EFFECT OF ORTHODONTIC TREATMENT ON THE FACIAL PROFILE

A Thesis

Presented to

The Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Antonios Haralambos Mamandras

Department of Preventive Dental Science

May 1980

EFFECT OF ORTHODONTIC TREATMENT ON THE FACIAL PROFILE

BY

ANTONIOS HARALAMBOS MAMANDRAS

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF SCIENCE

ACKNOWLEDGEMENTS

Completing this research project, I would like to express my sincere thanks and appreciation to the following people, whose efforts helped to make possible the realization of this thesis:

To Dr. A. T. Storey, Professor and Head, Department of Preventive Dental Science, for the opportunity to further my education under his astute guidance and for his constant help and encouragement during the development and preparation of this project.

To Dr. F. J. Hechter for his supervision and helpful suggestions throughout the preparation of this thesis.

To Drs. L. C. Melosky, E. Cohen, M. Rudisaile and E. Yen, Department of Preventive Dental Science and Dr. C. L. B. Lavelle, Professor and Head, Department of Oral Biology, who have made my stay at the University of Manitoba both an enjoyable and rewarding experience.

To Dr. F. S. Chebib for the invaluable assistance in the preparation and refinement of the computer programs for the statistical evaluation of the data.

To Dr. F. Popovich and the staff of the Burlington Growth Centre, Faculty of Dentistry, University of Toronto, who made the collection of the data, for the control sample, such a pleasant experience.

To Mr. A. Domokos, Mr. J. Kostur and Ms S. Stoltz for their tireless assistance with the photography and art work.

To the support staff of the Department of Preventive Dental Science and to the students in the Orthodontic Program, both past and present, particularly to Drs. A. Chamma and T. Carlyle, for their help and encouragement.

To Ms M. Reid, Miss N. Kan, Ms J. Gilbert and Ms M. Abdel-Hadi for the help in the typing and preparation of this thesis.

To my classmates Dr. P. Gold and Dr. M. Lack for their understanding and encouragement throughout this course and whose friendship will always be treasured.

My most heartfelt thanks go to Ellena and Maria and our families in Atalanti and Minneapolis, for their love, patience and understanding and whose many sacrifices made possible my graduate training.

Finally, my sincere thanks to the people of this friendly city for their hospitality throughout this course.

Bodily exercise, when compulsory,
does no harm to the body; but knowledge
which is acquired under compulsion
obtains no hold on the mind.

PLATO'S REPUBLIC

Effect of orthodontic treatment on the facial profile

by

Antonios Haralambos Mamandras

ABSTRACT

Using computerized cephalometric techniques, the effect of orthodontic treatment on the facial profile was quantitatively assessed. Seventy-four orthodontic patients treated at the University of Manitoba constituted the test sample, while twenty-eight untreated subjects obtained from the Burlington Growth Centre, Faculty of Dentistry, University of Toronto, served as a control sample. Utilizing serial lateral cephalometric films of both samples, linear horizontal, linear vertical, angular and cross-sectional measurements were performed. A mixed factorial analysis of variance was used to examine the effect of extraction versus non-extraction type of treatment in Class I, Class II Division 1 and Class II Division 2 malocclusion groups over the three stages of treatment (pre-treatment, post-treatment and post-retention).

The statistical assessment of the data suggests the following conclusions:

(1) The effect of orthodontic treatment in the cross-sectional areas of the maxillary and the mandibular lips is minimal. The observed increase in the cross-sectional area of both lips resulted from the effect of

growth.

(2) The maxillary lip followed the maxillary incisal retraction in a ratio of 0.7:1. As a result of this response, the thickness of the maxillary lip increased as measured linearly. This increase, however, was not detected cross-sectionally.

(3) The mandibular lip responded to maxillary rather than to mandibular incisal retraction, supporting the concept that lower lip protrusion is related to the prominence of the upper incisors.

(4) The soft tissue cephalometric points epidermic "A" and epidermic "B", showed a close association with the underlying skeletal framework. The retraction ratio between hard and soft tissue "A" and "B" points was found to be 1:1.

(5) The vertical interincisal relationship was affected by the orthodontic treatment as a result of incisal intrusion and clock-wise mandibular rotation.

(6) The orthodontic treatment caused no changes in the interlabial relationship.

TABLE OF CONTENTS

LIST OF TABLES

TABLE		Page

LIST OF FIGURES

INTRODUCTION

CHAPTER I

INTRODUCTION

Aesthetics is defined as the study or philosophy of beauty and from classical times, has played an important role in human life. As a source of inspiration, aesthetics has influenced the artistic expression in all its forms.

During the Golden Century of Athens, the ideal beauty was synonymous with concepts such as harmony and symmetry, and as Plato asserted,"The qualities of measure and proportion invariably... constitute beauty and excellence." Aesthetics, during the same time, became the area of study of the physiognomics which were based on a concept that there is a close relationship between bodily, especially facial features, and psychosynthesis. This relationship was expressed, during the era of Aristotle, with the apothegm "ΟΙΑ Η ΜΟΡΦΗ ΤΟΙΑΔΕ ΚΑΙ Η ΨΥΧΗ" which, in free translation means that the face reflects the soul.

Facial aesthetics embodied in classical sculpture of ancient Hellas, strongly influenced many early orthodontists, most notably, Angle at the beginning of this century. When Angle (1907) gave the description of the ideal soft tissue profile, in a chapter on facial art, he referred to Apollo Belvedere which exhibits a soft tissue profile expressing balance, harmony and beauty.

In the past few decades, the influence of orthodontic treatment on skeletal and integumental profile has been a subject of great interest. Numerous investigators, using different cephalometric approaches, have attempted to identify the interrelationships between profile changes and orthodontic treatment.

One of the main problems is that changes in the skeletal and soft tissue profile caused by treatment as well as those caused by growth, require to be identified. In addition, growth changes in the soft tissue profile are often not fully expressed on the completion of orthodontic therapy, depending on the sex and age of the patient. Consequently, the effects of growth and orthodontic treatment on the final morphology of the soft tissue facial profile may be difficult to discriminate. The lips in particular, have attracted considerable interest as they form one of the main components of the lower face. Many investigators, using cephalometry, have examined lip posture (Burstone, 1967) and the linear changes in vertical (Jacobs, 1978) and horizontal (Anderson et al, 1973, Roos, 1977, etc.) dimensions resulting from incisal retraction during and after orthodontic treatment. Unfortunately, there has been no study of cross-sectional changes in the area of the lips before, during and after orthodontic treatment, to examine what kind of effect the orthodontic treatment has on the lip volume and discern, if an interaction exists between form and function. Yet the absence of data on the separate effects of growth and orthodontic treatment inhibits our understanding on the role of the soft tissues on the facial profile. The objectives of this investigation were:

1) To evaluate quantitatively the influence of both growth and orthodontic treatment on various regions of the facial profile.
2) To evaluate cross-sectional soft tissue lip changes relative to underlying skeletal elements before, during and after orthodontic treatment.
3) To describe the interrelationships between the hard and the soft tissue profile changes occurring before, during and after orthodontic treatment.

REVIEW OF THE LITERATURE

CHAPTER II

REVIEW OF THE LITERATURE

The interest of investigators in the growth and development of the human facial profile and the face generally, has led to the development of various techniques which allow the standardization of methods. As a result, it is possible to analyse quantitatively changes in the facial profile.

Early Studies of the Face and the Facial Profile Prior to the Advent of Cephalometric Radiography

In 1872 Von Ihering devised a plane for the evaluation of the facial profile. This plane, known today as the Frankfort horizontal plane, is defined as a line passing through the highest point at the margin of the external acoustic meatus and the lowest point at the orbital margin. The Frankfort horizontal plane has been traditionally used by many workers in this field as a reference plane to study changes of the facial profile.

Dreyfus (1922) developed an alternative reference plane of measuring profile changes, using a vertical line through nasion point perpendicular to the Frankfort horizontal. Four years later, Simon (1926) devised a photographic method termed "photostatics" to assess the soft tissue growth and other facial changes. In this technique the head is divided into three planes. One of these planes the orbital plane, which passes through the two infraorbital foramina perpendicular to the Frankfort horizontal, has been used to measure the integumental profile.

While many methods were developed in order to assess facial growth and development, not much emphasis was placed on defining what characterizes a normal or abnormal facial profile.

Angle (1907) emphasized the importance of the soft tissue and considered the mouth as a very significant factor in making or marring the character of the face. He stated that the form and beauty of the mouth itself depended on the occlusal relationship of the teeth. Angle felt that a harmonious facial pattern could exist only with a full complement of teeth arranged in a normal occlusion and that the upper incisor, with its influence on both upper and lower lips, was the key to facial aesthetics.

Case (1921), like Angle, was one of the first orthodontists to be concerned with facial aesthetics. He made facial casts of patients to show the effect of malocclusion and subsequent orthodontic therapy on facial profile. Case considered that the facial outlines should be a guide in determining orthodontic treatment plans for all malocclusions. He demonstrated the futility of depending on normal occlusion for a complete diagnosis by showing three different profiles, each with a Class I malocclusion. Case therefore differed from Angle, the latter tending to disregard the profile in order to achieve a "normal" occlusion. Indeed, Case considered that the orthodontists should be trained in observing profiles and advocated extractions in some cases of bimaxillary protrusion in order to retract the procumbent lips.

Wuerpel (1937) stated that faces can be beautiful even though they are proportioned differently. The important factor was considered to be balance: i.e., that one part of the facial pattern must not be overemphasized at the expense of another.

The different treatment philosophies of Angle and Case generated great interest among their colleagues and placed facial aesthetics at the center of attention of the orthodontic world. Neither worker employed the use of measurements, however, as each relied upon subjective training in the ability to observe facial changes.

Hellman (1939) was one of the first to use anthropometric methods to study growth changes in individuals. Using rulers and calipers, Hellman analyzed facial measurements on 1,693 subjects from three to twenty-two years of age and concluded that as the face grows, depth increases most, height increases less, and width changes least of all. The relative increase in height was greater in the posterior (ramus height) than in the anterior (total face height), while the relative increase in width and depth was greater inferiorly (mandibular angle and body of the mandible) than superiorly (bizygomatic width and auriculonasion depth).

Standardization of the anthropometric methods, using craniostats and calipers, helped orthodontists to measure and investigate the facial growth at the quantitative as well as the qualitative level. This was subsequently elaborated in the design of more sophisticated tools, such as the cephalometer, which increased the data concerning growth and development of the human face.

Hard Tissue Assessment of the Facial Profile

Numerous studies followed the development of the cephalometer, by Broadbent (1931) in the United States and Hofrath (1931) in Germany. This heralded the beginning of a new era in the study of facial growth and development. Studying the cephalometric films of a cross-sectional group of children, Broadbent (1937) reported that growth of the facial structures occurred in a rather constant, orderly manner. This observation differed from previous assumptions that facial growth is a complex erratic process.

Brodie (1941), in a longitudinal study of growth in children of unspecified ethnic origin, from three months to eight years of age, found that the morphogenetic pattern of the head and face is established early in life and tends to remain constant. In a later longitudinal study (1953), utilizing nineteen males, age eight to seventeen years, Brodie noted that the late stages of growth are accompanied by a continuation of forward and downward movement of the anterior nasal spine and pogonion. By contrast the dental arch and its supporting bone tend to move more slowly and therefore "drop behind", decreasing the prominence of the dental arches. He found that a steady constant rate of growth occurs up to eight years of age, followed by a slowing down of growth until adolescence, at which time a definite growth spurt was seen.

Bjork (1947) studied a growing sample of three hundred and twenty-two boys, twelve years old, and a non-growing sample of two hundred eighty-one adult males, twenty-one and twenty-two years of age. He concluded that an increased prognathism of both jaws was characteristic of profile changes with age. He also noted that the increase was greater in the mandible which effectively straightened the facial profile in an anteroposterior dimension. The same conclusions were made by Bjork in a later longitudinal study (1951) of one hundred and fifty males at the age of twelve and again later at the age of twenty-one.

Lande (1952), in a longitudinal study of thirty-four males ages four to seventeen, concurred with Bjork that the mandible becomes more prognathic in relation to the remainder of the cranium during growth. This was found to be associated with a decrease in the inclination of the lower border of the mandible as well as a decrease in the angle of convexity. It is interesting, that the findings of both Bjork and Lande are supportive of Brodie's early work.

Tweed (1945) felt that a definite relationship existed between pleasing facial aesthetics and the orientation of the teeth. He attempted to correlate the angulation between the mandibular incisors and basal bone and what he considered to be balanced facial lines. Using cephalometrics as a tool, Tweed (1954) expanded this concept and stated that balanced facial aesthetics will be obtained when a Frankfort-mandibular incisor angle (FMIA) of sixty-five degrees is established.

Downs (1948, 1952, 1956), recognized the importance of the relationship between facial profile and the occlusion and incorporated a number of measurements indicative of the ideal position of the anterior teeth. He felt that excessive deviations from the means of measurements in his analysis usually express abnormalities or imbalance in particular areas of the facial profile.

Steiner (1953, 1959, 1960) presented angular and linear guidelines for the placement of the incisors as a function of the craniofacial skeleton. In the face which deviates from the normal, he suggested a series of "acceptable compromises" that could be utilized as treatment goals. These "compromises" were based on the maxillary-mandibular relation and provided for incisal placement that would provide an optimal soft tissue profile. Thus, Steiner's analyses and compromises enabled the orthodontist to plan a more realistic and aesthetic treatment goal based on the nature of existing skeletal discrepancies.

Many other orthodontists have used cephalometric methods for the evaluation of lateral cephalograms. Wylie (1947), Margolis (1953), Bjork (1947), Tweed (1946, 1954), Ricketts (1957, 1960), Sassouni (1955, 1958, 1960), Enlow (1975), have all contributed valuable methods for cephalometric analysis.

Soft Tissue Assessment of the Facial Profile

In orthodontics, there is primarily a two faceted view of an orthodontic problem, namely, the hard and the soft tissue components. The majority of analyses provide an assessment of the skeletal and dental elements of hard tissue component in a sagittal view. This assessment indicates the changes necessary to reorient the structures to more harmonious relationships.

Even though there is close approximation of hard and soft tissue, it was realized that analyses of the hard tissue was not sufficient in itself and study of the soft tissue was essential in order to have a clear view of the orthodontic problem. To aid in diagnosis and treatment planning various analyses have been formulated.

Burstone (1958), evaluating the integumental profile, felt that much variation exists between individuals in the thickness, length and posture of soft tissue overlying the skeletal foundation of the facial profile. He studied the profiles of the Herron sample (a group of good faces selected by a panel of three artists) and developed an integumental analysis. Burstone analyzed seven integumental landmark points and their interrelationships and compiled an integumental profile grid of acceptable young adult faces from which graphic comparison can be made. In a later study (1973), Burstone pointed out the existing variation in the form and length of the nose and he stated that it will be a mistake to use the nose as a major factor determining lip protrusion. Burstone proposed as a reference plane, for aesthetic evaluation of the soft tissue profile, the Sn-Pg plane, which he believes can be used advantageously in a non-growing individual since subnasale and pogonion areas are relatively unaffected by orthodontic treatment. He also found that in adolescent groups the soft tissue thickness from point A to subnasale is 4 mm greater than the thickness of the upper lip and chin and 3 mm greater than the thickness of the lower lip. All measurements represented harmonious interrelationship of the upper and lower lip in an aesthetically pleasing profile.

Ricketts (1957, 1961), believes that the nose is part of the profile and therefore should be included in the analysis of the soft tissue. He recommends as a plane of reference, for routine clinical use, the aesthetic or "E" plane which is made by a tangent line from the soft tissue chin to the tip of the nose. He found that in white adults the lower lip is located on the average about 4 mm posterior

(± 3 mm) to the "E" plane, slightly more in adult males due to sexual differences in chin and nose. Ricketts (1968) stated that in the evaluation of the soft tissue profile there is no single goal, but an acceptable range and in the normal mature caucasian, the lips are contained within the "E" plane, the outlines of the lips are smooth in contour, the upper lip is slightly posterior to the lower lip when related to that plane and the mouth can be closed without any visible strain. If the lower lip falls behind the upper lip, he feels that the profile is overtreated. Ricketts also pointed out the important role which the lower incisor plays in treatment planning as a result of its influence to upper incisor and lower lip and therefore to facial aesthetics. He recommended that the lower incisor should be placed 1 mm ahead of the A-Pg plane with acceptable range of -1 to +3 mm.

Steiner (1960), proposed for the evaluation of the soft tissue profile, a line tangent from the chin to the middle of the lower border of the nose. He said that the lips should fall on this line, while lips lying ahead are too full, and lips lying behind are too flat, relative to other parts of the profile. In this analysis, the lip position is more definitely defined than in Ricketts analysis and takes into consideration large or small nose, a large or small chin and harmonizes them with the lips. Both the Steiner and Ricketts analyses relate the three basic elements in profile development, namely the nose, the lips and the chin.

Holdaway (1956) in an attempt to relate skeletal with soft tissue landmarks, used the relationship of the lower incisor and pogonion to the N-B plane. He suggested that most pleasing aesthetics are achieved when these structures are proportionate and when the apical bases are ideally related. Holdaway (1963) developed the "H" angle which is made by the intersection of the N-B plane with the plane tangent to chin and the upper lip. This "H" angle should be 7 to 9 degrees when ANB angle is 1 to 3 degrees, and if ANB is greater or smaller than 1 to 3 degrees, then approximate amount can be added or subtracted from the "H" angle. He also suggested that the tip of the nose to the soft tissue plane should be about 9 mm.

Merrifield (1966), like Holdaway, also attempted to relate lip position to the underlying skeletal framework. He suggested the "Z" angle which is formed by the intersection of the Frankfort horizontal plane and the profile line made by a tangent from the chin to the most protrusive lip. According to Merrifield this "Z" angle should be 80 degrees in adults with normal FMA, IMPA, FMIA and ANB angles.

Both Holdaway's and Merrifield's proposed soft tissue analyses take into consideration the underlying skeletal foundation, but Holdaway's approach seems more practical and reliable in soft tissue diagnosis. The "H" angle with its association to N - B plane offers a stable basis for soft tissue evaluation, while the "Z" angle with its relation to Frankfort horizontal can show significant variation. Additionally, the N - B plane is directly associated to soft tissue facial profile and its underlying skeletal basis, while the Frankfort horizontal is not associated and its variation can create a problem in the analysis of the soft tissue.

Anderson et al (1973) studied soft tissue profile changes in seventy orthodontically treated cases in ten years out of retention and tested Rickett's "E" plane, Steiner's plane, Holdaway's "H" angle as well as Zimmer's reference plane (ANS - B point) to evaluate profile changes. He also concluded that the "H" angle, with its association to both hard and soft tissue facial profile, seemed to be a most practical approach for the analysis of the soft tissue profile.

Reidel (1950) sent soft tissue profile outlines to orthodontists who were asked to evaluate them only in terms of "good", "poor" or "fair". Skeletal analysis of the complete tracings showed that harmonious skeletal and dental components were reflected in a "good" profile. Riedel found that the relation of the maxillary and mandibular apical bases in an anteroposterior direction, the degree of convexity of the skeletal pattern of the face and the relation of the anterior teeth to their respective apical bases, have marked influence on the soft tissue profile. He also noted that in general the more convex the profile, the more upright the incisors must be to produce a good facial balance. Likewise, the more flattened the profile was, a greater degree of procumbency of incisors was needed to effect a good profile.

What is a good profile? According to Reidel (1957) in his study of beauty contestants at the Seattle Sea Fair, the facial profiles chosen were, with one exception, very flat. The upper and lower lip and the soft tissue chin all tend to fall on the same plane. If these profiles follow skeletal patterns, it follows therefore that changes in skeletal configuration should result in comparable changes in soft tissue configuration. Maxillary incisor retraction should be followed by upper lip retraction. Riedel concluded that there is a close relationship between hard and soft tissue facial profile. On the other hand, Burstone (1967) studying lip posture for both normal and malocclusion groups, found that there is an anteroposterior posture of the lip which is independent of the teeth and the alveolar process. He stated that it is most important to determine this relaxed lip position, as lip posture is perhaps the most important element in determining a stable position for the incisors. Burstone suggested that the maxillary incisors cannot be placed forward of the relaxed position of the lower lip, provided the overjet is normal and the patient maintains the habitual lip seal. He also suggested that one of the objectives in orthodontic treatment should be to minimize the amount of lip contraction from the relaxed to the closed position and therefore prevent any undesirable effects of the muscle on the occlusion.

Also, Burstone (1973) emphasized the significance of determining the antero-posterior position of the incisors in treatment planning and the importance of the soft tissue. There are, according to Burstone, three major reasons why the orthodontist should consider the soft tissue covering the dental-skeletal framework in the treatment planning. Soft tissue determines 1) facial aesthetics, 2) perioral function and 3) stability. It is each of these three considerations that will primarily determine the most desirable antero-posterior positioning of the incisors.

Reference Planes for the Study of the Facial Profile

Orthodontists in their effort to assess facial profile changes have used a number of cephalometric planes as reference.

Chaconas and Bartroff (1975) and Koch et al (1979) have selected the line connecting the soft tissue points glabella and pogonion as a reference plane, while Anderson et al (1973) have used the plane connecting the hard tissue points nasion and pogonion. The rationale of using these two facial planes is that both planes are closely related to facial aesthetics and therefore pertinent to assess facial profile changes (Koch et al, 1979). However, all investigators are aware of the fact that both these reference planes rely on the cephalometric pogonion point which is influenced significantly by mandibular growth and orthodontic treatment (extrusive or intrusive mechanics).

Hershey (1972) also used as a reference plane the nasion-pogonion line but he duplicated the pre-treatment sella-nasion-pogonion angle on the post-treatment film. His objective was to eliminate the mandibular growth effect from his assessments on post-treatment facial profile changes. The error involved in his technique resulted from any changes occurring at the points sella and nasion.

Downs (1956) studying the dentofacial profile, came to the same conclusions as Bjork (1947) that even though the anterior cranial fossa does not increase in size after the age of ten, the point nasion continues to move forward due to thickening of the cranio-frontal wall. Baume (1957) in an effort to understand the changes which are liable to occur at sella tursica, performed a histological study on a cranial base of the macaca rhesus monkey. He found that there is a continuous bone transformation at sella and the clinoid processess, the implication being that there could be considerable movement occurring at the cephalometric point sella. Lager (1958) investigating the growth of the cranial base of the macaca rhesus monkey, employed metallic implants on each side of the spheno-occipital synchodrosis, and concurred with Baume that there is growth along the spheno-occiptal synchrondrosis. He observed however, a greater amount of growth on the inferior side of the synchondrosis.

It appears that no ideal reference plane exists for assessing facial profile changes. Ricketts et al (1976) comparing two of the often used cephalometric planes, Frankfort horizontal and sella-nasion, concluded that the former is the most appropriate plane to be used for cephalometric orientation. They stated that there is a direct relationship of the Frankfort horizontal and the basic sense organs of sight and hearing, and therefore this plane is related to the face, while the sella-nasion plane is related to the brain and not to the face. Ricketts et al tested the accuracy between the two planes and found no significant differences when the true porion and not the machine ear rod was used for the Frankfort horizontal plane. Porter (1976) examined the reliability of various cephalometric planes and found that both sella-nasion and Frankfort horizontal were reliable planes demonstrating low variability.

