PROFILE CHANGES
IN CLASS III MALOCCLUSIONS
TREATED WITH
THE BEGG TECHNIQUE

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DEDICATION

This thesis is respectfully dedicated to the memory of my late mother whose selfless love and care I dearly cherished and sadly missed.

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CONTENTS

ERRATUM

Page 24, line 15	Lo (1982) should read Lo and Hunter (1982)
Page 45, line 22	Horowitz and co-workers should be Horowitz and Converse.
Page 64, line 5	Siriwat should read Siriwat and Jarabak.

SECTION II : ORIGINAL WORK

INTRODUCTION

Although enhancement of the appearance of the teeth has always been a basic aim of orthodontic treatment, improvement in the appearance of the associated soft tissues is still viewed as a desirable, but fortuitous consequence of treatment. This is because facial changes are not necessarily proportional to skeletal growth or orthodontic treatment influence. Thus the orthodontic literature is replete with studies on profile changes associated with growth and orthodontic treatment which reflect the efforts invested to determine the effect of orthodontic treatment on the growing face.

These studies employed the use of profile cephalometrics to measure the changes of the hard and soft tissues during growth and orthodontic treatment with different techniques. Different investigators used different reference planes for superimposition to determine the changes such as the palatal plane used in Bloom (1961) and Angelle (1973)'s studies, and the facial plane used by Rudee (1964), Hershey (1972), Anderson et al (1973) and Garner (1974). As expected, different results and conclusions were drawn due to differences in the measuring technique. Despite these discrepancies, the common objective of establishing a relationship between change of lip posture and incisor retraction is observed. Ratios such as 2.5 : 1 , 2.9 : 1 and 3 : 1 were suggested for upper incisor and upper lip retraction. Undoubtedly, the most dramatic profile changes apparently follow the retraction of the maxillary incisors and the consequent lip retraction.

However, not all malocclusions are treated by the retraction of the maxillary incisors. In some instances, proclination of the maxillary incisors is required and this is especially true in the correction of the Class III malocclusions. Does the lip position follow the incisor position in instances of incisor proclination as it does in incisor retraction ? Few reports were made on this matter and even then these were based on hypothetical situations where layers of wax were placed onto the surface of the upper incisors to simulate proclination and the resultant lip change (Powell 1976).

The Class III malocclusion has been looked upon as one of the most severe facial deformities. Goldstein (1947) reported that many patients afflicted with this condition had indicated "a willingness to face possible death rather than to continue to live thus deformed."

Fortunately, advances in orthognathic surgical techniques in recent years have done much to alleviate their plight and boost their morale. However, the risk involved in surgery is real and cases which are orthodontically treatable should not be subjected to these life-endangering situations.

Admittedly, orthodontic treatment has its limitations, particularly with respect to the improvement of the facial appearance and profile. Freijs (1981) commented that Class III treatment by orthodontic means alone would only involve an increase in the dental compensations to achieve a reasonable occlusion without influencing the profile significantly. A better alternative according to her is maxillary orthopedics which may induce favourable changes in the apical base relationship, thus improving the facial profile significantly. Literature on profile changes in orthodontic treatment of Class III malocclusions to support her statement were however seriously lacking.

Thus it is the purpose of the present study to investigate, with orientated cephalometric radiographs, the changes of the facial profile in Class III malocclusions treated with the Begg Technique which works on the principle of light forces to move teeth only, thus producing a purely orthodontic change. In addition, the present study also has the objective of identifying interrelationships between hard and soft tissue changes of the facial profile during orthodontic treatment and growth. It is not within the scope of this project to differentiate between changes due to growth and those due to treatment. Alterations in soft tissue profile in post-treatment records will be regarded as a result of orthodontic treatment supplemented by growth.

SECTION I

Review of literature

CHAPTER 1

FACIAL PROFILE AND ESTHETICS

Facial form may be abstracted in two planes of space namely frontal and sagittal. The midsagittal plane produces an outline which is commonly referred to as the profile of the face as seen from the side. Emphasis has been placed on the profile view of the face as many dento-facial malformations as well as therapy changes are more evident in this plane of space. A frontal facial evaluation is also of importance, as this is the view generally noted by the patient and other observers. (Burstone 1958; Lucker 1980).

1.1. FACTORS INFLUENCING ESTHETIC PERCEPTION AND PREFERENCES

Esthetic perception is the concept of beauty, taste and art acquired through our five senses. Thus each man's concept of beauty is a matter of his own innermost sensibility and understanding which is conditioned by his past experiences, motivational state and direction of attention. (Lucker 1980).

The face is the most important means of self-identification and self-presentation of a person in everyday life. Particular importance is placed on a pleasing facial appearance by society. Much evidence has been accumulated which suggests that an attractive and pleasant face enhances the social value of the individual and opens doors to social, educational and career opportunities.which results in their living more satisfying and comfortable lives than their unattractive peers. (Berscheid 1980). The profound psychological effects of facial esthetics on social interaction and development of self-image influence one's perception of facial beauty. Therefore, it is not merely vanity that prompts people to turn to facial alteration procedures such as cosmetic surgery or orthodontic therapy to seek improvement of their facial appearance. (Graber 1980; Jacobson 1984).

Beauty intimately involves the individual along with the educated eye of the beholder. Esthetic questions are not appraised by uniform standards although there is certainly considerable agreement among many of us that certain faces fall within the definition of beauty. Profile studies using judges as human attractiveness meters to determine the esthetic preferences of different groups and establish clear standards of profile beauty were inconclusive.

There have been two general approaches to the study of facial esthetics. One approach tries to identify subjects who are considered to be physically attractive and to determine what physical attributes make them attractive. These subjects are usually public figures celebrated for their good looks such as the thirty Seattle Seafair princesses in Riedel's sample (1957) and the fifty-two subjects consisting of beauty contest winners, professional models, actors and actresses in Peck and Peck's study. (1970). These individuals were photographed and X-rayed in standard positions, and cephalometric measures were obtained from these records. Both studies involved the general public's assessment of good facial esthetics but different conclusions were drawn from the results. Riedel noted that the public's concepts of acceptable facial esthetics were apparently in good agreement with standards established by the orthodontists on the basis of normal occlusion. In contrast, Peck and Peck found that the general public preferred a fuller, more protrusive dentofacial pattern than has been set as customary cephalometric standards.

The other approach commonly used in the study of facial esthetics requires one group of individuals to evaluate the attractiveness of another group of individuals. The individuals evaluated are usually chosen either to represent a normal population or to represent variability on particular dimensions. The work of Cox and van der Linden (1971) illustrated this second type of study. They randomly selected a group of eighty-seven male and eighty-seven female young adult students from over 400 dental school records. These records included people with good and poor facial esthetics. Silhouette photographs of the subjects were evaluated independently by ten orthodontists and ten layman of the Netherlands who were instructed to discriminate between the most and least attractive profiles using a Q-sort technique. Eighteen males and eighteen females with the best-rated facial harmony and eighteen males and eighteen females with the poorest-rated facial harmony were identified. The group with good facial esthetics was compared to that with poor facial esthetics on selected hard and soft tissue measures. Their findings indicated that there was no statistically significant difference in the ratings of the two professionally different groups of evaluators. Thus, esthetic preference was not due to difference in training or cultural background and sex of the raters as shown also by Foster (1973), Lines et al (1978) and Smit and Dermaut (1984) in similar studies. However, Tedesco et al (1983) reported significant race and sex differences in the perception and judgment of dento-facial attractiveness. Black raters judged all photographs to be more attractive than did white raters and female raters judged all photographs to be more attractive than did male raters. Cox and van der Linden, Foster, and Lines et al, recorded significant differences of opinion concerning male profiles as compared to female profiles. That is, there are different standards for male and female profile beauty although Smit and Dermaut's study concluded that the profile preferences for girls and boys were comparable. In addition, Foster noted that all the groups of raters preferred fuller profiles for younger ages and straighter profiles for the adults.

The observation that people do share a common basis for esthetic judgment regardless of nationality, age, sex or occupation seems not to be ill-founded. The uncanny esthetic agreement among diversified groups is not by sheer coincidence. Instead, it is largely the product of many cultural mechanisms and reinforcements operating in our society. The mass media such as television, motion pictures, newspapers and magazines are very influential in unifying people's tastes, providing daily reinforcement for facial stereotypes. (Srisuk 1982).

1.2. CHANGING CONCEPTS OF PROFILE BEAUTY

Man's awareness of facial and body esthetics extends beyond recorded history. There is abundant evidence of appreciation of beauty in prehistoric archaeological artifacts. A review of primitive art, sculptures, paintings, figurines and representations from Egyptian times through the Golden Age of Art in Greece around the fourth century B.C. revealed different standards of facial proportions which were considered ideal in the two eras. Egyptian culture depicted its ideal of beauty with statues of royalty. Statues of Egyptian Kings showed full lips with bimaxillary prognathism and prominent lower face while Greek female and male sculptures were portrayed with prominent nose, well-defined mentolabial sulcus and a flat or straight profile. (Peck and Peck 1970).

Facial esthetics embodied in classical Greek sculpture strongly influenced many early orthodontists, most notably Edward H. Angle, who is generally acknowledged as the founder of the modern specialty of orthodontics. Angle (1907) regarded the profile of Apollo Belvedere as a paragon of facial beauty. He was also probably the first to espouse the doctrine that facial "balance" and "harmony" should be a fundamental concern of orthodontists. He considered the mouth to be the most important factor in determining facial esthetics and believed that the beauty of the mouth depended on a full complement of teeth in normal occlusion and was definitely related to the position of the upper incisors which establish the curve of the lower lip. Therefore, lack of balance of the mouth exists just in proportion to the degree of malocclusion.

Wuerpel (1937), an art teacher and friend of Angle, emphasised the importance of biological variability of facial forms in different racial groups and cautioned that "to treat all human countenances according to a fixed rule would become an absurdity." Faces can be beautiful even though they are proportioned differently. Balance is the important factor in beauty rather than proportion. Balance is achieved when no part of the facial pattern is overemphasised at the expense of another. It connotes some kind of good interrelationship of facial parts over time. The orderly and pleasing arrangement of the facial parts in profile constitutes facial harmony. Under Wuerpel's influence, Angle disregarded the classic Greek profile of Apollo Belvedere as the norm to be applied universally in gauging the harmony or disharmony of other faces.

Since the introduction of cephalometric roentgenography in 1931, many methods of cephalometric analyses of facial relationships had evolved each incorporating a set of reference values or norms which were statistically derived mean values of population samples selected on the basis of having normal occlusions or pleasant faces by orthodontists, artists or the general public. Obvious variables like age, sex and racial or ethnic background were considered and norms were established for these different groups. These attempts towards the goal of establishing a so-called 'normal' facial pattern in reality, reduce the clinical problem to a series of numbers. The choice of an analysis to use is difficult as analyses multiplied rapidly in numbers and grew in complexity. Krogman and Sassouni counted forty-five analyses in 1957. The 'norm' concept of facial pattern is fraught with pitfalls of mathematical expression of morphological and physiological variation (Graber 1954).

Krogman (1958) suggested that the 'norm' concept should be viewed as just a relative framework; faces need not be moulded to it, they need only approximate it, thus granting a full measure of individuality. Baum (1968) stressed further the fallacy of the 'norm' concept of facial pattern and esthetics and reiterated that individual variation and change of the maturing face with time must be taken into consideration in diagnosis and treatment planning. Burstone (1975) stated that the 'norm' is useful as a basis for describing the variation one encountered in assessment of the facial profile. Casko and Shepherd (1984) and Trenouth et al (1985) expressed similar views.

Thus, the concepts of facial esthetics changed from culture to culture and from one age to another. Common to all these concepts was public recognition of the "esthetic ideal" of each period. Although society today still possesses ideals of facial esthetics, the fact that there is no such thing as an equation for facial beauty and that no numbers or devices can totally express the complexities of facial esthetics has been realized. Variation in facial appearance is and must continue to be the rule. (Peck and Peck 1970; Subtelny 1970).

1.3. EVALUATION OF THE FACIAL PROFILE

The first formal observations concerning profile esthetics and measurement were made by Angle in 1907. He developed a system for classifying the esthetic value of profiles based on the way the upper first molar and lower first molar were aligned. The Angle's classification system produced three facial types. A dental Class I occlusion is one in which there is a normal molar relation where the mesiobuccal cusp of the upper first permanent molar occludes with the mesiobuccal groove of the lower first permanent molar. This type of occlusion is usually associated with an orthognathic profile in which the bridge of the nose, upper and lower lip and the chin fall on a straight vertical line. Dental Class II malocclusions are those in which the lower first molar is in postnormal relationship to the upper. This usually results in a retrognathic profile, with the chin and lower lip posterior to their normal position. Dental Class III malocclusions comprise those cases where the lower first permanent molars are in prenormal occlusion, causing a prognathic profile with the lower lip protruding in front of the upper lip.

Although Angle's classification system remains very popular today, it is still basically a dental classification system and tells very little about the skeletal or soft tissue components of the facial profile. Other early orthodontists, such as Lischer (1926) and Hellman (1939), advocated more comprehensive measurement and analysis of the facial profile. They constructed lines, angles and proportions for diagnosis and classification either from photographs or directly on patient's faces. The development of cephalometrics through the use of a standardized X-ray technique by Broadbent (1931) and others provided the possibility of studying the underlying skeletal and dental structures along with the soft tissue profile and allowed comparability of all individuals in both longitudinal and cross-sectional studies.

1.3.1. Dental Analysis

The angulation of the lower incisor has long been a criterion used by many to judge facial balance. Tweed (1944, 1954) regarded the lower incisor as a factor of primary importance in attainment of good facial profile. He proposed that the long axis of the lower incisor should stand so that it intersects the Frankfort Horizontal plane at an angle of no less than 65 degrees for good facial esthetics. The axial inclination of the lower incisor can also be measured relative to many cephalometric planes such as the occlusal and mandibular planes as defined in Downs' analysis (1948) and the NB plane used in Steiner analysis (1953).

There were many investigations done to test Tweed's hypothesis. Riedel (1950) studied the skeletal and dental patterns of individuals deemed to have good and poor profiles. He observed that the axial inclination of the lower incisor to the mandibular plane did not indicate an absolute difference between good and poor profiles. The relation of the axial inclination of the lower incisor to the occlusal plane revealed more accurately the tendency for the lower incisor to be upright in good profiles. Bjork (1951)* demonstrated that there were variable acceptable angulations of the lower incisor depending on the specific facial patterns. A convex facial pattern can exhibit a greater protrusiveness and procumbency of the lower incisors. In a subsequent study in 1957, Riedel concluded that the relationship of the lower incisor to the A-Pogonion plane or facial convexity plane as Downs (1948) called it, provided a better measure of the esthetic relationship as the results indicated that there were dental compensations for variations in apical base relationships to produce good facial balance. Ricketts (1960) suggested that the position of the lower incisor to the A-Pogonion plane best described the spatial orientation of the lower incisor to the apical base which was important in establishing lower facial balance. Williams (1969) strongly supported his idea. He stressed that the linear antero-posterior position of the incisal edge of the lower incisor relative to the A-Pogonion plane was more important than its angulation in influencing upper and lower lip balance. To create well-balanced lips, the incisal edge of the lower incisor must lie at or near the A-Pogonion line which he concedes would change during treatment with growth and such changes must be anticipated in planning the position of the lower incisor after treatment.

While these investigators ardently proclaimed the influence of the lower incisor in maintaining facial balance, there were others who expressed their reservations. Wylie (1955) ascribed the improvement in facial profiles of Dr. Tweed's twenty-nine treated patients to both tooth movement and good mandibular growth which established a new and better position for the chin. Although he did not totally disregard the role of the lower incisor in facial esthetics, he remarked that if the inclinations of the teeth were important, then probably the retraction of the upper incisors would produce greater improvement in the facial profile than would be achieved by the retraction of the lower incisors alone. His views were reminiscent of Dr. Angle's teachings. In his discussion of Dr. Lindquist's paper (1958) on 'The lower incisor - Its influence on treatment and esthetics', Wylie (1959) reiterated the role of natural mandibular growth in producing the desirable facial changes. Recently, Saxby and Freer's study (1985) showed strong correlations of the upper and lower lip convexity with the angulation and the position of the upper incisor which suggests a greater importance for the role of upper incisor in facial esthetics than has been previously reported.

The axial inclination of the upper incisor can be measured relative to the Frankfort Horizontal plane and the sella-nasion plane as in Riedel's analysis or to the NA plane as defined by Steiner. Its linear position can be determined in a similar way relative to the A-Pogonion plane, the NA plane or the facial plane of Riedel. It is immaterial which reference plane is used in measurement of the angle and position to determine procumbency so long as consistency is maintained in the use of one base plane according to Graber (1958) who reported the proceedings and decisions arrived at the first Cephalometric Workshop.

1.3.2. SKELETAL ANALYSIS

Antero-posterior assessment

The skeletal analysis has as its major purpose an appreciation of the facial type and an appraisal of the antero-posterior apical base relationship, particularly with reference to Class II and Class III malocclusions. Downs (1948, 1952, 1956) discussed facial typing as correlated with the patient's posture. The angle formed by the intersection of the nasion-pogonion plane with the Frankfort Horizontal called the facial angle described the relative antero-posterior position of the mandible. As the Frankfort Horizontal plane varies with the natural head posture, the facial angle should be corrected for posture.

Facial types can be classified according to the magnitude of the facial angle. A mean value of 87.8 degrees is associated with a mesognathic face with normal position of the chin. Smaller angles indicate a retrognathic face with a retrusive chin while larger values show lower face prognathism with a prominent chin. According to Ricketts (1960, 1981), the facial angle is the most statistically reliable descriptor of chin depth. It expresses the forward or backward position of the chin and is both useful and dependable for a representation of relative mandibular prognathism.

Antero-posterior variations in the facial profile may be assessed by the angle of convexity which takes into account the influence of the chin button or prominence of the pogonion besides providing information similar to that from the ANB angle. Downs (1948) assessed convexity by measuring the variation of the reflex angle Nasion-A-Pogonion forward or backward of 180 degrees. A plus sign is assigned to the angle when point A falls anterior to the facial plane and a minus sign is given when it is posterior to the facial plane. When the angle of convexity is zero, the skeletal profile is straight. Convex and concave profiles are associated with positive and negative angles respectively. Convexity or concavity of the facial profile can also be recorded by the linear measurement of point A to the facial plane. Ricketts (1960) considered that this direct measurement yields a true variation of the profile from a straight line. The mean value is zero with a range of -3 mm. to +4 mm. Bjork (1951) conducted a longitudinal and cross-sectional study of profile changes with age in 150 and 603 Swedish males respectively and concluded from the results that the Swedish male profile becomes straighter as the individual matures due to increased mandibular growth. Downs (1952) and Ricketts (1981) maintained that the convexity of the face should be considered with respect to factors like age, sex and ethnic characteristics when assessing the facial profile. Ricketts' clinical findings showed that facial convexity decreases 0.7 mm. every three years and in males this trend continues until the age of 24.

The maxilla and mandible may be related to each other antero-posteriorly by the SNA and SNB angles. The antero-posterior skeletal discrepancy is obtained from the ANB difference.(Riedel 1950,1957). The mean value of the ANB angle is 2 degrees and significant deviations from this mean indicate an antero-posterior discrepancy of those basal structures which support the dentition. A high positive ANB angle indicates a maxilla which is forward, a retrognathic mandible, or a combination of these deviations. In children, the average ANB angle tends to be larger according to Riolo et al (1974). This method of establishing the antero-posterior discrepancy is dependent on the length and cant of the SN plane which varies in different individuals and hence can lead to misinterpretation of results. Bacon et al (1983) reported that the blacks have shorter cranial base which affect the values of SNA and SNB angles in this group. There were methods suggested to compensate for this inaccuracy such as the addition of 0.5 degrees to the value of ANB for every degree SNA is less than 81 degrees and vice versa. (Brown 1981). Jacobson (1975. 1976) offered the Wits appraisal of jaw disharmony as an alternative to the ANB angle. This diagnostic aid consists of a dental assessment, relating the jaws to each other utilizing their common plane- the functional occlusal plane. It is useful when results given by other methods are confusing, for example, when the ANB angle does not reflect a clinical assessment of the antero-posterior dysplasia. A limiting factor in the Wits assessment is the variation in the occlusal plane orientation which leads to difficulty in its identification in some cases. McNamara (1984) proposed yet another method of cephalometric evaluation of the skeletal components of the profile, relating the antero-posterior position of the maxilla and mandible to the constructed nasion perpendicular to the Frankfort Horizontal plane. The nasion perpendicular, as McNamara cautioned is not always a reliable line of orientation for determining maxillary and mandibular positions especially in Class III malocclusions in which a short anterior cranial base exists.

