantified the profile changes. The data from this study suggested that, in general, growth was associated with only minimal changes in the soft tissue profile over a study period of up to 36 months. The three clinically significant soft tissue changes that occurred in response to orthodontic treatment in their study were the retraction of the upper lip, the increase in the lower lip length, and the increase in the nasolabial angle. The length of the upper lip did not increase with either growth or orthodontic treatment. 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 caused by the complex anatomy and/or dynamics of the upper lip which could not be evaluated by using the available cephalometric techniques.

Battagel (1990) also examined the relationship between hard and soft tissue changes following treatment of Class II Div. 1 malocclusions using edgewise therapy. He found that the only hard tissue structure which had a clinically significant influence on the position of the upper lip prominence in edgewise therapy was the maxillary incisors. In edgewise therapy, greater absolute changes in upper lip and upper incisor retraction occurred, with a positive treatment related correlation between the two. There was an inverse correlation between lip thickness and upper lip retraction.

Attempts have been made to include an element of soft tissue profile assessment using reference lines, such as the Ricketts esthetic plane (1960), the Holdaway line (1983 and 1984), Steiner's S line (1953) and the Burstone soft tissue analysis in diagnosing and treatment planning and assessing changes induced by treatment. One of the drawbacks with many of the studies undertaken to date is that the reference points used in the methods of analysis are known to be undergoing changes during the period of

assessment, for example the Rickett's esthetic plane (1960) and Merrifield's Z angles (1966).

Burstone (1967) found in a study of lip posture that there was no truth in the hypothesis that lip posture followed the position of the underlying teeth. He further stated that in diagnosing an orthodontic case the soft tissue should be a criterion as well as the dental and skeletal structures because the soft tissue is the final determinant of facial aesthetics and harmony. He analyzed seven integumental landmark points and their interrelationships on the Herron sample (a group of forty acceptable faces as chosen by a group of three artists) and compiled an integumental profile grid of acceptable young adult faces from which graphic comparison could be made. From this he found that on average, the upper lip lies 3.5 mm, and the lower lip, 2.2 mm anterior to the Burstone B-line.

Long-term assessment of the soft-tissue profile must also consider normal maturational changes and the considerable individual variation. Growth of the nose and chin in untreated adolescents has been shown to far exceed concomitant change in lips. This normal maturational change tends to continue after adolescence, resulting in further "relative retraction" of the lips (Pelton and Elsasser, 1955; Subtelny, 1959; Nanda,

Meng, Kapila and Goorhuis, 1990). Nose and chin growth have also been shown to exceed the lip changes observed in adolescents undergoing active treatment (Koch, Gonzales and Witt, 1979; Anderson et al, 1973).

Subtelny (1959) found that not all parts of the soft tissue profile follow the same rate of growth as the underlying skeletal components. In studying changes in soft tissue thickness between the ages of three and eighteen years, he observed a proportionally greater increase in the thickness of the soft tissue covering the maxillary region than was found in the area of nasion and pogonion. The soft tissue overlying pogonion showed an increase of 2.4 mm in males and 1 mm in females. And in the maxillary region Subtelny (1959) also indicated that growth of the nose causes a thickening of the upper lip over point A, bringing the lip forward.

There have been only a few studies which have attempted to assess the long-term soft tissue lip changes induced by treatment. Mostly, these studies used Rickett's E-line and/or Steiner's S-line to evaluate the soft tissue changes. Burstone (1967) used a plane, the B-line connecting subnasale and soft tissue pogonion to evaluate relative protrusion or retrusion of the lips. The B-line is a plane of minimal variation in the area of the face. If the before and after treatment tracings of non-growing persons are

superimposed, subnasale and pogonion will not show marked change, provided that the headplate has been taken with the patient in the relaxed lip position (Burstone, 1967). Hsu (1993) found the B-line to be the analytical reference line with the most consistency and sensitivity when used as a reference for lip balance and harmony on the lateral facial profile tracing. When compared with other analytical reference lines, e.g., Ricketts E-line, the B-line has the smallest coefficient of variation; it provides the narrowest dispersion and the best consistency in terms of judging facial profiles. Due to its reliability and the fact that it is not affected by growth of the nose, the B-line was employed as the reference line of choice in this study.

The balance of facial structures is affected by both orthodontic treatment and growth. Most of the soft tissue growth changes at the nose, lips and chin suggest sexual dimorphism. Males exhibit greater increases, due to growth occurring over a longer time span than in females. Most of the soft tissue measurements in females have attained adult size by age 15 years, whereas in males these are increasing even at 18 years of age (Nanda and Ghosh, 1995). Investigations concerning balancing profiles have indicated that the position of the lips is usually responsive to orthodontic treatment and is therefore more critical in orthodontic diagnosis than are the nose and chin. Soft tissue changes that occur following orthodontic treatment are part of treatment

objectives. It would therefore be valuable to know whether these changes cease immediately following treatment or whether they continue to occur during the post-treatment period. When studying the long term soft tissue changes due to orthodontic treatment it is important to identify those changes induced by growth. Provision should be made to account for growth factors which could blur the treatment changes.

These observations would therefore justify a more in depth look at the long term lip changes in patients where growth can be excluded.

2.2 OBJECTIVES OF THIS INVESTIGATION

The daily challenge confronting the orthodontist is to treat the occlusion to excellent occlusal norms and at the same time to achieve a pleasing facial appearance. To-day the scenario of greater patient awareness of the effects of treatment as well as the improvements in orthodontic appliances have led to a more critical appraisal of the outcome of treatment. Of all the soft tissues, the lip profile is that which the orthodontist has the most potential to change. Therefore, by concentrating on lip changes and by using a relatively simple diagnostic tool such as the Burstone line it is hoped that the orthodontist can be aided in the quest for predictable lip changes. In order to achieve lasting results the orthodontist should be looking beyond the end of treatment. The understanding of the effects of treatment should therefore be extended to include the possible impact of intervention on the lateral facial profile well past the end of active treatment.

This study was undertaken to evaluate the soft tissue changes occurring in response to tooth movement not only immediately following orthodontic treatment but also to assess the long-term changes .

CHAPTER 3

MATERIALS AND METHODS

3.1 SAMPLE

The cephalometric records of patients who had undergone comprehensive orthodontic treatment with edgewise appliances in the Department of Orthodontics at the University of the Witwatersrand, Johannesburg, were evaluated for possible inclusion in this study.

Selection criteria:

1. Since most of the soft tissue measurements in females have attained adult size by age 15 years (Nanda and Ghosh, 1995), the sample was restricted to females only.

2. The cases were considered clinically to have been well treated according to the consultants in the Department of orthodontics.

3. Availability of good quality pre-treatment (T1), post- treatment (T2) and long-term follow-up (T3) lateral cephalometric radiographs exhibiting a clear soft-tissue profile was essential.

4. Any case exhibiting congenital abnormality was excluded, as well as those who had undergone surgical orthodontic correction.

5. As patients had been instructed to occlude in centric occlusion with lips lightly touching (lips in repose) (Burstone, 1967), any radiographs exhibiting obvious lip strain were excluded.

Difficulty in fulfilling selection criteria:

Difficulty was experienced in locating some of the female patients because of the passage of time since the completion of treatment.

Factors which made the collection of an adequate sample size difficult:

1. Patients had moved away from the immediate area of the University and were reluctant to return for assessment.

2. Some of the potential participants had married and because of a name change together with the fact that they had moved, tracing was very difficult.

3. Some of the potential pool of patients had emigrated.

As a result of these factors, the sample comprised 18 Caucasoid females only. No restriction could thus be placed on malocclusion type before the start of treatment. Therefore, the sample included Class I, Class II and Class III malocclusion types. The selected female Caucasian sample of 18 consisted of 14 extraction and 4 non-extraction cases. The mean age at commencement of treatment was 13.2 years with the range 10.5 - 19 years.

3.2 METHOD

The following hard and soft tissue landmarks were identified and traced on each radiograph (Figures 1 & 2):

***Hard tissue anthropological landmarks used in the study*:**

1.	Nasion	(N)
2.	Pogonion	(Pog)
3.	Sella turcica	(S)
4.	Subspinale (Downs' A-Point)	(A)
5.	Supramentale (Downs' B-Point)	(B)
6.	Upper incisor tip	(Uit)
7.	Lower incisor tip	(Lit)
8.	Anterior nasal spine	(ANS)
9.	Posterior nasal spine	(PNS)
10.	Lower incisor apex	(Lia)
11.	Upper incisor apex	(Uia)
12.	Gonion	(Go)
13.	Gnathion	(Gn)
14.	Orbitale	(Or)
15.	Porion	(Po)
16.	Menton	(Me)