Even though Ricketts et al and Porter underline the importance of using the anatomic porion instead of the machine ear rod, they do not mention anything about the reliability of the point orbitale. Richardson (1966) and Baumrind and Frantz (1971) examined the reliability of various cephalometric points and found that sella with mean estimating error of 0.49 ± 0.14 was one of the most reliable points followed by nasion with average error 0.73 ± 0.52.

The orbitale point was less reliable with mean estimating error 1.09 ± 0.65. Midtgard et al (1974) also assessed the error involved in the reproducibility of cephalometric landmarks and concurred with Richardson, Baumrind and Frantz. They stated that the greatest degree of certainty was found for point sella (0.41 mm) while the worst was for point orbitale (2.08 mm).

Based on the above considerations and since the anterior cranial base represents one of the most stable and dependable areas of the craniofacial skeleton (Moss and Greenberg 1955, Ford 1958, Scott 1967, Sicher and DuBrul 1970, Hoyt 1978) the sella-nasion line seems to offer a very reliable reference plane for cephalometric studies of the facial profile.

Hard and Soft Tissue Studies of the Facial Growth

After the plethora of studies of hard tissue facial growth, various investigators studied the effect of growth on both the soft and hard tissue facial profile.

In qualitative longitudinal cephalometric studies, Subtelny (1959, 1961) attempted to evaluate growth changes of the soft tissue profile in relation to the underlying skeletal framework. He obtained from the Broadbent-Bolton collection, serial cephalometric records of thirty patients from 3 months to 18 years of age with normal skeletal profile and equally divided as to sex. Subtelny found that with growth, both the skeletal and integumental chins assume a forward relationship relative to the cranium. The integumental chin tended to be in close relation to the degree of skeletal prognathism. The hard tissue facial profile becomes less convex with age, while the soft tissue profile was found to increase in convexity with the progression of growth. The nose has played a very important role in that increase of convexity and when it was excluded from the soft tissue profile, the facial convexity remained relatively stable regardless of the progression of the age. The soft tissue changes were not, therefore, analogous to those manifested by skeletal profile. The nose continues to grow downward and forward from one to eighteen years of age. The upper and lower lips were increasing in length due to growth and after the full eruption of the maxillary central incisors, both lips show a fairly constant vertical and anteroposterior relationship to the anterior teeth as well as to the underlying alveolar processes. The composite results of Subtelny's study indicate that the soft tissue profile does not exhibit the same growth changes as the skeletal profile.

Wisth (1972) studied growth changes in the soft tissue profile in children between the age of four to ten years. The hard and soft tissue SNA angles were noted to change differently: the former decreased, while the latter increased due to a thickening of the soft tissue overlying the skeletal A point. Wisth, like Subtelny, concluded that the nose seems to be responsible for most of the changes in profile convexity and when it is excluded the soft tissue profile does not show any change.

Bowker and Meredith (1956) examined the effect of growth on the soft tissue facial profile from serial radiographs of forty-eight children ages five to fourteen. They measured distances from the nasion-pogonion line to points on the soft tissue profile and found no significant sex differences for the age period studied. Bowker and Meredith also found that the anteroposterior distance from the reference plane to the tip of the nose increases much more than the distance from the most forward point on the integumental chin to the reference plane between the age of five and the age of fourteen. These authors, however, did not clarify whether adjustments were made for the difference between nasal and chin growth in order to compensate for the forward movement of the reference plane due to mandibular growth.

Pelton and Elsasser (1955), using a reference line at right angles to the Frankfort horizontal and twenty millimeters anterior to nasion, found that during childhood and adolescence, the average North-American caucasian boy and girl is characterized by slightly more forward development of the integumental profile in the region of subnasale than in the region of pogonion. They also studied vertical changes of the soft tissue profile and found that the upper face height (N - Sn) increases approximately 10 mm for the males and 6 mm for the females from the age of 5 to 7 up to the age of 20 to 24. During the same age period the lower face height (Sn - Me) increases approximately 12.5 mm for the males and 9 mm for the females. It must be noted that the measurements in this investigation were related to soft tissue profile landmarks overlying the skeletal foundation, so might differ from findings based directly on skeletal landmarks.

The importance of growth on the facial development and its uncertain pattern during orthodontic treatment, led investigators to try to develop a method to predict normal growth changes of the facial soft tissue profile and incorporate them in treatment planning.

Mauchamp and Sassouni (1973) studied fifty-one longitudinal series and measured the effect of growth on the skeletal and soft tissue profiles. On three planes passing through the skeletal points glabella, subnasale and pogonion and all parallel to the plane of reference (optic plane), the authors measured linear profile changes. Utilizing the hard and soft tissue angles of convexity and the difference between them, angular changes of the facial convexity were measured. They found that from the age of 7 to 18 years, soft tissue convexity showed no change while the skeletal convexity decreased by 4 degrees. Linear measurements on pogonion and subnasale showed an increase of 2 and 4 mm respectively. Mauchamp and Sassouni concluded that the changes occurring in the soft tissue profile are predictable as the changes in the skeletal profile when made over a 4 year period, but is not true when prediction is made over a 1 year span.

Chaconas and Bartroff (1975) studied longitudinal cephalograms of 46 caucasian children from the age of 10 to 16 years. Using as a plane of reference the line connecting the soft tissue points glabella and pogonion, they made fourteen linear soft tissue profile and two angular measurements, the "E" and the "H" angles. The mean millimetric and angular growth annual increments were measured for each age from 10 years up to 16 years of age. Also, multiple linear regression equations were computed to predict 16 year old measurements from the 10 year old ones. The objective was to individualize the growth forecast and secure a more accurate prediction of each area than is attainable through the use of average or mean measurements. They found that using these regression equations, the predicted value was highly correlated in each case to the actual value of the individual variable at age 16 years. In comparing the accuracy of the prediction method with the use of group averages, the standard deviation of the estimate was twice as large when using group averages as it was when using the prediction equation method.

Riolo et al (1974), Broadbent et al (1975), Johnston (1975), Popovich and Thompson (1977), Ricketts et al (1972), and Schulhof et al (1977) have all contributed to facial growth prediction and for review of the current status see Houston (1979).

Orthodontic Treatment Changes of the Facial Profile

Most of the studies concerning soft tissue profile have attributed changes in the facial profile to orthodontic treatment. The profile changes, however, are not exclusively the result of treatment, but are rather the combined effect of growth and treatment superimposed on the hard and soft tissue facial profile.

To factor out the growth effect, Hershey (1972) studied profile changes in postadolescent female patients who were treated by orthodontic means. Using as a reference plane the N - Pg line registered at nasion and in the same angular relationship with S - N as in the pretreatment records, Hershey investigated the response of the soft tissue to retraction of the incisors. He found a rather high degree of correlation for the maxillary incisal retraction, while the hard-soft tissue correlation was less pronounced in the mandible.

With increased maxillary incisal retraction the degree of correlation between tooth and lip displacement was reduced. The lower lip appears to be less dependent than the other profile points upon the underlying skeleton for its position in space. Hershey also found that the response of the soft-tissue profile to incisal retraction showed no difference between Class I and Class II cases.

Bloom (1961) reported that the perioral soft tissues are in close relationship with the underlying dento-skeletal framework. He felt that the maxillary incisors influenced the lower lip and the mandibular labial sulcus. Bloom concluded that soft tissue response is closely related to that of the orthodontically moved hard tissue structures and that the lower lip was following the movement of the lower incisor more closely than the upper lip followed the upper incisor.

Neger (1959) stated that a proportionate change of the soft tissue profile does not necessarily accompany extensive dentition changes. However, his measurements and his observations were based on black and white photographs of orthodontically treated and non-treated individuals.

Changes in the soft tissue profile in connection with orthodontic treatment were studied by Rudee (1964). He investigated the relationship between incisal retraction and lip response in 85 patients age 6 to 22 years. The distance from the nasion-pogonion line to the cutting edges of the incisors and to soft tissue points was measured before and after treatment. A relatively high degree of correlation (0.7) was found to exist between the retraction of the upper and lower incisors and the upper and lower lips. There was great individual variation, however, and because of this, it would hardly be possible to predict the lip profile a specified retraction of the incisors would produce in a specific case.

Anderson et al (1973) studied soft tissue profile changes using the N - Pg plane as a reference. They divided their study group into two parts according to their small or large overjet. Anderson et al found that the soft tissue thickness of the maxillary lip increased during treatment at the same time the lip was being retracted relative to facial plane. The ratio in both groups between the increase in maxillary lip thickness and maxillary incisor retraction was close to 1:1.5. The relationship between lower lip retraction and mandibular incisor retraction was in 1:1 ratio for the small overjet group and in 2:1 ratio for the large overjet group. This latter finding agrees with Angle's concept that protrusion of the lower lip is related to the prominence of the maxillary incisors.

Anderson et al also found that the soft tissue thickness overlying skeletal points A, B and pogonion became more prominent when related to the NB plane during and after treatment.

Ricketts (1960) studied longitudinal records of orthodontically treated and non-treated cases and found that the maxillary lip will thicken slightly with normal growth but, that it will thicken significantly when the upper incisor has been retracted. According to Ricketts, for every 3 mm of retraction of the maxillary incisors, 1 mm increase in upper lip thickness can be expected. The lower lip thickens very little, but it will curl backward as a result of the maxillary incisor retraction. With the retraction of the dental arches and the establishment of an ideal overjet, an increase in the soft tissue covering the chin will occur as a result of loss of lip strain and loss of elevation by the mentalis muscle. Ricketts found that the nose advanced about 1 mm per year during the usual age period of orthodontic treatment and concluded that growth of the nose, together with contraction of the lips after treatment, accounts for an aesthetic change that should be taken into consideration in the original orthodontic treatment plan for the patient.

Soft tissue changes were studied by Angelle (1973) who compared thirty-six orthodontically treated individuals with sixteen untreated "smile contest" winners. Angelle used as a plane of reference for his study, the palatal plane and perpendicular on it at ANS. He found that there was a progressive increase in the prominence of integumental chin for both groups and the untreated group showed a tendency to more prominent chin. In all subjects the nose length increased at a steady rate until late adolescence and in the treated group the upper lip was found to become thicker during treatment. He also found that a lengthening of the upper lip was noted in both the treated and untreated group.

Wisth (1974) studied the soft tissue response to upper incisor retraction in boys with slight (3 - 4 mm) and marked (8 - 10 mm) overjets. He found that the relationship between incisor retraction and upper lip response was approximately 2:1 in the small overjet group and 3:1 in the large overjet group. The lower lip thickness increase was slightly greater in the small overjet group but not statistically significant, thereby indicating an independence from the degree of upper incisor retraction. Wisth found also that the thickness of the upper lip sulcus and the chin, increased 1.9 mm and 1.3 mm respectively in both groups. This later finding agrees with Subtelny's (1959, 1961) findings, which were 2.5 mm and 1.4 respectively for upper lip sulcus and soft tissue chin. Wisth concluded that because of the great variability of the results, prediction of soft tissue changes in an individual case is impossible, particularly if the overjet is great.

Warfield (1975) examined twenty-five individuals with Class II Division 1 malocclusions who had been treated orthodontically and studied their profile changes during and after treatment. All the measurements were made from a vertical plane passing through the inferior point of the pterygomaxillary fissure and the intersection point of the greater wing of the sphenoid and the anterior cranial fossae. He found that all soft tissue points moved anteriorly except labrale superius which moved posteriorly but also increased in thickness. In contrast, labrale inferius moved anteriorly along with incisor inferius but did not become thicker.

The ratio between maxillary incisal retraction and upper lip response was 2:1.

Hill (1977), using the same reference axis as Warfield in his study, investigated changes of the integumental profile in orthodontically treated individuals. He found that the subnasale point came forward 1.16 mm and down 2.75 mm while there was no significant change in the ANS-subnasale dimension. The upper lip showed 2 mm of thickening to 3 mm of upper incisal retraction. Nasal growth in relation to subnasal was 1.67 mm forward and soft tissue pogonion grew forward 2.22 mm and downward 1.87 mm without any significant change in the soft tissue thickness of the chin. Hill also found no significant changes in the angular relationship between the palatal plane to SE - PTM line which was used as a reference plane.

Roos (1977) studied cephalometrically thirty patients with Class II Division 1 malocclusions. The mean age was 12 years and the mean overjet was 4.1 mm. As a reference axes he used the S - N plane and the perpendicular line on S - N at the point sella. The linear measurements were converted to indices by dividing the measurements for each subject by the sella-nasion distance determined for the same subject and multiplying the quotient by 100. Roos found a mean ratio of 2.5:1 between the displacement of the upper incisors and that of the upper lip, while the individual variation was considerable and the correlation was rather low (0.42). The mean ratio for the lower incisor retraction and the lower lip response was 1:0.9 and the correlation fairly high (0.82). The mean ratio between the retraction of the subspinale and that of the superior labial sulcus was 1:1.4 and the correlation analysis moderate (0.58), while the ratio between the retraction of the supramentale and that of the inferior labial sulcus was 1.2:1 and the correlation analysis fairly high (0.69). Roos concluded that on the average, the retraction of the subspinale, lower incisor and supramentale was accompanied by a practically equally large retraction of the respective soft-tissue points and the correlation between them was fairly high, whereas the correlation between maxillary incisor retraction and upper lip was rather poor. He also found large individual variations in the soft tissue response, which was in agreement with previous findings by other investigators, even though some numerical differences may have been developed due to the fact that Roos utilized the perpendicualr on S - N axis instead of N - Pg plane which had been used in most previous soft tissue studies.

In summary, it is apparent that a good deal of investigation has been undertaken in order to study the interrelationship of hard and soft tissue profile. The investigations referred to seem to indicate that changes in the skeletal profile are not always followed by fully equivalent changes in the soft tissue facial profile. With the advancement of age, the skeletal profile, under the influence of growth, becomes more concave while the soft tissue profile becomes more convex. In treated cases there is a rather high degree of correlation between incisor retraction and soft tissue response but, there are large individual variations, thereby, making the prediction of soft tissue facial profile changes a rather difficult task.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Composition of the Samples

The present investigation was carried out on one hundred and two caucasoids, 8 to 18 years of age. Seventy-four of them, who had undergone orthodontic treatment, formed the study sample and were selected from the completed files at the University of Manitoba Graduate Orthodontic Clinic. The remaining twenty-eight individuals had no orthodontic treatment and served as a control sample. They were obtained from the Burlington Growth Centre serial sample*.

Analysis of the two samples and description of the subjects based on Angle classification and sex is found in Tables I and II, while the type of treatment (extraction or non-extraction) for the study sample is summarized in Table III.

Due to the lack of statistically acceptable sample size, Angle Class III, surgical-orthodontic, cleft lip and/ or palate, "open bite" cases and patients with any cranio-facial syndromes or gross skeletal deformities were eliminated from the present study.

The Study Sample

The pre-treatment age range of the study sample extended from 8.5 years to 16.2 years. Means and standard

---

* Courtesy of the Burlington Growth Centre, Clinical Sciences Division, Faculty of Dentistry, University of Toronto

TABLE I

Study Sample

Summary of subjects based on type of treatment, Angle classification and sex

Angle Classification	Non extraction		Extraction		Total
	Male	Female	Male	Female	
Class I	7	2	5	13	27
Class II Division 1	7	8	7	17	39
Class II Division 2	1	3	2	2	8
Total	15	13	14	32	74

TABLE II

Control Sample

Summary of subjects based on Angle classification and sex

Angle Classification	Male	Female	Total
Class I	6	6	12
Class II Division 1	6	6	12
Class II Division 2	2	2	4
Total	14	14	28

TABLE III

Summary of study subjects based on type of treatment

I	Non-extraction	28
II	Extraction	
	1) Maxillary and mandibular first bicuspids	30
	2) Maxillary first bicuspids	10
	3) Maxillary first bicuspids and mandibular second bicuspids	4
	4) Maxillary and mandibular second bicuspids	2
	Total	74

TABLE IV

Means and standard deviations of ages for the subjects of the study sample.

Angle Classification	Sex	Number	Ages (in years) at Stages of Treatment		
			A	B	C
Class I Non-Extraction	FEMALES	2	11.9	15.8	18.6
	MALES	7	12.7 ± 1.4	15.4 ± 1.3	18.0 ± 0.5
Class I Extraction	FEMALES	13	12.9 ± 1.7	15.8 ± 1.3	18.3 ± 1.6
	MALES	5	12.2 ± 1.8	15.3 ± 1.3	18.3 ± 1.9
Class II Division 1 Non-Extraction	FEMALES	8	12.3 ± 1.4	15.1 ± 1.8	17.2 ± 1.8
	MALES	7	11.0 ± 2.3	14.5 ± 1.6	17.8 ± 2.0
Class II Division 1 Extraction	FEMALES	17	13.3 ± 1.6	15.9 ± 1.6	18.1 ± 1.4
	MALES	7	12.3 ± 1.7	15.6 ± 2.2	18.2 ± 2.4
Class II Division 2 Non-Extraction	FEMALES	3	11.8 ± 2.5	14.3 ± 2.4	16.4 ± 2.0
	MALES	1	12.1	13.6	15.0
Class II Division 2 Extraction	FEMALES	2	15.6	17.2	19.9
	MALES	2	14.2	17.0	18.2

TOTAL 45 FEMALES + 29 MALES = 74

deviations of ages for each Angle class, sex and stage of treatment is found in Table IV.

Three lateral cephalometric films were used for each subject of the study sample. They were labelled as follows: 1) "A" - pre-treatment, 2) "B" - immediate post-treatment (debanding) and 3) "C" - immediate post retention.

The mean duration of treatment (stage A to B) for all patients was 2.2 ± 1.0 years, while the retention period (stages B to C) was 2.8 ± 1.1 years. Summary of treatment periods for each of the Angle classes and type of treatment is shown in Table V.

The lateral cephalometric films had been taken with the technique pioneered by Broadbent (1931). A Broadbent-Bolton type of cephalometer had been used on the twenty-one subjects, while for the remaining fifty-three, a Moss Cephalometrix cephalometer* had been used. The Broadbent-Bolton cephalometer had an approximate focal point to film distance of 167.6 centimeters, while the Moss cephalometer had a focal point film distance of 152.4 centimeters. Magnification factors for each machine had been previously established (Frostat, 1966) and recently substantiated (Moir, 1978). The magnification was determined to be 7 percent on the Broadbent-Bolton cephalometer and 9 percent on the Moss Cephalometrix cephalometer. Appropriate corrections for the two magnifications were performed during the process of analysis (Chebib et al, 1976).

* Moss Corporation - Chicago, Illinois, U.S.A.

TABLE V

Means and standard deviations in years of duration of treatment (A to B) and retention (B to C).

I	Angle Class I Non-Extraction		N* = 9
	Treatment	1.9 ± 0.6 yr.	
	Retention	2.1 ± 0.9 yr.	
II	Angle Class I Extraction		N = 18
	Treatment	2.8 ± 2.0 yr.	
	Retention	3.6 ± 1.3 yr.	
III	Angle Class II Division I Non-Extraction		N = 15
	Treatment	2.1 ± 1.2 yr.	
	Retention	2.7 ± 1.6 yr.	
IV	Angle Class II Division I Extraction		N = 24
	Treatment	2.7 ± 1.1 yr.	
	Retention	3.6 ± 1.8 yr.	
V	Angle Class II Division 2 Non-Extraction		N = 4
	Treatment	1.9 ± 0.6 yr.	
	Retention	2.5 ± 0.5 yr.	
VI	Angle Class II Division 2 Extraction		N = 4
	Treatment	1.8 ± 0.5 yr.	
	Retention	2.2 ± 0.5 yr.	
VII	All Subjects		N = 74
	Treatment	2.2 ± 1.0 yr.	
	Retention	2.8 ± 1.1 yr.	

* Where N = number of subjects

The Control Sample

Six serial cephalometric films were used for each of the twenty-eight control subjects and were traced for the ages of eight, ten, twelve, fourteen, sixteen and eighteen years. A Wehmer cephalometer had been used for all the control individuals, with a focal point film distance of 167 centimeters. The magnification factor was 9.485 percent and all the measurements were corrected, from the cephalometric enlargement, to the actual size (Popovich, 1979).

Selection of Landmarks

Twenty-six hard and soft tissue landmarks were used in this study. Using previously described definitions by Cleall and Chebib (1971) and Popovich (1979), fifteen hard tissue and eleven soft tissue landmarks were defined. Figures 1, 2 and 3 illustrate these cephalometric points, while their description is found in Appendix II.