Vertical Assessment

Skeletal relationships in the vertical dimension can have a profound effect on the horizontal relationship of the maxilla and mandible and the overall facial balance as demonstrated by Sassouni and Nanda in 1964. In 1969, Dr. Sassouni classified facial types into two categories. The first category included the two basic types of vertical disproportions (skeletal deep bite and open bite) and the second category included the types of anteroposterior disproportions (skeletal II and III patterns). He used the archial analysis which he introduced in 1955 to define the four basic facial types. In skeletal deep bite cases, the four planes, namely the anterior cranial base plane, palatal, occlusal and mandibular planes are horizontal and nearly parallel and converge at a Center **O** which is far away from the profile. In skeletal open bite cases, the four planes are steep and sharply angulated to each other thus bringing the Center **O** closer to the profile. In addition, the Center **O** is high in skeletal III patterns and low in skeletal II types. Combinations of these disproportions in the two dimensions result in nine possible facial profile types including the normal.

The interrelationships of these planes can be more precisely determined by both angular and linear measurements. The mandibular plane angle measured relative to the Frankfort Horizontal plane (Tweed, Downs and Ricketts' analyses) provides a means of assessing vertical relation and the morphology of the lower third of the face. There were three definitions of the mandibular plane: the tangent to the lowermost border of the mandible (Tweed, Wylie and Bjork), the line joining the gonion with menton (Downs and Ricketts) and the line joining gonion and gnathion (Steiner). None demonstrated any clear superiority from the diagnostic point of the view as was reported by Graber (1958). The mandibular plane angle can also be measured in relation to the sella-nasion line (Steiner analysis) and the mean value is 32 degrees. High mandibular plane angles are frequently associated with anterior open bites and vertically growing facial patterns. Conversely, low or flat mandibular plane angles are frequently associated with deep anterior overbite and horizontal mandibular growth patterns. Large mandibular plane angles may also be associated with increased lower facial height in cases with low or negative ANB angle or with reduced lower facial height in cases with large ANB angle. Unlike the facial angle, the mandibular plane angle decreases with age due to rotational growth of the mandible and adaptive changes at the gonial angle. (Ricketts 1981).

The most common linear measures of face height are the upper anterior face height which is the vertical distance from nasion to the palatal plane and the lower anterior face height which is the distance from the palatal plane to menton. The ratio of these distances may be used to describe the vertical proportions of the face. An upper facial height that is approximately 43 percent of the total facial height has been shown to be fairly acceptable in growing faces, and this proportion can be used to indicate a good vertical relationship of the facial skeletal profile. (Thompson and Brodie 1942). Both the upper and lower anterior face heights increase with age and the increments are greater in males than females. (Riolo et al 1974).

1.3.3. INTEGUMENTAL PROFILE ANALYSIS

While Riedel (1957) believed that the soft tissue profile was closely related to the underlying skeletal and dental structures that comprised the bony profile, Burstone (1958, 1959) demonstrated that integumental structural extension and postural variations exist in the soft tissue veneer covering the teeth and bone which can exaggerate or mask the dentoskeletal disharmonies. Anthropologists had also shown that the external covering of the face made up of integument, adipose tissue, connective tissue and muscles does not always distribute itself in a uniform, orderly manner over the underlying dentoskeletal framework. Subsequent studies on profile changes during growth and treatment by many investigators revealed that the relationship between hard and soft tissues is a complex one. This implied that it is necessary to study directly the integumental contour of the face since hard tissue measurements can deviate considerably from the facial form which the patient expresses with the soft tissues.

Antero-posterior assessment

The convexity of the soft tissue profile is measured by the facial contour angle which Burstone suggested. This angle is formed by the upper facial plane (glabella to subnasale) and the lower facial plane (subnasale to soft tissue pogonion). It has a mean value of +12 degrees. As the angle of facial convexity becomes a smaller positive or a negative value, the profile is suggestive of a Class III skeletal and dental relationship. As the positive angle increases, the profile becomes more convex, suggesting a Class II skeletal and dental relationship. Subtelny (1959) used the soft tissue nasion instead of glabella as a reference point to measure this angle. Full soft tissue convexity assessment is determined by the angle formed by the intersection of the lines joining soft tissue nasion, pronasale and soft tissue pogonion. The mean is 137 degrees for men and 133 degrees for women. Unlike the skeletal profile, the soft tissue profile with the nose included becomes more convex with age. (Rakosi 1979).

The soft tissue facial angle is the angular measurement of a line joining soft tissue nasion (the point of intersection of sella-nasion line with the soft tissue profile) and soft tissue pogonion relative to the Frankfort Horizontal plane. It is the soft tissue analogue of the hard tissue facial angle with a mean value of 91 degrees. Holdaway (1983) who defined this angle in his analysis considered it to be a better assessment of the chin prominence due to the wide range of variations in soft tissue thickness over the symphysis. Similar soft tissue profile angles were defined earlier by Neger (1959) and Peck and Peck (1970) although the latter used a different plane of orientation constructed from the tragion to the midpoint of the facial plane on oriented profile photographs.

Angular and linear measurements have also been developed to characterize the nose which has a significant influence on the soft tissue profile. There are two soft tissue angles most commonly used in plastic and orthognathic surgery. The nasofacial angle is the angle formed by the intersection of the line joining glabella and soft tissue pogonion with the plane of the bridge of the nose, thus defining the protrusion of the nose from the facial plan. The columellar to lip angle (nasolabial angle) is formed by the intersection of the line from upper lip to glabella and the lower border of the nose, describing the vertical angulation of the nose tip. (Broadbent and Matthews 1957). There are several other definitions of the nasolabial angle. Edye (1974) measured the angle formed by the tangents to the columella of the nose and the philtrum. Legan and Burstone (1980) described it as the angle formed between the line connecting columella point and subnasale and the line from subnasale to labrale superius. They considered the nasolabial angle an important measurement in assessing anteroposterior maxillary dysplasias. The angle takes into account both the inclination of the columella of the nose and the position of the upper lip. The mean value is 102 degrees. An acute angle indicates upper lip prominence while an obtuse angle may indicate that added lip support is needed. Lo (1982) defined the nasolabial angle as the angle formed by the intersection of a line originating at subnasale tangent to the lower border of the nose and a line from subnasale to labrale superius. He concluded from the results of his study that the nasolabial angle does not change significantly with growth. According to Hunt and Rudge (1984), Epker and Fish suggested that the nasolabial angle be studied relative to the Frankfort Horizontal plane since the shape of the columella would influence the magnitude of this angle. The anterior angle formed between the Frankfort plane and a line tangent to the upper lip through subnasale should approximate 90 degrees. Holdaway

(1983) measured the prominence of the nose by means of the linear distance from the tip of the nose to the tangent at the vermilion border of the upper lip perpendicular to the Frankfort Horizontal plane. He considered those noses under 14 mm. to be small and those above 24 mm. to be large or prominent although he also stressed that nasal form should be judged on an individual basis.

Vertical Assessment

Angular and linear vertical measurement of the integumental profile can be performed in a similar manner as those described for the skeletal profile using soft tissue landmarks. The distance from eyebrow to subnasale and from subnasale to soft tissue menton should be approximately equal. When measured perpendicular to the Frankfort plane, the mean for this distance is 66 mm. in normal Caucasian males and 60 mm. in females as reported by Ricketts et al according to Hunt and Rudge (1984). The distances from subnasale to lower lip vermilion and from lower lip vermilion to soft tissue menton should be equal for ideal balance in the lower third of the face. The clinical average is 33 mm. in males and 30 mm. in females.

Ricketts (1981, 1982) proposed the concept of 'The Golden Section' or 'divine proportion' or 'phi' which he claimed is basic to the orderly arrangement and growth of the human face. This golden relation (1 : 1.618 or its reciprocal 0.618) can be found throughout Nature which has always attracted the art, satisfaction, serenity and euphoria of Mankind. This quality is recorded in the limbic system of the brain as beauty, harmony and balance, unity and grace. Thus the golden proportion can be used for analysis of structural harmony and balance of the face in all dimensions. For vertical proportion in the profile aspect, divine proportion is recognised in the height of the eye to chin and the face height from trichion (at the height of the wrinkled forehead) to the eye, the distance from chin to nose and from nose to the trichion and finally in the relation of the chin to the mouth and mouth to the eye. Harmony and balance is established when the skeleton, denture and soft tissues are arranged in these proportions which even transcend racial differences according to Ricketts who tested his hypothesis on a sample of varied racial types.

1.4. LOWER FACIAL PROFILE ASSESSMENT

The mouth defined by the lips is a most potent factor in making or marring the beauty and character of the face according to Angle in 1907. Orthodontists rightly emphasize lips and mouth relations in analysis and diagnosis since the lip region is the area of the soft tissue mass most susceptible to treatment changes (Hambleton 1964).

1.4.1. REFERENCE PLANES FOR LIP PROFILE ASSESSMENT

Among the orthodontic literature, many attempts have been made to quantify the essential elements of lip harmony. Ricketts (1960, 1968, 1981) proposed a line tangent to the chin and nose which he named the "E" or esthetic line to govern his law of normal lip relationship. In Caucasians by adulthood, the lips should be contained within this line with smooth contours, the upper lip being slightly posterior (2 mm) to the lower lip when related to this line and the mouth could be closed with no strain. The lips may lie on or ahead of the "E" line in the early ages of childhood; on it in adolescence and continue to retract behind it in adulthood. This can occur especially rapidly with maturation of males in the late teens or early twenties. Dentures that are forward (Class I bimaxillary protrusion and Class II division 1 malocclusions) produce a convex profile with the lips ahead of the "E" line. Straight or concave profiles (Class II division 2 and Class III malocclusions) are associated with retruded lips. However, racial characteristics such as short noses and thick lips must be considered when assessing lip balance. Ricketts felt that a good objective in these situations would be to achieve easy closure of the mouth with little or no strain, pursing or excessive mentalis action to produce harmony and balance.

Steiner (1964) suggested a line from the chin to the middle of the S curve formed by the lower border of the nose and the upper lip. In good faces the lips will often fall on this line at average orthodontic ages. Lips which are ahead of this line would be too full while those which fall behind this line would give too flat an appearance as related to other parts of the profile.

Holdaway (1964) recommended a line tangent to the soft tissue chin and the upper lip called the "H" line and measured the angle between this line and the hard tissue line NB named the "H" angle to assess profile acceptability. He believed that in many good faces of orthodontic ages, when the ANB angle is normal (1 to 3 degrees), the "H" angle should be between 7 to 9 degrees. Changes in angle ANB will also mean changes in the ideal "H" angle. Later in 1983, he revised the "H" angle and defined it as the angular measurement between the "H" line and the soft tissue facial plane nasion-pogonion which is a better indicator of the prominence of the upper lip in relation to the overall soft tissue profile. He also related the "H" angle to the skeletal profile convexity which is a linear measurement from point A to the hard tissue facial plane nasion-pogonion and takes into account the variability of the chin area not considered by the ANB angle. He demonstrated that there is no single "H" angle that can be set as an ideal for all types of faces but it will increase proportionately as the skeletal convexity increases. The lower lip position is considered ideal when it lies on the "H" line or 0.5 mm. anterior to it.

Merrifield (1966) constructed a line tangent to the soft tissue pogonion and the most procumbent lip extending superiorly to intercept the Frankfort Horizontal plane. The infero-posterior angle formed was called the Z angle which expresses the full extent of lip protrusion. The mean Z angle is 78 degrees in 11 to 15 year olds.

Burstone (1967) used a plane through subnasale and tangent to the soft tissue pogonion to evaluate the relative protrusion or retrusion of the lips. Linear measurements of the positions of the most prominent points of the upper and lower lips perpendicular to this plane were made. He found that in the normal adolescent sample, the upper and lower lips fall ahead of the subnasale-pogonion plane. On the average, the upper lip is 3.5 mm. anterior to the line and lower lies 2.2mm. anteriorly. Burstone (1975) considered the subnasale-pogonion plane of reference an advantageous plane to use since it is relatively unaffected by orthodontic treatment in non-growing individuals. Reference planes involving the nose may be useful in evaluating facial form but not useful in determining lip protrusion due to the extensive variations in nose form and length according to him.

There are innumerable linear measurements of the antero-posterior variability of the lips and chin. Some are measured from the surface of the teeth to the most anterior soft tissue point, while others are measured from intracranial and extracranial reference planes to the soft tissue points. Burstone (1959) determined the horizontal and vertical extensions of the integumental landmarks on the lips and chin from the corresponding skeletal and dental landmarks relative to the nasal floor as the horizontal plane of reference and the perpendicular to the nasal floor as the vertical plane of reference. He found age and sex differences in integumental extension patterns. The soft tissue mass of all areas from subnasale to menton is thicker in males, in particular, the horizontal extensions of the upper lip. At most ages, if the thickness from point A to subnasale is measured as a standard for comparison with the thickness of the upper lip, the lower lip and the chin, the following relationships would hold true: the thickness of the upper lip and chin are generally about 4 mm. smaller than the thickness at subnasale. In the adolescent group, the actual differences are for upper lip, 4 mm; lower lip, 3 mm; and chin 4 mm.

1.4.2. LIP POSTURE

The position of the lips is affected by a variety of variables including skeletal relationships, dental positions, soft tissue thickness as well as function. Postural variationsof the lips introduce inaccuracies in the evaluation of the lip profile. Burstone (1958) conceded that the lip posture is a variant which cannot be completely standardized. It is a muscle-determined position and, therefore, cannot have the reproducibility that is associated with measurements on hard tissue structures. It is a common observation that lip positions vary when the teeth are in occlusion.

Burstone (1967) described two normal postural positions of the lips. In the relaxed-lip position, the lips are apart and hanging loosely with no effort made at lip contraction. The interlabial gap between the inferior surface of the upper lip and the superior surface of the lower lip in this position vary with the length of the lips and the vertical dimension of the jaws as well as the magnitude of dental protrusion. In adolescents with acceptable faces,it is about 2 mm in centric occlusion. This relaxed-lip position is relatively reproducible according to Burstone, although emotional states can strongly influence the contraction and relaxation of the muscle fibres of the lip. The closed-lip position is characterized by minimal contraction of the lips in an effort to establish anterior oral seal in a normal individual. In persons with dentofacial disharmonies, there is a great amount of variation in the manner of lip closure during the change from the relaxed to the closed-lip position such as in Class II Division 1 and Class III malocclusions. The ensuing muscular imbalance due to overly stretched and flattened lips alters the soft tissue extention pattern. Hence the starting place for evaluating lip posture is the relaxed-lip position.

On the other hand, Ricketts (1968) believed that the closed-lip position could give a better insight into the patient's needs with regard to the musculature from the treatment planning point of view. When the jaws are together and the lips lightly closed, the strained conditions appear to be more obvious and are recorded in the roentgenogram.

Holdaway (1983) apparently supported Ricketts' contention and introduced the upper lip strain measurement as part of his soft tissue analysis. Lip strain is measured as the amount of taper of the upper lip from the base to the vermilion border. Excessive taper is indicative of the thinning of the upper lip as it is stretched over protrusive teeth and excessive vertical height. When the lip thickness at the vermilion border is larger than the basic thickness measurement, this usually identifies a lack of vertical growth of the lower face with a deep overbite and resulting lip redundancy.

Thus a good profile of a person is established as a result of a composite interrelationship of the craniofacial pattern in antero-posterior and vertical dimensions. The covering soft tissue drape ultimately modifies it. Although the concept of beauty is still a very subjective matter influenced by many factors, an objective appraisal, through making a series of pertinent measurements of the profile components and comparing them with established norms, is possible. No two faces are exactly alike but there is a particular average face and profile which all would accept. This is the rationale of the 'norm' concept. However, biological variability expressed in the morphology and relationship of the hard and soft tissue components of the face in the three dimensions of space and the fourth dimension of time must be taken into consideration when assessing facial profile and esthetics.

CHAPTER 2

THE CLASS III MALOCCLUSION

2.1. ANGLE'S CLASSIFICATION

A common problem in biologic and clinical sciences is the taxonomic one of defining and labelling subgroups of a population. In orthodontics, this process has been carried out traditionally by methods that are essentially subjective and therefore unable to deal with a whole other set of variables in an efficient, mathematically reliable way. The classic example is the Angle's classification of malocclusion. It is essential to have a classification for the convenience of description. Many classifications of malocclusions have been proposed but only Angle's classification, despite its drawbacks, has withstood the test of time and remains universally recognised.

Angle's classification is based on dental arch relationships in the sagittal plane. Angle (1907) believed that his classification also provided an index of jaw relationship but it is now recognised that this is not so and the skeletal pattern must be assessed separately. The key to assessment of occlusion in Angle's classification is the relation between the first permanent molars. The Class III malocclusion as defined by Angle is the mesial-to-normal occlusion of the lower arch in relation to the upper arch on one or both sides. The extent of mesial occlusion can range from one-half of the width of a single cusp on each side to the full width of a molar.

The drawbacks of Angle's classification are evident. The first permanent molars may be missing or they may have drifted mesially following early loss of deciduous teeth and have to be mentally repositioned before classification which is an obvious source of error. The molar relationship may differ between both sides. The classification does not consider vertical relationships of the arches which is very important in orthodontic diagnosis. The reliability of Angle's classification of malocclusion was assessed by Gravely and Johnson in 1974. Three experienced orthodontists were asked to classify 102 sets of pre-treatment study models and 80 malocclusions from examination of children using Angle's classification. It was found that the between-examiner consistency and within-examiner consistency was low generally before standardization of certain diagnostic criteria such as the presence of at least three maxillary incisors occluding lingually to the lower incisors or meeting their incisal edges in centric occlusion for classification as Class III. After these criteria were adopted, the between-examiner level of agreement was improved at least for the Class III cases.

Houston (1982) suggested that it might be wise to assess the general features of the occlusion and take into account canine relationships as well when classifying a case. If the canine and molar relationships are not in agreement, the cause for this discrepancy must be sought. Perhaps there has been a drift of the first permanent molar or possibly the canine has been crowded into an incorrect position. He also reported that many clinicians had found it useful to classify the incisor relationship separately from the buccal segment relationship according to the definitions of Ballard and Wayman (1964) which was found to be more reliable. Since a major objective of orthodontic treatment is to establish a normal incisor relationship, it is reasonable that a classification of malocclusion should take this into account. Although Angle's terms are used to describe the incisor relationship, it must be emphasized that this is not Angle's classification. Mills (1982) stated that the use of these terms to classify incisor relationship has been regularised in the British Standard Number 4492. The recent revised version read that in Class III malocclusions, the lower incisor edges lie incisal to the middle part of the palatal surfaces of the upper incisors and the overjet is reduced or reversed.

2.2. INCIDENCE

Angle commented that in the Class III malocclusion, "the marring of the facial lines is more noticeable and unpleasing than in either of the other classes, in advanced cases amounting to a striking deformity." It can develop to become the worst type of deformity the orthodontist can be called upon to treat. Fortunately, the incidence of Class III malocclusions is low.