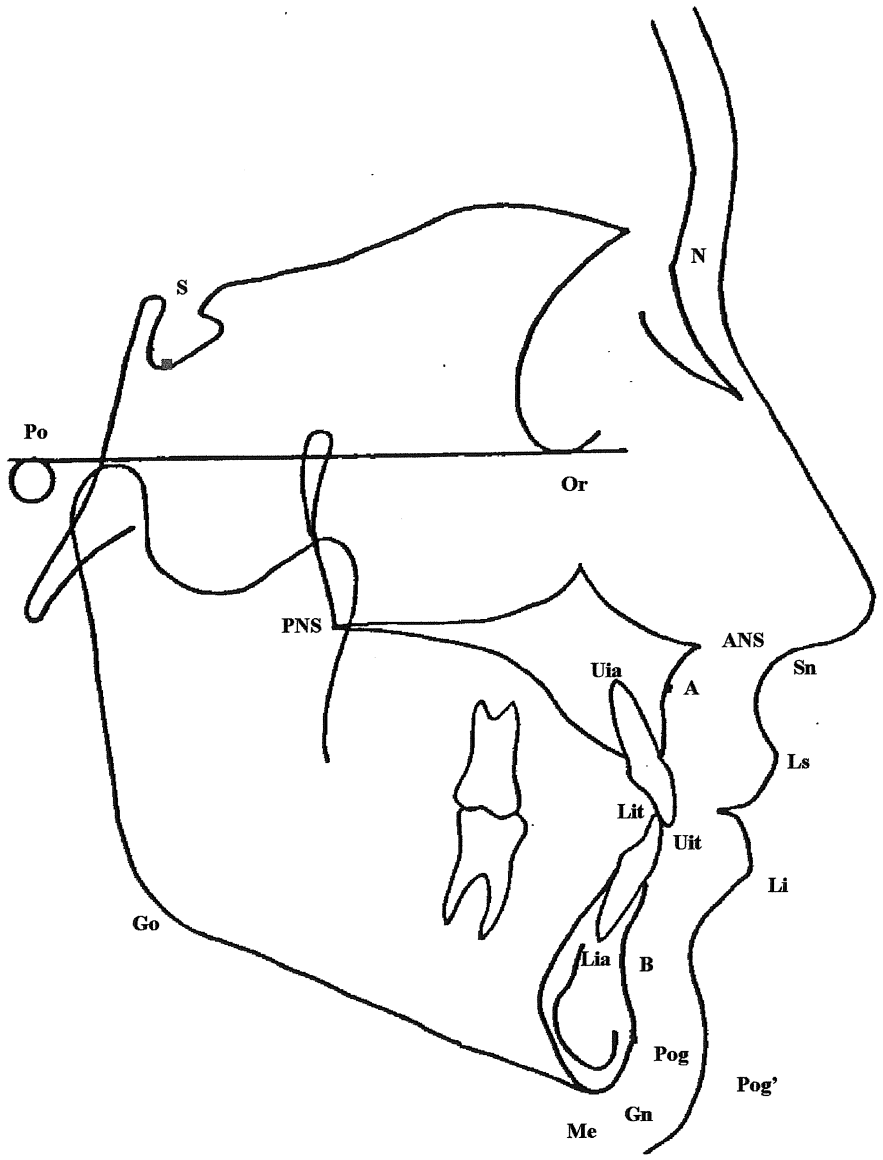

Figure 1. The soft and hard tissue landmarks employed in this study.

Soft tissue landmarks (Burstone, 1958):

1. Soft tissue pogonion (Pog')
2. Labrale Inferius (Li)
3. Labrale Superius (Ls)
4. Subnasale (Sn)

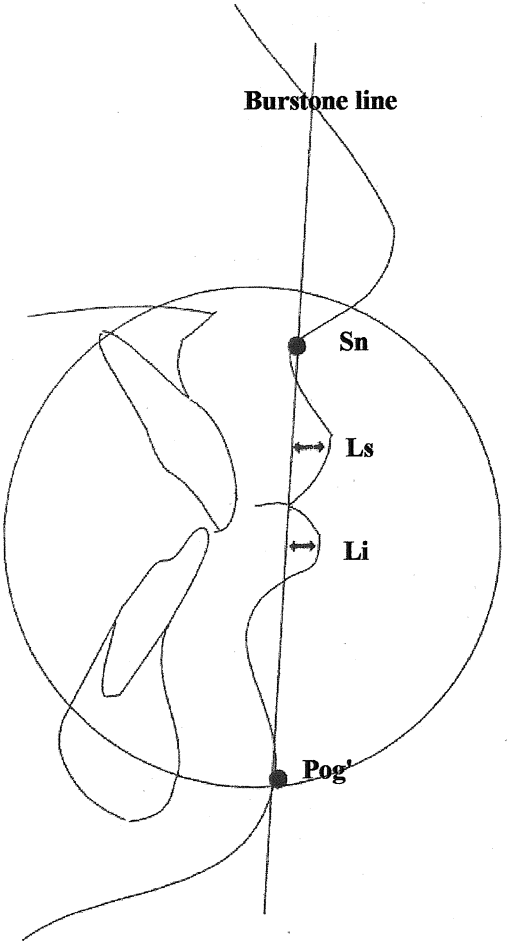

Figure 2. Horizontal lip posture. Lip protrusion measured perpendicular to subnasale-soft tissue pognion plane.

For the purpose of this study, the landmarks listed were defined as follows:

Sella Turcica (S): Constructed midpoint in the median plane of the pituitary fossa (Bjork, 1955).

Nasion (N): The intersection of the internasal suture with the fronto-nasal suture in the mid-sagittal plane (Ricketts, 1960).

Pogonion (Pog): The most prominent or anterior point on the contour of the bony symphysis of the mandible (Ricketts, 1960).

Gnathion (Gn): A point on the chin determined by bisecting the angle formed by the facial and mandibular planes (Williams, 1953).

Menton (Me): The most inferior point on the outline of the bony mandibular symphysis in the midsagittal plane (Downs, 1948).

Gonion (Go):	A point on the curvature of the angle of the mandible located by bisecting the angle formed by lines tangent to the posterior ramus and the inferior border of the mandible (Rakosi, 1993).
Supramentale (B):	The most posterior point in the concavity between the most superior point on the alveolar bone overlying the lower incisor (infradentale) and pogonion (Downs, 1948).
Subspinale (A)	The deepest midline point in the maxilla between the anterior nasal spine and the most inferior point on the alveolar bone overlying the incisors (prosthion) (Downs, 1948).
Anterior Nasal Spine (ANS):	This point is the tip of the nasal spine seen on x-ray film on norma lateralis (McNamara, 1984).

Posterior Nasal Spine (PNS): A point formed by the united projecting ends of the posterior borders of the palatine bones (McNamara, 1984).

Porion (Po): The most superiorly positioned point of the external auditory meatus (Ricketts, 1960).

Orbitale (Or): The lowest point on the inferior rim of the orbit (Salzmann, 1943).

Labrale Superius (Ls): The median point in the upper margin of the upper membranous lip (Burstone, 1958).

This was identified as the most anterior point of the upper lip and measured perpendicularly to the line Sn-Pog'.

Labrale Inferius (Li): The median point in the lower margin of the lower membranous lip (Burstone, 1958).

This was identified as the most anterior point of the lower lip and measured perpendicularly to the line Sn-Pog'.

Soft Tissue Pogonion (Pog'): The most prominent or anterior point on the soft tissue chin in the mid-sagittal plane (Burstone, 1958).

Subnasale (Sn): The point at which the nasal septum between the nostrils merges with the upper cutaneous lip in the mid-sagittal plane. If the depression is a gentle curve, Sn is interpreted as the most concave point in this area as measured by a line angled 45° from the nasal floor. (Burstone,1958).

Point subnasale was located along a line drawn tangent to the nasal base area and at an angle of 45° to the palatal plane (ANS - PNS). Practically this was achieved by using a 45° set square ruler. The base of the ruler was orientated along the palatal plane and then slid along this plane until the side of the ruler with a 45° angle was tangential to the nasolabial contour. Sn was located by marking the deepest point of the nasiolabial contour (Figure 3). This method was used in this study to accurately locate subnasale (Sn).

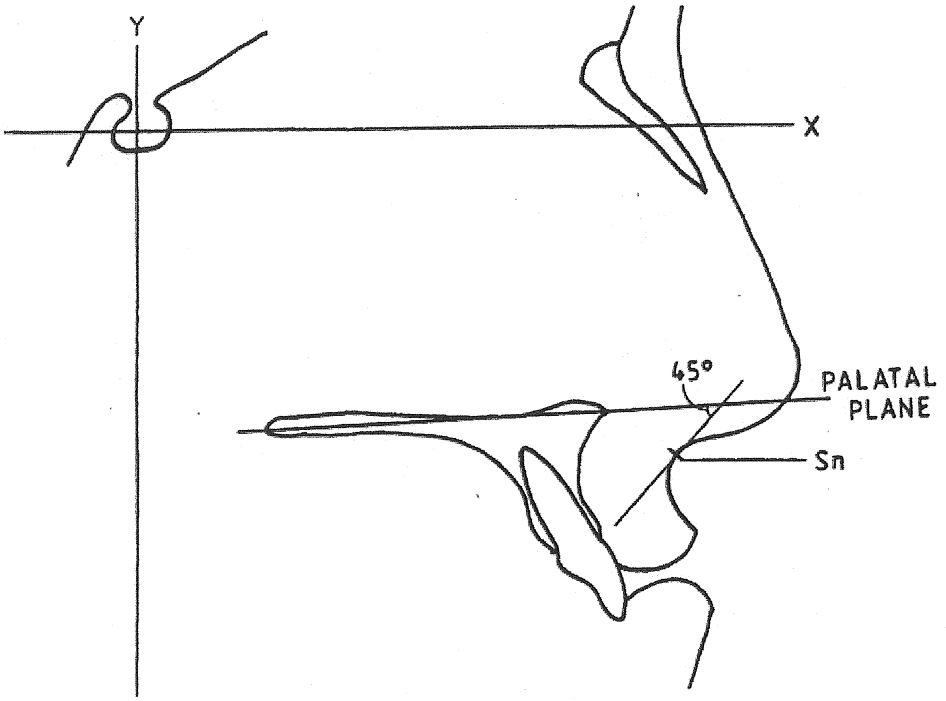

Figure 3. Location of Sn as the deepest point of the nasiolabial contour.

Hard Tissue Measurements:

ANB angle (anb) – The difference between the angles SNA and SNB. Norm = 2° (Steiner, 1953).

"Wits" measurements (linear) (wits) – The extent to which the jaws are related to each other anteroposteriorly. The functional occlusal plane is drawn through the region of maximum posterior cuspal interdigitation. Perpendiculars are drawn on the lateral cephalometric headfilm tracing from points A and B respectively onto the functional occlusal plane.The points of contact on the occlusal plane from points A and B are labeled AO and BO, respectively. The distance from AO to BO is measured. Average = 0 mm in females. (Jacobson, 1975).

Mandibular plane angle (mdp/Mand plane) – The angle formed between a line drawn from constructed gonion to gnathion, and the sella nasion line of the cranial base. Norm = 32°(Steiner, 1953).

N-S-Gn angle (y axis) - The angle formed by the intersection of lines drawn from nasion to sella and from sella to gnathion. Mean = 69° (Steiner, 1953).

Note: In this study, the y-axis of Down's analysis is represented by the N-S-Gn angle of Steiner.

Point-A to Nasion perpendicular to Frankfort Horizontal (linear)

(a nfh/A-N⊥FH) - The distance measured between point A and a vertical line drawn from nasion, perpendicular to the Frankfort Horizontal.Average =1 mm in adults (McNamara, 1984).