A teletype connected to a Ruscom Logisitic Trip Chart Digitizer* was used to enter the "X" and "Y" coordinates for each cephalometric film in a set sequence into the University of Manitoba Computer System (IBM 370-68). Since the cephalometric films, despite precautions, were taken at varying orientations and elevations, they were transformed to a standard orientation using the technique described by Cleall and Chebib (1971). This entailed the transformation of the landmarks of each individual's radiograph to standardized coordinates based on a common

* Ruscom Logics Limited - Rexdale, Ontario, Canada

Figure 1

Hard and soft tissue cephalometric landmarks

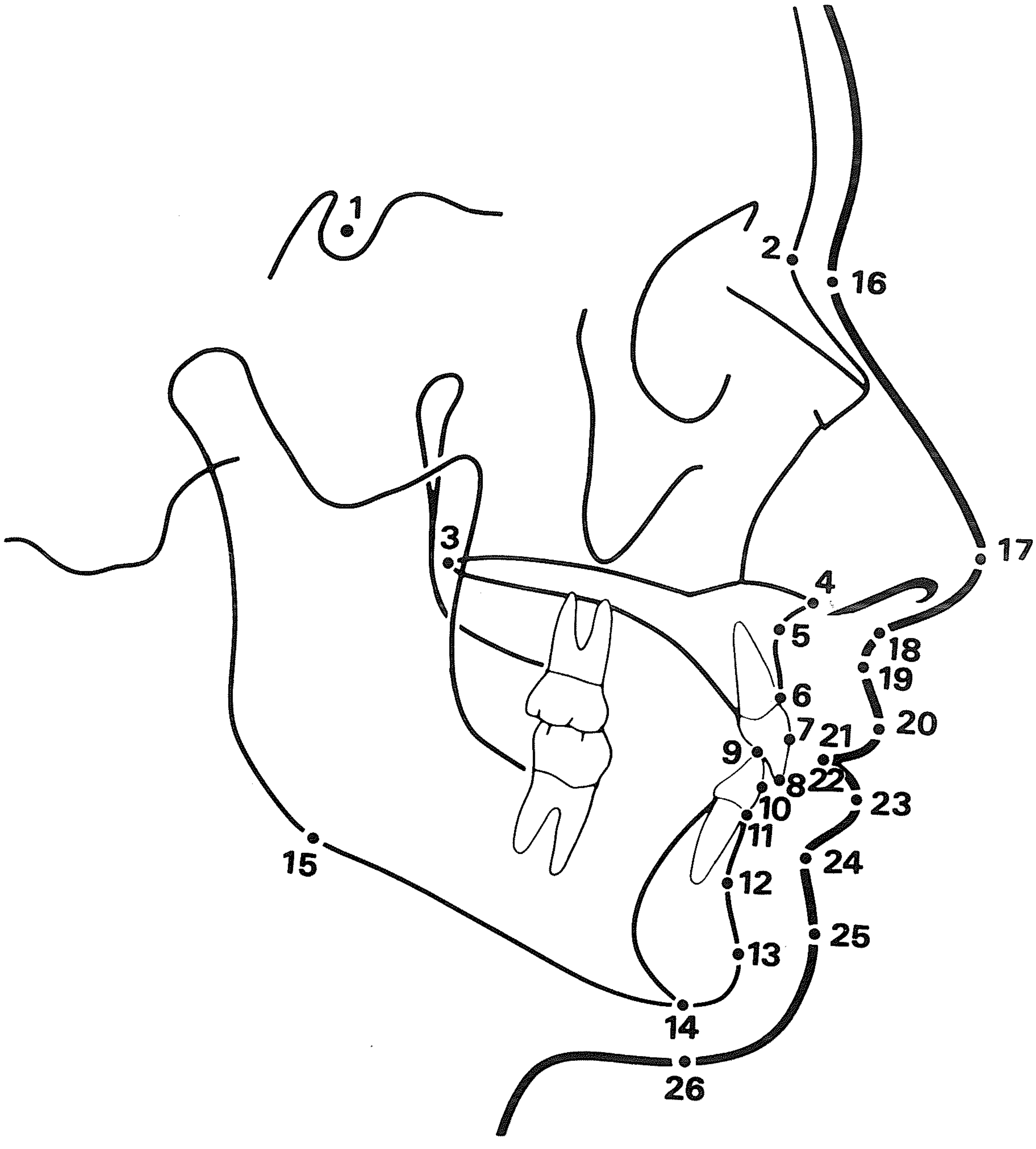

1
2
16
3
17
4
5
18
19
6
20
7
21
9
8
22
10
23
11
24
12
15
25
13
14
26

Figure 2

Hard tissue landmarks

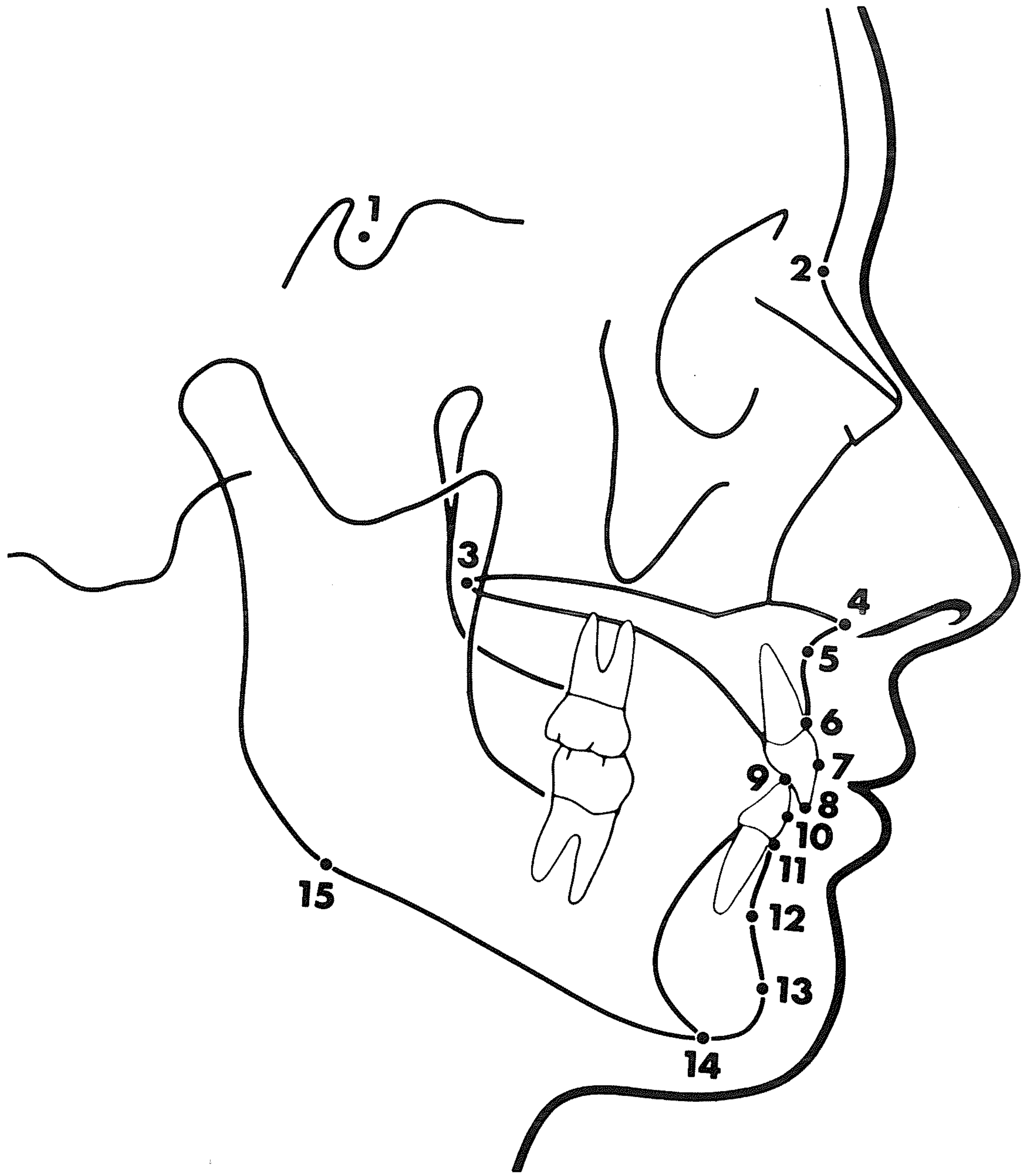
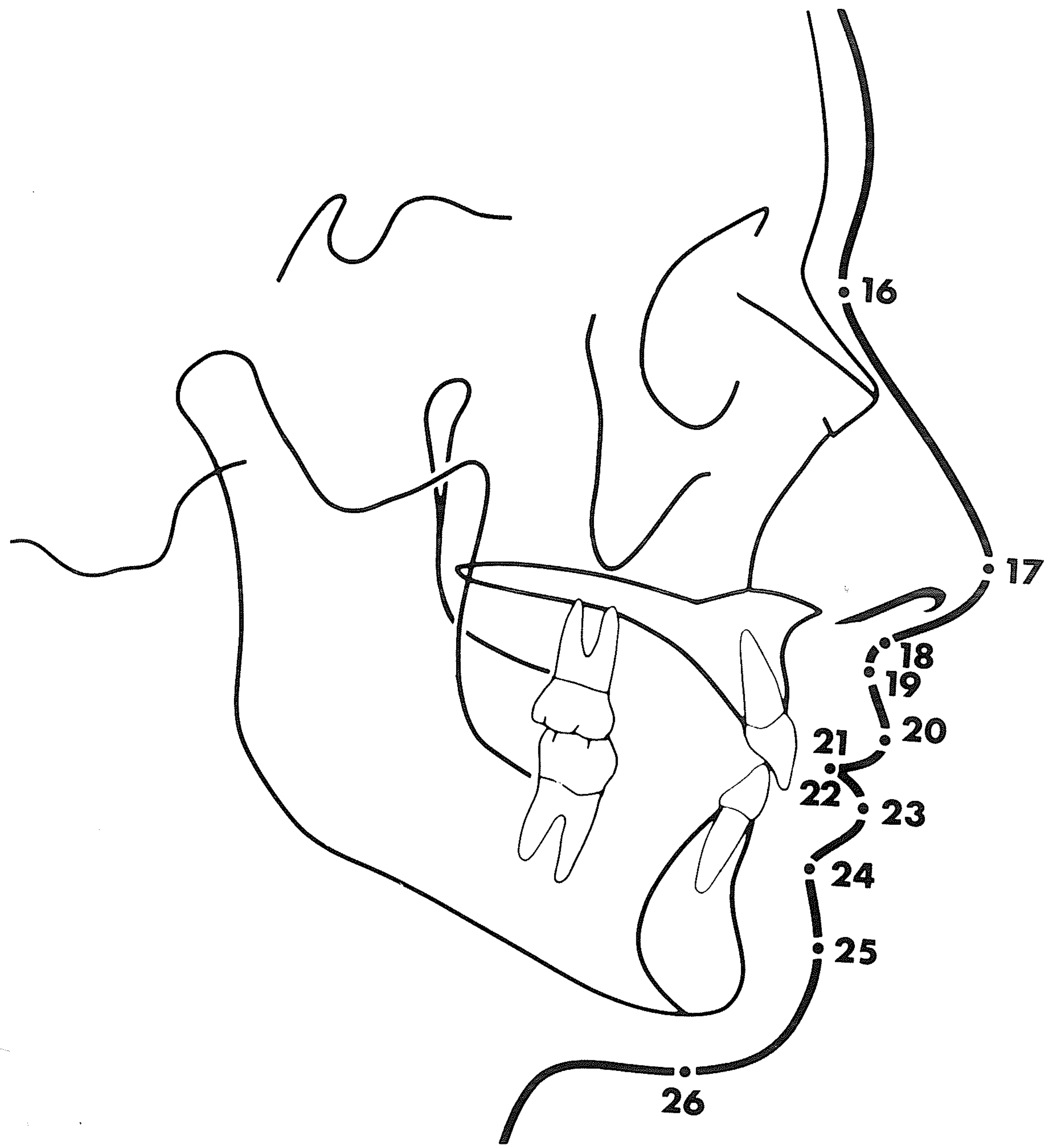

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Figure 3

Soft tissue landmarks


16
17
18
19
20
21
22
23
24
25
26

set of axes. These axes were predefined by a point of origin (No:1 - sella) and a directional point (No:2 - nasion) common to all radiographs (see figure 4). The axes for each cephalometric film were shifted to the point of origin (sella) and rotated around so the positive direction of the "X" axis passed through nasion. From the standardized coordinates on each radiograph, the linear and angular measurements used in this study were computed and stored directly in the University of Manitoba Computer System where they were analyzed. All linear measurements were recorded in millimeters while all angular measurements were recorded in degrees. Illustration of these measurements can be found in figures 5, 6, 7, 8 and 9.

In addition to linear and angular measurements, cross-sectional areas of upper and lower lips were also calculated. The cross-sectional area of the upper lip was defined as the region outlined anteriorly by the soft tissue line, posteriorly by the hard tissue line and the lower posterior third of the upper lip, inferiorly by the inferior lip border and superiorly by the line connecting the landmarks, subrhinal, and anterior nasal spine (see figure 10).

Similarly, the cross-sectional area of the lower lip was defined as the region outlined anteriorly by the soft tissue line, posteriorly by the hard tissue line and the upper posterior third of the lower lip, superiorly by

Figure 4

Reference planes

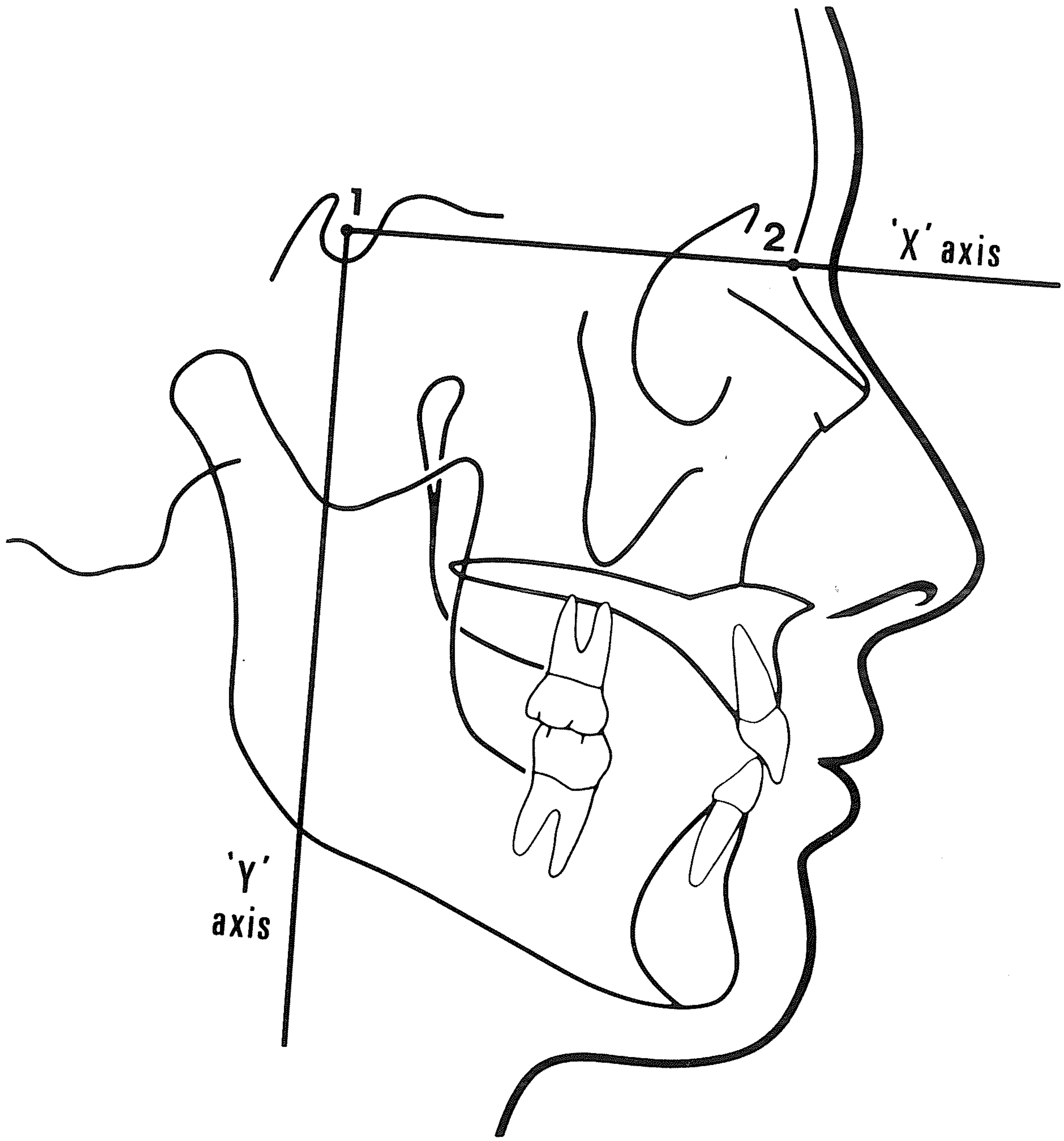

1
2
'X' axis
'Y'
axis

Figure 5

Horizontal hard tissue measurements

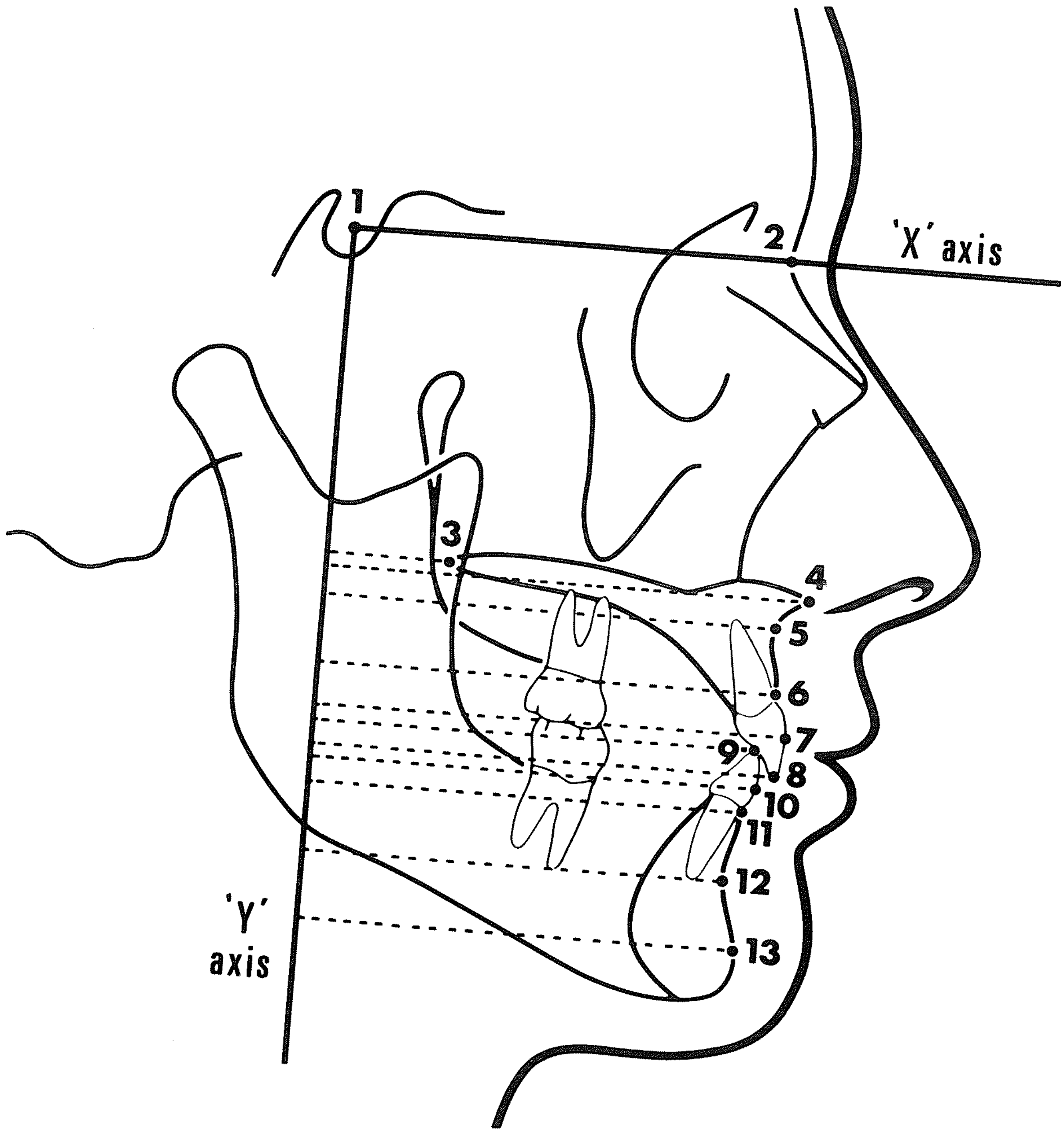

1
2
'X' axis
3
4
5
6
7
8
9
10
11
12
13
'Y' axis

Figure 6

Horizontal soft tissue measurements

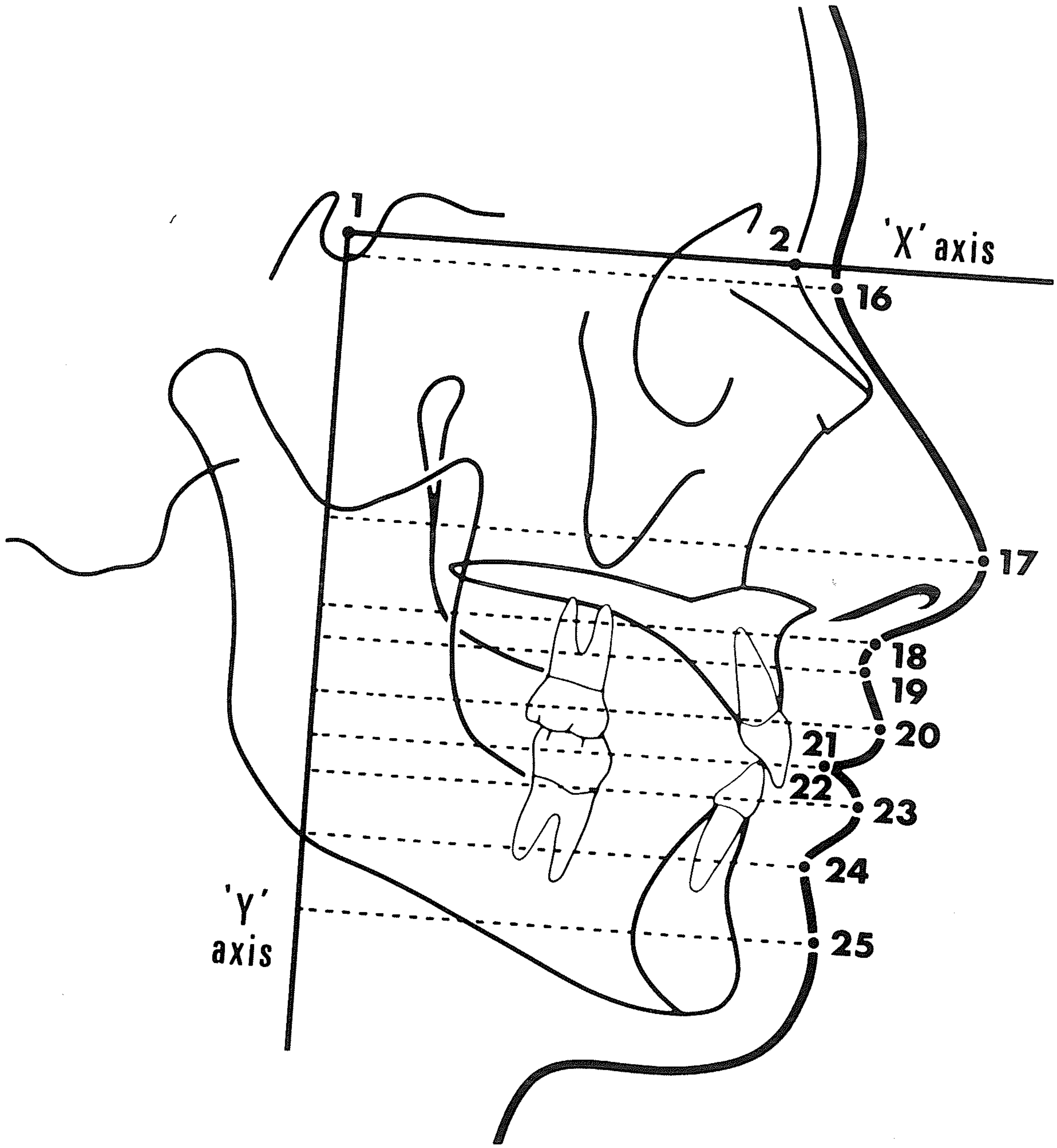
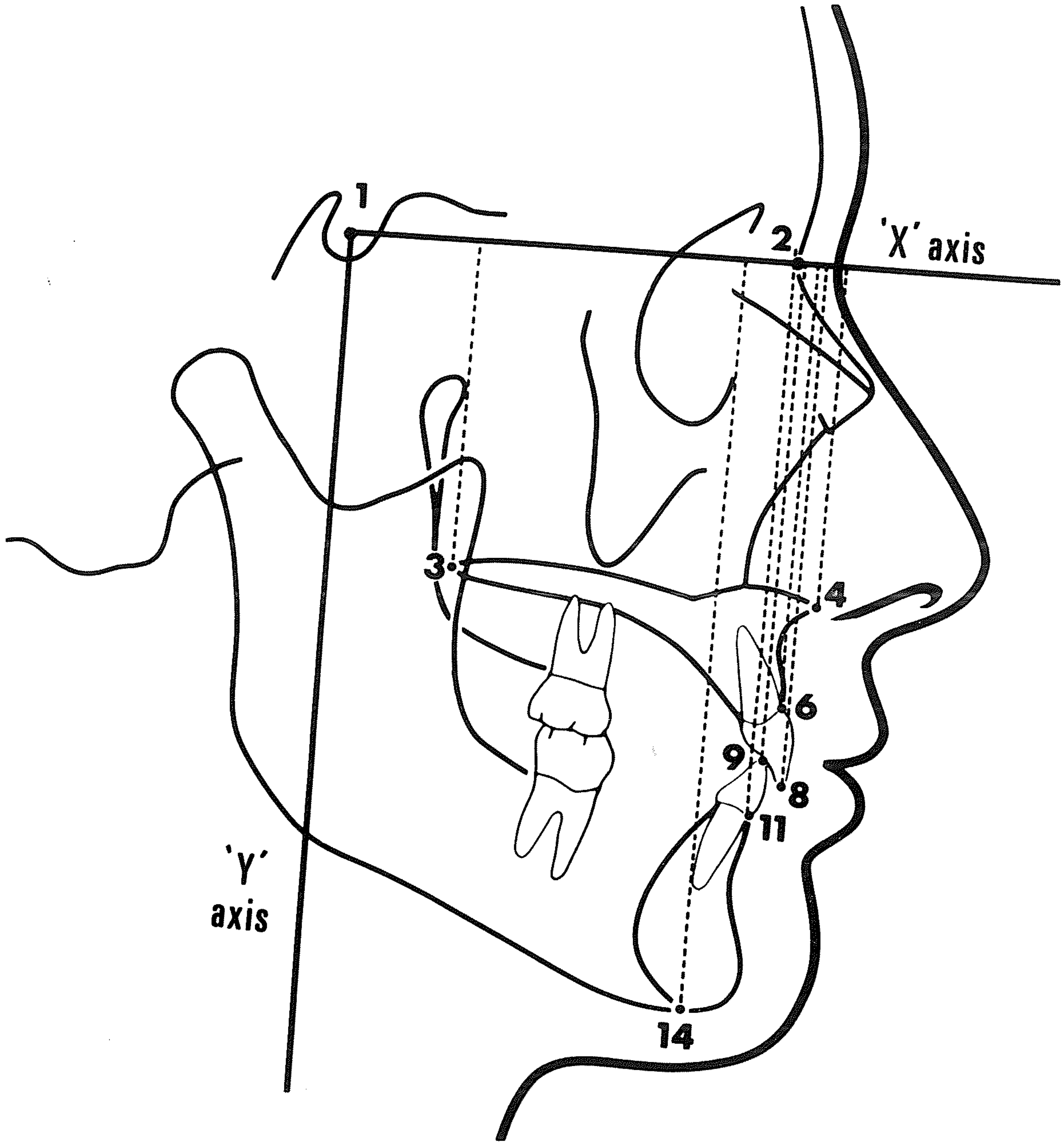