Angle reported 4.2% of Class III cases among the several thousand cases he had seen. Haynes (1970) noted that the prevalence of Class III malocclusion among the English children in the age group of 11 to 12 years old was about 2.5%, the incidence being higher in boys than girls. Litton and colleagues (1970) cited the results of five investigations on Caucasian children which placed the incidence of Class III to be from the range of 0.48 to 2.7%. Chan (1974) observed that the incidence of Class III malocclusion was high among Chinese children and quoted a range of 14.51 to 18.86% from the results of previous investigations by other workers. Sato (1975) reported that Susami had found an incidence of 3.9% of Class III malocclusion among the Japanese while Iwagaki arrived at a figure of 6% in his survey. According to Campbell (1983), Turpin's investigation showed that the incidence of Class III malocclusion was between 1 to 2% of the general population with the Japanese and Scandinavian populations having a higher incidence.

These findings suggest that there may be real ethnic difference in the distribution of malocclusion or it may just reflect the unreliability of Angle's classification as a method of assessment of the prevalence of malocclusions in different communities as Gravely and Johnson had pointed out. They suggested that comparisons of the distribution of malocclusions in different communities, classified according to Angle's system, should be made only when the observations in different communities were made by the same observer.

2.3. ETIOLOGY

Amongst the most notable families which exhibit an inherited prognathism, the Hapsburgs are well known. The typical protruding lower lip and prognathic lower jaw have been demonstrated in 33 out of 40 members of the family as reported by Jacobson et al (1974). This implied that there is strong genetic influence in the transmission of Class III malocclusion although the mode of transmission is unclear as shown by Litton et al (1970). They could not determine whether it was inherited as an autosomal dominant or recessive trait but were certain that it was not sex-linked and possibly a multifactorial inheritance. Markovic (1970) did a twin study to compare the concordance-discordance rate for Class III malocclusions between monozygous and dizygous twins. The results of this study strongly suggest that genetic factors play a predominant role in the etiology of Class III malocclusion. Nakasima and co-workers (1982) drew similar conclusions from the results of their study which showed strong correlations between parent and offspring for skeletal measurements which indicated that the skeletal pattern was more directly related to genetic factors.

Others have suggested that the soft tissues are important in the production of the malocclusion. Angle (1907) asserted that enlarged tonsils and the habit of protruding the mandible in an effort to maintain an airway were potent factors in causing the mesial locking of the permanent teeth as they erupt in the young. When once the mesio-buccal cusp of the upper first molar began to engage the distal incline of the disto-buccal cusp of the lower first molar, the mandible would be mechanically forced forward on each closure of the jaws. The muscles were thus made to exert force on the mandible abnormally and thereby stimulate it to abnormal growth and function. Ahlgren (1970) analysed the electromyographic activity of the masticatory muscles in 12 cases of Angle Class III malocclusions. The results confirmed his hypothesis that there was an abnormal muscle function pattern which could be correlated significantly with the dento-facial form of Angle Class III malocclusion. Comparable findings were furnished by Moss (1975) who identified different patterns of muscle activity in the different classes of malocclusions. In addition, the role of the tongue as a local epigenetic factor responsible for the anterior position of the mandible and a wide mandibular arch has been considered by Gensior (1970) who reported a case of large-tongue Class III malocclusion which self-corrected with favourable growth. Pascual (1975) suggested a therapeutic approach which involved modifying the tongue position to influence the horizontal growth of the mandible in the treatment of severe Class III malocclusion in the young patient.

Ross (1963) suggested that dental factors could be implicated in the genesis of Class III malocclusions. These include a bizarre pattern of eruption of the anterior teeth accompanied by an atypical swallowing habit. Another possibility is the prolonged retention of deciduous maxillary anterior teeth forcing the permanent maxillary anterior teeth to erupt lingually. There may also be congenitally missing maxillary anterior teeth resulting in an underdeveloped maxilla.

2.4. DIFFERENTIAL DIAGNOSIS

It is thus apparent that there are three components of the Class III malocclusion related to its causes namely, skeletal, dental and functional. These components can exist in different degrees of severity and in different combinations resulting in a wide variety of

Class III morphology. Many investigators tend to classify Class III malocclusions broadly into two groups based on the etiology. They are the true skeletal Class III exhibiting either maxillary deficiency, mandibular excess or a combination of both and the postural Class III which usually has a functional component. (Blyth 1959; Ross 1963; Gensior 1970; Grossman 1970; Moss 1976).

Postural Class III cases are also known as pseudo-Class III, acquired Class III, functional Class III or pseudo-prognathism. Essentially, the postural Class III is a forward positioning of the mandible attributed to occlusal interferences in the dentition, mandibular postural habits and visceral interferences such as enlarged lymphoid tissue and enlarged tongue which may cause accommodative changes in the posture of the mandible. The skeletal component is usually minimal or absent in this category of Class III (Gensior 1970).

Many authors had recommended that the most significant diagnostic criterion of postural Class III was that the mandible could be retruded comfortably with little effort to an edge-to-edge incisor relationship. (Hopper 1955; Ross 1963). However,there were others who believed that there was no clear demarcation between skeletal and postural Class III cases as the bulk of the cases seen clinically do not fit into either one of the categories but contain characteristics of both. (McCallin 1956; Grossman 1970). Gensior (1970) reported that postural Class III malocclusion due to visceral disturbances may result in an adaptive postural change of the mandible which cannot be altered by digital manipulation or retropositioning. Haralabakis and Spyropoulos (1973) investigated the clinical and cephalometric differences of true skeletal and postural Class III cases. They found that in postural Class III malocclusions, there was forward displacement of the mandible in occlusion associated with overclosure. The ANB angle at rest and in occlusion was comparatively greater than that in true skeletal Class III cases.

Moss (1975, 1976) suggested that a functional analysis of the muscle activities with electromyography might be of value in differentiating skeletal and postural Class III malocclusions. The position of the jaw depends on the interrelationship of the masseter and temporal muscles. A different pattern of muscle activity has been shown to be associated with normal occlusion, skeletal and postural Class III malocclusion in the habitual intercuspal relationship and the retruded contact relationship. Postural Class III malocclusions have a pattern of activity which is nearest to that of normal occlusion while the reverse is true for skeletal Class III cases. The activity of the masseter muscle is increased in postural Class III and reduced in skeletal Class III. The reverse is true for the activity of the posterior temporal muscle in both groups.

Maruyama and Masaaki (1981) also performed a functional analysis of six Class III malocclusions by measuring the antero-posterior distance between centric relation and centric occlusion using the mandibular kinesograph. They found that the antero-posterior distance between centric relation and centric occlusion was greater in functional than skeletal Class III cases.

Besides postural Class III cases, the skeletal Class III group is a heterogeneous combination of many skeletal configurations and the different types constitute differential diagnosis of Class III malocclusion. A thorough cephalometric investigation of the skeletal pattern is thus necessary in reaching a diagnosis and formulating a treatment plan. (Dietrich 1970; Jarabak 1970; Rakosi 1970).

2.5. SKELETAL AND DENTAL COMPONENTS OF CLASS III MALOCCLUSION

Cross-sectional studies in the literature usually compare Class III individuals to either a group of Class I or normal subjects or to existing cephalometric standards. Comparison of mean values is the most commonly employed analytical procedure in those studies. Different investigators used different cephalometric measurements to determine the position of the different parts of the facial skeleton. Generally, these measures of the craniofacial region can be divided into four sets based on the different antero-posterior criteria: maxillary skeletal position, maxillary dentoalveolar position, mandibular dentoalveolar position and mandibular skeletal position. In addition, the vertical configuration of the Class III patient has been considered. The Class III malocclusion results from numerous combination of these components.

Maxillary skeletal position

Sanborn (1955), Ahlgren (1970), Dietrich (1970), Rakosi (1970) and Jacobson and co-workers (1974)reported that the posterior positioning of the maxilla was a common finding in their sample of Class III malocclusions. There was maxillary skeletal retrusion in about one third of Sanborn's cases, 37% of Dietrich's and 25% of Jacobson et al's samples. Ellis and McNamara (1984) however, noted a great prevalence of maxillary skeletal retrusion ranging from 65 to 67% in his sample using the SNA angle and linear distance of point A to nasion perpendicular as the skeletal criteria. On the other hand, Horowitz and co-workers (1969) and Ridell and colleagues (1971) described the maxilla to be within the normal range of prognathism in their samples. In some Class III malocclusions, the maxilla may even be protruded as reported by Ellis and McNamara (1984) in 17 to 25% of their sample.

Maxillary dentoalveolar position

The maxillary anterior teeth may be retroclined, upright or proclined relative to the basal bone. In postural Class III cases, the upper incisors are usually upright or retroclined according to Grossman (1970). In true skeletal Class III malocclusions, maxillary dental protrusion in compensation for the skeletal discrepancy is a common finding as observed by Sanborn (1955), Ahlgren (1970), Rakosi (1970) and Jacobson et al (1974). An incidence of 71-80% of maxillary dental protrusion was reported in Ellis and McNamara's sample which also contained cases (13-20%) showing maxillary dental retrusion. Ridell et at (1971) stated that there was no statistically significant difference in the angulation of the upper incisors between their normal and Class III samples.

Mandibular dentoalveolar position

Like their maxillary counterparts, the mandibular anterior teeth may also be retroclined, upright or proclined relative to the basal bone. In postural Class III cases, the lower incisors are usually proclined due to the forward pressure exerted on them during the anterior slide into centric occlusion (Grossman 1970). On the other hand, mandibular dental retrusion seems to be the rule in the samples examined by Sanborn (1955), Ahlgren (1970), Rakosi (1970), Ridell et al (1971), Jacobson et al (1974) and Ellis and McNamara (1984) which exhibited true skeletal disharmony.

Mandibular skeletal position

The mandible has always been incriminated as the aberrant skeletal component in the Class III malocclusion. Many studies have shown that mandibular skeletal protrusion is, if not the principal anomaly, a major characteristic of the Class III malocclusion. However, there has been much controversy regarding the nature of this mandibular prominence. Mandibular prognathism can be expressed qualitatively or quantitatively in relation to the skeletal structures of the face. Stapf (1948) believed that the prognathic mandibles are qualitatively similar but quantitatively larger than normal mandibles and that both have the same growth pattern. Conversely, Timmons (1960) and Jacobson et al (1974) showed that the difference between the average normal and Class III mandible is not so much a difference of size but rather a difference of morphology. The primary deformity is frequently an increased obliqueness of the gonial angles of the mandible, which causes a normal mandibular body to be displaced anteriorly. In addition, mandibular prognathism may be true or relative due to a shortening and angular bending of the cranial base which also result in relative maxillary retrusion; to changes in the facial skeleton which tends to position the TMJ in a forward position associated with reduced joint angle (S-Ar-Go) and saddle angle (N-S-Ar). (Giorgia et al 1960; Dietrich 1970; Chan 1974).

Vertical development

There are two basic morphological types of Class III malocclusions based on the expression of vertical proportions in the lower anterior facial region. The convergent facial type is associated with a reduced anterior lower facial height seen commonly in the postural Class III cases while the divergent facial type with increased lower facial height are common in the true skeletal Class III cases. (Jacobson et al 1974; Rakosi and Schilli 1981). Stapf (1948) noted that the elongation of the face was the most distinguishing characteristic of his sample. Timmons (1960) had similar findings.

Combinations of components in the Class III malocclusion

The above-mentioned dental and skeletal parameters do not exist in isolation but interact to give the various types of skeletal and dental profiles that are associated with Class III malocclusions. If the law of permutation applies, then a total of 243 combinations of the five skeletodental components, each consisting of three classes namely excessive, normal and reduced, is possible. In fact, Ellis and McNamara (1984) demonstrated 69 actual combinations in their sample.

The relative frequencies of the various combinations of the dental and skeletal dysplasias present in the Class III malocclusion population has been determined by many investigators. The combination of prognathic mandible and normally positioned maxilla represented 45% of Sanborn's sample (1955), 31% of Dietrich's sample (1970), 49% of Jacobson et al 's sample (1974) and only 19.2% in Ellis and McNamara's sample (1984). Pure maxillary skeletal retrusion was noted in 33%, 37%, 25% and 19.5% of Sanborn, Dietrich, Jacobson et al and Ellis and McNamara's samples respectively. The combination of maxillary skeletal retrusion and mandibular skeletal protrusion was the most frequent combination of skeletal anomalies found in Ellis and McNamara's study, representing 30.1% of the sample. This was in contrast to the 9.5%, 1.5% and 6% in Sanborn, Dietrich and Jacobson et al's samples respectively. Ellis and McNamara (1984) also reported that the most prevalent combination of skeletal and dental components consisted of maxillary skeletal retrusion, maxillary dental protrusion, mandibular dental retrusion, mandibular skeletal protrusion and excessive lower facial height which constituted 12.3% of their sample of 302 adults.

2.6. CHARACTERISTICS OF THE CLASS III PROFILE

From the foregoing review, it can be seen that there is a broad spectrum of Class III malocclusions which imply that there is no single, typical facial skeletal pattern for individuals with this type of malocclusion. However, certain characteristics of the average Class III profile have been identified for evaluation and diagnostic purposes.

Sanborn (1955) claimed that the most striking difference between the Class III facial pattern and the normal was expressed in Downs' angle of convexity which is usually negative, indicating that the profile is concave in outline. Sperry and colleagues (1977) suggested that in profile evaluation of patients with Class III malocclusions, attention should be focussed on the facial contour angle, nasolabial angle and the relative protrusion of the lower lip since these are the distinguishing characteristics.

A typical Class III profile appears midfacially deficient with a prominent lower jaw, procumbent and everted lower lip and excessive chin height. The paranasal and canine fossae areas are often flat, the nasolabial angle is usually increased and there is a lack of labiomental contour or presence of a contour deficient chin. These characteristics exist in different degrees of severity. The soft tissue drape does not seem to be able to camouflage the skeletal deviations to produce facial harmony and balance. (McCallin 1956; Bell and Jacobs 1981; Carlotti and George 1981; Ellis and McNamara 1984).In addition, the soft tissue nose may even reveal a concave configuration along the dorsum according to Chaconas' findings (1969).

CHAPTER 3

GROWTH OF THE FACE IN PROFILE

Hellman (1933) studied the skulls of American Indians and soft tissue measurements of 526 males and 670 females in approximately the age range of 5 to 25 years. He concluded that the face grew most in depth, then in height and least in width. In the course of transformation, the face gradually moved forward and changed in relative position to the cranium. The female face became relatively longer and the male face relatively deeper.

Brodie (1941) conducted a longitudinal study on the postnatal facial growth pattern of 21 white male children from the third month to the eighth year of life. He observed that the facial profile was established at about 3 months of age and continued to grow proportionally until 8 years of age. In 1953, he presented the results of another longitudinal study on the facial growth pattern of another sample of 19 individuals (sex distribution not mentioned) from eighth year to approximately 17th years of age. His findings indicated that faces developed in an orderly manner, adhering to an original proportionality which contradicted the conclusions of Bjork's investigations in 1951. Bjork stated that an increased prognathism of both jaws was characteristic of profile changes with age but the increase was greater in the mandible than the maxilla which account for the straightening of the facial profiles from the age of 12 to 20 years in his sample comprising of Swedish males only.

Lande (1952) produced evidence to substantiate Bjork's findings. In a serial cephalometric study of 34 white males, he reported a very distinct difference in growth behaviour of the maxilla and the mandible in an antero-posterior direction from the age of 4 to 17 years. The mandible tended to become more prognathic between the ages of 7 to 17 years while the maxilla showed very little change and this reduced the convexity of the face.

It must be noted, however, that both Bjork and Lande based their inferences on measurements taken in references to skeletal landmarks. Contrasting information may be drawn from measurements related to soft tissue landmarks as shown by Pelton and Elsasser in 1955. It was an extensive cross-sectional growth study on profile changes of 3,676 white males and 3,153 white females in the age range of 5 to 24 years. They reported that facial prognathism increased with age in both sexes but the increase was greater in the upper jaw region, resulting in increased convexity of the facial profile with age in both sexes. This discrepancy in opinions was resolved in 1959 by Subtelny who performed a longitudinal study on the profile changes of 30 subjects of equal sex distribution with normal skeletal profiles from three months to 18 years of age. He explained that with growth, both the skeletal and integumental chins assumed a more forward relationship to the cranium. Although the bony and integumental chins were closely related, the soft tissue profile excluding the nose remained relatively constant after 6 years old unlike the skeletal profile which became less convex with age. When the nose was included in the profile analysis, increase in facial convexity with age was observed due to downward and forward growth of the nose.

The above review of early studies on growth of the skeletal and soft tissue profiles indicated that there is a difference in the growth pattern of the hard and soft tissues of the face. Growth of the face in profile is therefore the result of complex interaction of these different growth components with time.

3.1. GROWTH AS AN INTEGRAL PROCESS

Growth and development does not take place at a smooth orderly rate. Different parts of the body grow at different rates. This pattern of differential growth with periods of accelerations in growth velocities at different chronological ages is characteristic of craniofacial growth and development. Generally, the growth rate is highest immediately after birth, falling rapidly until five to six years of age, levelling out till there is a further increase during the pubertal growth spurt between the ages of ten to sixteen years old. Thereafter, the growth rate decreases till adulthood when growth is completed. (Bjork 1972; Woodside et al 1975). The timing of the infantile, juvenile and pubertal growth spurts for the various craniofacial dimensions are not synchronous within the same individual and vary between individuals of the same chronological age and may sometimes be absent. (Lewis et al 1985; Woodside et al 1975).

Facial dimensions in height and depth changes with the periodic character of growth. The total face height from nasion to menton increases rapidly after birth and is about 85-90% completed by the usual orthodontic age of about 10 to 12 years. The final 10-15% increase in facial height occurs during the pubertal growth spurt and extends into the third decade of life. The total facial height in males tends to be longer than in females.

Facial depth increases the least in the upper face and the greatest in the lower face area from the age of 5 to 14 years old. This is in accordance with the observation that the face grows out from beneath the brain case. The growth in depth of the midfacial region is between the two extremes. This differential growth in depth of the upper, middle and lower face suggests that the lower face grows downward and forward faster than the midface, which in turn grows faster than the upper face. That is, the child's convex profile presumably straightens as adulthood is reached. (Gianelly and Goldman 1971).

3.2. AGE CHANGES IN THE SOFT TISSUE DIMENSIONS

3.2.1. Nose

The form and profile of the nose depend upon both the bony and cartilaginous components and the overlying muscles and the integument. Its form and shape continue to change significantly after the age of 3 years and at least until the age of 18 years. There is an appreciable amount of growth during the later stages of development as well as during the earlier stages which implied that the rate of nasal growth does not seem to decrease appreciably with age as is typical of the growth pattern established for the skeletal structures of the upper face which form the nasal cavity. There may be a growth spurt in males between the 10 to 16 years of age and in females at about 12 years old associated with growth of the nasal bones. After the growth spurt, the nose continues to grow downward and forward but to a lesser degree than before. Generally, the bridge of the nose formed by the nasal bones and the cartilaginous aspect of the nose seemed to maintain conformity from age to age. However, in the majority of boys and relatively fewer girls who exhibit nasal growth spurt, there are concomitant changes in the relationship of the nasal bones to the cranium. The nasal bones show a tendency to deviate from their downward and forward path of growth and to project or become inclined in a more forward direction probably due to forward growth of the supporting nasal septal cartilages according to Chaconas (1969) and Chaconas and Bartroff (1975). This phenomenon is probably responsible for the concomitant manifestation of a hump or elevation in the profile of the bridge of the nose. (Subtelny 1959,1961). This elevation of the bridge would be less apparent if there is a comparable and associated forward positioning of the more inferior aspect of the nasal profile particularly the tip of the nose which usually seems not to be the case as shown by Posen (1967) and Wisth (1972) in their longitudinal studies.