Pogonion to NB line (linear) (Po-NB) - The perpendicular distance measured from pogonion to the NB- line. Mean = 0 mm (Steiner, 1953).

Upper incisor to NA (angular)- (ui naa/ UI to NA) The angle formed by the intersection of the NA-line with the long axis of maxillary central incisor (upper incisor apex (Uia) - upper incisor tip (Uit). This indicates the relative axial inclination of upper

incisors to the NA-line. Mean = 22° (Steiner, 1953).

Upper incisor to NA (linear) (ui nal/ UI to NA) - The distance from the most anterior point of the upper incisor crown to the NA-line. Mean = 4 mm (Steiner, 1953).

Lower incisor to NB (angular) (li nba/ LI to NB) - The angle formed by the intersection of the NB-line with the long axis of mandibular central incisor (lower incisor apex (Lia) - lower incisor tip (Lit). This indicates the relative axial inclination of lower incisors to the NB-line. Mean = 25° (Steiner, 1953).

Lower incisor to NB (linear) (li nbl/ LI to NB) - The distance from the most anterior point of the lower incisor crown to the NB-line. Mean = 4 mm (Steiner, 1953).

Lower incisor to APo line (apo/ LI to APo) - The distance from the tip of lower incisor measured perpendicularly to a line drawn from A-point to pogonion. Mean = 1 mm (Ricketts,1960).

Soft Tissue Measurements (Figure 2):

Upper Lip to B-Line (linear) (ul bl/UL to B-line) - The distance from the most anterior point of the upper lip (Ls) measured perpendicularly to the Burstone line (Sn - Pog'). Average = 3.5 mm anterior to B- line (Burstone, 1967).

Lower Lip to B-Line (linear) (ll bl/LL to B-line) - The distance from the most anterior point of the lower lip (Li) measured perpendicularly to the Burstone line (Sn - Pog'). Average = 2.2 mm anterior to B- line (Burstone, 1967).

3.3 CEPHALOMETRIC ANALYSIS:

The radiographs were traced utilizing a standard format on Ozatex 0.05mm DMN drafting film paper (Ozalid SA Pty Ltd), using a 6H lead pencil, and the measurements were made employing a Kontron Digital Analyzer (Image-Analysis-Systems, West Germany) (Figure 4) in the Department of Orthodontics at the University of Witwatersrand. The identification of the landmarks was based on the definitions detailed earlier in the text, and included were:- sella turcica, nasion, porion, orbitale, posterior and anterior nasal spine, hard tissue pogonion, menton, gnathion, gonion, A-point, B-point, upper incisor tip and apex, and lower incisor tip and apex, The soft tissue integumental landmarks were drawn according to Burstone (1958), and they included: subnasale, labrale superius, labrale inferius and soft tissue pogonion.

All the lateral cephalometric radiographs for the pre-treatment (T1) and the post-treatment (T2) periods were obtained using the same x-ray machine. A different machine was used for those cephalometric radiographs that were taken for the long term follow-up (T3) period. A magnification factor for the individual X-ray machines was calculated by measuring the difference in width between the nose piece (X1) as measured on the cephalometric unit itself and the projected width as measured on the

radiograph (X2). The difference between the X1 and X2 values reflected a positive or negative magnification factor (X). In order to standardize the results this magnification factor (X) was added to or subtracted from each of the linear measurements measured by the Kontron Digital Analyser. This procedure was applied to all the measurements throughout this study.

A standard sequence of digitizing was established and each measurement was repeated three times, thereby further decreasing variability (Houston, 1983). The computer programme automatically displayed the readings with both means and standard deviations. The recordings were repeated until the standard deviation of three consecutive readings was below 0,05%. The mean of these measurements was calculated and recorded by the computer for periods T1, T2 and T3 respectively.

All the recorded data were submitted for statistical analysis.



Figure 4. Kontron Videoplan Digitizing System.

CHAPTER 4

STATISTICAL EVALUATION

A series of statistical analyses of the data was conducted by the Institute of Biostatistics of the University of Witwatersrand using STATA RELEASE 8 Software. This included descriptive and correlative procedures.

1. Descriptive and Comparative Statistical Analyses

Means and Standard Deviations, (SD) were calculated for individual data for the pre-treatment (T1), post-treatment (T2) and long term follow-up (T3) time periods. Initially, the data for the extraction and non-extraction treatment therapy cases were handled separately. Taking into account the small sample size, the paired Student t-test was used to evaluate whether there was any statistically significant difference between the data of the extraction and non-extraction treatment groups at the pre-treatment (T1), post-treatment (T2) and the long term follow-up treatment (T3) intervals. The level of significance was set at $p \leq 0.05$.

i.e. P-value:	$p \leq 0.05$	Significant
	$0.05 \leq p \leq 0.1$	Marginally Significant
	$p \geq 0.1$	Not significant

2. Wilcoxon rank-sum test

A more sensitive test, the nonparametric two-sample Wilcoxon rank-sum (Mann-Whitney), test, was then employed to further identify the possible level of statistically significant differences between the data of the extraction and non-extraction groups.

3. Descriptive and Comparative statistical analysis (pooled data)

Once it was established that there were no statistically significant differences between the means of the data from extraction and non-extraction cases, the data were pooled. Thereafter, the pooled data of the pre-treatment, post-treatment and the long term follow-up intervals were subjected to descriptive and comparative statistical analyses. The overall lip changes at the post-treatment (T2) and long-term follow-up stages (T3) were then compared using Hotelling's T-squared test at the 0.05 level of significance. In order to assess the individual significance of upper and the lower lip changes these data were then subjected to the Student paired t-test

4. Correlation and Regression analysis

The relationships of quantitative variables (hard tissue, soft tissue, and dental tissue) for which statistically significant changes were found, were then subjected to correlation and regression analysis to assess the relationship between these changes.

5. Simple linear Correlation:

A simple linear or "straight line" correlation analysis was determined using thePearson's Coefficient of Correlation (r) equation. This was used as a measure of the strength of the relationship between two variables, having a range from -1.00 through 0 to +1.00.

strong correlation:	r = -1.00 or 1.00
no correlation:	r = 0
inverse relationship:	r = -ve value
direct relationship:	r = +ve value

6. Coefficient of Determination (R^2):

This Coefficient of Correlation (r) allowed for further calculations of the Coefficient of Determination (R^2) for those parameters which had been identified as demonstrating statistically significant differences. It is the proportion of the total variation in the

dependent variable (soft tissue lips) that is explained or accounted for by the variation in the independent variable (dental or hard tissues). In a case of simple linear regression $r = R$. For ease of interpretation the Coefficient of Determination (R^2) was expressed as a percentage using the following formula:

$$\text{Coefficient of Determination} = R^2 \times 100\%$$

It has been suggested (Glenn et al, 1987, cited by Battagel,1990) that where the correlation coefficient (r) reaches a value of 0.7 or above, this might be of clinical importance. However, lower values may still be of interest as these could suggest a partial cause and effect relationship.Since a correlation coefficient of 0.7 whilst statistically significant, explains only 50% of the total variation, all correlations need to be interpreted with caution. In interpreting correlation it is important to recognize that correlation does not necessarily imply causation. There may or may not be a causative correlation between the two variables. Moreover, this causative correlation may be indirect.It is also possible that with a large number of correlations apparent significance could occur by chance.

A Coefficient of Determination (R^2) of 60% for a specific dental and/or hard tissue parameter would imply that 60% of the change occurring in the soft tissue parameters could be explained by the changes occurring in the hard tissue parameter. A Coefficient of Determination of greater than 50% would indicate a good correlation (i.e. $R^2 \geq 0.7$).

7. Multiple regression analysis:

A multiple regression analysis was used to predict the value of the dependent variable (soft tissue lips) based on the independent variable (dental or hard tissues); and also to determine the regression equations when the correlation was statistically significant. The Coefficient of Determination was calculated to evaluate the strength of the relationship between lips and other dental and hard tissues.

8. Scatter diagram:

A chart that portrays the relationship between the two variables of interest. In this study, the variables were the relationship of the upper and lower lips to the B-line.

SUMMARY OF STATISTICS EMPLOYED

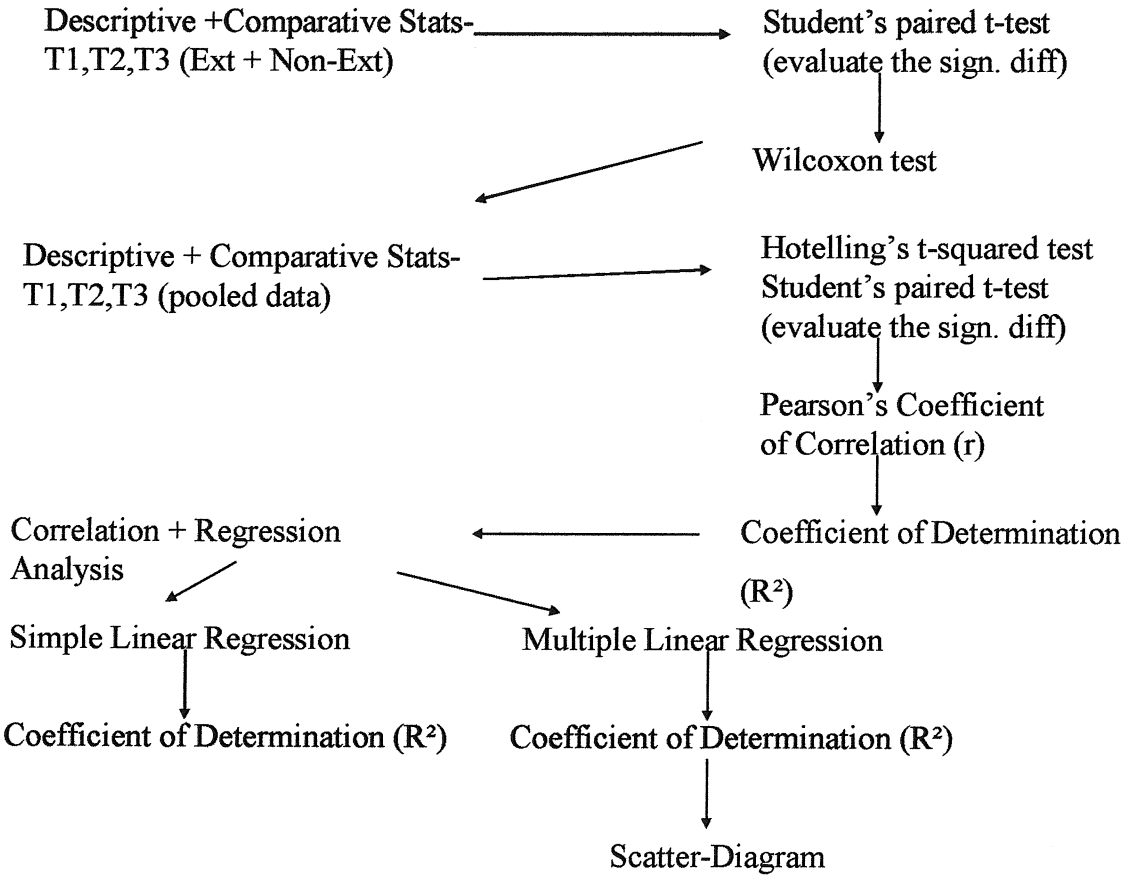

Figure 5. Summary of statistics employed.