1
2
'X' axis
16
17
18
19
20
21
22
23
24
25
'Y'
axis

Figure 7

Vertical hard tissue measurements



1
2
'X' axis
3
4
6
9
8
11
'Y'
axis
14

Figure 8

Vertical soft tissue measurements

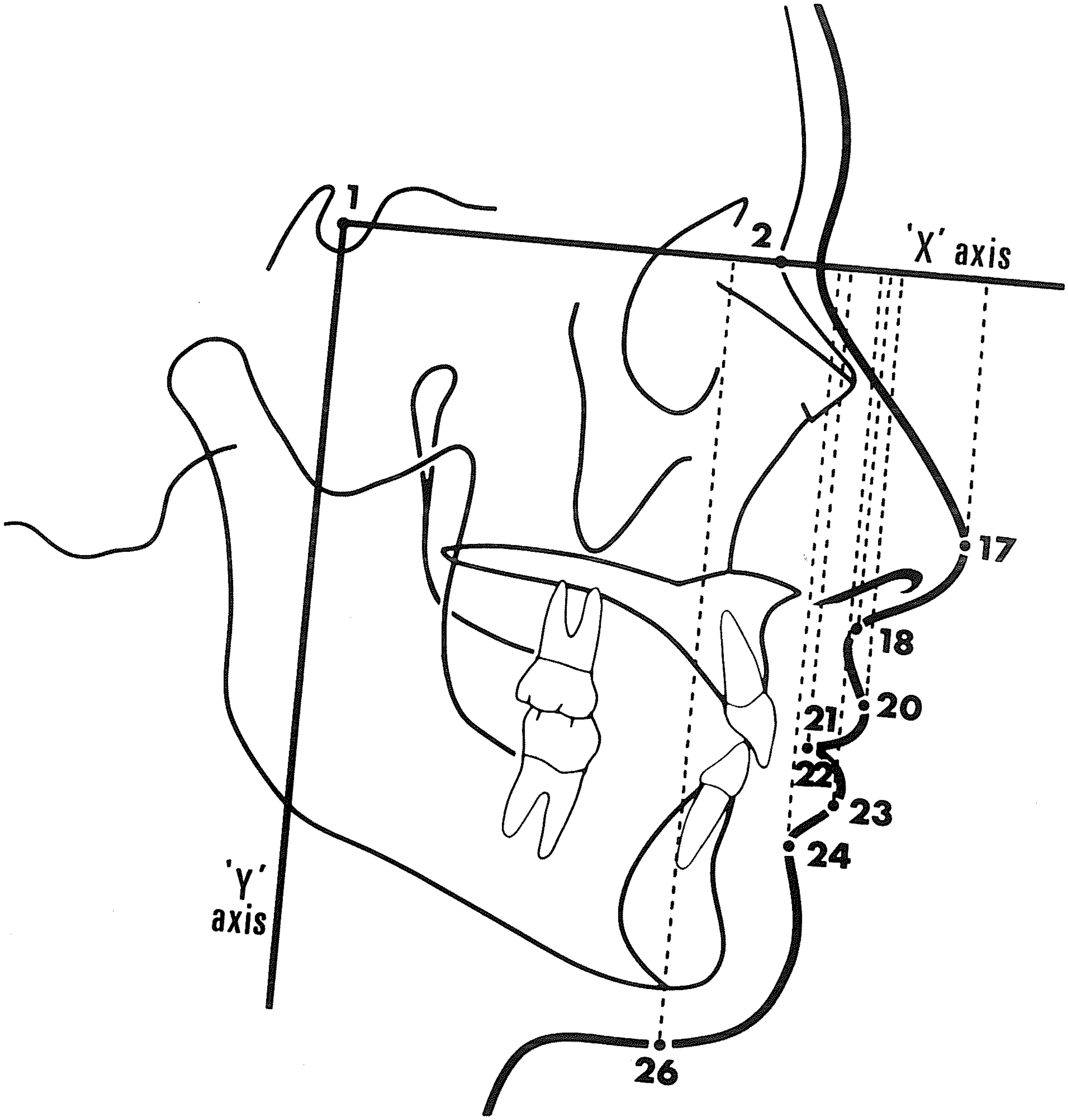
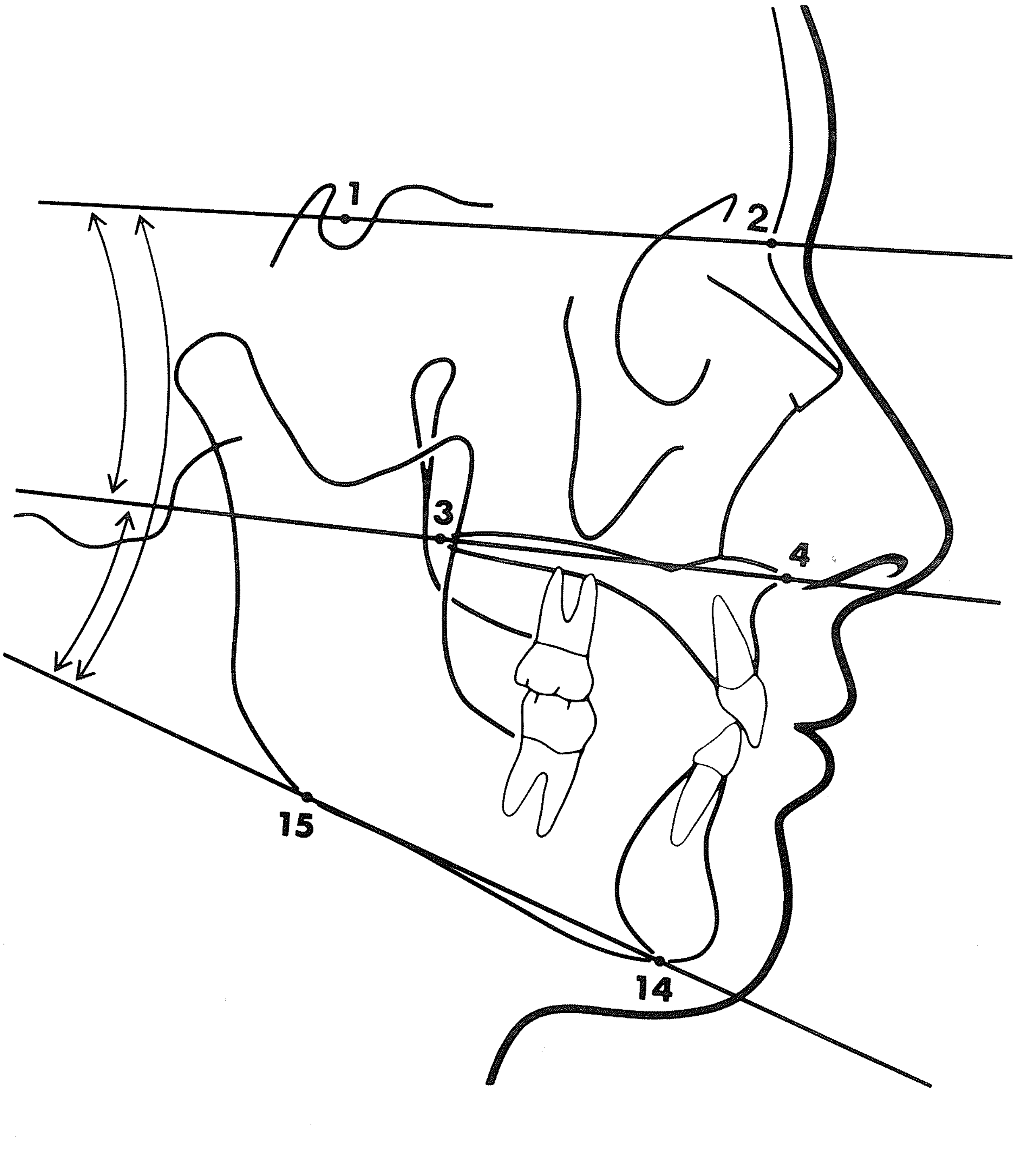

1
2
'X' axis
17
18
20
21
22
23
24
'Y'
axis
26

Figure 9

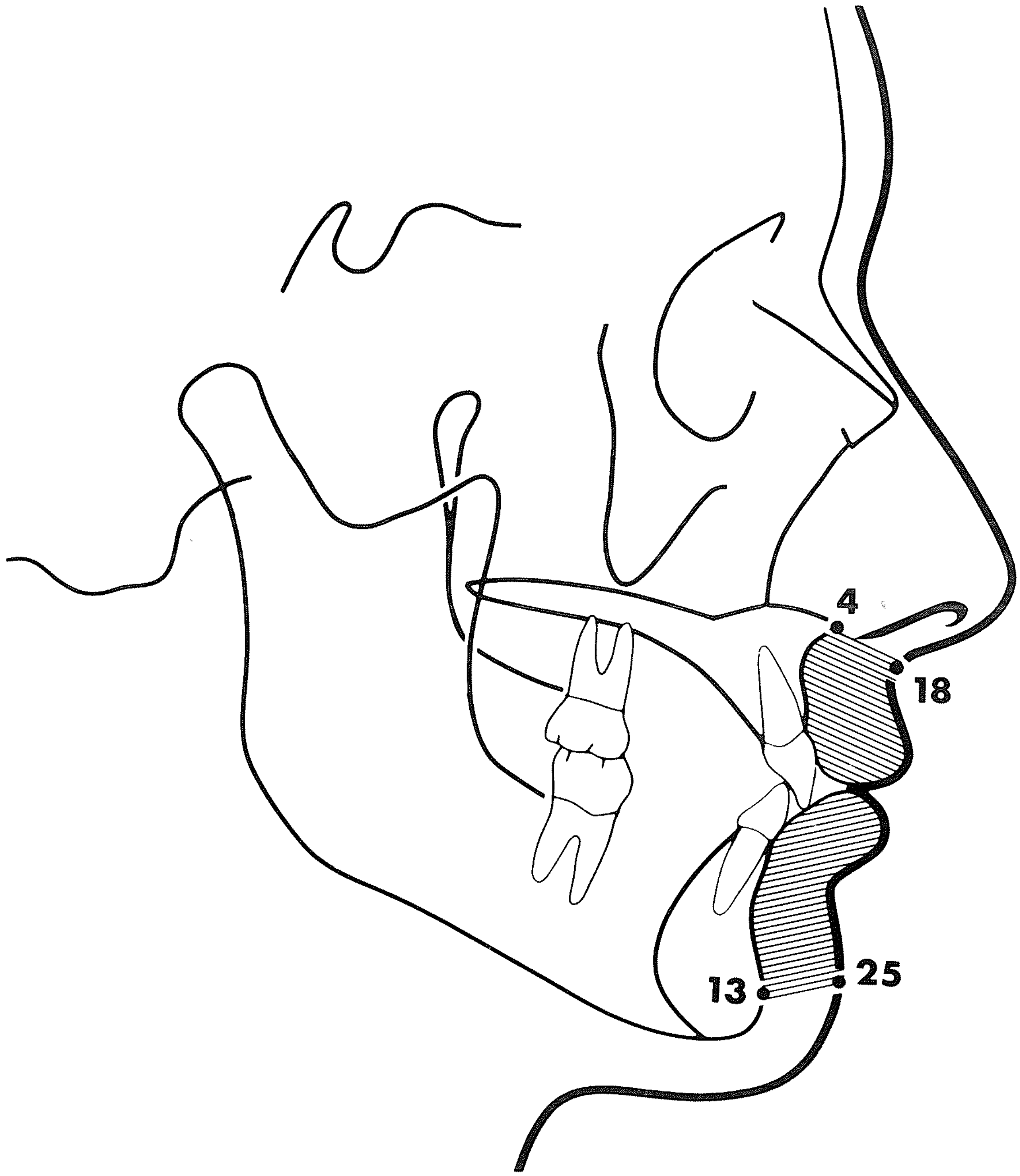
Angular measurements



1
2
3
4
15
14

Figure 10

Cross-sectional lip area measurements


4
18
13
25

the superior lip border and inferiorly by the line connecting the points of hard and soft tissue pogonion (see figure 10).

Each cross sectional area was determined through a specially designed computer program from the Department of Biostatistics (Chebib, 1978) using a Ruscom Digitizer connected to University of Manitoba computer system. In order to calculate an area, successive digitization of points outlining the area was performed. The accuracy of the program was tested on various geometrical designs and showed no error. The final cross-sectional area of each lip was recorded to the nearest square 0.001 cm.

Selection of Reference Plane

After considering the various reference planes cited in the Review of the Literature, the line connecting the cephalometric points sella and nasion was selected as the reference plane for this study. This plane was named "X" axis and was used in order to determine the vertical distances of the various cephalometric points considered. A plane perpendicular to the "X" axis at point sella was named the "Y" axis and was used to assess the horizontal distances of the facial profile points (figure 4).

Error of Measurement

Prior to the main investigation, three pilot studies were performed in order to examine the reliability of using the soft tissue on a lateral cephalometric film and to assess the error involved a) in the tracing and the calculation of the upper and lower lip and b) in the angular and linear measurements of hard and soft tissue cephalometric landmarks.

The first pilot study was designed and performed using as subjects five (5) male first year dental students and ten (10) female first year dental hygiene students. All subjects were randomly selected and had no orthodontic appliances in their mouths.

Four (4) cephalograms were taken from each subject with three (3) minute intervals. The first three (3) cephalograms were taken with the lips in light contact and the fourth with the lips apart. All cephalograms were limited in the anterior third of the lateral headview, including the facial profile region, while the rest of the head and the body of each subject were protected from radiation by a specially designed shield. The total amount of radiation received by each subject during the four (4) exposures was approximately 600 mr which was considered well below the safety level by the Department of Radiology at the Dental Faculty of the University of Manitoba.

The objectives of this pilot study were twofold:

1) To examine and calculate the error involved in the study of cross-sectional areas of the soft tissue facial profile.

2) To determine if any difference exists between the cross-sectional area of both the upper and lower lip when the lips are in contact and when they are apart.

The error involved in this study consists essentially of two errors 1) digitization of cross-sectional area and 2) an error due to the cephalometric machine. To assess the error due to digitization, ten (10) cephalograms, out of the total number of sixty (60), were randomly selected. The soft tissue cross-sectional area of the upper and lower lip, of each cephalogram, was digitized three times by the same observer.

The error of measurement expressed as the percentage of the standard deviation to the mean was calculated by the method described by Chebib and Burdick (1973) and was found to be 1.55 percent and 1.18 percent for the upper and the lower lip respectively.

The remainder of the sixty (60) cephalograms were used and with the same procedure, the cross-sectional areas of the upper and lower lip were digitized. Each area was calculated once on each cephalogram. Utilizing the analysis of variance, the standard deviation expressed in percentile (%) of the mean was found.

The percentile (%) found represents the combined error involved due both to digitization and to the cephalometric machine and was found to be 5.36% and 5.12% for the upper and lower lip respectively.

In order to compare the areas of the lips when they are in contact or apart, the mean value for the cross-sectional area of the upper and lower lips was calculated for each subject, from the three (3) cephalograms with the lips in contact. This mean value was called "closed lip area" (CLA) and it was compared with the value found from the cross-sectional areas of the upper and lower lips in the fourth cephalogram where the subjects had their lips apart.

Statistical comparison between closed (CLA) and open (OLA) lip area was performed using a paired "t" test. The "t" values computed were 2.025 and 2.061 for the upper and lower lips respectively, which were not statistically significant at a 5% level. This provided no apparent evidence of an additional source of error due to lip position.

The second pilot study was designed in order to determine the error encountered in tracing estimation of the soft tissue cross-sectional area of the upper and lower lip, as compared to the computation of the same area from the original cephalograms. This study became important due to unavailability of original cephalograms for part of the main research material.

Ten (10) cephalograms were randomly selected, and the soft tissue cross-sectional areas of the upper and lower lip, from each cephalogram, were traced on three separate tracings. The cross-sectional areas of the upper and lower lip, from the thirty (30) tracings, were determined. In the same manner, the cross-sectional areas of the upper and lower lip from the ten (10) original cephalograms were calculated three times for each lip.

The mean values from the tracing triple calculations and from the original cephalograms triple calculations were obtained for each upper and lower lip cross-sectional areas.

Statistical comparison between the mean values from the tracings and the mean values from the cephalograms was performed using a paired "t" test.

The findings indicate that there is no significant difference between the soft tissue cross-sectional areas of the upper and lower lip from the original cephalograms as compared to the soft tissue cross-sectional areas calculated from the tracings of the upper and lower lips. The "t" values were 0.117 and 0.036 for the upper and lower lips respectively, indicating a high degree of agreement between the two methods.

The error involved in this study, due to tracing, was also determined. Using analysis of variance, the standard deviation expressed in percentile (%) of the mean, was calculated. The percentile (%) found represented the error encountered when tracing the cross-sectional lip areas from the original cephalograms. The combined error due to tracing and the cephalometric machine was found to be 2.44%

for the upper lip cross-sectional area and 2.13% for the lower lip area.

The third pilot study was designed and performed in order to determine the error involved in the location and digitization of the hard and soft tissue cephalometric landmarks and subsequently in the assessment of the angular and linear horizontal and vertical hard and soft tissue measurements.

Fifteen (15) cephalometric films were randomly selected and the twenty-six (26) hard tissue and soft tissue points on each film, were digitized three times.

To calculate the error involved, three angular, six linear vertical and six linear horizontal measurements were selected and compared within each triple set of calculations.

The pooled standard deviations within each triple set of measurements, of each cephalometric film, were calculated as suggested by Burdick and Chebib (1973), and are reported for each measurement in the Table VI. In addition to the standard deviation of measurement error (s) were also calculated the expected mean error (e) and the maximum error (e_p) on 95 and 99% level using the following formulas:

$$s = \sqrt{\frac{\Sigma\left[\Sigma(x - \bar{x})^2\right]}{\Sigma(n - 1)}}\ , \ df = \Sigma(n - 1)$$

Where n is the number of times each radiograph was digitized

TABLE VI

Expected Mean Error ($\bar{e}$), Standard Deviation of Measurement Error, 95% Maximum Error and 99% Maximum Error, for Fifteen Cephalometric Skeletal and Dental Variables

Variable	Expected Mean Error	Standard Deviation of Error	95% Maximum Error	95% Maximum Error
Angular Measurements in (°)				
1. Angle 1-2, 3-4	0.19	0.24	0.49	0.66
2. Angle 1-2, 14-15	0.27	0.34	0.69	0.93
3. Angle 3-4, 14-15	0.29	0.37	0.75	1.01
Linear Measurements in (mm)				
4. Horizontal Y-4	0.23	0.28	0.58	0.78
5. Horizontal Y-5	0.23	0.29	0.59	0.79
6. Horizontal Y-13	0.22	0.27	0.55	0.75
7. Horizontal Y-18	0.28	0.35	0.70	0.95
8. Horizontal Y-20	0.24	0.31	0.62	0.84
9. Horizontal Y-25	0.17	0.21	0.43	0.57
10. Vertical X-8	0.21	0.26	0.54	0.73
11. Vertical X-9	0.21	0.26	0.54	0.73
12. Vertical X-14	0.20	0.25	0.51	0.69
13. Vertical X-15	1.14	1.43	2.93	3.94
14. Vertical X-18	0.29	0.36	0.74	0.99
15. Vertical X-26	0.22	0.28	0.56	0.76

for determination of the measurement error and in this case $n = 3$:

$$\bar{e} = \pm\sqrt{\frac{2}{\pi}}\, s = \pm\ 0.7979s$$

$$e_p = \pm t\ (95\%, df)\ s$$

$$e_p = \pm t\ (99\%, df)\ s$$

Where t is the student's t value for "df" degrees of freedom and probability "p" (95%) and (99%). This means that 95% of measurements will have a measurement error not exceeding ± 2.042 s and 99% of measurements will have a measurement error not exceeding ± 2.75 s (see Table VI).

Statistical Analysis

In order to compare the cross-sectional lip areas between the study and the control sample and eliminate the growth factor, the following method was used.

The mean values of the maxillary and mandibular cross-sectional lip area, for the control males and females of the three malocclusion groups, was determined for ages eight, ten, twelve, fourteen, sixteen and eighteen years, using the method previously described. To decrease the age intervals from two years down to one month, the mean values of two successive ages (e.g. eight and ten years) was calculated and then divided by 24 (2 years x 12 months) in order to determine the monthly interval. A compromise was made to accept this monthly interval as constant, while in reality this is not necessarily true.