The increase in nasal length measured from nasion to the tip of nose from 1 to 18 years of age is similar in both sexes although the average nasal length for boys is greater at all age levels than that observed for girls. Each three year interval revealed a 3 to 5 mm. increase in nasal length. In both sexes the increment in the vertical height of the nose with age was much greater than the average increment in the anteroposterior or horizontal dimension of the nose. That is, the nose tends to grow longer vertically in both sexes although the dimensions are larger in males. (Subtelny 1959; Posen 1967; Chaconas and Bartroff 1975). Sexual dimorphism was noted in the increase in horizontal growth of the nose by Subtelny (1961). According to Chaconas and Bartroff (1975), males had smaller horizontal nasal dimensions than females at about 10 years old but by 15 years old, they had surpassed the females by exhibiting 1.5 to 2 times as much growth in this dimension. Their findings supported Posen (1967)'s observations that boys tend to have larger nasal component dimensions than girls although girls appeared to have attained greater maturity in nasal and facial form than did boys at comparable ages. Thus the sum total of the effect of the growth of the nose on the configuration of the soft tissue profile is to make the facial profile more convex with age.

3.2.2. Lips

The upper and lower lips are two fleshy folds which surround the orifice of the mouth. They are lined with mucous membrane and contain the orbicularis oris muscle, blood vessels, nerves, areolar tissue, fat and labial glands.(Hambleton 1964). Hence the growth of the lips tend to follow the general growth curve for muscle and other connective tissue within the body. Both the upper and lower lips progressively increase in length until the age of 15 years when the rate of growth in length is reduced significantly. There is little discernible increment occurring between 15 and 18 years of age. The total increment in lower lip length from 1 to 18 years of age is slightly greater than that of the upper lip. There is no sex difference in increment of upper and lower lip length with growth. (Subtelny 1959, 1961).

Both upper and lower lips grow in thickness from 1 to 18 years of age. A marked increase in thickness occurred between the ages of 12 and 14 years according to Mamandras (1984). The increase in thickness of both lips is considerably greater at the vermilion level than in the region overlying skeletal point A, skeletal point B and skeletal pogonion. Sexual dimorphism was noted with the males showing greater increase in lip thickness especially in the upper lip than the females. (Burstone 1959; Subtelny 1959; Mamandras 1984).

There was a fairly constant vertical relationship of both upper and lower lips to their respective underlying alveolar processes and anterior teeth as was reported by Subtelny. After the full eruption of the maxillary central incisors, the upper lip was found to maintain a fairly constant vertical relationship to prosthion and the upper incisal edges. Similarly, the lower lip showed the same relative stability in its vertical relationship to infradentale and the lower incisal edges.

The anteroposterior posture of the lips was also closely related to the teeth and the alveolar processes according to Subtelny. In general, he observed that the dento-alveolar structures tended to recede and upright relative to the facial plane of the skeletal profile during the times of increase in mandibular prognathism and decrease in the convexity of the bony profile with age. The vermilion aspect of the lips, especially of the lower lip, was observed to concomitantly become more retruded in relation to the facial profile. In a few instances where the dentition and the alveolar processes became more protrusive relative to the facial plane with age, the lips also showed the same directional modification and were protrusive within the facial profile. Thus he concluded that there was a strong interrelationship between the lips and the dento-alveolar structures.

3.2.3. Chin

The bony chin is formed by the expression of differential growth potentials, in terms of timing and direction, between the basal bone of the mandibular body and the alveolar bone of the dento-alveolar complex. Presumably, the mandibular alveolar bone and the basal bone "shift" in such a way that the dentition regresses posteriorly while the mental protuberance progresses anteriorly. (Biggerstaff 1977).

Subtelny demonstrated that the integumental chin was very closely related to the position of the bony chin. As the bony chin assumed a more forward relationship to the cranium with growth, the integumental chin followed likewise. In addition, the amount of increase in the prominence of the soft tissue chin was closely correlated to the degree of change in the prominence of the skeletal chin. Sex differences were noted in the magnitude of increase in mandibular prognathism. Although females were more prognathic at a younger age, males showed "catch-up" growth at later ages with greater total increment in the degree of skeletal and soft tissue prognathism from 7 to 18 years of age.

3.2.4. Integumental covering

The average thickness of the soft tissue overlying the bony nasion tended to remain constant or decrease slightly with age in both sexes. However, the thickness was shown to be greater in males by Subtelny (1959). The thickness of the soft tissue overlying skeletal point A increased with growth in thickness of the upper lip and again the increase was greater in males. The soft tissue thickness overlying the bony chin also increased more in males with age.

Comparatively, the increment in soft tissue thickness overlying skeletal point A was considerably greater than the soft tissue change occurring at bony pogonion which in turn was greater than the change at bony nasion. Thus the soft tissue drape is not equally distributed in thickness over the midsagittal bony structures. The soft tissue profile convexity excluding the nasal structures will remain relatively stable with age despite forward growth of the bony and integumental chin due to the greater increase of soft tissue thickness overlying point A. (Subtelny 1961; Wisth 1972; Mauchamp and Sassouni 1973).

3.3. CLASS III GROWTH

The straightening of the skeletal profile with age in normal individuals implied that the Class III profile will worsen with time since the soft tissue covering of the face is unable to compensate for the extreme skeletal deviations which result in facial disharmony and imbalance of the Class III face. With normal growth in thickness of the soft tissue mass, the lower lip usually becomes more protruded and the integumental chin becomes more prominent as mandibular growth continues. (van der Linden 1983).

Generally, there are three patterns of growth associated with the Class III malocclusion. They are the hyperdivergent growth pattern commonly associated with posterior rotation and increased vertical growth, neutral growth pattern where growth is downward and forward and hypodivergent growth pattern associated with anterior growth rotation and predominantly horizontal growth. Siriwat (1985) conducted an epidemiologic study on the relationship between malocclusion and facial morphology in 500 patients. He found that among the subjects with Class III malocclusions, 18.8% had hyperdivergent growth pattern, 31.2% had neutral growth and the remaining 50% demonstrated hypodivergent growth. Bimler (1970) attributed these growth patterns to three types of systemic growth disturbances: hypodivergent pattern due to micro-rhinic dysplasia of the maxillary complex which result in decreased midfacial height and compensatory overclosure; hyperdivergent pattern due to leptoid dysplasia where all sagittal dimensions are reduced while the length of the mandible is increased; neutral growth pattern due to microtic dysplasia of the spheno-occipito-temporal complex which result in anterior positioning of the TMJ and Class III development.

Jacobson et al (1974) studied the differences in craniofacial and dental patterns between the child and adult Class III malocclusion and demonstrated dominance of mandibular growth. As anticipated, practically all the mean linear parameters were statistically significantly larger in the adult group than corresponding values in the children. Dominant mandibular growth was reflected by the significantly larger SNB angle in the adults as compared with that in the children which implied that point B is carried forward by growth. The upper and lower incisors exhibit more compensatory response to the anteroposterior dysplasia of the apical bases from childhood to adulthood. The lower incisor retroclination may be the result of a restraining effect upon the crowns by the encircling orbicularis oris musculature while the roots were being carried forward by active growth of the mandible.

Prediction of future growth of the Class III malocclusion is difficult as there is a diversity in growth pattern after puberty. Bassani (1970) reported that some individuals exhibit remarkable spurts in mandibular growth in the postadolescent period, especially the hereditary types of Class III. Schulhof et al (1977) identified four cephalometric 'predictor measurements' which would indicate the likelihood of the patient growing in an abnormal Class III manner. These were measurements of the ramus position, porion position, cranial base deflection and the Class III molar relationship. These data, according to them, would give the clinician insight as to which patients might require early orthopedic treatment, conventional orthodontic treatment, or surgical-orthodontic correction after growth is completed.

CHAPTER 4

BEGG TECHNIQUE AND CLASS III TREATMENT

4.1. PHILOSOPHY AND PRINCIPLES OF THE BEGG TECHNIQUE

The technique was developed by Dr. Begg following his studies on Stone Age Man's dentition as exemplified in the Australian aborigine's occlusion and realization of the need for an efficient orthodontic appliance that would permit, rather than restrict, tooth movement with application of relatively light pressures. (Begg 1954).

The concept of the Stone Age Man's attritional occlusion as the anatomically correct occlusion was the rationale for extraction of teeth in orthodontic treatment. The extraction of teeth simulated attrition when absent, and balanced tooth size and arch length discrepancies. (Begg 1956). In addition, mesial movement of posterior teeth was advocated to take advantage of the physiologic, mesial force; distal movement of teeth was considered unphysiological which would result in relapse and impaction of the third molars. (Sims 1964).

Light differential forces were utilized to move groups of teeth simultaneously, each group movement reciprocally assisting all other groups and producing a balanced flow of correctional movements. All the anchorage that was required for the various movements of the teeth was developed intraorally through the use of highly resilient "Wilcock" wires with anchorage bends and light elastic traction. No extraoral anchorage was used or deemed necessary with the Begg Technique. The use of light continuous forces or light stimulation had been shown to provide the optimum impetus to produce rapid tissue reactions, thus shortening treatment time. (Begg 1968).

The Begg Technique utilised light round archwires and orthodontic attachments incorporating a single point of contact and narrow mesio-distal dimensions for simple tipping movements of crowns of all teeth in all directions mesial to the anchor molars in Stage I and Stage II. The anchor molars were corrected and maintained in an upright position throughout treatment and this was the only incidence in Stage I and Stage II where there was application of force to prevent simple tipping of teeth and to effect root control. At the end of Stage II, the crowns of all teeth mesial to the anchor molars were tipped back. These teeth were then put back into their correct axial relations in Stage III through the use of auxiliaries which were placed simultaneously to position teeth in their correct axial inclinations and to establish correct occlusal function and esthetics. The inherent design of the Begg attachment permitted the use of these auxiliaries in conjunction with the main archwire. This delegation of the source of tooth-moving forces from the archwire to auxiliaries for the major portion of the treatment was a unique feature of the Begg Technique. Thus bodily movement of teeth was achieved by first tipping the crowns back and then the roots through the use of torquing and uprighting auxiliaries. (Begg 1968; 1977).

4.1.1. THE THREE STAGES OF TREATMENT(Begg and Kesling 1977)

There were three stages of treatment, each stage with its own objectives which should be accomplished prior to the commencement of the next stage to ensure a balanced and continuous flow of tooth movements for the rapid attainment of the final treatment results.

Objectives of Stage I

These include the overcorrection of the incisor relationship in both horizontal and vertical planes, achieving an edge-to-edge incisor relationship in Class I and II malocclusions and positive overjet and overbite in Class III cases. Alignment of upper and lower anterior teeth, overcorrection of rotations and mesio-distal relationship of the buccal segments and correction of posterior crossbites were the other objectives of Stage I.

Objectives of Stage II

All corrections achieved in Stage I were maintained in this Stage with closure of any remaining posterior extraction spaces.

Objectives of Stage III

The axial inclinations of all teeth were corrected at this Stage while maintaining the corrections achieved in Stage I and II.

4.1.2. ANCHORAGE

Hocevar (1981) defined anchorage as that which experiences and provides resistance to the reaction of a force system employed to achieve a desired tooth movement. Anchorage control in orthodontic treatment has been a 'continuing crisis' according to Sims (1975).

In the Begg Technique, anchorage was totally derived intra-orally via the tip-back or anchorage bends. The tip-back bends produced a distally directed force on the crown of the molars and mesially directed force on their root apices. Together with the use of light intermaxillary elastics, a dynamic anchorage system was developed which was efficient in the correction of deep anterior overbites, severe overjet or reverse overjet and overbite in Class III cases. (Sims 1971).

Anchorage variation with the Begg Technique could be achieved through changing the position and degree of the tip-back bend and varying the diameter of the archwire. Thus, in selected cases where augmentation of anchorage or promotion of its loss was desired, the dynamic variation of the anchorage system would produce differential forces to bring about the desired tooth movement. (Sims 1971, 1977).

4.1.3. ELASTIC TRACTION

Elastic traction function as a synergistic component of Begg appliance as was stressed by Sims (1971). Optimal intermaxillary elastic traction would not strain anchorage while excessive elastic force would result in movement of the anchor teeth in both the horizontal and vertical planes.

In addition, the appropriate direction of the elastic force could reinforce 'vertical anchorage' as was shown by Adler (1969) and Hocevar (1982). In low-angle cases where overbite reduction was difficult, both Adler and Hocevar suggested the usage of intermaxillary "check elastics" with one end over the posterior end of the upper archwire, both strands under the end of the lower archwire and the other end attached to the canine circles. This configuration of elastic traction would counteract the distal tipping of the lower and upper molars, thus increasing the efficiency of bite opening in Stage I and anchorage maintenance against the adverse effects of torquing and uprighting auxiliaries in Stage III.

4.1.4. FINISHING

The concept of finishing in the Begg Technique was to minimise relapse rather than to overcome relapse. All cases were finished with the teeth in superocclusion; the teeth were placed in overcorrected positions with deliberate controlled irregularities which tend to simulate the reversed pattern of the original malocclusion. Balanced occlusion was finally attained through the gradual settling of the teeth under physiological stresses in function. (Begg and Kesling 1977).

A Stage IV has been added to the Begg Technique by Thompson (1981, 1985) with the objectives of achieving final detailing of tooth positions and precision finishing. However, is precision finishing necessary and justified as occlusion is not static but in dynamic function within the oral environment which is also in a dynamic equilibrium? Will today's equilibration be equal to tomorrow's functional imbalance?

4.2. CLASS III TREATMENT

Generally, there are three methods of treatment of the Class III malocclusion, namely the orthodontic, orthopedic, and combination of surgical and orthodontic approaches. The choice of the method of treatment is largely determined by the severity of the underlying skeletal III pattern. Jacobson et al (1974) recommended an ANB angle of up to -3.5 degrees as a limiting factor in adopting the orthodontic approach. Antero-posterior discrepancy greater than -3.5 degrees would generally require surgical intervention. However, they stressed that this suggestion should be viewed as a guideline rather than the rule. Sperry and co-workers (1977) found that the orthodontically treatable Class III group generally had a significantly smaller mandibular plane angle and exhibit the convergent facial pattern. Class III cases which are already severely overcompensated are not amenable to orthodontic treatment. (Rakosi and Schilli 1981).

4.2.1. TIMING OF TREATMENT

The timing of treatment in relation to growth is especially important in Class III malocclusions in order to achieve stability of treatment results. Early treatment with orthopedic appliances such as the chin cup, reverse headgear or functional corrector III was advocated by many investigators including Rakosi (1970), Grossman (1970), Neumann (1970) and Rakosi and Schilli (1981). The aims of early treatment is to correct the reversed incisor relationship which has a restricting effect on the growth and development of the maxilla so that optimal growth of the maxilla can take place. In addition, it was believed that inhibition and redirection of the mandibular growth was possible through the application of heavy orthopedic forces in the young patient. The mandible rotates downwards and backwards during treatment, resulting in an improvement in the apical base relationship. However, redirection of growth of the mandible is successful only in cases who exhibit a lack of posterior vertical development of the maxillary and mandibular alveolar processes. On the other hand, there were other workers who were sceptical of the rationale of early treatment. Kloeppel (1970) believed that not all Class III cases would get worse with age. On the basis of favourable genetic background, mild mandibular prognathism would not change unless there were variations in the environmental factors. Instead, he advocated that treatment should commence after eruption of the permanent incisors. Stockli (1970) expressed similar views.

Orthodontic treatment in the permanent dentition stage should be undertaken at the end of the pubertal growth spurt in order to reduce relapse due to precocious growth of the mandible (Kameda 1982). Treatment consists of achieving dento-alveolar compensations for the skeletal discrepancy and partial skeletal improvement is possible (Rakosi and Schilli 1981).

4.2.2. TREATMENT WITH THE BEGG TECHNIQUE

There is a scarcity of literature on the use of the Begg appliance in the correction of the Class III malocclusion. Dr Begg (1977) himself only made a passing remark that this class of malocclusion should be treated as early as possible in order that normal function and growth can take place. However, this does not imply that the technique is unsuitable for the treatment of Class III malocclusions. According to Rodesano (1971, 1974), the correction of the Class III incisor relationship by the reciprocal proclination of the upper incisors and retroclination of the lower incisors is most easily achieved with the Begg appliance which permits free tipping of all teeth mesial to the anchor molars in Stage I. Normal incisor relationship is usually achieved within the first two months of treatment.

The treatment of Class III malocclusion has been regarded as equivalent to the treatment of a Class II Division I malocclusion in the inverted manner. Stage I archwires are designed with vertical loops for antero-posterior expansion of the arch. A molar stop may be incorporated mesial to the molar tube. Class III intermaxillary traction is used to correct the incisor relationship. Anchorage bends need not be steep as its role is mainly to preserve anchorage. (Rodesano 1974).

Adequate overbite retention is necessary to minimise relapse of the corrected incisor relationship. (Mills 1966; Chan 1974). The Class III elastic traction has an extrusive effect on the upper molars and the lower incisors which lead to canting of the occlusal plane. Rodesano considered the canting desirable in achieving overbite control. However, Kameda (1983) felt that the extrusion of the upper molars would result in a reduction of the overbite and the retroclination and extrusion of the lower incisors would result in a long and narrow symphysis. These effects were considered detrimental to the stability of the treatment results as the original cant of the occlusal plane would return after treatment. Furthermore, the vertical step between the extruded upper first molar and the second molar would cause occlusal disharmony and associated TMJ dysfunction. Therefore, he suggested the use of Class III elastics should be minimised as far as possible. An alternative would be the use of lower intramaxillary elastics to achieve normal incisor relationship in Stage. I. This would result in excessive retroclination of the lower incisors and possible fenestrations on the labial alveolar plate. Both Mills (1966) and Rodesano (1971, 1974) believed that the best method of correction of the Class III incisor relationship was to procline the upper incisors with simultaneous retroclination of the lower incisors so that they remained in a position of muscular balance. Rodesano (1974) also stated that lingual root torque of the lower incisor root apices would enhance the stability of the occlusion after treatment. Continued forward growth of the mandible would then move the apices labially, with the overbite maintaining the incisor crown position.

Cheng (1984) stressed that the key to success in the orthodontic treatment of Class III malocclusion lay in the expansion of the upper arch both laterally and antero-posteriorly to compensate for its deficiency. Whenever possible, the maximum number of teeth should be kept in the upper arch. Extractions should be done in the lower arch whenever there is a need to retrocline the lower incisors.

4.2.3. LIMITATIONS OF ORTHODONTIC TREATMENT

The orthodontic correction of the Class III malocclusion is restricted to changes in the axial inclination of the teeth; that is building in more dental compensations for the skeletal aberrations. The post treatment stability is limited by the unfavourable growth tendencies of the mandible and improvement in facial aesthetics is limited to improvement of lip balance and harmony. The total prognathic facial profile is altered very little by orthodontic treatment. Overcompensations of the anterior teeth to 'mask' the skeletal discrepancy can lead to traumatic bite resulting in alveolar bone loss and loosening of the teeth and all its consequences. (Grossman 1970).

Unlike Class II elastics which has an activator effect on the growth of the mandible, Class III elastics have very limited influence on the actual growth of the mandible or maxilla. Shortening of the mandible or inhibition of its growth is not accomplished. The elastics merely extrude the upper molars as the maxillary dentition moves forward. This rotates the mandible and the lower teeth downwards and backwards, trading a Class III prognathism for a potential long face. (Creekmore 1978).

The present study on profile changes in Class III malocclusions treated with the Begg Technique has the objectives of verifying these limitations of orthodontic treatment on improvement of the Class III facial profile and the associated hard and soft tissue changes.

SECTION II

Original Work

CHAPTER 5

MATERIALS AND METHODS OF PRESENT STUDY

5.1. SUBJECT SELECTION

The sample consisted of 44 true lateral cephalograms of 11 females and 11 males with mean ages of 14.4 years and 15.1 years respectively at the commencement of treatment. These cases were selected from the files of the Orthodontic department at the United Dental Hospital, Westmead Centre and The Royal Adelaide Hospital. Sample selection was based on these criteria:

A) Presence of Class III incisor relationship (excluding anterior open bite and anterior cross-bite related to craniofacial anomalies including clefts of the lip and palate) as determined from the pre-treatment lateral cephalogram, study casts, photographs and clinical diagnosis of the operator. No skeletal criteria were used.