CHAPTER 5

RESULTS

5.1 ERROR OF THE METHOD

5.1.1 Measurement accuracy

The accuracy of all measurements used in this study was evaluated in a pilot study in which ten randomly selected cephalometric films were traced and then digitized three times by the same operator at the same time on different days. The pooled standard deviation of the measurement error within each set of three measurements of each cephalometric film was calculated. The results showed that the error did not exceed one mm in any of the linear measurements and one degree in any of the angular measurements.

5.1.2 Intra-examiner accuracy (TABLE 1)

To test the proficiency of the operator in using the Kontron Videoplan System, a single lateral cephalogram was randomly chosen. On this radiograph the landmarks were identified and the linear and angular measurements were made and recorded at the same time on 10 separate days. The coefficient of variation (CV) of each of the 13 variables was calculated to assess the accuracy of the digitizing and the measuring procedures. As can be seen from Table 1 the coefficient of variation (CV) ranged between 1% and 10% for the hard tissue, skeletal and dental measurements, and between 11% and 13% for the soft tissue measurements. The accuracy was deemed acceptable, bearing in mind the small values of the linear and angular measurements being recorded.

$$\text{Coefficient of Variation (CV)} = \text{SD/Mean} \times 100\%$$

Table 1. Intra-examiner and inter-examiner accuracy of landmark identification and measurements (Means, SD and CV) for each parameter.

	INTRA-EXAMINER			INTER-EXAMINER			DIFFERENCE	
	Mean	SD	CV	Mean	SD	CV	Mean -D	CV -D
ANB (°)	1.7198	0.1212	7%	1.5895	0.2867	18%	-0.1303	11%
Mand plane (°)	39.0618	0.4828	1%	38.4262	0.7416	2%	-0.6356	1%
A(pt)-N⊥FH (mm)	-5.6061	0.1924	3%	6,7605	0.7638	11%	12.367	8%
Y- axis (°)	73.9598	0.5684	1%	72.9898	0.1639	0.2%	0.97	0.8%
Po- NB (mm)	4.2402	0.2658	6%	4.3495	0.5532	13%	0.1093	7%
Wits (mm)	-1.2305	0.1234	10%	2.1381	1.7597	82%	3.3686	72%
Ui to NA (°)	12.3485	0.5068	4%	13.3134	2.1162	16%	0.9649	12%
Li to NB (°)	10.2483	0.5237	5%	10.3181	0.6206	6%	0.0698	1%
Ui to NA (mm)	3.1171	0.0811	1%	3.6329	0.4626	13%	0.5158	12%
Li to NB(mm)	1.2432	0.0981	8%	1.6568	0.3088	19%	0.2107	11%
Li to APo (mm)	-2.5805	0.1327	5%	2.6248	0.3055	12%	5.2053	7%
UL to B-line (mm)	0.6138	0.0665	11%	0.6538	0.6277	96%	0.04	85%
LL to B-line (mm)	0.3491	0.0464	13%	0.3455	0.3618	105%	0.036	92%

5.1.3 Inter-examiner accuracy (Table 1)

On a randomly chosen cephalogram various landmarks were identified on separate days by ten visiting orthodontists in the Department of Orthodontics at the University of the Witwatersrand. The variables were then digitized using the landmarks on each of the ten tracings and the data were subjected to statistical analysis. A marked discrepancy between the intra- and inter-examiner recordings was noted (Table 1).

The difference (Table 1) between the coefficient of variation (CV) of the intra-examiner and inter-examiner recordings were very large especially for the following: wits (72%), ul bl (85%), and ll bl (92%). These results indicates a wide range of interpretation of specific cephalometric landmarks, especially those landmarks that are not frequently used. However, the greatest discrepancy occurred on those measurements which are inherently small and the intra-examiner results confirmed a well standardized technique for identifying the landmarks concerned. For future studies, however, the prescribed procedure and technique followed by the multiple-examiners should be more precise and rigidly controled.

5.2 DESCRIPTIVE AND COMPARATIVE STATISTICAL ANALYSIS OF EXTRACTION vs NON-EXTRACTION GROUPS (Tables 2,3,4)

Descriptive and comparative statistical analyses were carried out on the data from the extraction and non-extraction groups (Tables 2, 3 and 4) to evaluate whether there was any significant difference between the two groups. No statistically significant differences were detected. A more sensitive test, the Wilcoxon test (used for a small sample size) was also employed. This also confirmed the absence of statistically significant differences between the two separate groups.

Table 2. Descriptive statistics of the pre-treatment (T1) measurements of the non-extraction (NE) (n = 4) and extraction (E) groups (n = 14)

T1		Mean	SD	Min	Max
SKELETAL					
ANB (°)	E	4.753	2.404	-0.156	8.87
	NE	4.551	2.496	2.271	8.094
Wits (mm)	E	0.02	3.067	-4.266	6.864
	NE	1.465	1.176	0.311	2.62
Mand plane (°)	E	33.969	4.678	27.882	43.892
	NE	28.531	4.731	22.266	32.741
Y-axis (°)	E	69.69	3.427	63.593	75.001
	NE	67.654	5.694	62.223	74.199
A-N⊥FH (mm)	E	1.265	3.136	-5.562	5.98
	NE	1.223	5.664	-3.239	9.154
Po-NB (mm)	E	1.328	1.817	-1.865	4.576
	NE	2.358	0.860	1.205	3.239
DENTAL					
UI to NA (°)	E	22.119	6.104	11.273	32.396
	NE	19.299	8.272	9.706	28.899
UI to NA (mm)	E	5.868	1.602	3.685	8.243
	NE	4.025	1.946	2.077	5.709
LI to NB (°)	E	29.337	7.440	10.984	41.632
	NE	22.97	7.131	16.513	33.108
LI to NB (mm)	E	6.262	2.731	1.642	11.547
	NE	3.596	1.65	2.059	5.749
LI to APo (mm)	E	3.017	3.298	-3.039	9.935
	NE	-1	2.243	-3.412	1.276
SOFT TISSUE					
UL to B-line (mm)	E	5.518	2.03	0.682	8.068
	NE	3.529	1.064	2.425	4.984
LL to B-line (mm)	E	4.680	2.285	0.305	7.848
	NE	1.484	1.668	-0.509	3.569

Table 3. Descriptive statistics of the post-treatment (T2) measurements of the non-extraction (NE) (n = 4) and extraction (E) groups (n = 14)

T2		Mean	SD	Min	Max
SKELETAL					
ANB (°)	E	3.43	2.148	-0.779	7.857
	NE	4.133	2.585	2.2	7.935
Wits (mm)	E	-0.834	2.287	-3.641	4.174
	NE	1.385	1.003	0.452	2.722
Mand plane (°)	E	31.401	7.113	14.06	38.322
	NE	25.167	8.873	14.06	35.325
Y-axis (°)	E	70.271	4.225	64.149	77.968
	NE	68.072	6.468	64.035	77.602
A-N⊥FH (mm)	E	0.35	3.549	-6.665	5.69
	NE	2.952	4.487	-2.626	7.839
Po-NB (mm)	E	1.9	2.333	-2.27	5.665
	NE	2.307	0.515	1.911	3.039
DENTAL					
UI to NA (°)	E	19.039	7.229	6.075	35.091
	NE	18.977	5.076	11.907	23.923
UI to NA (mm)	E	4.078	1.487	1.395	7.301
	NE	2.897	1.198	2.059	4.654
LI to NB (°)	E	25.501	4.451	18.467	32.891
	NE	27.949	3.946	25.115	33.568
LI to NB (mm)	E	4.968	2.072	2.38	10.025
	NE	4.846	1.223	3.752	6.373
LI to APo (mm)	E	1.723	2.177	-1.961	6.347
	NE	1.176	1.352	-0.249	2.506
SOFT TISSUE					
UL to B-line (mm)	E	4.097	2.148	-0.404	7.972
	NE	2.696	0.790	1.574	3.384
LL to B-line (mm)	E	2.662	2.154	-0.787	7.849
	NE	2.063	0.81	0.904	2.712

Table 4. Descriptive statistics of the long term follow-up (T3) measurements of the non-extraction (NE) (n = 4) and extraction (E) groups (n = 14)

T3		Mean	SD	Min	Max
SKELETAL					
ANB (°)	E	3.103	1.989	0.219	7.347
	NE	3.534	2.064	2.038	7.07
Wits (mm)	E	-0.874	2.286	-3.575	3.639
	NE	1.625	1.255	0.294	3.085
Mand plane (°)	E	32.777	5.994	25.596	48.809
	NE	23.846	8.026	13.37	34.035
Y-axis (°)	E	69.832	5.168	60.623	77.65
	NE	67.946	4.87	62.867	74.022
A-N⊥FH (mm)	E	-0.117	3.713	-6.905	4.068
	NE	0.435	5.627	-5.382	8.781
Po-NB (mm)	E	2.330	2.609	-1.582	6.648
	NE	3.092	0.797	2.305	4.324
DENTAL					
UI to NA (°)	E	19.862	5.794	9.971	27.583
	NE	18.52	8.009	6.938	28.322
UI to NA (mm)	E	4.758	1.64	2.291	8.106
	NE	3.751	1.142	2.435	5.351
LI to NB (°)	E	25.902	6.017	13.914	35.699
	NE	25.801	4.637	20.932	33.118
LI to NB (mm)	E	5.103	2.489	2.156	10.807
	NE	4.341	1.585	2.771	6.242
LI to APo (mm)	E	2.186	2.508	-1.477	7.549
	NE	1.011	0.936	-0.196	2.051
SOFT TISSUE					
UL to B-line (mm)	E	3.222	2.429	-1.178	6.676
	NE	1.953	1.653	-0.596	3.923
LL to B-line (mm)	E	2.298	2.161	-1.276	6.275
	NE	1.235	2.187	-2.269	3.045

Table 5. Means, SD and the level of significance for the upper and the lower lip changes tested with the t-test and the Wilcoxon test.