This allowed the construction of a growth curve for each of the six experimental groups (two sexes x three malocclusions) separately for the maxillary and mandibular lips. The growth curve for each malocclusion group and sex, was used to adjust the cross-sectional lip area that was calculated from the cephalometric tracings, to an "average" lip area using the formula:

$$A' = A - A_t + \bar{A}$$

where

A' = adjusted lip area

A = lip area calculated from the tracings

A_t = the control "curve" lip area from the age and sex of the patient

$\bar{A}$ = the standard mean lip area

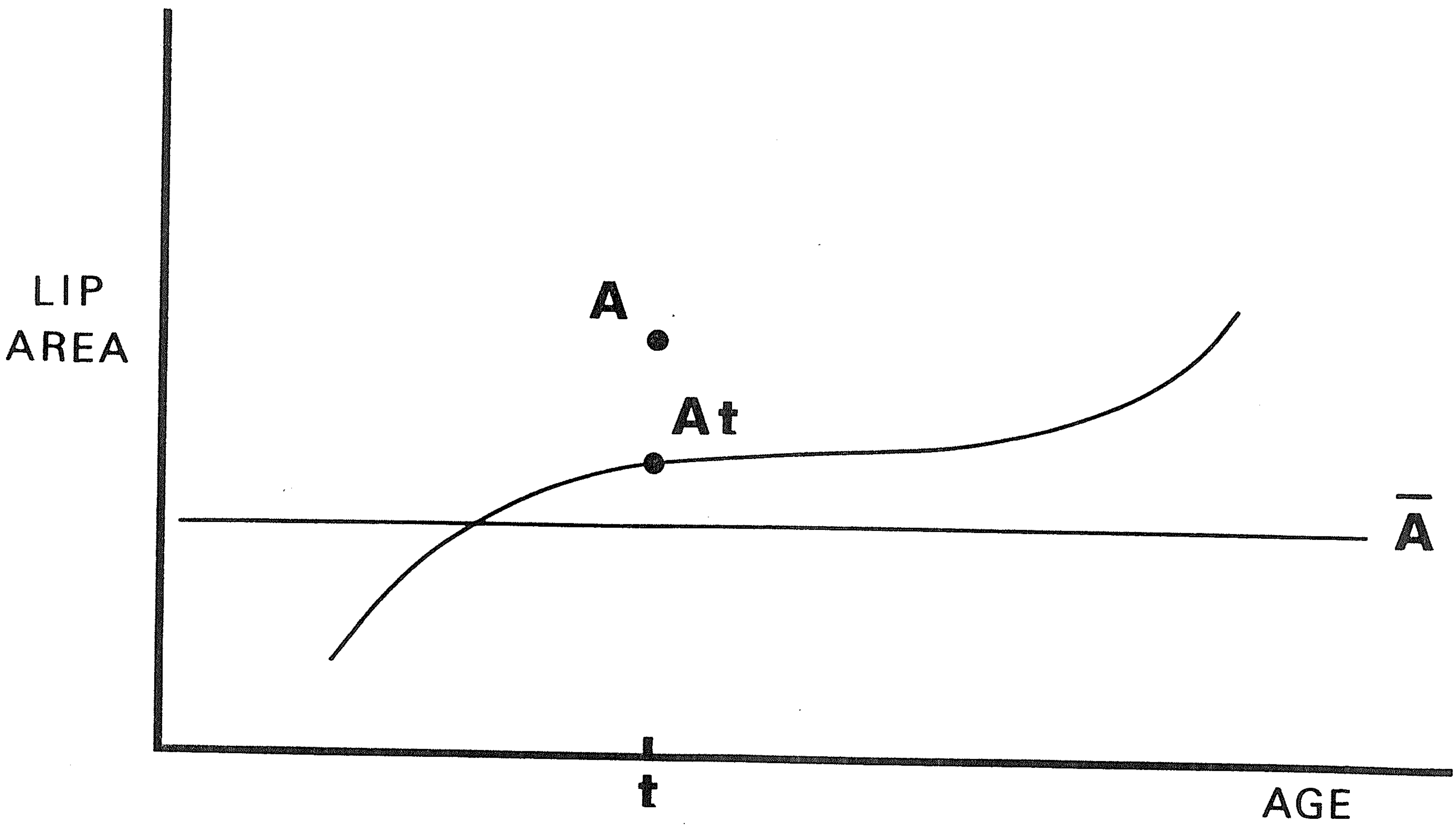
The above formula is graphically illustrated in figure 11.

A special computer program was designed for these adjustments, by the Department of Biostatistics (Chebib, 1979), in such a way as to eliminate the variables of age and sex. The corrected cross-sectional values of the upper and lower lips of the study sample may then be statistically analyzed without being masked by growth.

Similar procedures were carried out for the adjustment of the linear measurements, both vertical and horizontal.

Figure 11

Graphic illustration of the equation $A'=A-A_t+\bar{A}$


LIP
AREA
A
At
Ā
t
AGE

In order to describe the changes between the groups, a factorial analysis of variance was utilized. The sample breakdown was based on the type of treatment (extraction versus non-extraction and Angle's classification (Table I). The sexes were combined due to small numbers in each group.

The factors were as follows:

Treatment at 2 levels: extraction vs non-extraction

Angle Class at 3 levels: Class I vs Class II Division 1 vs Class II Division 2

State of treatment at 3 levels: A vs B vs C

As one of the factors (stage) varies across subjects (correlated levels) while the other two (treatment and class) vary between subjects (independent levels) the 2 x 3 x 3 factorial design was analyzed by a mixed analysis of variance as described by Becker and Chebib (1969). The mixed analysis of variance was performed on each horizontal, vertical and angular measurement and the 221 degrees of freedom were available from 74 subjects at the 3 stages of treatment. All mean squares of main effects and interactions were tested for significance by the variance "F" tables.

RESULTS

CHAPTER IV

RESULTS

The results of this study are presented in the following six sections. The first section contains the results of the mixed analysis of variance for the soft tissue cross-sectional areas of the maxillary and mandibular lip.

The second section shows the results of the mixed analysis of variance for the horizontal measurements of the hard tissue facial profile. The third section describes the results for the horizontal measurements of the soft tissue facial profile.

The fourth and fifth sections indicate the results of the mixed analysis of variance for the vertical measurements of the hard and soft tissue facial profile respectively. The sixth section gives the results of the mixed analysis of variance for the three angular measurements.

In every section the study sample was organized according to the type of treatment (non-extraction or extraction), Angle classification (Class I, Class II Division 1 and Class II Division 2) and stage of treatment (pre-treatment, immediate post-treatment and immediate post-retention), while the two sexes were combined. The mixed factorial analysis of variance, independent from sex and age, estimated the effect of type of treatment in each of the three class groups over the three stages of treatment, and the interaction between them. The results of these analyses for each cross-sectional, horizontal, vertical or angular measurement, are presented as mean squares as well as significance levels for all the variables.

1. Mixed Analysis of Variance for the Soft Tissue Cross-Sectional Areas of the Maxillary and Mandibular Lips

Utilizing the control sample, the effect of growth on the cross-sectional lip area of the study sample has been factored out. The mixed factorial analysis of variance of the corrected cross-sectional measurements, indicated the effect of orthodontic treatment on the maxillary and mandibular lips.

The mean squares and levels of significance for mixed analysis of variance for the upper and lower lip are presented in the Table VII. Examination of this table reveals significant differences ($p < 0.05$) of the cross-sectional lip areas for the two types of treatment. The non-extraction groups show greater cross-sectional lip areas than the extraction groups for both the maxillary and mandibular lips and the calculated values in cm^2, for the three stages of treatment, can be found in Table IX.

Further examination of Table VII demonstrates a highly significant difference between the three stages of treatment at the ($p < 0.005$) significance level for the upper lip and ($p < 0.01$) for the lower lip. The same table reveals a highly significant difference ($p < 0.05$) for the interaction of the factors class and stage for the maxillary lip area. Table VIII summarizes the analyses of this interaction for the three malocclusion groups, illustrated in figures 12 and 13. The non-extraction groups show a greater cross-

TABLE VII

Mean Squares and Levels of Significance for Mixed Analysis of Variance for the Upper and the Lower Lip Cross-Sectional Areas.

		Mean Squares of Variables	
Source of Variation	df+	Upper Lip Area	Lower Lip Area
Treatment	1	3.1349*	5.6545*
Class	2	0.2014	0.4083
Treatment x Class	2	0.5223	0.6103
Between Subjects Error	68	0.7898	1.4376
Stage	2	1.1090***	0.4353**
Treatment x Stage	2	0.0180	0.0227
Class x Stage	4	0.2281***	0.0623
Treatment x Class x Stage	4	0.0548	0.0704
Within Subjects Error	136	0.0526	0.0751

+ degrees of freedom
* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$

TABLE VIII

Effects of Stage and Angle Classification

a) Upper Lip Cross-Sectional Area in cm^2

Angle Classification		Stages A	B	C	Classes
Class I	Mean	3.169	3.378	3.356	3.301
N = 27	S.E.	±0.044	±0.044	±0.044	±0.099
Class II Div. 1	Mean	3.240	3.245	3.275	3.253
N = 39	S.E.	±0.037	±0.037	±0.037	±0.082
Class II Div. 2	Mean	3.114	3.435	3.595	3.381
N = 8	S.E.	±0.081	±0.081	±0.081	±0.081
Stages	Mean	3.174	3.352	3.409	3.312
	S.E.	±0.027	±0.027	±0.027	±0.060

b) Lower Lip Cross-Sectional Area in cm^2

Angle Classification		Stages A	B	C	Classes
Class I	Mean	5.469	5.669	5.671	5.603
N = 27	S.E.	±0.053	±0.053	±0.053	±0.133
Class II Div. 1	Mean	5.479	5.498	5.493	5.490
N = 39	S.E.	±0.044	±0.044	±0.044	±0.111
Class II Div. 2	Mean	5.557	5.686	5.773	5.672
N = 8	S.E.	±0.097	±0.097	±0.097	±0.245
Stages	Mean	5.502	5.618	5.646	5.588
	S.E.	±0.032	±0.032	±0.032	±0.080

TABLE IX

Effects of Stage and Treatment

a) Upper Lip Cross-Sectional Area in cm^2

Treatment		Stages A	Stages B	Stages C	Treatment
Non-Extraction N = 28	Mean S.E.	3.278 ±0.043	3.485 ±0.043	3.540 ±0.043	3.434 ±0.097
Extraction N = 46	Mean S.E.	3.070 ±0.034	3.220 ±0.034	3.278 ±0.034	3.189 ±0.076
Stages	Mean S.E.	3.174 ±0.027	3.352 ±0.027	3.409 ±0.027	3.312 ±0.060

b) Lower Lip Cross-Sectional Area in cm^2

Treatment		Stages A	Stages B	Stages C	Treatment
Non-Extraction N = 28	Mean S.E.	5.645 ±0.052	5.791 ±0.052	5.823 ±0.052	5.753 ±0.131
Extraction N = 46	Mean S.E.	5.358 ±0.040	5.444 ±0.040	5.469 ±0.040	5.424 ±0.102
Stages	Mean S.E.	5.502 ±0.032	5.618 ±0.032	5.646 ±0.032	5.588 ±0.080

Figure 12

Treatment effect on the upper lip cross-sectional area by stage of treatment and type of malocclusion

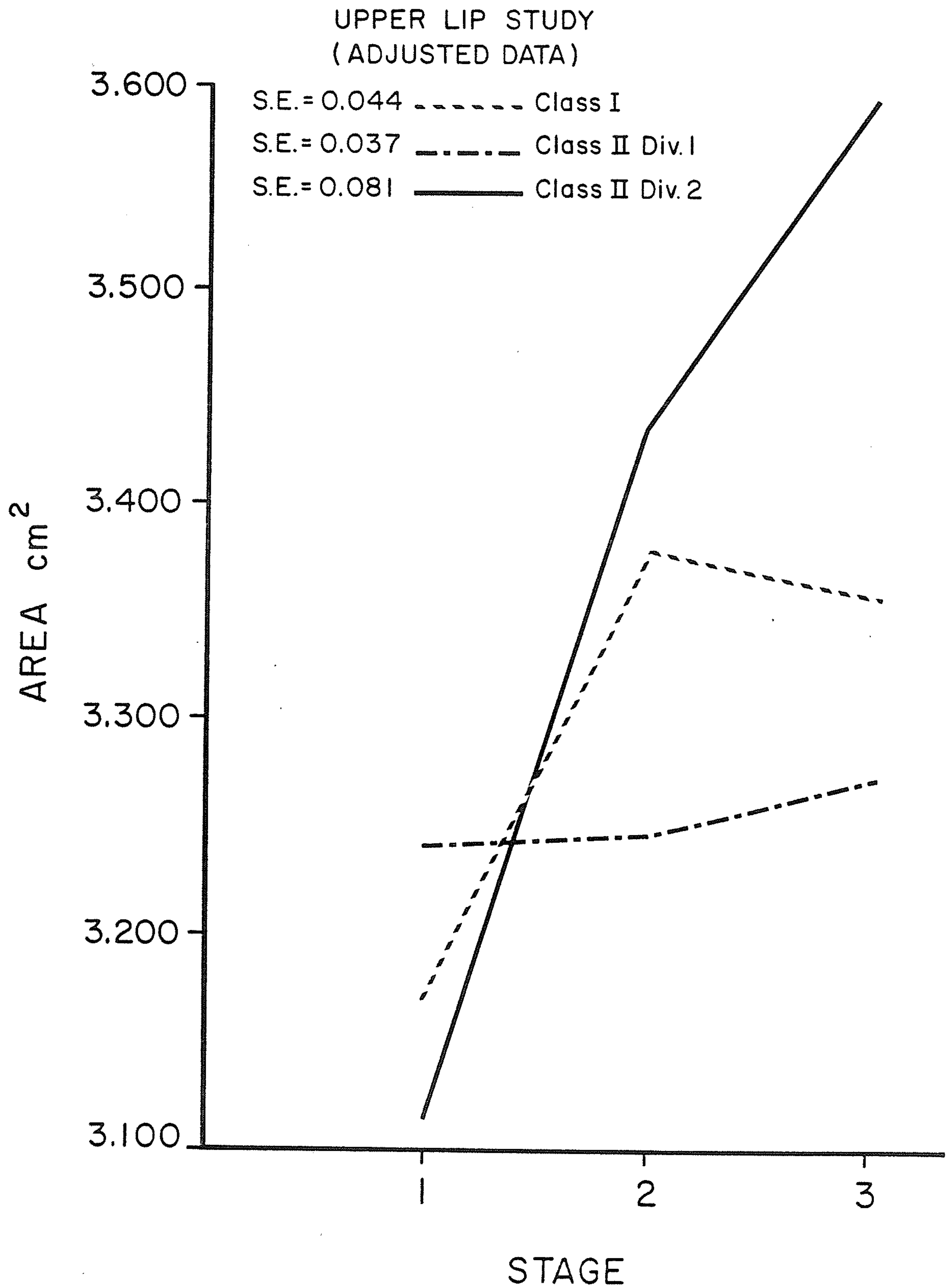
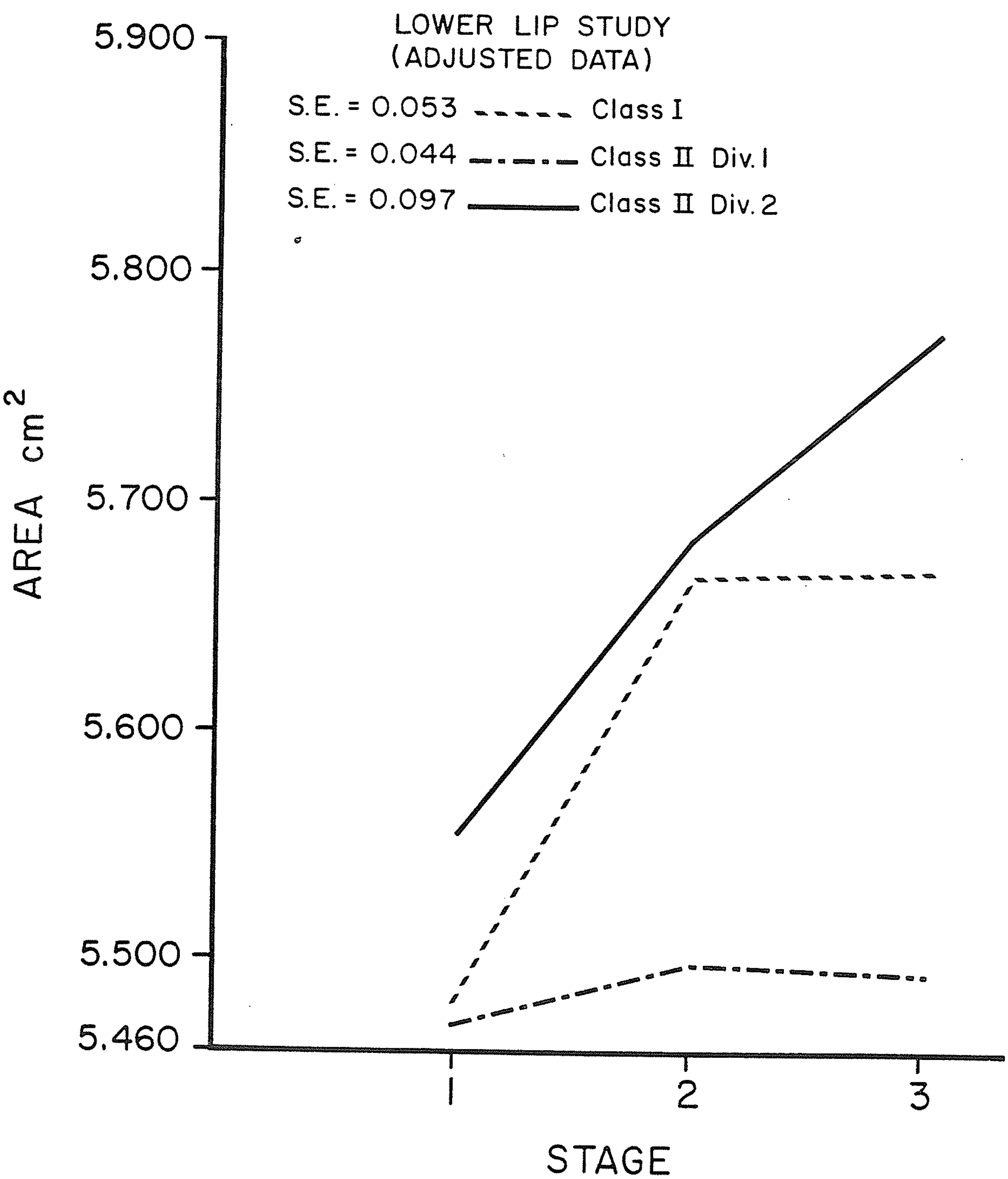

UPPER LIP STUDY
(ADJUSTED DATA)
S.E.= 0.044 Class I
S.E.= 0.037 Class II Div. 1
S.E.= 0.081 Class II Div. 2
3.600
3.500
3.400
3.300
3.200
3.100
AREA cm2
1
2
3
STAGE

Figure 13

Treatment effect on the lower lip cross-sectional area by stage of treatment and type of malocclusion


LOWER LIP STUDY
(ADJUSTED DATA)
S.E. = 0.053 Class I
S.E. = 0.044 Class II Div. 1
S.E. = 0.097 Class II Div. 2
5.900
5.800
5.700
5.600
5.500
5.460
AREA cm²
1
2
3
STAGE

sectional area in comparison to the extraction groups, however, over the three stages of treatment, both groups behave similarly showing a lack of statistical interaction (Table IX).

Tables X and XI demonstrate the effect of growth on the cross-sectional areas of the upper and the lower lips for the control sample, while figures 14 and 15 illustrate this effect.

TABLE X

Cross-Sectional Area in cm^2 of the Upper Lip for the Control Sample

Angle Classification		Age in Years 8	10	12	14	16	18
Class I N = 12	Mean	2.509	2.733	2.918	3.373	3.744	3.626
	S.E.	±0.089	±0.089	±0.089	±0.089	±0.089	±0.089
Class II Div. 1 N = 12	Mean	2.504	2.693	3.050	3.404	3.565	3.594
	S.E.	±0.089	±0.089	±0.089	±0.089	±0.089	±0.089
Class II Div. 2 N = 4	Mean	2.440	2.536	2.641	3.126	3.357	3.402
	S.E.	±0.153	±0.153	±0.153	±0.153	±0.153	±0.153

TABLE XI

Cross-Sectional Area in cm^2 of the Lower Lip for the Control Sample

Angle Classification		Age in Years 8	10	12	14	16	18
Class I N = 12	Mean	3.785	4.096	4.248	4.974	5.593	5.457
	S.E.	±0.127	±0.127	±0.127	±0.127	±0.127	±0.127
Class II Div. 1 N = 12	Mean	3.624	4.115	4.532	5.111	5.467	5.563
	S.E.	±0.127	±0.127	±0.127	±0.127	±0.127	±0.127
Class II Div. 2 N = 4	Mean	3.626	3.970	4.097	4.903	5.181	5.379
	S.E.	±0.220	±0.220	±0.220	±0.220	±0.220	±0.220

Figure 14

Growth effect on the upper lip cross-sectional area by age and type of malocclusion