B) Orthodontic treatment instituted had been according to the philosophy and principles of the Begg Technique and should be successfully completed with the establishment of normal incisor relationship and normal buccal occlusion.

C) Availability of true lateral cephalograms taken before commencement of treatment and at bands off which satisfied the following cephalometric criteria:

a) Good hard and soft tissue definition on the radiograph.

b) Teeth in centric occlusion and lips reposed on the radiograph as verified by photographs and study casts.

c) No orthodontic appliances in place on the radiograph.

d) Both pre- and post-treatment radiographs should be taken with the same cephalometric X-ray unit and orientated with the same cephalostat with consistent source-target-film distance to ensure uniformity of magnification in both films of each patient.

5.2. DEFINITION OF HARD AND SOFT TISSUE LANDMARKS AND CEPHALOMETRIC PLANES

Eleven hard tissue and nine soft tissue landmarks that could be related to stable reference planes before and after treatment were selected to evaluate profile changes both quantitatively and qualitatively. (Figure 5.1.). These landmarks were identified according to the following definitions by Graber (1958), Burstone (1959), Riolo et al (1974) and Holdaway (1983).

Hard Tissue Landmarks

Sella (S) The centre of the contour of pituitary fossa of the sphenoid bone determined by bisecting the sagittal diameter of the fossa and the height from tuberculum sellae to the floor of the fossa.

Nasion (N) The most anterior and superior point of the fronto-nasal suture on the midsagittal plane.

Subspinale (A) The deepest point on the midline contour of the alveolar process between anterior nasal spine and prosthion. It is usually at the level and anterior to the apex of the upper central incisor.

Upper incisor apex (UIA) The root tip of the upper central incisor.

Incision Superius (Is) The incisal edge of the crown of the most anterior upper central incisor.

Incision Inferius (Ii) The incisal edge of the crown of the most anterior lower central incisor.

Supramentale (B)	The deepest point on the midline contour of the alveolar process between infradentale and pogonion. It is usually anterior to and slightly below the apex of the lower central incisor.
Lower incisor apex (LIA)	The root tip of the lower central incisor.
Pogonion (Pog)	The most anterior prominent point on the contour of the bony chin or symphysis of the mandible.
Menton (Me)	The lowest point of the contour of the mandibular symphysis.
Gonion (Go)	The most posterior, inferior and outward point on the angle of the mandible.

Soft Tissue Landmarks

Glabella (G)	The most prominent point in the midsagittal plane of the forehead.
Soft Tissue Nasion (N')	The point of intersection of the sella-nasion line with the soft tissue profile.
Columella (Cm)	The most anterior point on the columella of the nose.
Subnasale (Sn)	The point at which the nasal septum between the nostrils merges with the upper cutaneous lip in the midsagittal plane.
Superior Labial Sulcus (SLS) (Sulcus Superius)	The point of greatest concavity in the midline of the upper lip between subnasale and labrale superius.
Labrale Superius (LS)	The median point in the upper margin of the upper membranous lip.
Labrale Inferius (LI)	The median point in the lower margin of the lower

membranous lip.

Inferior Labial Sulcus (ILS) (Sulcus Inferius): The point of greatest concavity in the midline of the lower lip between labrale inferius and soft tissue pogonion.

Soft Tissue Pogonion (pog'): The most prominent or anterior point of the chin in the midsagittal plane.

Cephalometric Planes

Sella-Nasion Plane: The line joining sella and nasion which indicates the anteroposterior extent of the anterior cranial base.

Mandibular Plane: The line joining gonion and menton as defined in Downs' analysis. (1948).

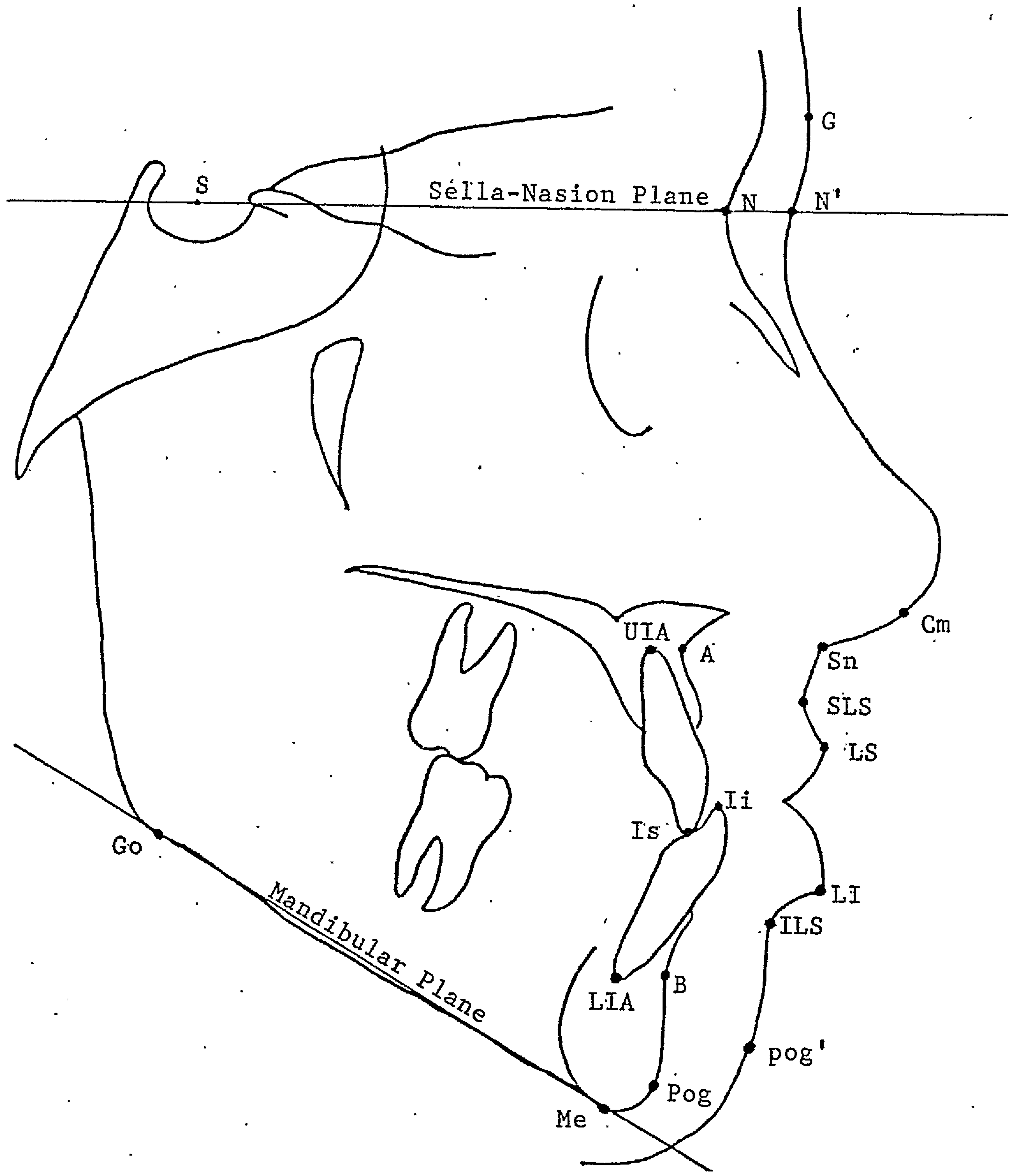

Figure 5.1. Hard and soft tissue landmarks and cephalometric planes used in this study.

5.3. LINEAR AND ANGULAR MEASUREMENTS

Tracings of the hard and soft tissue structures and landmarks on each radiograph were made on 0.003 inch thick matte acetate tracing papers which were firmly attached to the headfilms placed on an illuminated view box. The tracings were done with a well-sharpened medium hard (No. 3H) pencil and angular measurements were made with the Baum's cephalometric protractor to the nearest 0.5 degree. Four dentoskeletal and three soft tissue angles were constructed and measured. (Figures 5.2. and 5.3.). The angles of convexity of the skeletal profile and the soft tissue profile were assigned positive and negative signs to denote the degree of convexity and concavity. The change in the magnitude of each of these seven angles was determined by subtracting the pre-treatment values from the post-treatment results. A positive change indicated that there was an increase in the size of the angle after treatment. The reverse was true for negative changes. A positive change in the angles of convexity of the skeletal and soft tissue profiles implied that there was a decrease in the concavity of the profile or an increase in convexity.

Linear changes of hard and soft tissue landmarks which were susceptible to treatment effects were determined by the superimpositional method, using sella-nasion plane and the constructed perpendicular to sella-nasion plane at sella as the horizontal and vertical reference planes respectively. The sella-nasion plane was chosen in preference to the Frankfort Horizontal because unlike the Frankfort Horizontal plane which was based on bilateral structures (orbitale and porion), the sella-nasion plane was constructed with the aid of the midsagittal structures which were displaced to a minimum degree by projection and which could be more readily located, thus reducing the sources of error. (Krogman 1958).

The horizontal and vertical reference planes were constructed on the pre-treatment tracing. The post-treatment tracing was then superimposed on the pre-treatment tracing to obtain maximum coincidence for the anterior wall of the sella turcica, the anterior contours of the middle cranial fossa, the contour of the cribriform plate and the cerebral surfaces of the orbital roofs which were considered stable structures of the anterior cranial base according to Bjork and Skieller (1983). The sella-nasion line and the constructed perpendicular at sella on the pre-treatment tracing were then transferred to the post-treatment tracing. (Figure 5.4.). A transparent grid with one millimetre squares was then placed over the superimposed tracings. The linear horizontal and vertical displacements of Point A, Incision Superius, Incision Inferius, Point B, Subnasale, Superior Labial Sulcus, Labrale Superius, Labrale Inferius, and the Inferior Labial

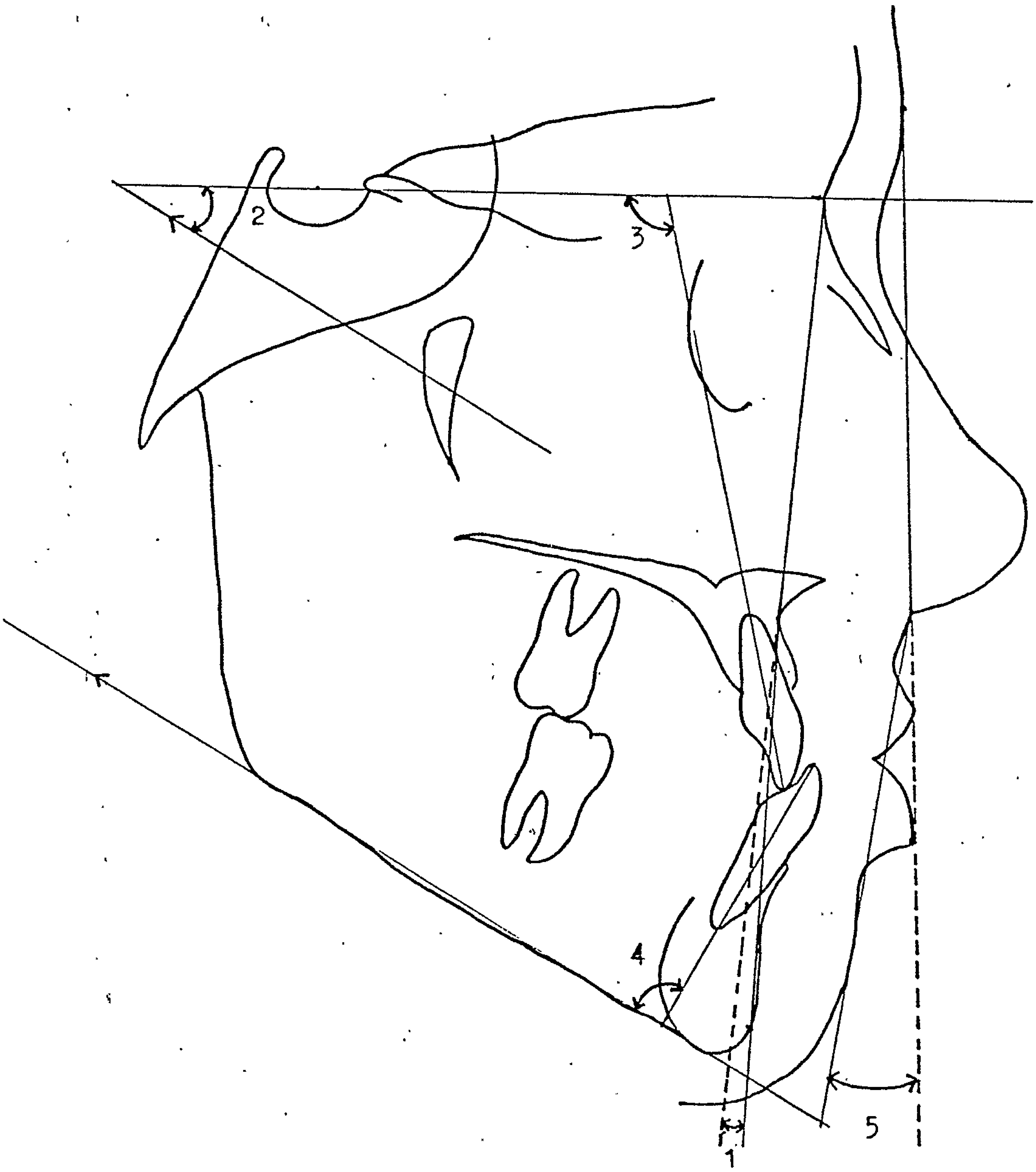

Figure 5.2. Angular Measurements.

1. Angle of convexity of the skeletal profile;
2. Mandibular plane angle;
3. Upper incisor to SN angle;
4. Lower incisor to Mandibular plane angle;
5. Angle of convexity of the soft tissue profile.

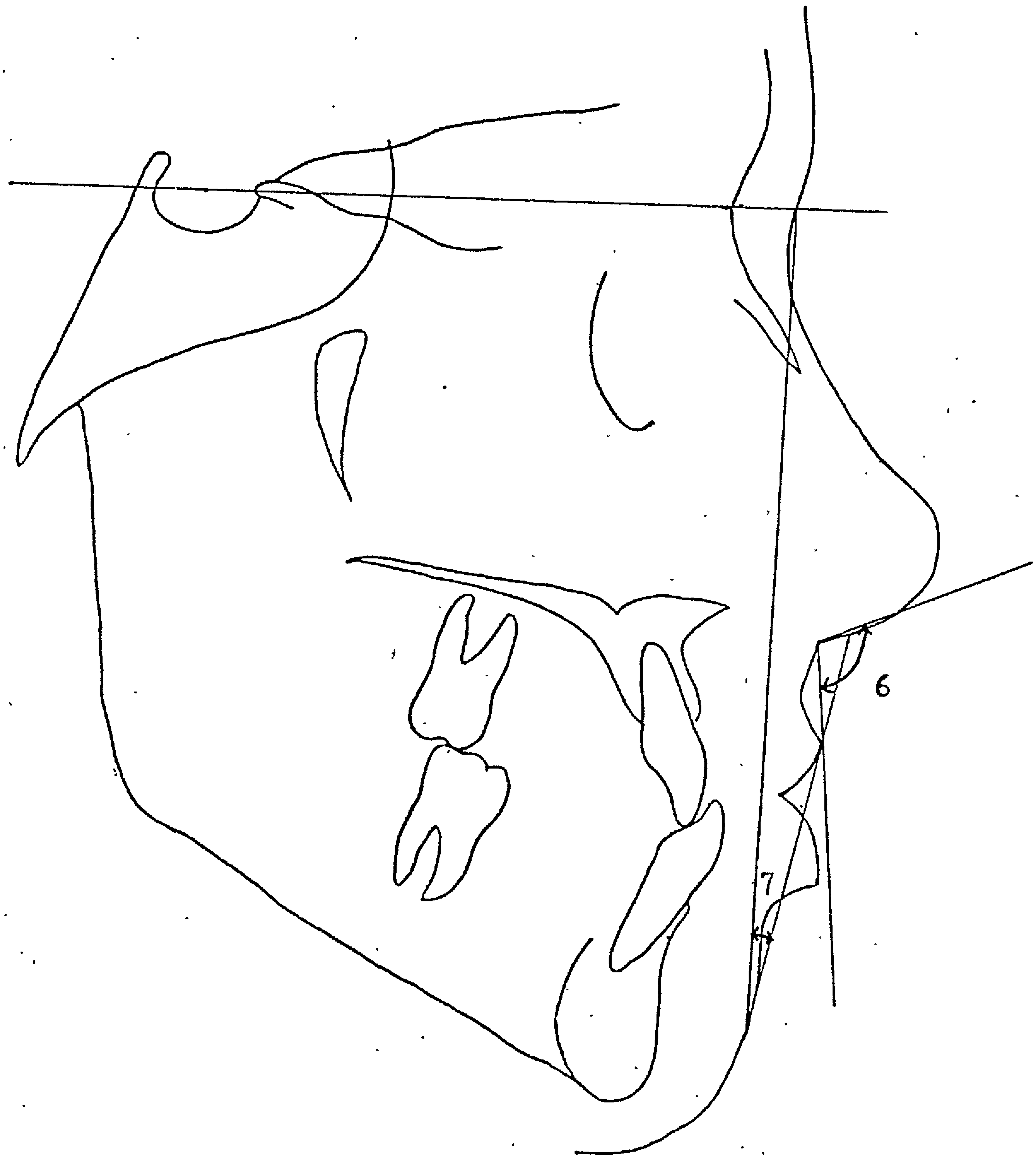

Figure 5.3. Angular measurements.

6. Nasolabial angle;

7. Holdaway angle.

Sulcus relative to sella-nasion line and the perpendicular at sella were determined by the number of squares between the landmarks at the two timepoints. (Figure 5.5.). The net vertical and horizontal movement of each point was noted with a positive sign for downward and forward displacement and negative sign for upward and backward displacement relative to the reference planes. All linear measurements were made to the nearest 0.5 mm.

5.4. ERROR OF THE METHOD

Errors due to projection and wrong positioning of the patient's head during exposure were minimised by using midsagittal landmarks as far as possible. If bilateral structures appeared as two shadows such as the point Gonion, the average point was plotted and measured. According to Broadbent et al (1975), the error in averaging right and left side structures at a 60 inch anode-object distance was about 0.043 mm. or negligible. In addition, the use of angular measurements for these structures would further minimise the error of projection. (Krogman 1958).