Variables	**Mean and SD** Extraction	**Mean and SD** Non-Extraction	**t-test** Two-sample	**Wilcoxon test** Two-sample
UL to B-line (mm) T2-T3	0.875 (Mean) 1.172 (SD)	0.105 (Mean) 0.948 (SD)	$p = 0.249$	$p = 0.243$
LL to B-line (mm) T2-T3	0.364 (Mean) 1.077 (SD)	-0.047 (Mean) 1.168 (SD)	$p = 0.516$	$p = 0.915$

$p \leq 0.05$ Significant

$p \geq 0.1$ Not significant

Table 5 displays the means, standard deviations and the level of statistical significance for the upper and the lower lip changes at T2-T3 periods tested with both methods, the Student's t-test and the Wilcoxon's test. The results of both tests showed no statistically significant difference between the extraction and nonextraction groups, the p-value being greater than 0.1.

5.3 DESCRIPTIVE AND COMPARATIVE STATISTICAL ANALYSIS OF THE POOLED DATA

5.3.1 Pre-treatment recordings (T1) (Table 6)

Burstone (1967) found that in a "normal" adolescent sample the upper and lower lips were positioned ahead of the subnasale-pogonion plane (B-line). On average, the upper lip was 3.5 mm (SD = 1.4 mm) anterior to the line and the lower lip 2.2 mm (SD = 1.6 mm) anteriorly (Figure 2). These normal values were not gender sensitive as no significant differences in lip protrusion were found between male and female subjests.

Since the cases chosen for this study included Class I, II, and III malocclusions, both the upper and lower lips exhibited a wide range of protrusion or retrusion relative to the Burstone line before orthodontic treatment. The mean projection of the upper lip before treatment was recorded at 5.05 mm whereas mean lower lip protrusion was 3.93 mm. This relative lip protrusion could be due to upper and lower incisor inclinations that ranged from 9.71° to 32.4° when measured to the NA-line (mean = 21.56°) and 10.98° to 41.63° when measured to the NB-line (mean = 27.84°), respectively. In addition,

the lower incisor to Apo-line also demonstrated a wide range, namely -3.41 mm to +9.94 mm (mean = 2.07 mm).

In this mixed sample, the type of malocclusion was not a limiting factor in the sample selection, but the mean values obtained were close to normal. However, the ranges of the data were large.

Table 6. Means and Standard deviations of pre-treatment measurements (T1) (n = 18).

	Mean	SD	Min	Max
SKELETAL				
ANB (°)	4.705	2.347	-0.156	8.57
Wits (mm)	0.36	2.777	-4.266	6.864
Y-axis (°)	69.211	3.9598	62.223	75.001
Mand plane (°)	32.689	5.125	22.266	43.892
A-N⊥FH (mm)	1.255	3.659	-5.562	9.154
Po-NB (mm)	1.570	1.679	-1.865	4.576
DENTAL				
UI to NA (°)	21.455	6.503	9.706	32.396
UI to NA (mm)	5.434	1.812	2.077	8.243
LI to NB (°)	27.8391	7.668	10.984	41.632
LI to NB (mm)	5.635	2.732	1.642	11.547
LI to APo (mm)	2.072	3.491	-3.412	9.935
SOFT TISSUE				
UL to B-line (mm)	5.050	2.015	0.682	8.068
LL to B-line (mm)	3.928	2.528	-0.509	7.848

5.3.2 Post-treatment recordings (T2) (Table 7):

The post-treatment values in almost all the variables, skeletal, dental or soft tissues, were close to normal values. The mean ANB was slightly high at 3.59° (SD = 2.19°), with a range of -0.78° to 7.94°. The "Wits" mean value was -0.34 mm (SD = 2.25 mm), with a range of-3.64 mm to 4.17 mm.

Table 7. Means and Standard Deviations of post-treatment measurements (T2) (n = 18).

T2	Mean	SD	Min	Max
SKELETAL				
ANB (°)	3.586	2.191	-0.779	7.935
Wits (mm)	-0.341	2.253	-3.641	4.174
Y-axis (°)	69.782	4.681	64.035	77.968
Mand plane (°)	32.01	7.113	14.06	47.546
A-N⊥FH (mm)	0.928	3.798	-6.665	7.839
Po-NB(mm)	1.99	2.059	-2.27	5.665
DENTAL				
UI to NA (°)	19.025	6.671	6.075	35.091
UI to NA (mm)	3.815	1.483	1.395	7.301
LI to NB (°)	26.045	4.358	18.467	33.568
LI to NB (mm)	4.941	1.884	2.38	10.025
LI to APo (mm)	1.602	2.001	-1.961	6.347
SOFT TISSUE				
UL to B-line (mm)	3.786	1.9995	-0.404	7.972
LL to B-line (mm)	2.529	1.931	-0.787	7.849

The measurements for the upper and lower lip to the B-line were within the normal values as described by Burstone (1967). The upper lip to the B-line mean value was 3.79 mm (SD = 2 mm), although the range varied from -0.4 mm to +7.97 mm. The lower lip to B-line mean value was 2.53 mm (SD = 1.93 mm), with a range of -0.79

mm to 7.85 mm. These values reflected the reduction in protrusion that resulted from treatment and maxillary values hardly changed.

The upper incisor to NA mean angulation was 19.03° (SD = 6.67°), while the lower incisor was positioned at a mean value of 26.05° (SD = 4.36°). The lower incisor to APo-line mean was 1.60 mm (SD = 2 mm).

5.3.3 Long term follow-up (T3) (Table 8)

In general, the long-term follow-up cases demonstrated minimal change or no change at all in the values that were recorded post-treatment (T2) and also with reference to the norms. The lip measurements showed continuous slight reduction over the long term follow-up. Upper lip to B-line mean of 2.89 mm compared with that of 3.78 at time T2. The lower lip mean was 2.02 mm compared with 2.53 mm at T2 (Table 8).

Table 8. Means and Standard Deviations of long-term follow-up measurements (T3) (n = 18).

	Mean	SD	Min	Max
SKELETAL				
ANB (°)	3.217	1.9599	0.219	7.347
Wits (mm)	-0.216	2.324	-3.575	3.639
Y-axis (°)	69.336	5.028	60.623	77.65
Mand plane (°)	30.426	7.522	13.37	48.809
A-N⊥FH (mm)	0.284	4.1298	-6.905	8.781
Po-NB (mm)	2.531	2.275	-1.582	6.648
DENTAL				
UI to NA (°)	19.508	6.234	6.938	28.322
UI to NA (mm)	4.493	1.562	2.291	8.106
LI to NB (°)	25.876	5.561	13.914	35.699
LI to NB (mm)	4.903	2.2696	2.156	10.807
LI to APo (mm)	1.877	2.241	-1.477	7.549
SOFT TISSUE				
UL to B-line (mm)	2.888	2.280	-1.178	6.676
LL to B-line (mm)	2.018	2.160	-2.269	6.275

The mean ANB was still slightly high at 3.22° (SD = 1.96°), with a range of 0.22° to 7.35°. The "Wits" mean value was -0.22 mm (SD = 2.32 mm), with a range of -3.58 mm to 3.63 mm. Teeth tended to procline slightly with time, especially the lower incisors possibly because they were over-retracted during treatment. The upper incisor angulation increased slightly and the mean value was 19.51° (SD = 6.23°) with a range

of 6.94° to 28.32°. The mean for lower incisor angulation was 25.88° (SD = 5.56°) with a range of 13.91° to 35.7°. This was also displayed in the measurements of lower incisor to the APo-line, which recorded a mean of 1.88 mm (SD = 2.24 mm), with a range of -1.48 mm to 7.55 mm.

5.4 CHANGES RECORDED

5.4.1 Changes during treatment (T1-T2) (Table 9)

Descriptive and comparative statistics were calculated for the data from T1 to T2 time intervals. The mean change in percentage was calculated as follows:

$$\text{Mean Change (\%)} = \text{Mean Difference (T1-T2)} \div \text{Mean (T1)} \times 100$$

An evaluation of the mean value changes achieved (Table 9) shows that there were large changes in some of the values when expressed as a percentage. The absolute mean changes may indicate significant differences, while the mean change expressed as a percentage may not indicate a significant difference and vice versa. To evaluate the significance of the means of the differences between T1 and T2 values, a paired

Student's t-test was performed . A level of $P \leq 0.05$ was chosen to represent significance and a level of $P \geq 0.1$ was chosen to represent non significance. The upper lip underwent a mean change of 1.272 mm relative to the B-line (-32.8%) which was statistically significant. The lower lip showed a mean change of 1.549 mm (-22.2%), but these changes were not statistically significant.

Dental protrusion of the upper and the lower incisors, expressed as both linear and angular measurements relative to the NA, NB and APo lines, were reduced during treatment. However, only the linear relationship of the upper incisor to the NA-line, which reduced by 1.506 mm (-23. 5%), was statistically significant. This could possibly be a factor contributing to the reduction in upper lip protrusion relative to the Burstone line during treatment. However, changes occuring in underlying skeletal structures, for example the A-point relative to the line N perpendicular to Frankfort Horizontal, pogonion to NB line, "Wits", and Y-axis, collectively could have influenced the changes occuring in the overlying soft tissues.

Table 9. Changes effected during treatment (T1- T2).