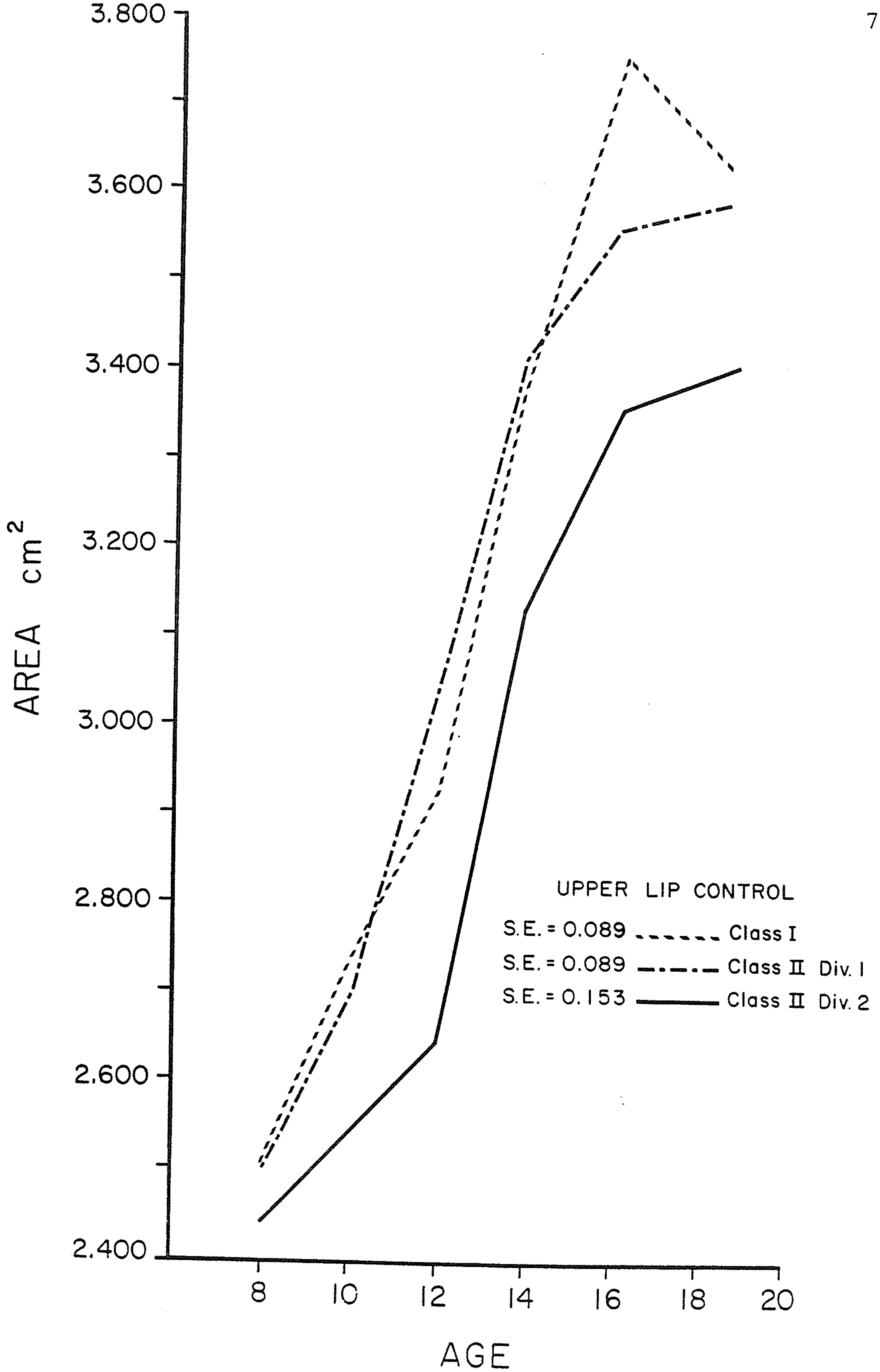
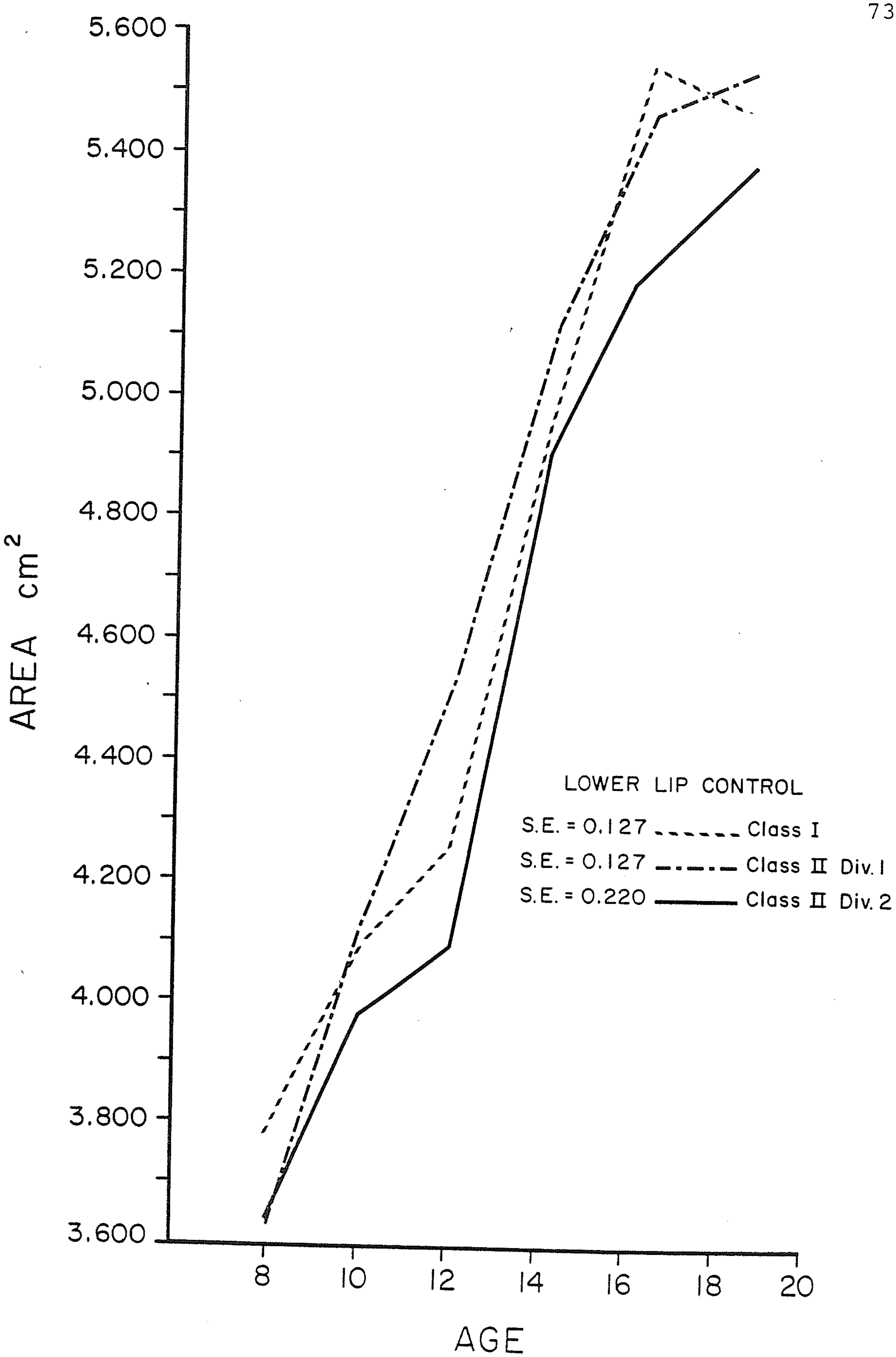

3.800
3.600
3.400
3.200
3.000
2.800
2.600
2.400
AREA cm2
8
10
12
14
16
18
20
AGE
UPPER LIP CONTROL
S.E. = 0.089 Class I
S.E. = 0.089 Class II Div. 1
S.E. = 0.153 Class II Div. 2

Figure 15

Growth effect on the lower lip cross-sectional area by age and type of malocclusion



5.600
5.400
5.200
5.000
4.800
4.600
4.400
4.200
4.000
3.800
3.600
AREA cm²
8
10
12
14
16
18
20
AGE
LOWER LIP CONTROL
S.E. = 0.127 Class I
S.E. = 0.127 Class II Div. 1
S.E. = 0.220 Class II Div. 2

2. Horizontal Measurements of the Hard Tissue Facial Profile

In order to facilitate the presentation of the results for the horizontal measurements of the hard tissue facial profile, the skeletal and dental variables will be presented separately. Table XII contains the mean squares and levels of significance for mixed factorial analysis of variance for the skeletal points "A", "B" and pogonion. All variables show highly significant difference ($p < 0.005$) over the three stages of treatment. In addition, the variable "B" point demonstrates significant difference ($p < 0.05$) between the three malocclusion groups. Means and standard errors for the three variables can be found in Tables XXVIII and XXIX (Appendix I) where also can be found means and standard errors for the remaining skeletal variables.

Table XIII shows that for the factor treatment the variables upper mid-crown point and upper incisor exhibit significant difference ($p < 0.05$) between the non-extraction and the extraction groups. Further examination of Table XIII reveals that all the three dental variables of the maxillary incisor show highly significant difference ($p < 0.005$) for both the main effects of class and stage, with the exception of the variable upper cemento enamel junction which shows significant difference at the 5% confidence level for the factor class. The same table also indicates that there is interaction between the main effects of class and stage for the variables upper and mid-crown

TABLE XII

Mean Squares and Levels of Significance for Mixed Analysis of Variance for the Horizontal Distances of the Skeletal Points "A", "B" and Pogonion

Source of Variation	df+	Mean Squares of Variables "A" point	"B" point	Pogonion
Treatment	1	0.8570	1.5048	1.6962
Class	2	0.7810	3.0254*	3.1170
Treatment x Class	2	0.0835	0.8744	1.6017
Between Subjects Error	68	0.5569	0.9312	1.2097
Stage	2	0.8722***	0.4237***	0.2527***
Treatment x Stage	2	0.0292	0.0788	0.0525
Class x Stage	4	0.0200	0.0108	0.0119
Treatment x Class x Stage	4	0.0070	0.0327	0.0419
Within Subjects Error	136	0.0192	0.0310	0.0390

+ degrees of freedom
* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$

TABLE XIII

Mean Squares and Levels of Significance for Mixed Analysis of Variance for the Horizontal Distances of the Three Maxillary Incisal Points

Source of Variation	df+	Mean Squares of Variables U.C.E.J.	U.M.C.P.	U.I.
Treatment	1	2.3643	2.8965*	4.4006*
Class	2	2.3817*	3.8620***	6.3071***
Treatment x Class	2	0.1486	0.0841	0.0821
Between Subjects Error	68	0.6298	0.6816	0.7661
Stage	2	1.9708***	2.0229***	1.9017***
Treatment x Stage	2	0.0358	0.0695	0.0741
Class x Stage	4	0.0420	0.1432**	0.3518***
Treatment x Class x Stage	4	0.0017	0.0077	0.0246
Within Subjects Error	136	0.0254	0.0389	0.0567

\+ degrees of freedom
* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$

point and upper incisor significant at the 1% and the 0.5% confidence level respectively. Table XIV demonstrates this interaction for the two variables, while means and standard errors for the factor stage of the variable upper cemento enamel junction can be found in Table XXIX (Appendix I).

The mean squares and levels of significance for mixed analysis of variance for the three mandibular incisal points are presented in Table XV.

Examination of this table indicates that all three variables exhibit highly significant differences ($p < 0.005$) for the factor stage, while for the factor class the variable, lower cemento enamel junction, is significant at the 0.5% confidence level and the remaining two variables at the 1% confidence level. The lower mid-crown point and the lower incisor also demonstrate significant difference at the 5% confidence level for the main effect treatment, while the lower cemento enamel junction does not. Table XV also indicates some interaction between the factors treatment and stage significant at 1% level for the first variable and at 5% level for the other two. Means and standard error for each of the dental variables of the mandibular incisor, for treatment, stages and their interaction can be found in Table XVI.

TABLE XIV

Effects of Stage and Angle Classification

a) Upper Incisor to "Y" Axis (mm)

Angle Classification		Stages A	B	C	Classes
Class I N = 27	Mean S.E.	57.81 ±0.46	55.13 ±0.46	54.14 ±0.46	55.69 ±0.97
Class II Div. 1 N = 39	Mean S.E.	58.42 ±0.38	53.67 ±0.38	53.19 ±0.38	55.09 ±0.81
Class II Div. 2 N = 8	Mean S.E.	49.09 ±0.84	49.52 ±0.84	48.79 ±0.84	49.13 ±1.79
Stages	Mean S.E.	55.11 ±0.28	52.77 ±0.28	52.04 ±0.28	53.31 ±0.59

b) Upper Mid-Crown Point to "Y" Axis (mm)

Angle Classification		Stages A	B	C	Classes
Class I N = 27	Mean S.E.	59.15 ±0.38	56.68 ±0.38	55.88 ±0.38	57.24 ±0.92
Class II Div. 1 N = 39	Mean S.E.	59.85 ±0.32	55.66 ±0.32	55.19 ±0.32	56.90 ±0.76
Class II Div. 2 N = 8	Mean S.E.	52.93 ±0.70	52.04 ±0.70	51.51 ±0.70	52.16 ±1.69
Stages	Mean S.E.	57.31 ±0.23	54.79 ±0.23	54.19 ±0.23	55.43 ±0.55

TABLE XV

Mean Squares and Levels of Significance for Mixed Analysis of Variance for the Horizontal Distances of the Three Mandibular Incisal Points

Source of Variation	df+	Mean Squares of Variables L.C.E.J.	L.M.C.P.	L.I.
Treatment	1	2.9725	3.0817*	4.5947*
Class	2	4.3557***	3.8605**	3.4967**
Treatment x Class	2	0.2303	0.0497	0.0537
Between Subjects Error	68	0.7643	0.7286	0.7125
Stage	2	0.5494***	0.4710***	0.3282***
Treatment x Stage	2	0.1454**	0.1368*	0.1260*
Class x Stage	4	0.0053	0.0117	0.0208
Treatment x Class x Stage	4	0.0170	0.0105	0.0077
Within Subjects Error	136	0.0307	0.0303	0.0342

+ degrees of freedom
* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$

TABLE XVI

Effects of Stage and Treatment

a) Lower Incisor to "Y" Axis (mm)

Treatment		Stages A	B	C	Treatment
Non-Extraction N = 28	Mean S.E.	52.31 ±0.35	52.62 ±0.35	51.26 ±0.35	52.07 ±0.92
Extraction N = 46	Mean S.E.	50.09 ±0.27	48.73 ±0.27	48.49 ±0.27	49.10 ±0.72
Stages	Mean S.E.	51.20 ±0.22	50.67 ±0.22	49.88 ±0.22	50.58 ±0.57

b) Lower Mid-Crown Point to "Y" Axis (mm)

Treatment		Stages A	B	C	Treatment
Non-Extraction N = 28	Mean S.E.	51.39 ±0.33	51.57 ±0.33	50.04 ±0.33	51.00 ±0.93
Extraction N = 46	Mean S.E.	49.70 ±0.26	48.15 ±0.26	47.87 ±0.26	48.57 ±0.73
Stages	Mean S.E.	50.54 ±0.20	49.86 ±0.20	48.95 ±0.20	49.78 ±0.57

c) Lower Cemento Enamel Junction Point to "Y" Axis (mm)

Treatment		Stages A	B	C	Treatment
Non-Extraction N = 28	Mean S.E.	49.24 ±0.33	49.19 ±0.33	47.95 ±0.33	48.79 ±0.95
Extraction N = 46	Mean S.E.	47.75 ±0.26	45.87 ±0.26	45.60 ±0.26	46.41 ±0.74
Stages	Mean S.E.	48.49 ±0.20	47.53 ±0.20	46.78 ±0.20	47.60 ±0.59

3. Horizontal Measurements of the Soft Tissue Facial Profile

The results of mixed analysis of variance for the three variables of the maxillary lip are presented in Table XVII. Examination of this table reveals that all three variables present highly significant difference ($p < 0.005$) for the main effect stage. The variable epidermic "A" point shows significant interaction, at the 5% confidence level, between the factors class and stage. This interaction is analyzed in Table XVIIIa. The effects of stage and angle classification for the variable upper lip are shown in Table XXa, while means and standard errors for the variable subrhinal point for the three stages of treatment can be found in Table XXIX (Appendix I).

Mean squares and levels of significance of mixed analysis of variance, for the horizontal measurements of the three variables of the mandibular lip, are contained in Table XIX. The variables epidermic "B" point and lower lip exhibit significant difference at the 5% confidence level for the main effects of treatment and class. Further examination of Table XIX reveals that all three variables show highly significant difference ($p < 0.005$) for the main effect stage. In addition the variable, epidermic "B" point, indicates significant interaction at the 5% confidence level between the factors treatment and stage. Table XVIIIb demonstrates this interaction, while Table XXb shows the effects of stage and Angle classification for the variable

TABLE XVII

Mean Squares and Levels of Significance for Mixed Analysis of Variance for the Horizontal Distances of the Three Maxillary Lip Points

Source of Variation	df+	Mean Squares of Variables Subrhinal	 Epidermic "A" point	 Upper Lip
Treatment	1	1.0443	1.6774	1.8355
Class	2	1.0130	0.8784	1.0912
Treatment x Class	2	0.0896	0.1310	0.2177
Between Subjects Error	68	0.5195	0.5922	0.7022
Stage	2	0.4557***	0.8761***	1.1427***
Treatment x Stage	2	0.0213	0.0306	0.0478
Class x Stage	4	0.0567	0.0688*	0.0802
Treatment x Class x Stage	4	0.0195	0.0101	0.0368
Within Subjects Error	136	0.0282	0.0250	0.0360

+ degrees of freedom
* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$

TABLE XVIII

Effects of Stage and Angle Classification

a) Epidermic "A" Point to "Y" Axis (mm)

Angle Classification		Stages A	B	C	Classes
Class I N = 27	Mean S.E.	69.48 ±0.30	68.35 ±0.30	67.41 ±0.30	68.41 ±0.86
Class II Div. 1 N - 39	Mean S.E.	70.40 ±0.25	67.81 ±0.25	67.11 ±0.25	68.44 ±0.71
Class II Div. 2 N = 8	Mean S.E.	66.72 ±0.56	65.67 ±0.56	65.85 ±0.56	66.08 ±1.57
Stages	Mean S.E.	68.87 ±0.18	67.28 ±0.18	66.79 ±0.18	67.64 ±0.52

Effects of Stage and Treatment

a) Epidermic "B" Point to "Y" Axis (mm)

Treatment		Stages A	B	C	Treatment
Non-Extraction N = 28	Mean S.E.	55.85 ±0.36	55.60 ±0.36	54.34 ±0.36	55.26 ±0.99
Extraction N = 46	Mean S.E.	53.76 ±0.28	51.85 ±0.28	51.40 ±0.28	52.33 ±0.77
Stages	Mean S.E.	54.81 ±0.22	53.72 ±0.22	52.87 ±0.22	53.80 ±0.61

TABLE XIX

Mean Squares and Levels of Significance for Mixed Analysis of Variance for the Horizontal Distances of the Three Mandibular Lip Points

		Mean Squares of Variables		
Source of Variations	df+	Epidermic Pogonion	Epidermic "B" point	Lower Lip
Treatment	1	2.3605	4.4804*	4.5790*
Class	2	1.4998	2.6367*	3.1315*
Treatment x Class	2	2.1306	0.2281	0.0046
Between Subjects Error	68	1.2001	0.8259	0.8190
Stage	2	0.4135***	0.6965***	1.1033***
Treatment x Stage	2	0.0359	0.1190*	0.0906
Class x Stage	4	0.0228	0.0208	0.0344
Treatment x Class x Stage	4	0.0189	0.0348	0.0499
Within Subjects Error	136	0.0420	0.0358	0.0398

+ degrees of freedom
* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$

TABLE XX

Effects of Stage and Angle Classification

a) Upper Lip to "Y" Axis (mm)

Angle Classification		Stages A	B	C	Classes
Class I N = 27	Mean S.E.	70.94 ±0.36	69.48 ±0.36	68.70 ±0.36	69.71 ±0.93
Class II Div. 1 N = 39	Mean S.E.	71.37 ±0.30	68.33 ±0.30	67.65 ±0.30	69.12 ±0.77
Class II Div. 2 N = 8	Mean S.E.	67.59 ±0.67	66.46 ±0.67	66.51 ±0.67	66.85 ±1.71
Stages	Mean S.E.	69.97 ±0.22	68.09 ±0.22	67.62 ±0.22	68.56 ±0.56

b) Lower Lip to "Y" Axis (mm)

Angle Classification		Stages A	B	C	Classes
Class I N = 27	Mean S.E.	65.12 ±0.38	63.58 ±0.38	62.42 ±0.38	63.71 ±1.01
Class II Div. 1 N = 39	Mean S.E.	63.65 ±0.32	61.71 ±0.32	60.49 ±0.32	61.95 ±0.84
Class II Div. 2 N = 8	Mean S.E.	59.48 ±0.71	58.43 ±0.71	58.10 ±0.71	58.67 ±1.85
Stages	Mean S.E.	62.75 ±0.23	61.24 ±0.23	60.34 ±0.23	61.44 ±0.61

lower lip. Means and standard errors for the variables epidermic pogonion for the three stages of treatment can be found in Table XXIX (Appendix I).

4. Vertical Measurements of the Hard Tissue Facial Profile

Mean squares and levels of significance of mixed analysis of variance for vertical measurements of hard tissue points are presented in Table XXI. Examination of this table shows that the variable of the upper incisor demonstrates significant difference at the 5% confidence level for the main effects of treatment and stage. The variable of the lower incisor exhibits highly significant difference at the 1% and the 0.05% confidence level for the factors treatment and stage respectively. The same variable also shows significant interaction at the 5% level between the factors class and treatment as well as class and stage. Further examination of Table XXI reveals that the third variable menton presents highly significant difference ($p < 0.005$) for the factor stage. Means and standard errors for the variable menton point for the three stages of treatment are presented in Table XXIX (Appendix I). The interaction between the factors class and stage for the variable lower incisor is analyzed in Table XXIIb, where the effects of stage and Angle classification are also described for the variable upper incisor (Table XXIIa).

TABLE XXI

Mean Squares and Levels of Significance for Mixed Analysis of Variance for the Vertical Distances of the Maxillary Incisor, Mandibular Incisor and the Menton Point

Source of Variation	df+	Mean Squares of Variables U.I.	L.I.	Menton
Treatment	1	1.7384*	2.5136**	3.1568
Class	2	0.1690	0.1449	0.5329
Treatment x Class	2	1.0064	1.6775*	1.7908
Between Subjects Error	68	0.3350	0.3625	0.8440
Stage	2	0.0606*	1.8615***	0.8881***
Treatment x Stage	2	0.0249	0.0387	0.0323
Class x Stage	4	0.0233	0.0806*	0.0265
Treatment x Class x Stage	4	0.0026	0.0129	0.0146
Within Subjects Error	136	0.0179	0.0257	0.0382

\+ degrees of freedom
* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$

TABLE XXII

Effects of Stage and Angle Classification

a) Upper Incisor to "X" Axis (mm)

Angle Classification		Stages A	B	C	Classes
Class I N = 27	Mean S.E.	75.13 ±0.26	75.92 ±0.26	75.50 ±0.26	75.52 ±0.64
Class II Div. 1 N = 39	Mean S.E.	76.38 ±0.21	76.53 ±0.21	76.80 ±0.21	76.57 ±0.54
Class II Div. 2 N = 8	Mean S.E.	75.30 ±0.47	75.16 ±0.47	76.23 ±0.47	75.57 ±1.18
Stages	Mean S.E.	75.60 ±0.16	75.87 ±0.16	76.18 ±0.16	75.88 ±0.39

b) Lower Incisor to "X" Axis (mm)

Angle Classification		Stages A	B	C	Classes
Class I N = 27	Mean S.E.	72.55 ±0.31	74.43 ±0.31	73.34 ±0.31	73.44 ±0.67
Class II Div. 1 N = 39	Mean S.E.	71.26 ±0.26	74.65 ±0.26	74.06 ±0.26	73.32 ±0.56
Class II Div. 2 N = 8	Mean S.E.	70.03 ±0.57	73.85 ±0.57	73.42 ±0.57	72.44 ±1.23
Stages	Mean S.E.	71.28 ±0.19	74.31 ±0.19	73.61 ±0.19	73.07 ±0.40

5. Vertical Measurement of the Soft Tissue Facial Profile

Examination of Table XXIII reveals that for the factor treatment the variable upper stomion indicates significant difference at the 5% confidence level, while for the factor class the variable subrhinal point shows significant difference at the same confidence level. The later variable, together with the variable upper lip, present highly significant difference at the 0.5% confidence level for the main effect stage. Further examination of Table XXIII shows that the variable upper lip exhibits significant interaction at the 1% confidence level, between the factors class and stage, illustrated in Table XXIVa. Means and standard errors for the variables subrhinal and upper stomion point can be found in Tables XXVII, XXVIII and XXIX (Appendix I).