No correction was made for the linear magnification error although linear measurements were made of the landmarks lying in the midsagittal plane. This was because there was uniformity of magnification in both pre- and post-treatment films and only absolute values of hard and soft tissue changes were considered. In addition,

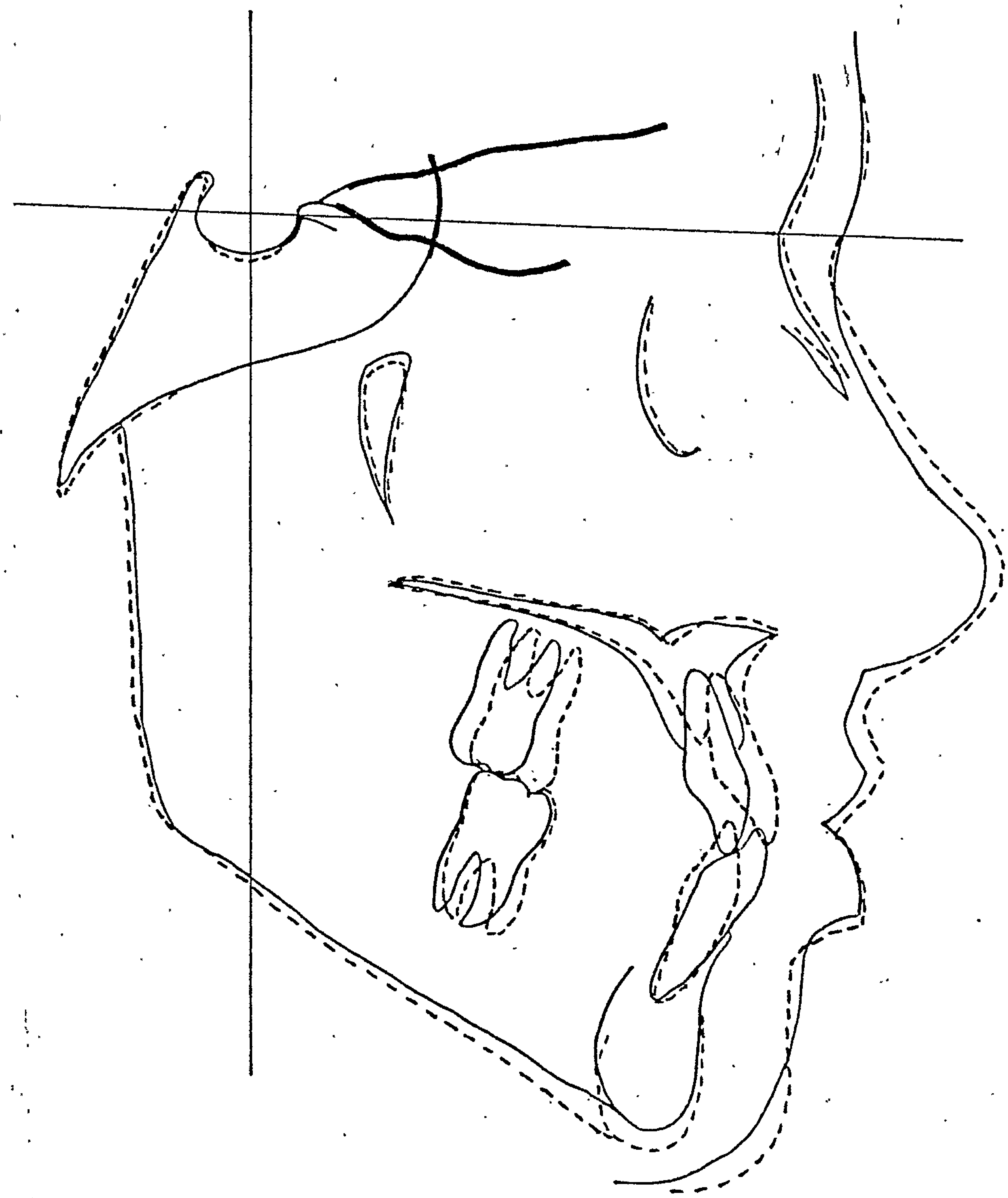

Figure 5.4. Superimposition on anterior cranial base structures (stressed contours) and horizontal and vertical reference planes.

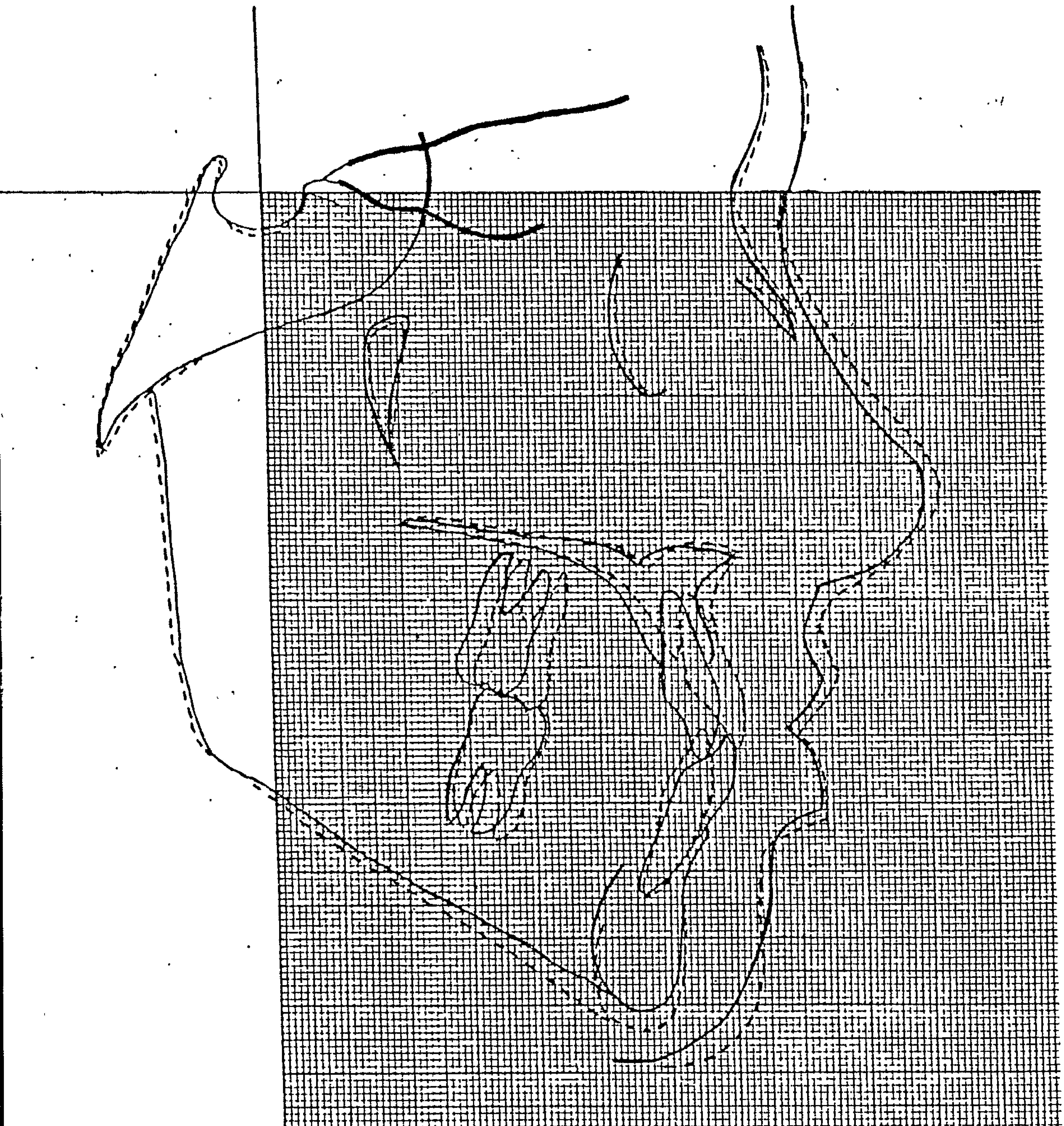

Figure 5.5. Linear vertical and horizontal changes measured with a one millimetre square grid.

changes which were one millimetre or less would be disregarded in the final analysis of results as these were probably insignificant. Graber (1958) has shown that the magnification error using the standardised Broadbent cephalometric technique was less than one millimetre or the width of the pencil line in tracing.

The combined error in locating the anatomic landmarks, tracing, superimposition and measurement was determined by the double determination method. All the radiographs were traced and measured twice by the same investigator on two occasions separated by an interval of about two weeks with the exception of the seven cases whose records were at the Royal Adelaide Hospital. For these seven cases, only the superimposition and measurement procedures were repeated.

The mean difference between the first and second determination for each linear and angular variable was calculated. The significance of the mean difference from zero for each linear and angular variable was assessed usingthe 't' test. The calculated values of 't' for each linear and angular variable were found to be lower than the 't' value at the 50% level. This impliedthat there was insufficient evidence to reject the null hypothesis at this level. Thus there was no significant difference between the two sets of measurements at the 50% level.

The combined error of the method was insignificant and would not influence the accuracy of the analysis.

The average of the two determinations for each linear and angular variable was used in the statistical analysis of the results.

CHAPTER 6

RESULTS

A statistical analysis of the data was applied according to accepted standard procedures. The mean, standard deviation and range of linear and angular changes were shown in Table I.

It was deemed unnecessary to group the data to reflect age and sex responses since the objective of the study was to determine the relationship of changes within the individual rather than between individuals.

6.1. OVERALL PROFILE CHANGES

Both the angles of convexity of the skeletal and soft tissue profiles showed a mean positive change of 0.66 and 1.23 degree respectively after treatment. These changes were very small and probably not noticeable clinically. The larger change in the soft tissue angle was probably associated with the forward growth of the nose which continued into adulthood. (Subtelny 1959).

The mean change in the convexity of the upper lip as measured by the change in the Holdaway angle was 0.23 degree which was negligible.

The mandibular plane angle opened by an average of 0.44 degrees which was again negligible. Thus the correction of the Class III occlusion was not achieved by the backward rotation of the mandible with extrusion of the upper molars through the use of Class III elastic traction.

The mean changes in the angulation of the upper and lower incisors to the sella-nasion plane and the mandibular plane respectively were large. The upper incisors were proclined by an average of 5.24 degrees while the lower incisors were retroclined by an average of 7.22 degrees.

The upper incisal edges moved downwards and forwards by an average of 0.80 mm. and 2.39 mm. respectively due to growth and treatment. The lower incisal edges were displaced upwards and backwards by an average 0.16 mm. and 2.43 mm. respectively. The vertical changes were small and negligible compared to the anteroposterior movements of the incisors which were largely manifestation of treatment effects.

Skeletal points A and B were both displaced downwards relative to the sella-nasion reference plane by 1.17 mm. and 0.63 mm. respectively. These were probably growth changes and they were insignificant. Point A moved forwards by an average of 0.91 mm. while point B was retracted backwards by an average of 0.30 mm. These treatment changes in both directions were small and insignificant.

The upper lip became more prominent after treatment as reflected in the decrease in the nasolabial angle by an average of 1.81 degrees. Both the superior labial sulcus and labrale superius moved forwards by an average of 1.36 mm. and 1.58 mm. respectively with growth and treatment. The larger change at the vermilion border indicated that the upper lip form or curl was maintained. There was also a downward displacement of the superior labial sulcus by an average of 1.81 mm. and the labrale superius by an average of 1.42 mm. These vertical movements were a combination of growth and treatment effects as Rakosi (1970) had reported that the upper lip would become thinner and longer with proclination of the incisors.

Subnasale moved downwards and forwards by an average of 1.25 mm. and 1.14 mm. which indicated that nasal growth had occurred.

The lower lip was retracted by 0.53 mm. and 0.34 mm. at labrale inferius and inferior labial sulcus respectively. These treatment changes were small and insignificant. Labrale inferius and inferior labial sulcus moved inferiorly by an average of 1.19 mm. and 1.00 mm. due to growth and treatment.

Table I. Linear and angular changes of hard and soft tissue variables with treatment. (n = 22)

	VARIABLE		MEAN CHANGE	STD. DEV.	VARIANCE	STD ERROR OF MEAN CHANGE	COEFF. OF VARIATION	MEDIAN	MINIMUM	MAXIMUM	RANGE
1.	N A Pog		0.66	2.88	8.31	0.61	437.29	0.38	-5.50	5.25	10.75
2.	MPL SN		0.44	1.88	3.52	0.40	423.55	0.75	-3.50	4.25	7.75
3.	1 to SN		5.24	6.64	44.15	1.42	126.83	3.50	-4.00	17.25	21.25
4.	1 to MP1		-7.22	3.93	15.41	0.84	-54.41	-6.88	-13.50	-1.25	12.25
5.	G Sn pog'		1.23	2.25	5.05	0.48	183.16	1.13	-4.00	5.50	9.50
6.	NASOLABIAL		-1.81	4.80	23.02	1.02	-263.88	-0.38	-14.00	5.50	19.50
7.	HOLDAWAY		0.23	2.82	7.97	0.60	1242.15	0.25	-5.00	6.75	11.75
8.	POINT A:	A-P change	0.91	1.34	1.78	0.28	146.88	0.50	-1.50	3.00	4.50
9.	POINT A:	S-I change	1.17	2.07	4.28	0.44	176.80	0.50	-3.00	6.00	9.00
10.	INCISION SUPERIUS:	A-P change	2.39	2.86	8.17	0.61	119.79	2.00	-2.00	8.00	10.00
11.	INCISION SUPERIUS:	S-I change	0.80	2.39	5.69	0.51	299.83	0.50	-3.00	5.50	8.50
12.	INCISION INFERIUS:	A-P change	-2.43	2.26	5.12	0.48	-93.05	-2.75	-6.25	1.75	8.00
13.	INCISION INFERIUS:	S-I change	-0.16	2.67	7.13	0.57	-1678.91	-0.25	-4.50	6.25	10.75
14.	POINT B:	A-P change	-0.30	2.06	4.24	0.44	-696.60	0.00	-4.00	5.00	9.00
15.	POINT B:	S-I change	0.63	2.54	6.44	0.54	406.19	0.00	-5.50	5.50	11.00
16.	SULCUS SUPERIUS:	A-P change	1.36	1.66	2.75	0.35	121.57	1.50	-1.75	4.75	6.50
17.	SULCUS SUPERIUS:	S-I change	1.81	2.12	4.50	0.45	117.32	1.00	-1.25	5.00	6.25
18.	LABRALE SUPERIUS:	A-P change	1.58	2.20	4.86	0.47	139.56	1.63	-2.25	6.00	8.25
19.	LABRALE SUPERIUS:	S-I change	1.42	2.54	6.45	0.54	178.86	0.75	-2.75	7.50	10.25
20.	LABRALE INFERIUS:	A-P change	-0.53	2.45	6.01	0.52	-459.15	0.00	-7.00	4.00	11.00
21.	LABRALE INFERIUS:	S-I change	1.19	3.65	13.29	0.78	305.55	2.38	-4.50	6.50	11.00
22.	SULCUS INFERIUS:	A-P change	-0.34	2.05	4.21	0.44	-601.98	0.00	-4.00	4.25	8.25
23.	SULCUS INFERIUS:	S-I change	1.00	2.65	7.05	0.57	265.59	1.25	-6.00	6.00	12.00
24.	SUBNASALE:	A-P change	1.14	1.76	3.10	0.38	154.93	1.00	-2.00	5.00	7.00
25.	SUBNASALE:	S-I change	1.25	1.72	2.95	0.37	137.32	0.50	-1.00	4.00	5.00

Key:
1 - 7 were angular variables
8 - 25 were linear variables
A - P denotes antero-posterior change
S - I denotes supero-inferior change

Table II. Correlation matrix between dentoskeletal and soft tissue variables.

Correlation between two variables was significant for values above 0.43 or below -0.43 at $P < 0.05$. Values above 0.65 or below -0.65 were highly significant at $P < 0.001$.

****** CORRELATION MATRIX ******

v1	1.00																								
v2	0.40	1.00																							
v3	-0.006	-0.20	1.00																						
v4	-0.10	-0.23	0.32	1.00																					
v5	0.53	0.22	0.18	-0.25	1.00																				
v6	0.20	0.08	-0.43	0.13	-0.16	1.00																			
v7	0.38	0.24	0.52	0.00	0.70	-0.45	1.00																		
v8	0.08	0.32	-0.15	-0.22	-0.22	0.39	-0.27	1.00																	
v9	0.08	-0.02	0.01	0.09	-0.12	-0.05	-0.16	0.14	1.00																
v10	0.38	0.24	0.11	0.21	0.11	0.36	0.21	0.19	-0.38	1.00															
v11	-0.09	-0.22	0.01	-0.04	-0.26	-0.10	-0.17	-0.01	0.77	-0.39	1.00														
v12	0.19	-0.03	0.14	-0.29	0.34	0.04	0.08	0.27	-0.22	0.39	-0.07	1.00													
v13	0.21	0.005	0.19	-0.009	-0.02	-0.03	0.18	0.04	0.54	0.04	0.66	-0.14	1.00												
v14	0.02	0.27	-0.07	-0.20	0.17	0.13	-0.03	0.47	-0.11	0.26	-0.15	0.76	-0.33	1.00											
v15	0.04	0.02	-0.10	-0.04	-0.11	-0.12	0.09	-0.08	0.47	-0.17	0.55	-0.44	0.82	-0.50	1.00										
v16	0.47	0.10	-0.11	0.09	0.05	0.51	0.01	0.42	-0.10	0.61	-0.18	0.26	0.22	0.26	0.04	1.00									
v17	-0.22	-0.54	-0.10	0.17	-0.52	0.13	-0.36	0.008	0.49	-0.21	0.61	-0.35	0.56	-0.46	0.57	0.19	1.00								
v18	0.39	0.16	-0.10	0.13	0.05	0.35	0.01	0.46	-0.002	0.53	-0.17	0.27	0.05	0.45	-0.10	0.89	0.09	1.00							
v19	-0.28	-0.46	-0.17	0.20	-0.38	0.17	-0.34	-0.12	0.40	-0.24	0.51	-0.44	0.55	-0.62	0.67	0.03	0.86	-0.16	1.00						
v20	0.33	0.32	0.10	-0.27	0.47	0.04	0.28	0.27	-0.14	0.45	-0.19	0.78	0.009	0.77	-0.22	0.48	-0.43	0.49	-0.46	1.00					
v21	0.04	-0.02	-0.22	0.02	-0.36	0.10	-0.39	0.39	0.49	-0.20	0.43	-0.28	0.41	-0.21	0.51	0.22	0.59	0.31	0.50	-0.28	1.00				
v22	0.30	0.02	0.15	-0.05	0.41	0.11	0.27	0.15	-0.02	0.44	-0.006	0.83	-0.01	0.74	-0.30	0.39	-0.25	0.40	-0.38	0.82	-0.26	1.00			
v23	0.15	0.00	-0.34	0.08	-0.46	0.24	-0.43	0.50	0.40	-0.19	0.42	-0.28	0.46	-0.08	0.56	0.26	0.54	0.27	0.50	-0.22	0.89	-0.31	1.00		
v24	0.30	0.11	-0.14	0.07	0.21	0.10	0.06	0.19	0.47	0.20	0.25	0.31	0.18	0.46	0.07	0.42	0.13	0.62	-0.08	0.39	0.28	0.56	0.13	1.00	
v25	0.02	-0.31	0.08	0.25	-0.34	0.24	-0.27	0.12	0.62	-0.02	0.70	-0.19	0.79	-0.37	0.66	0.22	0.81	0.10	0.78	-0.23	0.59	0.12	0.57	0.16	1.00
	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v 12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	v24	v25

v1 - N A Pog; v2 - MPL SN; v3 - 1 to SN; v4 - 1 to MPL; v5 - G Sn pog'; v6 - Nasolabial; v7 - Holdaway;
v8 - Point A: A-P; V9 - Point A: S-I; v10 - Incision Superius: A-P; v11 - Incision Superius: S-I;
v12 - Incision Inferius: A-P; v13 - Incision Inferius: S-I; v14 - Point B: A-P; v15 - Point B: S-I;
v16 - Sulcus Superius: A-P; v17 - Sulcus Superius: S-I; v18 - Labrale Superius: A-P; v19 - Labrale Superius; S-I;
v20 - Labrale Inferius: A-P; v21 - Labrale Inferius: S-I; v22 - Sulcus Inferius: A-P; v23 - Sulcus Inferius: S-I;
v24 - Subnasale: A-P; v25 - Subnasale: S-I

6.2. RELATIONSHIPS BETWEEN HARD AND SOFT TISSUE CHANGES

The interrelationships among hard and soft tissue variables were studied primarily by means of correlation coefficients. The matrix of correlation between dentoskeletal and soft tissue variables were shown in Table II. By applying the **'t'** test, the level of significance was determined for the correlation coefficients. Correlation between two variables in this study was significant for values above 0.43 or below -0.43 at $P < 0.05$. Values above 0.65 or below -0.65 represent highly significant correlations at $P < 0.001$.