	Mean	**SD**	**Mean change %**	**p-value**
SKELETAL				
ANB (°)	1.187	0.887	0.7%	0.9785
Wits (mm)	0.655	0.967	-57.9%	0.1354
Y-axis (°)	-1.12	1.325	*1.6%	0.0037
Mand plane (°)	-0.622	2.021	1.9%	0.2059
A-N⊥FH (mm)	0.929	1.405	-34.2%	0.3255
Po-NB (mm)	-0.622	0.904	34.7%	0.1342
DENTAL				
UI to NA (°)	2.147	8.304	-4%	0.6772
UI to NA (mm)	1.506	1.584	*-23.4%	0.029
LI to NB (°)	2.4	5.426	-3.5%	0.5972
LI to NB (mm)	0.731	1.524	-4%	0.6069
LI to APo (mm)	0.562	2.370	-51.8%	0.1783
SOFT TISSUE				
UL to B-line (mm)	1.272	1.088	*-32.8	0.037
LL to B-line (mm)	1.549	1.426	-22.2%	0.2254

Marginally Significant: $0.05 \leq p \leq 0.1$

* Significant: $p \leq 0.05$

5.4.2 Changes during follow-up (T2-T3) (Table 10)

Lip protrusion relative to the B-line continued to reduce during the long term follow-up period. The upper lip showed slight changes (-9.2%), whereas the lower lip demonstrated greater change(-53.8%). Although the mean percentage changes recorded for T2-T3, for both lips were relatively large, they were not statistically significant. Changes continued to occur in both negative and positive directions in the skeletal and dental structures. However, none of these changes were statistically significant except for the linear measurement for the upper incisor to NA line. Marginally significant changes for ANB, mandibular plane angle and pogonion (Po) to NB line were also recorded.

It would appear from these changes that the continued decrease in the ANB angle could be explained by constant uprighting of the incisors into adulthood.

Table 10. Mean changes effected during the follow-up (T2-T3).

	Mean	SD	Mean Change %	P-value
SKELETAL				
ANB (°)	0.304	1.04	#-29.5%	0.0885
Wits (mm)	-0.097	1.472	0.8%	0.9733
Y-axis (°)	0.596	1.887	-0.9%	0.1930
Mand plane (°)	1.783	2.193	#-11%	0.0601
A-N⊥FH (mm)	0.599	1.707	33.5%	0.5755
Po-NB (mm)	-0.442	0.45	#12.1%	0.0538
DENTAL				
UI to NA (°)	0.006	6.013	6.1%	0.4740
UI to NA (mm)	-0.704	1.813	*30.6%	0.0261
LI to NB (°)	0.136	4.558	0.2%	0.9748
LI to NB (mm)	-0.075	1.266	1.4%	0.8337
LI to APo (mm)	-0.39	1.753	-30.6%	0.5670
SOFT TISSUE				
UL to B-line (mm)	0.704	1.148	-9.2%	0.5736
LL to B-line (mm)	0.273	1.077	-53.8%	0.1217

Marginally Significant: $0.05 \leq p \leq 0.1$

* Significant: $p \leq 0.05$

5.4.3 Changes from pre-treatment to follow-up (T1-T3)

No significant differences were found in the soft tissue changes from intervals T2 to T3. Consequently, the significant changes found between T1 and T3 reflect those found from T1 to T2. Therefore, a separate consideration of composite changes that occurred from T1 to T3, was deemed not necessary.

The soft tissue integument for both upper and lower lips changed markedly from pre-treatment (T1) to the long term follow-up (T3). Both lips underwent reduction in protrusion; more during treatment and to a lesser extent during the long term follow-up. However, these changes were not statistically significant. The hard tissues followed a similar pattern.

5.5 THE CORRELATION AND REGRESSION ANALYSES

5.5.1 Interdependence of variables (simple correlation analysis)

To determine whether there was any association between two variables, i.e, lip position at T2-T3 and either a dental or hard tissue parameter, a series of correlation coefficients were calculated (Table 11) using the Pearson Coefficient of Correlation (r).

Simple scattergram regression equation.

Simple regression graphs (scattergrams), were constructed from values obtained from Table 11. These were obtained by plotting the changes at lower lip relative to the Burstone line against the lower incisor relative to the NB line linear (mm) ($r = 0.1665$; $p = 0.5091$) (Figure 4) and upper lip relative to Burstone line against upper incisor relative to NB-line ($r = 0.761$; $p = 7642$) (Figure 5). The graphs confirmed that the soft tissue lip to incisor ratios had no statistically significance relationships. This demonstrated clearly that the soft tissue response during treatment could vary widely for a given amount of tooth movement.

Table 11. Pearson's Coefficients of Correlation (r) and their level of significance with entire sample (n =18).

	ul bl	ll bl	anb	mdp	a nfh	y axis	ui naa	li nba	wits	ui nal	ll nbl	apo	p nbl
ul bl (r)	1.000												
(mm) (p)													
ll bl (r)	0.543	1.000											
(mm) (p)	*0.019												
anb (r)	0.086	-0.077	1.000										
(°) (p)	0.734	0.763											
mdp (r)	0.448	0.303	-0.129	1.000									
(°) (p)	#0.062	0.222	0.609										
a nfh (r)	0.26	0.053	-0.029	-0.285	1.000								
(mm) (p)	0.298	0.834	0.909	0.252									
y axis (r)	0.218	0.117	-0.217	0.097	-0.168	1.000							
(°) (p)	0.384	0.643	0.388	0.703	0.505								
ui naa (r)	-0.033	0.429	-0.02	-0.183	0.470	-0.126	1.000						
(°) (p)	0.896	#0.076	0.938	0.467	*0.049	0.62							
li nba (r)	-0.08	0.359	-0.239	-0.052	0.121	0.281	0.58	1.000					
(°) (p)	0.753	0.144	0.339	0.838	0.632	0.259	*0.012						
wits (r)	-0.194	-0.305	0.096	0.237	-0.469	0.123	-0.24	-0.074	1.000				
(mm) (p)	0.44	0.211	0.705	0.344	*0.049	0.626	0.338	0.771					
ui nal (r)	0.076	0.438	-0.635	0.188	0.043	0.157	0.378	0.412	-0.181	1.000			
(mm) (p)	0.764	#0.069	*0.005	0.456	0.866	0.535	0.122	#0.089	0.473				
li nbl (r)	0.182	0.167	-0.345	0.213	0.065	0.24	0.439	0.533	0.159	0.542	1.000		
(mm) (p)	0.47	0.509	0.161	0.395	0.798	0.338	#0.069	*0.023	0.529	*0.020			
apo (r)	-0.176	0.278	-0.497	-0.153	0.038	0.227	0.494	0.728	-0.024	0.648	0.588	1.000	
(mm) (p)	0.484	0.263	*0.036	0.544	0.881	0.365	*0.037	*0.001	0.924	*0.004	*0.010		
p nbl (r)	0.08	0.065	-0.487	0.226	-0.143	-0.297	-0.385	-0.314	-0.374	0.159	-0.181	-0.190	1.000
(mm) (p)	0.753	0.12	*0.040	0.367	0.572	0.232	0.115	0.205	0.123	0.528	0.473	0.450	

* Significant

\# Marginally Significant

In a case of simple linear regression r = R

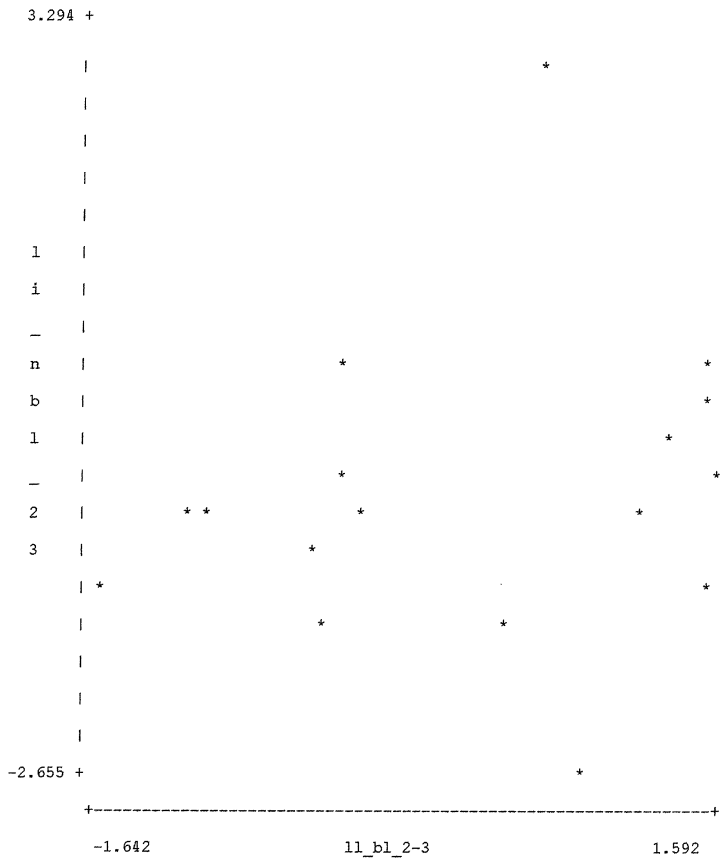

Figure 6. Horizontal linear change of lower lip to Burstone-line compared with horizontal linear changes of lower incisor to the NB line during time interval T2-T3 (2-3).