Table XXV contains the results for mixed analysis of variance for the vertical measurements of the soft tissue points on the mandibular lip. All three variables, in this table, exhibit highly significant difference at the 5% confidence level for the factor stage. In addition, the variable lower lip shows significant difference at the 5% confidence level for the main effect treatment and at the 1% confidence level, the same variable, exhibits significant interaction between the factors class and stage. Table XXIVb demonstrates this interaction. Means and standard errors for the factor stage of the variables epidermic

TABLE XXIII

Mean Squares and Levels of Significance for Mixed Analysis of Variance for the Vertical Distances of the Subrhinal Point, the Maxillary Lip and the Maxillary Stomion Point

Source of Variation	df+	Mean Squares of Variables Sub-rhinal	Upper Lip	Upper Stomion
Treatment	1	0.3032	0.9285	2.2073*
Class	2	1.0911*	0.7541	0.1580
Treatment x Class	2	0.4821	0.6579	1.0575
Between Subjects Error	68	0.2755	0.3581	0.3511
Stage	2	0.3909***	0.4028***	0.0638
Treatment x Stage	2	0.0160	0.0047	0.0011
Class x Stage	4	0.0282	0.0948**	0.0665
Treatment x Class x Stage	4	0.0138	0.0201	0.0207
Within Subjects Error	136	0.0226	0.0263	0.0240

+ degrees of freedom
* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$

TABLE XXIV

Effects of Stage and Angle Classification

a) Upper Lip to "X" Axis (mm)

Angle Classification		Stages A	B	C	Classes
Class I N = 27	Mean S.E.	67.16 ±0.31	68.15 ±0.31	67.42 ±0.31	67.58 ±0.66
Class II Div. 1 N = 39	Mean S.E.	69.28 ±0.26	68.70 ±0.26	70.21 ±0.26	69.73 ±0.55
Class II Div. 2 N = 58	Mean S.E.	68.15 ±0.57	69.98 ±0.57	71.18 ±0.57	69.77 ±1.22
Stages	Mean S.E.	68.20 ±0.19	69.28 ±0.19	69.61 ±0.19	69.03 ±0.40

b) Lower Lip to "X" Axis (mm)

Angle Classification		Stages A	B	C	Classes
Class I N = 27	Mean S.E.	84.08 ±0.41	84.67 ±0.41	84.46 ±0.41	84.40 ±0.74
Class II Div. 1 N = 39	Mean S.E.	84.73 ±0.34	85.47 ±0.34	86.23 ±0.34	85.48 ±0.62
Class II Div. 2 N = 8	Mean S.E.	83.36 ±0.76	85.05 ±0.76	86.32 ±0.76	84.91 ±1.36
Stages	Mean S.E.	84.05 ±0.25	85.06 ±0.25	85.67 ±0.25	84.93 ±0.45

TABLE XXV

Mean Squares and Levels of Significance for Mixed Analysis of Variance for the Vertical Distances of the Epidermic Menton Point, the Mandibular Lip and the Mandibular Stomion Point

		Mean Squares of Variables		
Source of Variation	df+	Epidermic Menton	Lower Lip	Lower Stomion
Treatment	1	3.2763	2.0994*	1.1703
Class	2	1.3155	0.1386	0.1174
Treatment x Class	2	0.1917	0.6154	0.6778
Between Subjects Error	68	0.9703	0.4437	0.3103
Stage	2	2.6421***	0.4945***	0.2157***
Treatment x Stage	2	0.2027	0.0067	0.0080
Class x Stage	4	0.1596	0.0691**	0.1255
Treatment x Class x Stage	4	0.1691	0.0215	0.0354
Within Subjects Error	136	0.0807	0.0462	0.0350

+ degrees of freedom
* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$

menton and lower stomion are presented in Table XXIX (Appendix I).

6. Angular Skeletal Measurements

Examination of Table XXVI, listing the three angular variables, reveals that all the variables exhibit significant difference for the factors class and stage. For the factor class the variables SN - palatal plane, and SN - mandibular plane present significant difference at the 5% confidence level, while the variable palatal plane - mandibular plane shows highly significant difference at the 0.5% confidence level. The former two variables also demonstrate highly significant difference at the 0.5% confidence level for the factor stage, while the later variable exhibits significant difference ($p < 0.05$) for the same factor.

Means and standard errors for factor stage for the three angular variables can be found in Table XXIX (Appendix I). Table XXVIII (Appendix I) shows the means and standard errors for the three angular variables in each malocclusion group.

TABLE XXVI

Mean Squares and Levels of Significance for Mixed Analysis of Variance for the Three Angular Measurements, SN-P.P., SN-Mn.P., P.P.-Mn.P. (SN-Palatal Plane, SN-Mandibular Plane, Palatal Plane-Mandibular Plane)

Source of Variation	df+	Mean Squares of Variables SN-P.P.	SN-Mn.P.	p.p.-Mn.P.
Treatment	1	81.7805	48.7261	0.2266
Class	2	134.8309*	338.5537*	835.4570***
Treatment x Class	2	3.4863	69.4809	71.7944
Between Subjects Error	68	34.3161	79.3463	102.1195
Stage	2	22.9232***	39.0475***	8.5996*
Treatment x Stage	2	2.5383	0.3399	3.0369
Class x Stage	4	1.0776	0.1015	1.7249
Treatment x Class x Stage	4	0.3913	2.0943	3.0091
Within Subjects Error	136	1.6879	1.7778	2.3158

\+ degrees of freedom
* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$

DISCUSSION

CHAPTER V

DISCUSSION

Effect of Orthodontic Treatment on the Cross-Sectional Area of the Lips as Determined from the Mixed Analysis of Variance

A review of the orthodontic literature reveals that the lips as part of the soft tissue profile have always been included in examining the effect of incisal retraction during orthodontic treatment. In all studies cited in the review of the literature, however, changes on the lips were determined by angular or linear measurements. In addition, the observed lip changes resulted from the combined effect of growth and orthodontic treatment, unless the study was performed in a non-growing sample as the one by Hershey (1972).

As the present study was based on a growing study sample, an attempt was made to eliminate the effect of growth on the facial profile. The lip changes subsequent to orthodontic treatment were studied by measuring the cross-sectional areas of the maxillary and mandibular lips prior to and after the orthodontic treatment.

Table VIII illustrates the interaction between the main effects of class and stage for the upper lip area in the three malocclusion groups over the three stages of treatment. The Class I and Class II Division 2 groups show marked increase in the cross-sectional area of the upper lip from stage A to stage B, while the Class II Division 1 group shows no such change. Between stages B and C the Class I groups shows some slight decrease but, taking into account the size of the standard error, the upper lip cross-sectional area, after the end of the treatment, remains essentially the same. This is not true for the Class II Division 2 group where an increase between the stages B and C is apparent even though the magnitude of this increase is smaller than that between the stages A and B (figure 12). The Class II Division 1 group, as during treatment, exhibits no change after the completion of orthodontic treatment. These changes are in contrast to the changes which occurred in the control group where growth was the exclusive cause of the changes measured. As is illustrated in figure 14, all three malocclusion groups demonstrated an increase in the cross-sectional area of the upper lip with the advancement of age, until the age of 18 where a levelling off was noted. The changes exhibited by the cross-sectional area of the upper lip in the Class I and Class II Division 2 malocclusion groups of the study sample are in agreement with the results presented by Rudee (1964), Hershey (1972), Burstone (1973), Wisth (1974), Roos (1977), even though all their assessments were linear and not cross-sectional. All these investigators found that the maxillary lip response to the retraction of the maxillary incisor was always smaller than 1 to 1, meaning that for 1 mm incisal retraction, the maxillary lip retraction was less than 1 mm and in most cases about 0.5 mm. Therefore, they concluded that there was an increase in the thickness of the soft tissue of the upper lip during treatment. Ricketts (1960) offering a practical rule, stated that for every 3 mm of retraction of the maxillary incisors, 1 mm increase in upper lip thickness could be expected.

Among the three malocclusion groups studied, the Class II Division 1 group exhibited the largest mean overjet value, approximately 5.3 mm, and consequently the greatest incisal retraction took place in this group. According to the findings in the above mentioned studies, a clear increase in maxillary lip thickness was anticipated. Table VIII, however, reveals that the cross-sectional area of the upper lip for the Class II Division 1 group remains practically the same during the treatment as well as after the orthodontic treatment.

Posen (1976) assessing maximum lip tonicity in different malocclusion groups, stated that if maximum lip tonicity, as measured with the pommeter in the Class II Division 1 group, is significantly lower than the hypotonic end of the normal range, the treatment response will be less favorable and will require longer treatment time. This observation made by Posen points out the possibility that if the Class II Division 1 group of the study sample exhibited hypotonicity, then the duration of time studying cross-sectional lip changes in this malocclusion group, may not have been long enough to detect any cross-sectional lip area changes.

Vig and Cohen (1979) assessed the vertical growth of the maxillary and mandibular lips using as reference planes the palatal and the mandibular planes respectively. Their study was based on fifty subjects whose serial lateral cephalometric films were taken from age four to twenty at two or three year intervals. These workers found that with the advancement of age, the height or length of the lips increases and that the lower lip grows more than the upper lip, both numerically and proportionally. Their findings are in agreement with the results of the present study even though their assessments were linear, while this study assessed cross-sectional areas. Vig and Cohen found that the height of the maxillary lip from age five to eighteen demonstrated a proportional increase of 20%, while the mandibular lip for the same age range increased 27%. Subtelny (1959, 1961) in his longitudinal cephalometric studies found that not only the length, but also the thickness of the lips, increased with the advancement of age. However, he observed that the increase in the thickness of the lips is not equally distributed, so the thickness at the vermilion border increased slightly more than in the region overlying the points A, B and pogonion. Subtelny found that the thickness increase of the lips at the vermilion border is similar for both lips up to age 14. After 14 years of age, males continued to show an increase in thickness of the upper lip while the females did not. Even though these assessments are qualitative, this finding suggests that the effect of growth has a proportional influence on both length and width increases of the lips. In the sample used by Vig and Cohen, if proportional increase of the width of the lips due to growth took place during the same age period, then it would be possible to calculate that the cross-sectional area of the lips of these fifty subjects could have increased approximately 40% for the upper lip and 54% for the lower. These values are very close to the ones computed in this study for the control subjects to be found in Tables X and XI and illustrated in figures 14 and 15. The upper lip cross-sectional area under the influence of growth increased from age eight to eighteen for the Class I malocclusion group from 2.509 to 3.626 cm^2 or 45%, for the Class II Division 1 group from 2.504 to 3.594 cm^2 or 44%, and for the Class II Division 2 group from 2.440 to 3.402 cm^2 or 39%. During the same age period, the cross-sectional area of the mandibular lip increased from 3.785 to 5.593 cm^2 or 48% for the Class I group, from 3.624 to 5.563 cm^2 or 54% for the Class II Division 1 group and from 3.626 to 5.379 cm^2 or 48% for the Class II Division 2 group. If these three percentiles are pooled, since Vig and Cohen had not divided their sample according to the type of malocclusion, a 43% and a 50% increase for the cross-sectional area of the upper and lower lip respectively would result from age 8 to 18, which is very close to one estimated for the unsegregated sample used by Vig and Cohen.

The mean ages of the study sample that had orthodontic treatment were between 12 to 18 years and, therefore, it is important to examine the effect of growth during this age period.

For the control group, age 12 to 18 years, the cross-sectional area of the upper lip increased from 2.918 to 3.626 cm^2 or 24% for the Class I malocclusion group. During the same age period for the Class II Division 1 group the area of the upper lip increased from 3.050 to 3.594 cm^2 or 18%, while for the Class II Division 2 group the area increased from 2.641 to 3.402 cm^2 or 29%. These changes were the result of growth alone and were quite large in comparison to the area increases which occurred in the study sample under the influence of the orthodontic treatment.

The treatment effect on the cross-sectional area of the upper lip in the study sample may be summarized as follows. In the Class I group the upper lip area, from stage 1 to stage 3, increased from 3.169 to 3.380 cm^2 or 7%, while the increase in the upper lip area for the Class II Division 1 and Class II Division 2 groups was from 3.240 to 3.275 cm^2 or 1% for the former group and from 3.114 to 3.595 cm^2 or 15% for the latter group. Comparing the effect of growth separately from the effect of treatment, the effect of treatment is very small with the exception of the Class II Division 2 group in which the treatment effect is about half that attributed to growth.

While there is an agreement among investigators that the thickness of the maxillary lip increases during orthodontic treatment, there is no concurrence on thickness changes of the mandibular lip. Roos (1977) found that orthodontic treatment causes a decrease of mandibular lip thickness, while Ricketts (1960) and Anderson et al (1973) reported that there is no change in the thickness of the lower lip during orthodontic treatment. Wisth (1974), on the other hand, found that the thickness of the lower lip increases as a result of the orthodontic therapy. It should be noted here, that all these investigators have based their conclusions on linear assessments. Vig and Cohen (1979) measuring the growth effect linearly on the mandibular lip height found the lower lip increases 27% from 35.89 to 46.06 mm using as reference line the mandibular plane. As mentioned previously, if proportional increase of the lower lip thickness also took place, then the total area of the lower lip during the same age period would increase approximately 54%. This increase is in agreement with the increase found for the cross-sectional area of the lower lip in the control group. For the three malocclusion groups of the control sample, the pooled increase of the lower lip cross-sectional area was 50% from age 8 up to age 18. That suggests that during the period of 10 years, the cross-sectional area of the lower lip increased 48% for the Class I malocclusion group, from 3.785 to 5.593 cm^2, 54% for the Class II Division 1 group from 3.624 to 5.563 cm^2 and 48% for the Class II Division 2 group from 3.626 to 5.379 cm^2. If the age range is decreased and adjusted to the age period during which the patients in the study sample underwent orthodontic treatment, the percentiles are smaller. Under the influence of growth between age 12 and 18, the area of the lower lip increased 32% for the Class I group and 23% and 31% for the Class II Division 1 and Division 2 groups, respectively. Even though with the advancement of age the influence of growth on the cross-sectional area of the lower lip decreases to a large extent, it is still large enough in comparison to the small effect that orthodontic treatment has on the lower lip area. The orthodontic treatment between stages A and C resulted in a 4% increase on the cross-sectional area of the lower lip for the Class I and Class II Division 2 groups, while apparently causing no change to the Class II Division 1 malocclusion group. It is obvious that the changes caused by the treatment per se, are rather insignificant in comparison to the changes in the lip area, caused by growth.

Assessing the cross-sectional areas of the maxillary and mandibular lips and the subsequent changes caused separately by growth and orthodontic treatment, it is possible to avoid some of the often encountered limitations, due to lip form and position. Burstone (1973) points out the difficulty of measuring accurately lip changes by linear or angular assessments, in subjects whose lips may bulge away from the incisors as a result of excessive lip length or significantly decreased lower face height. Also, changes in lip position from relaxed to closed can cause a considerable reduction in lip thickness (average 2.5 mm) as Hillesund et al (1978) found. Besides the independent assessment of lip form and position, the advantage of using the cross-sectional technique to determine lip changes was that the whole lip outline was taken into account, not just a point. However, the lateral cephalogram offers a two dimensional picture of a three dimensional structure and that in itself creates a disadvantage in an effort to measure changes of the lip volume which, due to limitations of the conventional cephalometry, have been substituted by cross-sectional lip area. Computed tomography of the lips would permit a volumetric assessment.

Effect of Orthodontic Treatment on the Facial Profile as Determined from the Mixed Analysis of Variance

The present investigation was undertaken in order to study the influence orthodontic treatment has on the facial hard and soft tissue profile. Alterations occurring during the treatment as well as during the retention and post-retention periods in the facial profile of growing individuals, are the combined effect of growth and orthodontic treatment. In this study, an attempt has been made to eliminate the effect of growth and, therefore, to identify and assess the remaining effect of orthodontic treatment. For this purpose an untreated serial growth sample obtained from the Burlington Research Centre, University of Toronto, was used as a control. Utilizing a special computer programme (Chebib, 1979), which superimposed the two samples, the linear horizontal, linear vertical and angular assessments of the study sample were corrected for the effect of growth so that the orthodontic treatment responses alone were identified. Since the two sexes were pooled together during these adjustments, the linear and angular assessments were independent from the growth effect and sex variation.

Due to close association between the hard tissue framework and the soft tissue drape, it is understandable that changes in the skeletal facial profile would be accompanied by analogous soft-tissue changes. However, since orthodontic treatment effects changes mainly on the teeth and their supportive skeletal foundations, the lower facial soft tissue profile would obviously be influenced most. This was supported by the fact that cephalometric points away from the perioral area, like nasion, showed no significant changes during the three stages of treatment.

The mixed analysis of variance for the three upper incisal points (Table XIII) shows a significant difference at 0.5% confidence level for all of them during the three stages of treatment. Since all these points, due to their association with the maxillary incisor, were affected similarly, the changes of the upper incisor point only will be discussed. For the Class I malocclusion group, the incisal retraction from stage A to stage C was 3.67 mm while for the Class II Division 1 and Division 2 groups was 5.23 and 0.3 mm respectively (Table XIV). The very small change in the Class II Division 2 group is in contrast to the large incisal retraction of the other two groups, causing a significant interaction at 0.5% confidence level for the main effects of class and stage (Table XIV). However, this small change in the Class II Division 2 group is expected since during orthodontic treatment, the incisor crown is torqued labially at the same time as the incisors are retracted.

The maxillary lip follows the retraction of the maxillary incisor and for the Class I malocclusion group between the three stages of treatment it was retracted 2.24 mm. For the Class II Division 1 and Division 2 groups the upper lip retraction during the three stages of treatment was 3.72 mm for the former and 1.08 mm for the latter group.

If the incisal retraction is compared with the subsequent labial retraction for the Class I malocclusion group, a ratio of 3.67:2.24 (approximately 1:0.6) may be computed. This suggests that for 1 mm of maxillary incisal retraction, the maxillary lip will follow 0.6 mm. The ratio for the Class II Division 1 malocclusion group is approximately 1:0.7. For the Class II Division 2 group, a small sample size and small retraction makes a retraction ratio spurious.

Anderson et al (1973) studied seventy orthodontically treated cases of unspecified malocclusion and noted a ratio between maxillary incisal and labial retraction of approximately 1:0.7. This is the same ratio as in the present investigation if all three malocclusion groups are pooled together.

Other investigators, however, have found different ratios between incisal and labial retraction. For instance, Roos (1977) studied 30 Class II Division 1 subjects and found that for 1 mm maxillary incisal retraction the subsequent labial retraction was 0.4 mm. Rudee (1964) reported a 1:0.3 ratio between incisal and labial retraction. Wisth (1974) divided his sample according to small or large overjet. The group with small overjet (between 3 to 4 mm) showed a ratio of 1:0.5 between maxillary incisal and labial retraction, while the other group with large overjet (between 8 to 10 mm) had a ratio 1:0.3.

Warfield (1975) examined twenty-five orthodontically treated individuals with Class II Division 1 malocclusions. He found a 1:0.5 ratio between maxillary incisal retraction and upper lip response. Hill (1977) in a similar study reported that the upper lip showed 2 mm of thickening to 3 mm of upper incisal retraction or 1:0.3 ratio between tooth and lip movement.

Hershey (1972) in an effort to avoid the effect of growth in his study, limited his sample to 36 postadolescent female patients with Class I and Class II Division type of malocclusion. Assessing profile changes subsequent to incisal retraction, he found that when the maxillary incisor was retracted 1 mm the upper lip dropped back 0.5 mm.

Even though all the studies cited indicate that there is no equal movement between maxillary incisal and lip retraction, considerable variation still exists between incisal retraction and lip response to permit accurate prediction.

As far as the mandibular lip response to mandibular incisal retraction is concerned, the results reported from different studies are at variance.

Rudee (1964) found that for 1 mm mandibular incisal retraction the lower lip response was 0.6 mm. However, the standard deviations reported are very large in relation to the mean retractions, minimizing the significance of the ratio found. Hershey (1972) gave an approximate ratio of 1:1.2 between lower incisal and labial retraction, while Roos (1977) reported a 1:0.9 ratio between these two profile components. Wisth (1974) on the other hand, found a 1:0.4 ratio for the small overjet group and 1:0.8 ratio for the large overjet group between mandibular incisal and labial retraction respectively.

Anderson (1973) reported a ratio of 1:1 when the overjet was smaller or equal to 3 mm, while for overjet greater than 3 mm, the ratio between incisal retraction and lower lip response was 1:2.5. This latter ratio is in agreement with the findings of the present investigation which indicates a ratio of 1:3 between mandibular incisal retraction and lower lip movement. This finding is understandable if the mandibular lip is associated with the upper rather than the lower incisor. It also supports Angle's (1907) concept that protrusion of the lower lip is related to the prominence of the maxillary incisors.

Cephalometric points influenced by the orthodontic treatment were also the points A and B as well as the corresponding soft tissue points epidermic A and epidermic B. The ratio of retraction for these two pair points was 1:1, indicating a close association between hard and soft tissue movement.

It is obvious from the present findings that the effect of the orthodontic treatment tends to flatten the facial profile with the posterior displacement of the maxillary incisors primarily, but also, the lower incisors, the points A and B and the soft tissue drape. A comparison of the soft tissue thickness prior to and after the orthodontic treatment indicates that the maxillary lip increases in width during the retention period. Examining the cross-sectional changes of the maxillary lip as a result of the orthodontic treatment, especially in the Class II Division 1 group, however, no difference was detected. The variation between linear and cross-sectional assessments can be explained if realization is made that the cross-sectional assessments are independent of the lip position and displacement, while the linear assessments are related to specific cephalometric points which are affected by the lip position and movement. Since these points are moving not only in an antero-posterior direction, but also in a superior-inferior one, they should be examined both horizontally and vertically.

Vertical assessments in this investigation indicate that the maxillary incisor while being retracted was slightly extruded (about 0.48 mm), while the mandibular incisor was intruded 3.03 mm during treatment and relapsed 0.7 mm during the retention and post-retention period. Since the point menton moved downward 2.15 mm during treatment, however, the net mandibular incisal intrusion was approximately 1 mm. The rest of the change was possibly the effect of extrusion of the buccal segments causing clockwise rotation of the mandible.

Jacobs (1978) studying vertical lip changes consequent to maxillary incisal retraction, stated that if no extrusion of the maxillary incisors had occurred during treatment, the interlabial gap closed vertically at a ratio of about 1 mm for every 2 mm of horizontal retraction. This phenomenon, however, was not observed in this study, where even though the mean average incisal retraction was about 3 mm and the maxillary lip point descent 1.40 mm, the distance between maxillary and mandibular lip points remained the same. This can be accounted for by the mandibular lip point descent (on the average 1.60 mm) due to mandibular rotation.

The rotational effect on the mandible resulting from bite opening mechanics, caused a minor decrease in the horizontal distance of the point pogonion, which could not have been justified otherwise. Since cephalometric points in the molar region of the lateral cephalograms were not examined, direct evidence of molar extrusion does not exist.

However, the vertical change of the point menton indirectly supports the rotational effect hypothesis which is further supported with the finding of increased angulation between the anterior cranial base and the mandibular plane from 28.5 to 29.8 degrees.

In summary, the present investigation indicates that the soft tissue profile does not in all respects reflect changes of the underlying skeleto-dental profile resulting from orthodontic treatment. The actual situation, however, indicates that certain parts of the soft-tissue profile show a stronger association with changes in the underlying skeletal framework, while other parts tend to be more independent of changes in the skeletal profile.