Significant positive correlation was found between the changes in the angles of convexity of the skeletal and soft tissue profiles. (Coefficient of correlation $r = 0.53$). Thus an increase in the convexity of the skeletal profile with treatment would be followed by an increase in the soft tissue profile convexity. The change in the convexity of the skeletal profile was also correlated with the change in the antero-posterior position of the superior labial sulcus ($r = 0.47$).This suggests that an increase in the convexity of the skeletal profile at skeletal point A would result in the forward positioning of its soft tissue analogue, the superior labial sulcus.

The change in the mandibular plane angle was correlated with the change in the vertical position of the upper lip in the opposite direction (**r** = - 0.54 at superior labial sulcus, **r** = - 0.46 at the labrale superius). As the upper lip was positioned inferiorly with growth, there was a corresponding reduction in the mandibular plane angle which was also largely a manifestation of growth changes.

There were correlations between the change in the angulation of the upper incisor and the change in the nasolabial angle as well as the Holdaway angle (**r** = - 0.43 for nasolabial angle; **r** = 0.52 for Holdaway angle). Thus as the upper incisors were proclined during treatment, the nasolabial angle would become more acute with increased prominence of the upper lip resulting in an increase in the Holdaway angle.

No significant correlation was noted between the change in the angulation of the lower incisor to the mandibular plane and any of the soft tissue variables. This implied that the angulation of the lower incisor was not a good indicator of its anteroposterior spatial position since the linear vertical and horizontal changes of the lower incisal edge relative to the reference planes were highly correlated with some of the soft tissue variables, particularly with the horizontal position of the lower lip.

There was a highly significant positive correlation of 0.83 between the change in the anteroposterior position of incision inferius and the change in the horizontal position of the sulcus inferius of the lower lip. The horizontal spatial position of the lower incisor was also closely related to the horizontal position of the labrale inferius of the lower lip (**r** = 0.78). Thus the retraction of lower incisors would influence the position of the lower lip which was highly desired in Class III individuals whose lower lips were usually protruded. A negative correlation of 0.44 was noted between the supero-inferior movement of labrale superius of the upper lip and the position of the incision inferius. Thus as the lower incisors were retracted, the upper lip would move downwards as a result of both treatment and growth.

The linear vertical change in the position of the lower incisor was more closely correlated with the change in the vertical position of the upper lip than the lower lip (**r** = 0.56 for sulcus superius ; **r** = 0.55 for labrale superius ; **r** = 0.46 for sulcus inferius). These correlations could be attributed to the change in postural position of both the upper and lower lips with treatment, possibly more in the upper lip due to the correction of the reversed incisor relationship and, of course, to growth changes.

The correlation between the change in the anteroposterior position of the upper incisor and the upper lip at sulcus superius and labrale superius was not as highly significant as that observed for the lower lip and lowerincisor changes (**r** = 0.61 for sulcus superius ; **r** = 0.53 for labrale superius). However, these correlations were more significant than that determined for the upper incisor and lower lip changes at sulcus inferius and labrale inferius (**r** = 0.44 for sulcus inferius; **r** = 0.45 for labrale inferius). These findings corroborated the results of Ricketts (1981) and Saxby and Freer (1985)'s studies which support the role of the upper incisor in establishing both upper and lower lip balance.

A similar pattern of correlation was expressed in the linear vertical changes of the positions of the upper incisor, upper and lower lips. There was better correlation between upper incisor and upper lip changes than between upper incisorand lower lip changes (**r** = 0.61 for sulcus superius ; **r** = 0.51 for labrale superius ; **r** = 0.43 for labrale inferius).

Skeletal points A and B were closely related to their soft tissue analogues in both directions of movements. The coefficients for antero-posterior change of point A and B with the sulcus superius and sulcus inferius were 0.46 and 0.74 respectively. In the vertical direction, the correlation coefficients for change of points A and B with their soft tissue counterparts were 0.49 and 0.56 respectively. Again this reflected that there was better correlation between hard and soft tissue structures in the horizontal plane in the lower lip region than in the region of the upper lip. Thus the repositioning of points A and B due to tooth movement would be accompanied by similar changes at sulcus superius and sulcus inferius.

In summary, it was evident from the correlation analysis that the relative protrusion and retrusion of the lips was closely related to the antero-posterior position of the incisors. The correlation between the lower lip and lower incisor was stronger than that between the upper lip and upper incisor which was in turn stronger than that between the lower lip and upper incisor. In terms of vertical relationships, there was a difference in the correlation patterns. Stronger correlation was noted between the upper incisor and upper lip in the vertical plane than between the lower incisor and lower lip. Both upper and lower incisor seemed to have equal influence on the vertical position of the lower lip. In addition, it was observed that the vertical position of the upper lip was also closely related to the vertical position of the lower incisor in this sample of Class III cases. As shown in Table III, it was found that the mean ratio for the retraction of the lower incisor in relation to the lower lip was 1.1 : 1. Proclination of the upper incisor was related to the upper lip in the ratio of 2 : 1.

Table III. Summary of statistical evaluations

	r	mean ratios
Upper incisor : upper lip	+ 0.53	2.0 : 1
lower incisor : lower lip	+ 0.78	1.1 : 1

CHAPTER 7

DISCUSSION

Many studies have been done to determine profile changes concurrent with orthodontic treatment. This tendency reflects the importance of facial esthetics and the role the orthodontist might have in influencing facial balance. In fact, the desire to improve one's facial appearance has been the motive of many who seek orthodontic treatment and, consequently, it is not surprising that orthodontists include improvement of facial esthetics as one of their goals in treatment.

Orthodontic treatment is confined to dento-alveolar changes in the mouth which can affect lip balance and harmony if the soft tissue mass is indeed a drape over the underlying skeletal and dental framework. However, the studies of Burstone (1958, 1959) and Subtelny (1959, 1961) clearly indicate that there are differences in the morphology and posture of the soft tissues in different individuals which may enhance the facial profile or exaggerate its disharmony and imbalance.

In addition, the soft tissue mass exhibits a growth pattern which is quite different from the supporting skeletal structures. The nose in particular, continues to grow into adulthood. This has an important influence on the overall facial profile and can give an aged or "dished-in" look to the individual if the lips and the underlying dentition are retracted too far back. Variation has always been the rule in biology and this applies to the soft tissue response and behaviour during growth and treatment. Improvement of the occlusion with treatment is not always accompanied by a corresponding improvement in the facial appearance and profile.

Therefore, it is important to the orthodontist to be able to identify and establish any interrelationships between hard and soft tissue changes during treatment which could enable him to predict the soft tissue response to a given amount of tooth movement. This explains the voluminous literature on studies done with these objectives in mind.

Studies by Bloom (1961), Rudee (1964), Hershey (1972), Angelle (1973), Wisth (1973), Anderson et al (1973), Garner (1974) and many others in recent years all tend to relate the movement of lips to incisor movement, particularly to the retraction of the upper incisors in the treatment of Class II division 1 malocclusions. A survey of the orthodontic literature revealed that very few studies have been done to evaluate profile changes and quantitate hard and soft tissue changes in the orthodontic treatment of Class III malocclusions, let alone treated with the Begg Technique.

The lack of emphasis on determination of profile changes with orthodontic treatment of Class III malocclusions could be attributed to the low incidence of Class III malocclusions in the general population which makes the collection of a sample of reasonable size to implement a proper study extremely difficult. Furthermore, many of these Class III cases are usually treated surgically for it is believed that orthodontic treatment would not correct the mandibular prognathism and improve the total facial profile.

This retrospective study was conducted within the constraint of difficulty in sampling which resulted in a small heterogeneous collection of individuals of different ages, sex and ethnic origin treated by different operators at different places. All these factors could affect the accuracy of the findings and the validity of the conclusions drawn from the study. Although the method of analysis of profile changes using cephalograms was considered adequate by many investigators, there were limitations related to the inherent difficulty in using soft tissue landmarks due to their relative instability. Changes in facial expression would result in change in positions of these soft tissue points. However, the replicability of the relaxed lip position which was the lip posture chosen for assessment in this study has been tested and found to produce errors of statistically insignificant magnitude by Burstone (1967) and Hershey (1972). Therefore the use of this parameter would generate minimum errors in the analysis. However, all conclusions drawn from the statistical analysis must be considered in the light of the overall measurement error which was real although shown to be statistically insignificant.

There was an improvement in the overall profile as reflected by the positive change in the angles of convexity of both the hard and soft tissue profiles. However, the change was very small especially for the skeletal profile convexity and could be attributed to measurement error. This finding was in contrast to that reported by Lin et al (1985) who demonstrated a large increase of 3.08 and 5.46 degrees in the skeletal and soft tissue profile convexity respectively after treatment with upper removable and lower fixed appliances and Class III traction. Although direct comparison cannot be made between this study and their study since the samples were different in composition, a similar trend in the relationship between hard and soft tissue changes was noted. The soft tissue change appeared to be bigger and could be attributed to the forward growth of the nose at subnasale.

There was virtually no change in the Holdaway angle in spite of the labial movement of the upper incisor which increased the prominence of the upper lip relative to the overall soft tissue profile. This stable relationship between the chin and the upper lip was also reported by Koch et al (1979) who explained that continued forward growth of the chin tends to cancel out the effect of proclination of the upper incisors on the upper lip prominence.

The mandibular plane angle remained relatively constant with treatment, a finding which was also reported by Mills (1966) and Lin et al (1985). Class III elastic traction did not seem to have an extrusive effect on the upper molars which would bring about cant of the occlusal plane as was reported by Kameda (1983).

The Class III incisor relationship was corrected by reciprocal proclination of the upper incisors and retroclination of the lower incisors. The Class III elastic traction did not have any significant effect on the apical base relationships as was shown by the relatively insignificant changes at both skeletal points A and B. This observation corroborated the findings of studies by Mills (1966), Rodesano (1971, 1974), Kameda (1983) and Lin et al (1985).

The correlation analysis revealed that there was a definite relationship of the hard and soft tissue structures in the region of the mouth. There was significant correlation between the movements of the lips and incisors in both the horizontal and vertical planes. These findings compared favourably with the results of Subtelny's (1959, 1961) studies which showed that there was a constant horizontal and vertical relationship of the lips with the underlying dento-alveolar structures. A strong correlation was noted between the lower lip and lower incisor which was also reported by Bloom (1961) and Rudee (1964) although in their studies, the lower lip was retracted in relation to the retraction of both the upper and lower incisors. This tendency of the lower lip to follow the lower incisor movement is favourable in the improvement of the lower facial profile in Class III cases whose lower lips are usually protruded.

There was also strong correlation between the labial movement of the upper incisor and the upper lip. The nasolabial angle became more acute indicating that the upper lip has moved forward. Koch et al (1979) had similar observations although they could not quantify the amount of labial movement of the upper lip which was favourable in the improvement of the Class III lip profile.

In this study, an attempt was also made to identify the vertical relationships of the incisors and the lips. A significant relationship was noted between the vertical position of the upper lip and the lower incisor. Comparison of this finding with other studies could not be done as there were no investigations in this direction.

SUMMARY AND CONCLUSIONS

Relatively few studies have been done to qualify and quantify the effects of orthodontic treatment on the facial profiles of individuals with Class III malocclusions. The present study was carried out with the objectives of evaluating the net hard and soft tissue changes of the Class III profile with Begg orthodontic treatment. Pre- and post-treatment lateral cephalograms of 11 males and 11 females with mean ages of 15.1 years and 14.4 years respectively were selected according to a few criteria. Under standardised conditions, pre- and post-treatment (at bands off) tracings of 11 hard tissue and 9 soft tissue landmarks as well as the associated hard and soft tissue structures of the facial profile were made for each case. Angular change was determined by subtracting the pre-treatment values from the post-treatment results. Horizontal and vertical linear changes of selected landmarks were measured relative to the sella-nasion plane and its perpendicular at sella of the pre-treatment tracing after superimposition on the anterior cranial base structures. The error of the method was tested by the double determination method and shown to be statistically insignificant.

Significant changes were noted in the angulations of the upper and lower incisors. The upper incisor was proclined by an average of about five degrees while the lower incisor was retroclined by a slightly greater amount which averaged about seven degrees. Corresponding significant changes were observed in the linear antero-posterior position of the upper and lower incisal edges. The mean change was about two millimetres in both anterior and posterior directions. Linear and angular changes of the skeletal profile and the dental bases represented by points A and B were small and insignificant.

Significant angular change of the soft tissue was reflected in the nasolabial angle which decreased by an average of about two degrees. The soft tissue profile increased in convexity by an average of about one degree which was small but significant compared to the change in the skeletal profile. Linear changes of the upper and lower lips were smaller compared to the linear changes of the incisors. The average change ranged from about 1 to 1.5 mm. in the antero-posterior direction. Linear vertical changes of the soft tissues were generally insignificant with the exception of the upper lip which moved downwards by an average of two millimetres.

Correlation analysis confirmed the interrelationships of incisor movements and lip positions. There were significant correlations between the retraction of the lowerincisorand lower lip ($r = 0.78$) as well as the proclination of the upper incisor and forward movement of the upper lip ($r = 0.53$). Significant correlation was also noted between the vertical position of the upper lip and the lower incisor ($r = 0.55$). The mean ratio of retraction of the lower incisor to lower lip was found to be 1.1 : 1 and the mean ratio of proclination of the upper incisor to anterior movement of the upper lip was 2 : 1.

Thus it can be concluded that:

1. Begg orthodontic treatment has little or no effect on any hard tissue structures other than dento-alveolar processes.
2. Orthodontic correction of the Class III incisor relationship was achieved by the reciprocal proclination and retroclination of the upper and lower incisors respectively.
3. Light Class III intermaxillary traction has insignificant effect on the vertical position of the maxillary molars.
4. The overall soft tissue profile seemed to have improved with increase in convexity. However, the change was very small which indicated that definite conclusion cannot be made.
5. Lip profile seemed to have improved with forward movement of the upper lip and backward movement of the lower lip, thus reducing the relative fullness of the

lower lip which is a characteristic of the Class III profile. However, the changes were again very small, and therefore definite conclusions cannot be drawn.

6. Orthodontic treatment of Class III malocclusion can influence mainly the perioral soft tissues, chiefly the position of the lips.
7. The position of the lips was closely related to the configuration of the underlying hard tissues chiefly the position of the anterior teeth.
8. Both retraction and proclination of the incisors would be accompanied by corresponding lip changes of a smaller magnitude generally.
9. The vertical position of the upper lip was closely related to the vertical position of both the upper and lower incisors in Class III cases.

As this was a retrospective study, the limitations of availability of reliable records drastically reduce the size of the sample pool which together with the constraint of the low incidence of Class III malocclusion in the general population made it extremely difficult to standardise the composition of the sample. Standardisation is certainly ideal in enhancing the accuracy of the results and increasing its clinical applicability. A prospective study is thus indicated in order that the size of the sample can be increased without compromising on its uniformity and homogeneity.

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Appendix

I SUMMARIES OF DATA

Table A - 1. Ages of males at commencement of treatment treatment and duration of active treatment.

Case	Ages (yrs.)	Duration of active treatment (yrs.)
3	16	2.3
6	16	2.5
8	22	1.7
10	15	1.6
11	14	0.8
14	11	1.3
16	14	1.1
17	13	1.6
19	17	2.0
21	13	0.4
22	15	0.6

Mean age = 15.1 years.
Mean duration of active treatment = 1.5 years.

Table A - 2. Ages of females at commencement of treatment and duration of treatment.

Case	Ages (yrs.)	Duration of active treatment (yrs.)
1	14	1.8
2	15	1.3
4	14	2.6
5	25	1.9
7	15	1.3
9	10	1.8
12	12	1.5
13	15	1.3
15	11	1.8
18	13	0.9
20	14	0.9

Mean age = 14.4 years.
Mean duration of active treatment = 1.6 years.

Table A - 9. Values of first and second determinations for each linear and angular variable.

Linear and angular variables

First determination

CASE	N A Pog	MPL SN	1 to SN	1 to MPL	G Sn Pog	NASOLABIAL	HOLDAWAY	Pt A A-P change	Pt A S-I change	Incision Superius A-P change	Incision Superius S-I change	Incision Inferius A-P change	Incision Inferius S-I change	Pt B A-P change	Pt B S-I change	Sulcus Superius A-P change	Sulcus Superius S-I change	Labrale Superius A-P change	Labrale Superius S-I change	Labrale Inferius A-P change	Labrale Inferius S-I change	Sulcus Inferius A-P change	Sulcus Inferius S-I change	Subnasale A-P change	Subnasale S-I change
1	-1.50	0.00	- 0.50	- 0.50	- 1.50	0.00	- 5.00	3.00	2.00	3.00	5.00	2.00	3.00	2.00	3.00	2.00	5.00	2.00	3.50	1.50	6.00	1.50	-3.00	2.00	4.00
2	-1.00	0.50	7.00	-10.00	2.00	- 4.00	2.50	-2.00	0.00	0.00	0.00	-3.50	-4.50	0.00	-2.50	0.00	1.00	0.00	2.00	-2.50	1.00	-2.00	0.00	1.00	0.00
3	1.00	-1.50	- 1.00	- 5.00	- 1.00	6.00	- 2.00	0.50	2.00	-2.00	4.00	-4.00	1.50	-2.00	4.00	0.00	3.00	-1.00	8.00	-2.00	4.50	-2.00	4.00	0.00	4.00
4	3.00	0.50	3.00	-11.00	3.00	3.00	- 1.00	1.00	2.00	-1.00	1.00	-6.00	-2.00	-4.00	1.00	-1.50	5.00	-1.00	4.00	-7.00	2.00	-4.00	0.00	0.00	2.00
5	5.00	1.00	13.50	- 4.00	5.50	- 3.00	6.00	1.00	0.00	5.00	-3.00	-5.00	-2.00	-3.00	1.00	4.00	5.00	4.00	6.00	-2.00	3.00	-2.00	1.00	0.00	2.00
6	3.00	3.00	10.00	- 8.00	0.00	0.00	1.00	1.00	1.50	5.00	1.00	-6.00	4.00	-4.00	6.00	1.00	2.00	0.00	4.00	-5.00	5.00	-3.00	6.00	0.00	4.00
7	-4.50	-4.50	12.00	- 2.00	- 4.00	- 9.00	- 1.00	3.00	-1.00	9.00	-3.00	2.50	-4.50	5.00	-5.00	3.00	-2.50	4.50	-3.50	5.00	-5.00	4.50	-1.00	2.00	0.00
8	3.00	1.00	- 1.00	-12.00	2.00	0.00	1.00	4.00	-2.50	2.50	-4.00	1.50	-4.00	1.00	-1.00	2.00	0.00	2.00	0.00	0.00	4.00	0.00	2.00	1.00	0.00
9	1.00	-2.00	12.00	-12.00	5.00	- 3.00	1.00	1.00	3.50	2.00	1.00	-4.50	-2.50	1.00	0.00	0.00	1.00	2.00	-1.00	-2.50	4.00	-2.00	2.00	4.00	0.00
10	3.00	1.00	1.00	-11.00	0.50	- 7.00	1.50	2.00	4.00	-1.00	2.00	-4.00	-1.00	0.00	0.00	1.00	1.00	3.00	0.00	0.00	6.00	-2.50	4.50	2.50	0.00
11	4.50	2.00	4.00	- 7.50	3.00	- 1.00	2.00	3.00	0.00	5.00	1.00	-3.00	0.00	0.00	0.00	2.00	1.00	2.50	0.00	0.00	3.00	-2.00	3.50	-2.00	2.00
12	-2.00	-1.50	- 2.50	- 8.00	1.00	0.00	- 2.00	1.00	0.00	1.00	2.00	-1.00	-1.00	1.00	2.00	1.00	2.00	0.00	2.50	0.00	-5.00	2.00	2.00	2.00	0.00
13	2.00	2.00	2.00	- 3.00	1.00	5.00	- 1.00	0.00	1.00	0.00	1.00	-2.00	0.00	-1.00	-1.00	-1.50	1.00	-2.00	0.00	-2.00	0.00	-2.00	0.00	-2.00	0.00
14	-1.00	2.00	7.50	- 2.00	1.00	7.00	- 1.00	0.00	1.00	1.00	0.00	0.00	1.00	0.00	-1.00	0.00	0.00	0.00	0.00	2.50	-3.00	1.00	-3.00	1.00	1.00
15	-7.00	-2.00	- 0.50	- 4.00	1.50	- 1.00	0.50	0.50	5.00	3.00	5.00	0.00	2.50	0.00	1.00	3.00	6.00	7.00	2.00	0.00	6.00	3.00	4.00	5.00	4.00
16	-1.00	1.00	18.50	- 4.50	4.50	-14.00	6.50	0.00	-3.00	7.00	-1.00	-2.00	-1.00	0.00	0.00	4.00	2.00	5.00	0.00	2.00	0.00	0.00	0.00	2.00	0.00
17	1.00	4.00	- 3.50	- 9.00	2.50	- 5.50	0.00	1.00	6.00	0.00	4.00	-6.00	6.50	-2.00	5.00	2.00	5.00	2.00	4.00	-1.00	3.00	-1.00	3.00	3.00	4.00
18	0.00	0.00	1.00	-14.00	- 3.00	- 3.00	- 4.50	0.00	0.00	0.00	0.00	-3.00	-3.00	0.00	2.00	0.00	0.00	-1.00	-2.00	0.00	-2.00	0.00	-2.00	-1.00	-1.00
19	0.00	2.00	- 3.50	-11.00	1.50	- 1.00	- 0.50	1.00	-2.00	0.00	0.00	-4.00	-1.50	0.00	-2.00	0.00	0.00	0.00	0.00	-2.00	-2.50	-2.00	0.00	-0.50	-0.50
20	5.50	-3.00	9.50	- 1.50	2.00	0.00	- 2.00	2.00	1.00	4.00	-1.00	-2.00	0.00	-1.00	1.00	2.00	-1.00	1.50	0.00	0.00	-3.00	0.00	0.00	2.00	0.00
21	-0.50	1.00	14.50	- 5.00	- 1.00	4.00	0.00	-1.50	0.50	6.00	1.00	-1.00	0.00	-2.00	0.00	0.00	0.00	-1.00	1.00	0.00	-4.00	1.50	-6.00	1.00	1.00
22	-1.00	0.50	12.50	-10.00	1.00	- 9.00	1.00	0.00	0.00	4.00	-1.00	-2.50	2.00	0.00	4.00	2.00	1.00	3.50	1.00	2.00	3.00	0.00	2.00	2.00	1.00