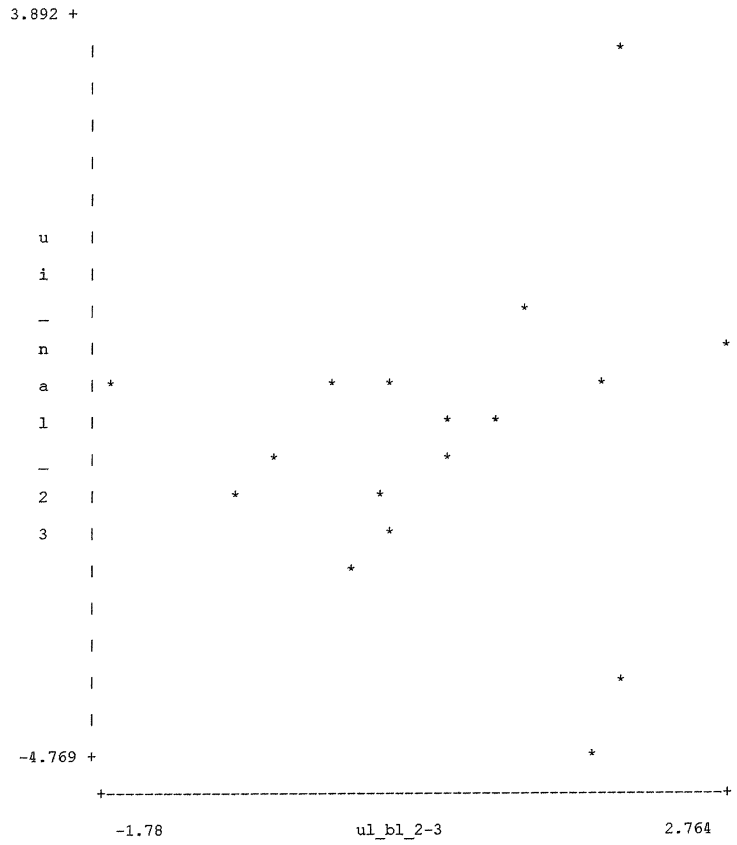

Figure 7. Horizontal linear change of upper lip to Burstone-line compared with horizontal linear changes of upper incisor to the NA line during time interval T2-T3 (2-3).

Table 12. Summary of significant correlation values obtained from TABLE 11.

Soft / Soft (r)	Soft / Hard (r)	Soft / Dental (r)	Hard / Hard (r)	Hard / Dental (r)	Dental / Dental (r)
ul bl - ll bl (0.54)	**ul bl - mdp (0.45)**	**ll bl - ui naa (0.43)**	**anb - p nbl (-0.49)**	**anb - ui nal(-0.63)**	**ui naa - li nba (-0.44)**
		ll bl - ui nal (0.44)	**a nfh - wits (-0.47)**	**a nfh - ui naa(0.47)**	**ui naa - li nbl (0.44)**
				apo- wits (-0.02)	**li nba - ui nal (0.41)**
				anb -apo (-0.5)	**li nba - li nbl (0.53)**
					li nbl - ui nal (0.54)
					apo - ui naa (0.49)
					apo - linba (0.73)
					apo - linbl (0.59)
					apo - ui nal (0.64)

The highest positive correlation between two variables was observed in the assessment of the relationship between lower incisor to APo-line (linear) and lower incisor to NB-line (angular) (r = 0.73). Here the observed changes have a direct relationship. The greatest negative correlation was observed between the changes in the ANB angle and upper incisor to NA-line, linear (mm) (r = -0.63). In this instance they have an inverse relationship (Table 12).

5.5.2 Combination of variables (multiple regression analysis)

Regression models were built for the upper as well as the lower lip. These were used to predict separately the lip changes relative to different variables during treatment. A correlation coefficient (r) equal to or greater than 0.70 was considered to be significant.

The multiple regression analysis was performed using the relationships of both upper and lower lip to B-line at T2-T3 vs those variables with the highest Pearson's Coefficients of Correlation taken from Table11 (see Table 13). The coefficient of determination (R^2= 50%) showed that there was a non-significant relationship between lower lip to the Burstone line measurement and the mandibular plane, Ui to NA (°), Li to NB, Wits, Ui to NA (mm), Li to NB (mm) and Li to APo .

Table 13. Multiple Linear Regression for the lower lip changes.

LL to bl 2-3	**Coef.**	**Std. Err.**	**t**	**p > |t|**	**[95% Conf. Interval]**	
Mand plane(°)2-3	0	0	1.71	0.119	-0.00002	0.0001
Ui to NA (°)2-3	0.06925	0.05396	1.28	0.228	-0.05099	0.18948
Li to NB (°)2-3	0.03884	0.08727	0.45	0.666	-0.15561	0.23329
Wits (mm)2-3	-0.161	0.19152	-0.84	0.42	-0.58773	0.26572
Ui to NA (mm)2-3	0.127419	0.212282	0.6	0.563	-0.34677	0.60.161
Li to NB (mm)2-3	-0.27664	0.27852	-0.99	0.344	-0.89726	0.34398
Li to APo (mm)2-3	0.53623	0.27647	0.19	0.85	-0.56239	0.66964
constant	0.22013	0.279034	0.79	0.448	-0.40159	0.84185

A backward stepwise regression analysis was also carried out to determine whether the treatment changes could be used in the determination of predictors of lip position relative to the B-line post-treatment (T2), as well as the long term T3 (Table 14). This was perfomed by excluding those variables with $p \geq 0.2000$. The coefficient of

determination (R^2 = 42%) showed that compared with the full model, the combined effects of mandibular plane angle, upper incisor to NA line (°) and the Wits measurement had a reduced strength of relationship with the response of the lower lip to treatment.

Table 14. Backward stepwise regression for the Lower lip to B-line.

LL to B-line T2-T3	**Coef.**	**Std. Err.**	**t**	**p > | t |**	**[95% Conf. Interval]**
Mand plane (°) T2-T3	0.001	0	2.16	0.049	3.61e-07 0.00014
Ui to NA (°) T2-T33	0.07858	0.03787	2.07	0.057	-0.00266 0.15982
Wits (mm) T2-T3	-0.22482	0.15654	-1.44	0.173	-0.56058 0.11093
constant	0.13455	0.22092	0.61	0.552	-0.33928 0.608391

The resulting multiple regression equation for the lower lip was found to be:

ll bl 2-3 = 0.134 + 0.0007 (mdp 2-3) + 0.0786 (ui naa 2-3) -0.2248 (wits 2-3)

These variables affected the lower lip significantly. However, because of their extremely small size, they were considered to have no clinical significance.

Following a similar procedure it was found from the observed changes that upper lip change depended on the lower lip only and the relationship was described by:

ul bl 2-3 = 0.583 + 0.5792 (ll bl 2-3) with a coefficient of determination (R^2) of 29%.

From these observations it can be concluded that lip changes over the long term follow-up period revealed no significant changes. The lips remained, relatively, in the same position that they had attained immediately after treatment. This was the case for both the extraction and non-extraction cases.

CHAPTER 6

DISCUSSION

Orthodontics has progressed from merely examining the occlusion on study models after treatment to appreciating the changes that orthodontic treatment may have produced in the facial soft tissues. In order to gain some perception of facial aesthetics orthodontists have traditionally evaluated soft tissue profiles by means of either profile silhouettes or by analyzing linear and angular measurements made on tracings of lateral cephalometric radiographs. These methods have their limitations. The profile radiograph alone is not sufficient to determine the balance of the face as this is only showing two-dimensions of a three dimensional object. Facial attractiveness has a great deal to do with individuality and self-perception and today there is a greater patient awareness of the effects of treatment. This together with the advancements in orthodontic appliances and the advent of computers in orthodontics has led to a more careful approach to the planning and hence outcome of treatment. However, there is no specific method for measuring aesthetics. Balance and harmony of facial components do not necessarily mean an attractive face. Aesthetics has no set standards and the most beautiful face as percieved by the public may not necessarily concur with the opinion of the orthodontist.

As no technological means currently exist that can precisely define or assess aesthetics, the orthodontist needs to use careful judgment of the profile as well as the frontal aspects of the face together with the patient's own aesthetic desires in treatment planning.

Retrospective studies, by their nature, carry limitations in interpretation because the original reasoning leading to the diagnosis and treatment planning for each case can never be fully determined. This particularly applies to samples chosen from a pool treated by a number of different clinicians or when clinical objectives may have differed from contemporary treatment practices or beliefs. In an effort to overcome such issues, the sample for this study was chosen from a university department of othodontics. The patients were treated by postgraduate students under supervision of the same experienced orthodontists who observed consistent biomechanical principles. The choice of subjects in the sample was limited by the sex and age of the subject.

A second limitation which accompanies any radiographic soft tissue study involves the influence of voluntary and involuntary muscle activity on soft tissue contours. As noted by Zierhut et al (2000), lip tensions vary between individuals and even from time to time in one individual. An inability to quantify or control this variable remains a shortcoming

of this type of study. In response to this concern, every effort was made to eliminate those subjects displaying obvious soft tissue strain. Any radiograph showing obvious forced lip closure together with mentalis distortion and strain was excluded

Pretreatment and long term follow up comparisons between groups should provide the clinician with some insight as to the criteria on which the extraction or non-extraction decision was based. The cephalometric differences between the pre-treatment extraction and nonextraction groups indicated that the upper and lower lips were more protrusive, relative to the Burstone line, in the extraction group. On the other hand, there were no differences between the two groups in any of the dentofacial parameters compared, except possibly for the lower incisor to the APo line. As a result, it would seem that lip protrusion could have been an important quantifiable profile characteristic on which the extraction decision was made. Prior to treatment, in the extraction group, the lower incisor was on average positioned further forward (APo) and was more proclined relative to the skeletal landmarks (NB). The mean position and inclination of the upper incisor was the same in the two groups. Despite this difference in lower incisor position, the two groups did not differ in mean pretreatment ANB angle. This was 4.75° in the extraction group and 4.55° in the non-extraction group. Another difference noted was that the non-extraction group presented with a slightly larger hard tissue chin button.

Post-treatment comparisons are useful in determining differences between the extraction and nonextraction groups after completion of the orthodontic and orthopedic treatment. It should be emphasized that such direct comparisons do not determine, *per se*, whether one group looks better than the other.