SUMMARY AND CONCLUSIONS

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of the present investigation was to study and quantitatively evaluate the effect of orthodontic treatment on the hard and soft tissue facial profile.

The pre-treatment, immediate post-treatment and immediate post-retention lateral cephalometric radiographs of seventy-four orthodontically treated patients, were analyzed using linear horizontal, linear vertical, angular and cross-sectional measurements. To eliminate the effect of growth, serial lateral cephalograms of twenty-eight untreated subjects, age 8 to 18 years, served as a control. Both treated and untreated samples were grouped according to type of malocclusion (Class I vs Class II Division 1 vs Class II Division 2).

A mixed factorial analysis of variance was used to analyze the effect of orthodontic treatment on the linear, angular and cross-sectional measurements between the three malocclusion groups over the three stages of treatment.

The results of this investigation suggest the following conclusions:

(1) The effect of orthodontic treatment in the cross-sectional areas of the maxillary and the mandibular lips is minimal. The observed increase in the cross-sectional area of both lips resulted from the effect of growth.

(2) The maxillary lip followed the maxillary incisal retraction in a ratio of 0.7:1. As a result of this response, the thickness of the maxillary lip increased as measured linearly. This increase, however, was not detected cross-sectionally.

(3) The mandibular lip responded to maxillary rather than to mandibular incisal retraction, supporting the concept that lower lip protrusion is related to the prominence of the upper incisors.

(4) The soft tissue cephalometric points epidermic "A" and epidermic "B", showed a close association with the underlying skeletal framework. The retraction ratio between hard and soft tissue "A" and "B" points was found to be 1:1.

(5) The vertical interincisal relationship was affected by the orthodontic treatment as a result of incisal intrusion and clock-wise mandibular rotation.

(6) The orthodontic treatment caused no changes in the interlabial relationship.

BIBLIOGRAPHY

BIBLIOGRAPHY

Anderson, J.P., Joondeph, D.R. and Tuppin D.L.: A cephalometric study of profile changes in orthodontically treated cases ten years out of retention. Angle Orthod., 43:324-336, 1973.

Angelle, P.L.: A cephalometric study of the soft tissue changes during and after orthodontic treatment. Trans. Europ. Orthod. Soc., 267-280, 1973.

Angle, E.H.: Malocclusion of Teeth. Seventh edition, S.S. White Dental Manufacturing Company, Philadelphia, 1907.

Baume, L.J.: A biologist looks at the sella point. Trans. European Orthod. Soc., 150-159, 1957.

Baumrind, S. and Frantz, R.C.: The reliability of head film measurements. Am. J. Orthod., 60:111-127, 1971.

Becker, G. and Chebib, F.S.: Simplified computational programming for mixed analysis of variance designs with equal and unequal subclass numbers. Psych. Reports, 25:767-772, 1969.

Biggerstaff, R.H.: A vertical cephalometric analysis of the human craniofacial complex. Am. J. Orthod., 72: 397-405, 1977.

Bjork, A.: The face in profile. Svensk Tandlakase-tidskrift, Suppl. 40 (No.5B), 1947

Bjork, A.: The significance of growth changes in facial pattern and their relationships to changes in occlusion. Dent. Rec., 71:197-208, 1951.

Bloom, L.A.: Perioral profile changes in orthodontic treatment. Am. J. Orthod., 47:371-379, 1961.

Bowker, W.D. and Meredith, H.J.: A metric analysis of the facial profile. Angle Orthod., 29:149-160, 1959.

Broadbent, B.H.: A new x-ray technique and its application to orthodontics. Angle Orthod., 1:45-66, 1931.

Broadbent, B.H.: The face of the normal child. Angle Orthod., 7:182-208, 1937.

Broadbent, B.H. Sr., Broadbent, B.H. Jr. and Golden, W.G.: Bolton Standards of Dentofacial Developmental Growth. C.V. Mosby Co., Saint Louis, 1975.

Brodie, A.G.: On the growth pattern of the human head from three months to eight years. A. J. Anat., 68: 209-262, 1941.

Brodie, A.G.: Late growth changes in the human face. Angle Orthod., 23:146-157, 1953.

Burstone, C.L.: The integumental profile. Am. J. Orthod., 44:1-25, 1958.

Burstone, C.L.: Integumental contour and extension patterns. Angle Orthod., 29:93-104, 1959.

Burstone, C.L.: Lip posture and its significance in treatment planning. Am. J. Orthod., 53:262-284, 1967.

Burstone, C.L.: Soft tissue factors in treatment planning. In: Transactions of the Third International Orthodontic Congress. J.T. Cook, editor, Crosby Lockwood Staples, London, 1973, pp26-34.

Case, C.S.: A Practical Treatise on the Technics and Principles of Dental Orthopedia. Second edition, C.S. Case Co., Chicago, 1921.

Chaconas, S.J. and Bartroff, J.D.: Prediction of normal soft tissue facial changes. Angle Orthod., 45:12-25, 1975.

Chebib, F.S. and Burdick, J.A.: Estimation of measurement error. J. Gen. Psych., 89:47-58, 1973.

Chebib, F.S. and Cleall, J.F. and Carpenter, K.: On-line computer system for the analysis of cephalometric radiographs. Angle Orthod., 46:305-311, 1976.

Chebib, F.S.: Personal communication, 1979.

Cleall, J.F. and Chebib, F.S.: Coordinate analysis applied to orthodontic studies. Angle Orthod., 41:214-218, 1971.

Downs, W.B.: Variation in facial relationships: Their significance in treatment and prognosis. Am. J. Orthod., 34:812-840, 1948.

Downs, W.B.: The role of cephalometrics in orthodontic case analysis and diagnosis. Am. J. Orthod., 38:162-192, 1952.

Hill, F.J.: A clinical cephalometric appraisal of changes in integumental profile based on subnasale in skeletal class II's. M.S. Thesis, Georgetown University, 1977.

Hillesund, E., Fjeld, D. and Zachrisson, B.J.: Reliability of soft tissue profile in cephalometrics. Am. J. Orthod., 74:537-549, 1978.

Hofrath, H.: Die Bedeutung der Rontegenfern-und Abstandsaufnahme fur die Diagnostic der kieferanomalien, Fortschr. Orthodont., 1:232-240, 1931.

Holdaway, R.: Changes in relationship of points A and B during orthodontic treatment. Am. J. Orthod., 42:176-193, 1956.

Holdaway, R.: Presentation, Jarabak Society Meeting, February, 1963.

Houston, W.J.B.: The current status of facial growth prediction: A review. Br. J. Orthod., 6:11-17, 1979.

Hoyte, D.A.N.: Personal communication, 1978.

Jacobs, J.D.: Vertical lip changes from maxillary incisor retraction. Am. J. Orthod., 74:396-404, 1978.

Johnston, L.E.: A simplified approach to prediction. Am. J. Orthod., 67:253-257, 1975.

Koch, R., Gonzales, A. and Witt, E.: Profile and soft tissue changes during and after orthodontic treatment. Europ. J. Orthod., 1:193-199, 1979.

Lager, H.: A histological description of the cranial base in macaca rhesus. Trans. Europ. Orthod. Soc., 147-156, 1958.

Lager, H.: Orthodontic treatment analysis by the aid of metallic implants. Trans. Europ. Orthod. Soc., 396-403, 1958.

Lande, M.J.: Growth behavior of the human bony facial profile as revealed by serial cephalometric roentgenology. Angle Orthod., 22:78-90, 1952.

Margolis. H.I.: A basic facial pattern and its application in clinical orthodontics. Am. J. Orthod., 39: 425-443, 1953.

Mauchamp, O. and Sassouni, V.: Growth and prediction of the skeletal and soft-tissue profiles. Am. J. Orthod., 64:83-94, 1973.

Merrifield, L.L.: The profile line as an aid in critically evaluating facial esthetics. Am. J. Orthod., 52: 804-822, 1966.

Midtgard, S., Bjork, G. and Linder-Aronsen, S.: Reproducibility of cephalometric landmarks and errors of measurements of cephalometric cranial distances. Angle Orthod., 44:56-61, 1974.

Moir, R.W.: A cephalometric craniofacial analysis of a North American Indian tribe, a cross-sectional study. M.Sc. Thesis, University of Manitoba, 1978.

Moss, M.L. and Greenberg, S.N.: Postnatal growth of the human skull base. Angle Orthod., 25:77-84, 1955.

Neger, M.: A quantitative method for the evaluation of the soft tissue facial profile. Am. J. Orthod., 45: 738-751, 1959.

Pelton, W.J. and Elsasser, W.E.: Studies of dentofacial morphology. IV Profile changes among 6,829 white individuals according to age and sex. Angle Orthod., 25:199-207, 1955.

Popovich, F. and Thompson, G.W.: Craniofacial templates for orthodontic case analysis. Am. J. Orthod., 71: 406-420, 1977.

Popovich, F.: Personal communication, 1979.

Porter, P.J.: A description of the trisomy 21 phenotype based on the stability of craniofacial reference lines. M.Sc. Thesis, University of Manitoba, 1976.

Richardson, A. : An investigation into the reproducibility of some points, planes and lines used in cephalometric analysis. Am. J. Orthod., 52:637-651, 1966.

Ricketts, R.M.: Planning treatment on the basis of the facial pattern and an estimate of its growth. Angle Orthod., 27:14-27, 1957.

Ricketts, R.M.: A foundation for cephalometric communication. Am. J. Orthod., 46:330-357, 1960.

Ricketts, R.M.: Cephalometric synthesis: An exercise in stating objectives and planning treatment with tracings of the head roentgenograms. Am. J. Orthod., 46:647-673, 1960.

Ricketts, R.M.: Analysis and synthesis. Angle Orthod., 31: 141-156, 1961.

Ricketts, R.M.: Esthetics, environment and the law of lip relation. Am. J. Orthod., 54:272-289, 1968.

Ricketts, R.M., Bench, R.W., Hilgers, J.J. and Schulhof, R.: An overview of computerized cephalometrics. Am. J. Orthod., 61:1-28, 1972.

Ricketts, R.M., Schulhof, R.J. and Bagha, L.: Orientation-sella-nasion of Frankfort horizontal. Am. J. Orthod., 69:648-654, 1976.

Riedel, R.A.: Esthetics and its relation to orthodontic therapy. Angle Orthod., 20:168-178, 1950.

Riedel, R.A.: An analysis of dentofacial relationships. Am. J. Orthod., 43:103-119, 1957.

Riolo, M.L. Moyers, R.E., McNamara, J.A. and Hunter, W.S.: An Atlas of Craniofacial Growth. Centre of Human Growth and Development, University of Michigan, Ann Arbor, Michigan, 1974.

Roos, N.: Soft tissue changes in class II treatment. Am. J. Orthod., 72:165-175, 1977.

Rudee, D.A.: Proportional profile changes concurrent with orthodontic therapy. Am. J. Orthod., 50:421-434, 1964.

Sassouni, V.: Roentegenographic cephalometric analysis of cephalo-facio-dental relationships. Am. J. Orthod., 41:735-764, 1955.

Sassouni, V.: Diagnosis and treatment planning via roentgenographic cephalometry. Am. J. Orthod., 44:433-463, 1958.

Sassouni, J.: The Face in Five Dimensions. Philadelphia Center for Research in Child Growth. Philadelphia, 1960.

Schulhof, R.J., Nakamura, S. and Williamson, W.V.: Prediction of abnormal growth in class III malocclusions. Am. J. Orthod., 71:421-430, 1977.

Scott, J.H.: Dento-facial Development and Growth. New York: Pergamon Press, 1967.

Sicher, H. and DuBrul, E.L.: Oral Anatomy. Fifth edition, C.V. Mosby Co., St. Louis, 1970.

Simon, P.W.: Fundamental Principles of Systematic Diagnosis of Dental Anomalies. The Stratford Co., Boston, 1926.

Steiner, C.C.: Cephalometrics for you and me. Am. J. Orthod., 39:729-755, 1953.

Steiner, C.C.: Cephalometrics in clinical practice. Angle Orthod., 29:9-29, 1959.

Steiner, C.C.: The use of cephalometrics as an aid to planning and assessing orthodontic treatment. Am. J. Orthod., 46:721-735, 1960.

Subtelny, J.D.: A longitudinal study of soft tissue facial structures and their profile characteristics, defined in relation to underlying skeletal structures. Am. J. Orthod., 45:481-507, 1959.

Subtelny, J.D.: The soft tissue profile, growth and treatment changes. Angle Orthod., 31:105-122, 1961.

Tweed, C.H.: Philosophy of orthodontic treatment. Am. J. Orthod., 31:74-103, 1945.

Tweed, C.H.: The Frankfort-mandibular plane angle in orthodontic diagnosis, classification, treatment planning, and prognosis. Am. J. Orthod. Oral Surg., 32:175-230, 1946.

Tweed, C.H.: The Frankfort-mandibular incisor angle (FMIA) in orthodontic diagnosis, treatment planning and prognosis. Angle Orthod., 24:121-169, 1954.

Vig, P.S. and Cohen, A.M.: Vertical growth of the lips: A serial cephalometric study. Am. J. Orthod., 75: 405-415, 1979.

Warfield, E.H.: Profile changes resulting from orthodontic treatment. M.S. Thesis, University of West Virginia, 1975.

Wisth, P.J.: Changes of the soft tissue profile during growth. Trans. Europ. Orthod. Soc., 123-131, 1972.

Wisth, P.J.: Soft tissue response to upper incisor retraction in boys. Br. J. Orthod., 1:199-204, 1974.

Wuerpel, E.: On facial balance and harmony. Angle Orthod., 7:81-89, 1937.

Wylie, W.L.: The mandibular incisor - its role in facial esthetics. Angle Orthod., 25:32-41, 1955.

APPENDICES

TABLE XXVII

Main Effects of Treatment (Non-Extraction vs Extraction)

Variables		Treatments Non-Extraction (N = 84)	Extraction (N = 138)
U.M.C.P. to "Y" Axis (mm)	Mean S.E.	56.61 ±0.90	54.25 ±0.70
U.I. to "Y" Axis (mm)	Mean S.E.	54.77 ±0.96	51.84 ±0.75
L.M.C.P. to "Y" Axis (mm)	Mean S.E.	51.00 ±0.93	48.57 ±0.73
L.I. to "Y" Axis (mm)	Mean S.E.	52.07 ±0.92	49.10 ±0.72
Epidermic "B" Point to "Y" Axis (mm)	Mean S.E.	55.26 ±0.99	52.33 ±0.77
Lower Lip to "Y" Axis (mm)	Mean S.E.	62.92 ±0.99	59.96 ±0.77
U.I. to "X" Axis (mm)	Mean S.E.	76.80 ±0.63	74.97 ±0.49
L.I. to "X" Axis (mm)	Mean S.E.	74.16 ±0.66	71.97 ±0.51
Upper Stomion to "X" Axis (mm)	Mean S.E.	74.45 ±0.65	72.39 ±0.50
Lower Lip to "X" Axis (mm)	Mean S.E.	85.93 ±0.73	83.93 ±0.57

TABLE XXVIII

Main Effects of Class (Class I vs Class II Division 1 vs Class II Division 2)

Variables		Class I (N = 81)	Class II Div. 1 (N = 117)	Class II Div. 2 (N = 24)
"B" Point to "Y" Axis (mm)	Mean S.E.	45.17 ±1.07	42.63 ±0.89	40.15 ±1.97
U.C.E.J. to "Y" Axis (mm)	Mean S.E.	56.64 ±0.88	56.31 ±0.73	52.63 ±1.62
U.I. to "Y" Axis (mm)	Mean S.E.	55.69 ±0.97	55.09 ±0.81	49.13 ±0.79
L.C.E.J. to "Y" Axis (mm)	Mean S.E.	50.34 ±0.97	48.09 ±0.81	44.37 ±1.78
L.M.C.P. to "Y" Axis (mm)	Mean S.E.	52.25 ±0.95	50.42 ±0.79	46.68 ±1.74
L.I. to "Y" Axis (mm)	Mean S.E.	52.82 ±0.94	51.35 ±0.78	47.58 ±1.72
Epidermic "B" Point to "Y" Axis (mm)	Mean S.E.	56.08 ±1.01	53.92 ±0.84	51.39 ±1.86
Lower Lip to "Y" Axis (mm)	Mean S.E.	63.71 ±1.01	61.95 ±0.84	58.67 ±1.85
Subrhinal to "X" Axis (mm)	Mean S.E.	54.11 ±0.58	56.67 ±0.49	56.76 ±1.07
Angle SN-P.P. in (^{o})	Mean S.E.	6.99 ±0.65	8.67 ±0.54	10.35 ±1.20
Angle SN-Mn.P. in (^{o})	Mean S.E.	32.12 ±0.99	29.15 ±0.82	26.82 ±1.82
Angle P.P.-Mn.P. in (^{o})	Mean S.E.	27.05 ±1.12	22.62 ±0.93	18.71 ±2.06

TABLE XXIX

Main Effects of Stage (A vs B vs C)

		Stages A (N = 74)	Stages B (N = 74)	Stages C (N = 74)
Nasion Point to "Y" Axis (mm)	Mean S.E.	65.61 ±0.10	65.85 ±0.10	65.57 ±0.10
A.N.S. Point to "Y" Axis (mm)	Mean S.E.	63.56 ±0.18	62.63 ±0.18	61.95 ±0.18
"A" Point to "Y" Axis (mm)	Mean S.E.	55.16 ±0.16	53.59 ±0.16	53.08 ±0.16
"B" Point to "Y" Axis (mm)	Mean S.E.	43.50 ±0.20	42.41 ±0.20	42.04 ±0.20
Pogonion Point to "Y" Axis (mm)	Mean S.E.	47.81 ±1.22	45.04 ±1.02	44.72 ±2.25
U.C.E.J. to "Y" Axis (mm)	Mean S.E.	57.05 ±0.19	54.55 ±0.19	53.98 ±0.19
Epidermic Nasion to "Y" Axis (mm)	Mean S.E.	70.98 ±0.12	71.41 ±0.12	71.29 ±0.12
Rhinal Point to "Y" Axis (mm)	Mean S.E.	87.39 ±0.18	86.97 ±0.18	86.64 ±0.18
Subrhinal Point to "Y" Axis (mm)	Mean S.E.	71.01 ±0.20	69.88 ±0.20	69.51 ±0.20
Epidermic Pogonion to "Y" Axis (mm)	Mean S.E.	56.36 ±0.24	55.30 ±0.24	54.92 ±0.24
Rhinal Point to "X" Axis (mm)	Mean S.E.	48.19 ±0.18	49.18 ±0.18	49.77 ±0.18
Subrhinal Point to "X" Axis (mm)	Mean S.E.	55.02 ±0.17	56.13 ±0.17	56.39 ±0.17
Upper Stomion to "X" Axis (mm)	Mean S.E.	73.08 ±0.18	73.55 ±0.18	73.62 ±0.18
Lower Stomion to "X" Axis (mm)	Mean S.E.	73.57 ±0.22	74.03 ±0.22	74.64 ±0.22

continued -

TABLE XXIX - continued

Variables		Stages A (N = 74)	B (N = 74)	C (N = 74)
Menton Point to "X" Axis (mm)	Mean S.E.	107.20 ±0.23	109.35 ±0.23	108.64 ±0.23
Epidermic Menton to "X" Axis (mm)	Mean S.E.	113.84 ±0.33	117.48 ±0.33	116.53 ±0.33
Angle SN-P.P. in (^{o})	Mean S.E.	8.03 ±0.15	9.04 ±0.15	8.94 ±0.15
Angle SN-Mn.P. in (^{o})	Mean S.E.	28.53 ±0.15	29.88 ±0.15	29.67 ±0.15
Angle P.P.-Mn.P. in (^{o})	Mean S.E.	22.40 ±0.18	23.03 ±0.18	22.95 ±0.18

APPENDIX II

GLOSSARY OF LANDMARKS, PLANES AND MEASUREMENTS

I. LANDMARKS: 1 - 15 Hard Tissue Cephalometric Points

16 - 26 Soft Tissue Cephalometric Points

1. Sella (S)

   The centre of the sella turcica (pituitory fossa).

2. Nasion (N)

   The mid-point of the fronto-nasal suture at its most anterior margin.

3. Posterior Nasal Spine (PNS)

   The process formed by the united projecting ends of the posterior borders of the palatal processes of the palatal bones.

4. Anterior Nasal Spine (ANS)

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

5. "A" Point

   The deepest point on the midline contour at the alveolar process, between the anterior nasal spine and the alveolar crest of the maxillary central incisor.

6. Upper Cemento-Enamel Junction (UCEJ)

   The point of cemento enamel junction on the labial surface of the maxillary central incisor.

7. Upper Mid-Crown Point (UMCP)

   On the labial surface of the maxillary incisal crown, approximately half way between maxillary incisal edge and maxillary cemento enamel junction.

8. Upper Incisor (UI)

   The lowest point of the maxillary central incisal crown.

9. Lower Incisor (LI)

   The most superior point of the mandibular central incisal crown.

10. Lower Mid-Crown Point (LMCP)

   On the labial surface of the mandibular incisal crown, approximately half way between mandibular incisal edge and mandibular cemento enamel junction.

11. Lower Cemento-Enamel Junction (LCEJ)

   The point of cemento enamel junction on the labial surface of the mandibular central incisor.

12. "B" Point

   The deepest point on the midline contour of the mandible between the alveolar crest of the mandibular central incisor and pogonion point.

13. Pogonion

The most anterior point on the contour of the chin.

14. Menton

The most inferior point on the symphysis menti of the mandible.

15. Gonion

The most inferior point on the posterior one-third of the lower border of the mandible.

16. Epidermic Nasion

The most concave point on the soft tissue overlying the area of the frontonasal suture.

17. Rhinal

The most anterior point on the contour of the soft tissue nose.

18. Subrhinal

The most concave point of the area where the columella and maxillary lip meet.

19. Epidermic "A" Point

The most posterior point on the philtrum of the maxillary lip.

20. Upper Lip

The most anterior point on the maxillary lip.

21. Upper Stomion

The most inferior point on the maxillary lip.

22. Lower Stomion

The most superior point on the mandibular lip.

23. Lower Lip

The most anterior point on the mandibular lip.

24. Epidermic "B" Point

The most posterior point on the contour between the mandibular lip and the epidermic pogonion.

25. Epidermic Pogonion

The most anterior point on the contour of the soft tissue covering the chin.

26. Epidermic Menton

The soft tissue point corresponding to menton point. Defined as the point where a perpendicular dropped from hard tissue menton intersects with the soft tissue covering the lower chin.

II. PLANES

1. Sella-Nasion (SN) - A line connecting points sella and nasion.
2. Palatal Plane (PP) - A line connecting the anterior and the posterior nasal spines.
3. Mandibular Plane (MP) - A line tangent to the inferior border of the mandible from menton to gonion.
4. "X" Axis - A line connecting points sella and nasion.
5. "Y" Axis - A line perpendicular on "X" axis at point sella.

III. MEASUREMENTS

1. Linear Horizontal - The perpendicular distances of the hard and soft tissue cephalometric points on the "Y" axis.
2. Linear Vertical - The perpendicular distances of the hard and soft tissue cephalometric points on the "X" axis.
3. Angular - The angles formed by the SN, PP and MP planes.
4. Cross-Sectional Lip Area - The maxillary and mandibular lip areas as illustrated in figure 10.