Measurements and clinical observations of soft tissues require careful attention because of individual variations in soft tissue thickness and regional independence of the underlying skeleton. Changes in profile appear to be related to variables such as pretreatment lip strain, variations in lip structure and thickness, and the extent of incisor retraction. It is important that the orthodontist be conscious of changes brought about by late adolescent and postpubertal growth. Various studies have detailed the changes that take place in the soft tissues in the period from childhood to adulthood. Bishara, al (1998), found that in untreated cases the upper and lower lips become markedly more retruded in relation to the aesthetic line (E-line) between 15 and 25 years in males and 10 and 15 years in females. This trend continued between 25 and 45 years of age in both males and females for the upper lip, but at a much smaller magnitude. Between 25 and 45 years, the lower lip became more protrusive in males but slightly more retrusive in female. This was also observed in the current study. Finnoy, Wisth and Boe (1987), found mean changes of -3.3 mm for the upper lip to the E line and -2.5 mm for the lower

lip to the E line in a sample of 30 Class II, Div 1 extraction cases treated with edgewise appliances. According to Battagel (1989), these changes were -4.4 mm for the upper lip to the E line and -2.3 mm for the lower lip to the E line in a group of 30 patients, with a mean age of 12.7 years, treated with edgewise appliances after the extraction of upper first premolars. In a study by Drobocky and Smith (1989), the upper and lower lips moved back an average of 3.4 mm and 3.6 mm relative to the E line in a sample of 160 patients after removal of four first premolars. Similar changes were reported by Bravo (1994). Zierhut et al (2000) observed considerably greater retraction of the lower lip relative to the E plane and the S plane in the extraction group, -4.2 mm and -3. 8 mm respectively. Retraction of the upper lip relative to the E plane occurred with no significant difference between the two groups. In this study a mean difference of 1.4 mm for the upper lip to the B-line and 2.0 mm for the lower lip to the B line was observed in the extraction group. The mean linear changes in these variables were very similar to those noted in the other studies albeit at a slightly lower value.

The use of the E line to assess profile aesthetics is often critized because it is excessively influenced by the size of the nose and its remaining growth. In this study, the upper and lower lips (as measured to the B-line) moved slightly back after treatment in the extraction group when compared with the non-extraction group (Tables 2,3 and

4). In addition, the pooled data showed continued reduction in both upper and lower lip protrusion on the long term follow-up (Table 8).

Some variables were found to have larger standard deviations. These large standard deviations indicate that these measurements displayed a great degree of individual variability. This suggests that when cephalometric evaluations are undertaken, comparisons should be made utilizing the range and not just the mean values for a particular measurement. This is based on the fact that variation around the mean can still maintain an average profile contour. It also confirms the fact that not only the cephalometric numbers should be the deciding factor but other factors such as the soft tissue thickness and ethnic variations should also be taken into consideration when a treatment plan is to be formulated.

Measuring aesthetics is very difficult if not impossible to achieve. Improvement in one measurement may not result in favourable changes in another. Angular measurements for a patient may be within normal ranges, while the linear measurements may indicate protrusion of the incisors and the upper and lower lips. A comparison of different soft tissue analyses in the determination of Anatolian Turkish beauty by Erbay and Canikliogl (2002) indicated that among the seven aesthetic lines used to evaluate the

soft tissue profile, only Ricketts norms for upper and lower lips corresponded to the values for an attractive profile. In contrast to the E line, the B line has been advocated for this study because it is not affected by the size of the nose. Hsu (1993) also confirmed that the B line was the best analytical reference in terms of consistency and sensitivity. From the point of clinical practicality, the E line is of great value because its anterior location makes it convenient for the clinician to use. Hsu found, however, that those analytical reference lines that transverse the anatomic landmark of the nose have poor consistency and sensitivity. Therefore, profile aesthetics should not be judged purely on one parameter alone. As many parameters as possible should be incorporated into the assessment. Other factors such as ethnic and racial norms should be factored into the assessment as well.

After successful completion of treatment, comparison between extraction and non-extraction groups revealed no differences in any measures of soft tissue profile. Following an average post-treatment period of approximately ten years, group comparison also revealed no differences in profile measurements. However, the lips were retruded relative to the B-line. In the present study, the mean changes that occurred from post-treatment to long term follow-up were not statistically significant. The mean changes for the upper and lower lip were 0.88 mm and 0.36 mm, respectively

for the extraction group. The non-extraction group showed 0.11 mm and -0.05 mm mean changes for upper and lower lip respectively (See Table 10). In short, the facial profiles of extraction and non-extraction groups were the same following treatment and long term post-treatment. However, there was a slight tendency for the profile to flatten despite the fact that the patients had stopped growing. These findings are in agreement with those reported by Zierhut et al (2000) who found similar morphology of hard, dental and soft tissue profiles in their comparison of extraction and non-extraction groups approximately fourteen years post-treatment. The mean changes different in the two groups were not statistically significant. The upper and lower lip measurements to the E plane were -2.12 mm and -1.44 mm, respectively, for extraction group and -3.06 mm and -2.28mm for the non-extraction group. Finnoy, Wisth and Boe (1987) also found that the lip structure in relation to E-line displayed a continuous retraction in both extraction and non-extraction groups three to five years after the end of treatment. The mean changes for the extraction group for upper and lower lip were -1.4 mm and -1.2 mm respectively. Those for the non-extraction group were -1.2 mm and -0.5 mm, respectively.

Paquette, Beattie and Johnston (1992) examined borderline extraction/non-extraction cases 14.5 years out of treatment and found that in the long term the non-extraction

patients had profiles that were two mm fuller. A similar study by Luppanapornlap and Johnston (1993) evaluated carefully selected first premolar extraction cases and nonextraction cases over a similar post-treatment period. The findings indicated that the extraction of first premolars tended to flatten the profile by two - three mm when compared with nonextraction treatment.

The findings of this study regarding the pooled data demonstrated marginally statistically significant differences with respect to both upper and the lower lips when measured to the Burstone line during the long term follow-up, with significant changes for the upper lip and no significant changes for the lower lip. When comparing the two groups, there were no statistically significant differences between the extraction and non extraction groups over the long term follow-up. The simple linear regression analysis revealed no correlation between the changes in the dentition, bony structures, and the lips (Table 11). Stepwise regression was employed to identify not only those post-treatment variables with the most likely influence on lip changes, but also to attempt to describe the extent of variability in lip response that might have been explained by those variables. This analysis was conducted with the aim of perhaps providing the clinician with a tool to estimate the type and direction of lip response relative to changes in either bony or dental tissues. The low percentage of prediction of the lower lip to the B line

(42%) and upper lip to the B line (29%) was considered not to be clinically relevant and these relationships should therefore be interpreted with caution. Suprisingly, changes in the lower lip in response to orthodontic tooth movement were more predictable in this study than were those of the upper lip. The low degree of predictability of the upper lip response to orthodontic treatment may be caused by complex anatomy and/or dynamics of the upper lip which could not be evaluated by using the presently available cephalometric techniques. The findings revealed a complex interaction between dental movement, skeletal, and soft tissues as well as an involved relationship within the soft tissues themselves. This interaction indicated that treatment planning cannot rely on mean cephalometric standards for skeletal and soft tissues. Simple ratios of lip response to incisor movement, particularly the lower incisors, are of little value in obtaining those goals when applied to an individual subject.

The pertinent clinical question is whether the post-treatment changes are desirable or detrimental to the facial profile. In addition, will these changes be progressively detrimental over the long term? Such a determination could be attempted by comparing the treatment changes with those observed over the long term follow-up study. During the post-treatment period, flattening of the profile continued to occur. Consequently, the long term facial profile responded in a similar manner, independent of whether or not

premolar extraction had been performed. This continued "straightening" of the profile was also reported by Finnoy, Wisth and Boe (1989) and Zierhut et al (2000). The average lip protrusion in both groups, however, remained close to the Burstone normal values.

An important clinical variable that influences the extraction decision is the presence of a crowded dentition. There are additional factors that may also influence the decision to extract teeth but these may be more subjective and may include the inclination of the incisors, the treatment philosophy of the clinician, the biomechanical principles practiced, the growth potential of the patient, the type of growth predicted and the severity of the anteroposterior and vertical dentofacial discrepancies.

When a decrease of lip protrusion is desirable, extracting premolars and retracting incisors is a viable option to achieve these objectives. However, individual variation in response is large. Incisor retraction in one patient might lead to a large amount of lip retraction, whereas, in another patient, a similar amount of retraction might lead to only minimal improvement in lip protrusion. This would then indicate that other factors such as lip thickness, lip strain, lip activity, facial type, muscle tone, skin texture, underlying

facial bony prominence and even body posture could collectively or individually play a role in altering the lip response to tooth movement.

The pendulum in treatment decisions over the past number of years swung decidedly towards the nonextraction treatment modalities. Thus, it would be better to err on the side of nonextraction as this would tend to support the soft tissues better and maintain the "youthfulness" of the face over time. A full complement of teeth allows for a fuller smile without dark corridors in buccal segments and also allows soft tissues support over the long term.

influenced by whether or not teeth had been removed. The overall aesthetics achieved as a result of the changes in the facial soft tissue profile are very difficult to quantify and, to a large degree, this is a matter of subjective evaluation.

4. Although it was observed that the lips were more retrusive in the long term follow-up records, their values were not very different from the normal values of the untreated cases reported by Burstone in 1967. These findings support the notion that suggests for better long term aesthetics outcome, it is important to finish the treated case with a profile that is slightly fuller than flatter, because with aging, the lips tend to lose their elasticity, and as a result, the profile becomes flatter over the long term.

5. There is a low degree of predictability of both upper and lower lip response to orthodontic treatment over the long term. The lack of general consistency in post-treatment correlations between dental variables and soft tissue form supports the hypothesis that the soft tissues might have their own inherent architecture and therefore the lips remains relatively in the same position that they attained at the end of treatment.

7.2 Suggestion for further investigation

Soft tissue changes induced by orthodontic treatment are an ongoing interest factor for orthodontists. We try our best to standardise procedures and to eliminate as many variables so that the information obtained is as meaningful as possible. This is pertinent as we are dealing with very small amount of soft tissue movement. Therefore, there is a need to establish precise protocols for the various procedures. The very nature of an Orthodontic Department dictates that there should be these strict protocols. Starting from the beginning, the various protocols should be established. For example:,

1. Radiographic technique incorporating magnification factors.

2. Patients receiving treatment should be willing to make themselves available for research purposes in the Department in the future.

3. Patient follow-up protocols should be employed in the Department for long term studies.

4. As many variables as possible, e.g., lip thickness, lip strain, lip activity, facial type, muscle tone, skin texture, underlying facial bony prominence and body posture should be defined and protocols established for their measurements.

From this, possibly a long term study could be designed for continuous assessment of the treated cases in the department, so as to establish a more evidence based approach to our treatment decisions.

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