Second determination

CASE	N A Pog	MPL SN	1 to SN	1 to MPL	G Sn Pog	NASOLABIAL	HOLDAWAY	Pt A A-P change	Pt A S-I change	Incision Superius A-P change	Incision Superius S-I change	Incision Inferius A-P change	Incision Inferius S-I change	Pt B A-P change	Pt B S-I change	Sulcus Superius A-P change	Sulcus Superius S-I change	Labrale Superius A-P change	Labrale Superius S-I change	Labrale Inferius A-P change	Labrale Inferius S-I change	Sulcus Inferius A-P change	Sulcus Inferius S-I change	Subnasale A-P change	Subnasale S-I change
1	0.50	0.00	1.50	- 2.00	1.00	1.00	- 5.00	2.50	4.00	3.00	6.00	1.00	3.50	1.00	3.50	1.50	5.00	1.00	4.50	1.00	7.00	0.00	5.00	2.00	4.00
2	0.00	1.50	4.00	11.00	3.00	0.00	2.00	-1.00	1.00	0.00	-1.00	-4.00	-4.50	-1.00	-1.00	1.00	0.00	2.00	0.00	-1.00	0.00	-2.00	0.00	1.00	0.00
3	1.00	-1.00	0.50	- 5.50	2.00	5.00	- 2.00	0.00	3.50	-2.00	4.50	-4.00	2.00	-2.00	4.00	0.00	6.00	0.00	7.00	-2.00	6.00	-1.50	3.00	0.00	4.00
4	2.00	1.00	3.00	-11.00	3.00	0.00	- 0.50	-1.00	2.50	-1.00	2.50	-6.50	-1.50	-4.00	-1.00	-1.00	5.00	-1.00	4.00	-7.00	2.50	-4.00	0.00	0.00	2.00
5	5.00	2.00	13.00	- 6.50	5.50	- 4.00	6.00	1.50	0.00	5.00	-3.00	-4.50	-1.00	-3.00	0.00	4.00	5.00	3.50	5.00	-2.00	2.50	-2.00	2.00	0.00	2.00
6	3.00	2.50	11.00	- 5.00	1.00	0.00	2.00	0.00	2.00	4.00	3.00	-6.00	5.00	-4.00	5.00	1.50	4.50	0.00	5.00	-4.50	5.50	-4.00	6.00	0.00	4.00
7	-6.00	-2.50	14.00	- 2.00	- 4.00	-10.00	- 3.00	2.00	0.00	7.00	-2.00	1.00	-3.00	5.00	-6.00	2.00	0.00	3.00	-2.00	3.00	-3.00	4.00	-2.00	2.00	0.00
8	3.00	0.50	- 0.50	-12.00	0.50	- 0.50	1.50	2.00	0.00	0.00	-2.00	-2.00	-2.00	1.00	-1.00	2.00	0.00	2.00	0.00	0.00	4.00	0.00	2.00	1.00	0.00
9	0.50	-1.50	13.00	-13.00	6.00	- 7.00	1.00	2.00	2.00	3.50	0.00	-3.00	-3.00	2.50	0.00	0.00	0.00	3.50	-2.00	-1.00	3.00	0.00	0.00	4.00	0.00
10	3.00	0.50	0.50	-10.50	2.00	- 7.00	2.00	3.50	3.00	1.00	1.00	-2.00	-1.50	2.00	0.00	2.50	0.00	4.00	0.00	2.00	5.00	0.00	3.00	2.50	0.00
11	4.50	2.00	4.00	- 7.00	2.50	1.00	2.50	3.00	-1.00	5.00	0.00	-3.00	0.00	0.00	0.00	3.00	1.00	3.00	1.00	-1.00	2.00	-2.00	3.00	-2.00	2.00
12	-3.00	-1.00	- 3.00	- 9.00	1.00	2.00	- 2.00	0.00	1.00	1.00	2.00	-2.00	-1.00	2.00	0.00	0.00	3.00	0.00	3.00	0.00	-4.00	2.00	2.00	2.00	0.00
13	2.00	0.50	- 2.00	- 3.00	- 2.00	0.00	- 2.00	0.00	0.00	-1.00	1.00	-3.00	-1.00	-2.50	-1.50	-2.00	0.00	-2.50	0.00	-3.00	0.00	-2.00	0.00	-2.00	0.00
14	0.00	2.00	8.00	- 2.00	- 1.00	0.00	- 1.50	0.00	3.00	2.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	3.00	-4.00	2.00	-2.00	1.00	1.00
15	-4.00	-1.00	1.00	- 8.50	0.00	- 1.00	0.50	2.00	4.00	2.00	5.00	0.00	2.00	2.00	-1.00	5.00	4.00	5.00	2.00	0.00	6.00	3.00	3.00	5.00	4.00
16	0.00	1.00	16.00	- 2.00	3.00	-14.00	7.00	0.00	-3.00	8.00	-2.00	0.00	1.00	0.00	0.00	5.50	1.50	6.00	0.00	2.00	-1.50	2.00	-2.00	2.00	0.00
17	3.50	4.50	- 4.50	-12.00	1.50	- 4.00	- 0.50	1.50	6.00	1.00	4.00	-5.00	6.00	-1.00	6.00	3.00	4.00	2.50	3.50	1.00	3.00	1.00	2.00	3.00	4.00
18	-2.00	0.00	2.00	-13.00	- 2.00	- 2.00	- 5.50	0.00	0.00	0.00	0.00	-3.00	-2.50	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	-2.50	0.00	0.00	-1.00	-1.00
19	0.00	3.00	- 0.50	-10.00	2.00	0.00	- 0.50	0.00	0.00	-2.00	0.00	-3.00	-1.00	-1.00	-1.00	1.00	2.00	0.00	-1.00	-3.00	-2.00	-2.00	-2.00	-0.50	-0.50
20	5.00	-3.00	11.00	- 2.50	2.50	1.00	4.00	2.00	2.00	5.00	0.00	-2.00	0.00	0.00	0.00	2.00	0.00	2.00	0.00	0.00	-2.00	0.00	0.00	2.00	0.00
21	-0.50	1.00	14.00	- 5.00	- 1.00	4.00	0.00	-1.50	0.50	6.00	1.00	-1.00	0.00	-2.00	0.00	0.00	0.00	-1.00	1.00	0.00	-4.00	1.50	-6.00	1.00	1.00
22	-1.00	0.50	12.50	-10.00	1.00	- 9.00	1.00	0.00	0.00	4.00	-1.00	-2.50	2.00	0.00	4.00	2.00	1.00	3.50	1.00	2.00	3.00	0.00	2.00	2.00	1.00

KEY : A-P denote antero-posterior change

Table A - 4. Mean values of the two determinations for each angular and linear variable.

LINEAR AND ANGULAR VARIABLES.

CASE	N A Pog	MPL SN	1 to SN	1 to MPL	G Sn pog'	NASOLABIAL	HOLDAWAY	Point A: A - P change	Point A: S - I change	Incision Superius: A - P change	Incision Superius: S - I change	Incision Inferius: A - P change	Incision Inferius: S - I change	Point B: A - P change	Point B: S - I change	Sulcus Superius: A - P change	Sulcus Superius: S - I change	Labrale Superius: A - P change	Labrale Superius: S - I change	Labrale Inferius: A - P change	Labrale Inferius: S - I change	Sulcus Inferius: A - P change	Sulcus Inferius: S - I change	Subnasale: A - P change	Subnasale: S - I change
1	-0.50	0.00	0.50	- 1.25	-0.25	0.50	-5.00	2.75	3.00	3.00	5.50	1.50	3.25	1.50	3.25	1.75	5.00	1.50	4.00	1.25	6.50	0.75	4.00	2.00	4.00
2	-0.50	1.00	5.50	-10.50	2.50	- 2.00	2.25	-1.50	0.50	0.00	-0.50	-3.75	-4.50	-0.50	-1.75	0.50	0.50	1.00	1.00	-1.75	0.50	-2.00	0.00	1.00	0.00
3	1.00	-1.25	- 0.25	- 5.25	0.50	5.50	-2.00	0.25	2.75	-2.00	4.25	-4.00	1.75	-2.00	4.00	0.00	4.50	-0.50	7.50	-2.00	5.25	-1.75	3.50	0.00	4.00
4	2.50	0.75	3.00	-11.00	3.00	1.50	-0.75	0.00	2.25	-1.00	1.75	-6.25	-1.75	-4.00	0.00	-1.25	5.00	-1.00	4.00	-7.00	2.25	-4.00	0.00	0.00	2.00
5	5.00	1.50	13.25	- 5.25	5.50	- 3.50	6.00	1.25	0.00	5.00	-3.00	-4.75	-1.50	-3.00	0.50	4.00	5.00	3.75	5.50	-2.00	2.75	-2.00	1.50	0.00	2.00
6	3.00	2.75	10.50	- 6.50	0.50	0.00	1.50	0.50	1.75	4.50	2.00	-6.00	4.5	-4.00	5.50	1.25	3.25	0.00	4.50	-4.75	5.25	-3.50	6.00	0.00	4.00
7	-5.25	-3.50	13.00	- 2.00	-4.00	- 9.50	-2.00	2.50	-0.50	8.00	-2.50	1.75	-3.75	5.00	-5.50	2.50	-1.25	3.75	-2.75	4.00	-4.00	4.25	-1.50	2.00	0.00
8	3.00	0.75	- 0.75	-12.00	1.25	- 0.25	1.25	3.00	-1.25	1.25	-3.00	-0.25	-3.00	1.00	-1.00	2.00	0.00	2.00	0.00	0.00	4.00	0.00	2.00	1.00	0.00
9	0.75	-1.75	12.50	-12.50	5.50	- 5.00	1.00	1.50	2.75	2.75	0.50	-3.75	-2.75	1.75	0.00	0.00	0.50	2.75	-1.50	-1.75	3.50	-1.00	1.00	4.00	0.00
10	3.00	0.75	0.75	-10.75	1.25	- 7.00	1.75	2.75	3.50	0.00	1.50	-3.00	-1.25	1.00	0.00	1.75	0.50	3.50	0.00	1.00	5.50	-1.25	3.75	2.50	0.00
11	4.50	2.00	4.00	- 7.25	2.75	0.00	2.25	3.00	-0.50	5.00	0.50	-3.00	0.00	0.0	0.00	2.50	1.00	2.75	0.50	-0.50	2.50	-2.00	3.25	-2.00	2.00
12	-2.50	-1.25	- 2.75	- 8.50	1.00	1.00	-2.00	0.50	0.50	1.00	2.00	-1.50	-1.00	1.50	1.00	0.50	2.50	0.00	2.75	0.00	-4.50	2.00	2.00	2.00	0.00
13	2.00	1.25	- 2.00	- 3.00	-0.50	2.50	-1.50	0.00	0.50	-0.50	1.00	-2.50	-0.50	-1.75	-1.25	-1.75	0.50	-2.25	0.00	-2.50	0.00	-2.00	0.00	-2.00	0.00
14	-0.50	2.00	7.75	- 2.00	0.00	3.50	-1.25	0.00	2.00	1.50	0.50	0.50	0.50	0.50	-0.50	0.50	0.00	0.00	0.00	2.75	-3.50	1.50	-2.50	1.00	1.00
15	-5.50	-1.50	0.25	- 6.25	0.75	- 1.00	0.50	1.25	4.50	2.50	5.00	0.00	2.25	1.00	0.00	4.00	5.00	6.00	2.00	0.00	6.00	3.00	3.50	5.00	4.00
16	-0.50	1.00	17.25	- 3.25	3.75	-14.00	6.75	0.00	-3.00	7.50	-1.50	-1.00	0.00	0.00	0.00	4.75	1.75	5.50	0.00	2.00	-0.75	1.00	-1.00	2.00	0.00
17	2.25	4.25	- 4.00	-10.50	2.00	- 4.75	-0.25	1.25	6.00	0.50	4.00	-5.50	6.25	-1.50	5.50	2.50	4.50	2.25	3.75	0.00	3.00	0.00	2.50	3.00	4.00
18	-1.00	0.00	1.50	-13.50	-2.50	- 2.50	-5.00	0.00	0.00	0.00	0.00	-3.00	-2.75	0.00	1.00	0.00	0.00	-0.50	-1.50	0.00	-2.25	0.00	-1.00	-1.00	-1.00
19	0.00	2.50	- 2.00	-10.50	1.75	- 0.50	-0.50	0.50	-1.00	-1.00	0.00	-3.50	-1.25	-0.50	-1.50	0.50	1.00	0.00	-0.50	-2.50	-2.25	-2.00	-1.00	-0.50	-0.50
20	5.25	-3.00	10.25	- 2.00	2.25	0.50	1.00	2.00	1.50	4.50	-0.50	-2.00	0.00	-0.50	0.50	2.00	-0.50	1.75	0.00	0.00	-2.50	0.00	0.00	2.00	0.00
21	-0.50	1.00	14.50	- 5.00	-1.00	4.00	0.00	-1.50	0.50	6.00	1.00	-1.00	0.00	-2.00	0.00	0.00	0.00	-1.00	1.00	0.00	-4.00	1.50	-6.00	1.00	1.00
22	-1.00	0.50	12.50	-10.00	1.00	- 9.00	1.00	0.00	0.00	4.00	-1.00	-2.50	2.00	0.00	4.00	2.00	1.00	3.50	1.00	2.00	3.00	0.00	2.00	2.00	1.00

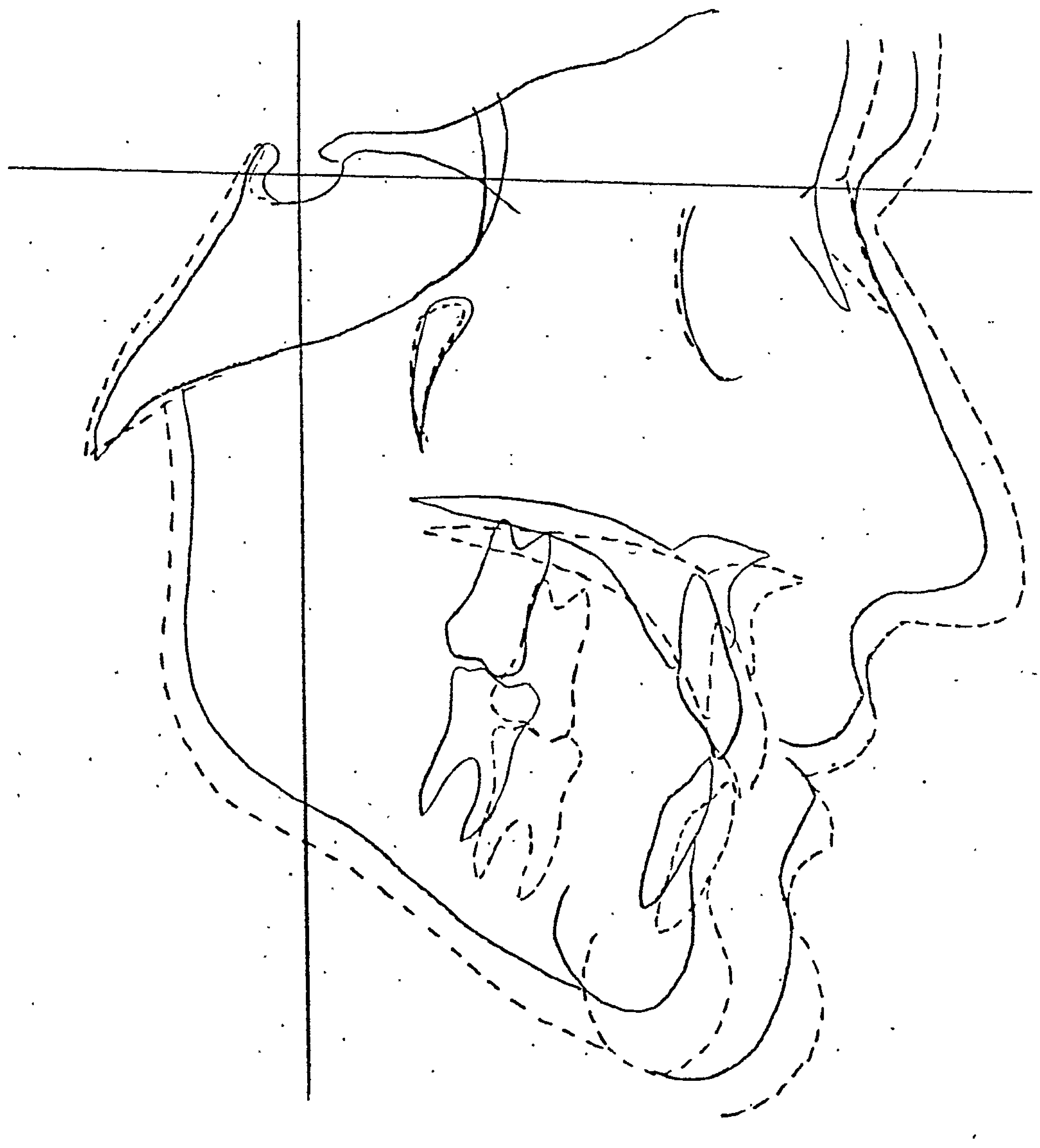

Figure A - 1 . PROFILE CHANGES IN CASE 1.

———————— pre-treatment tracing.

--------- Tracing at bands off.

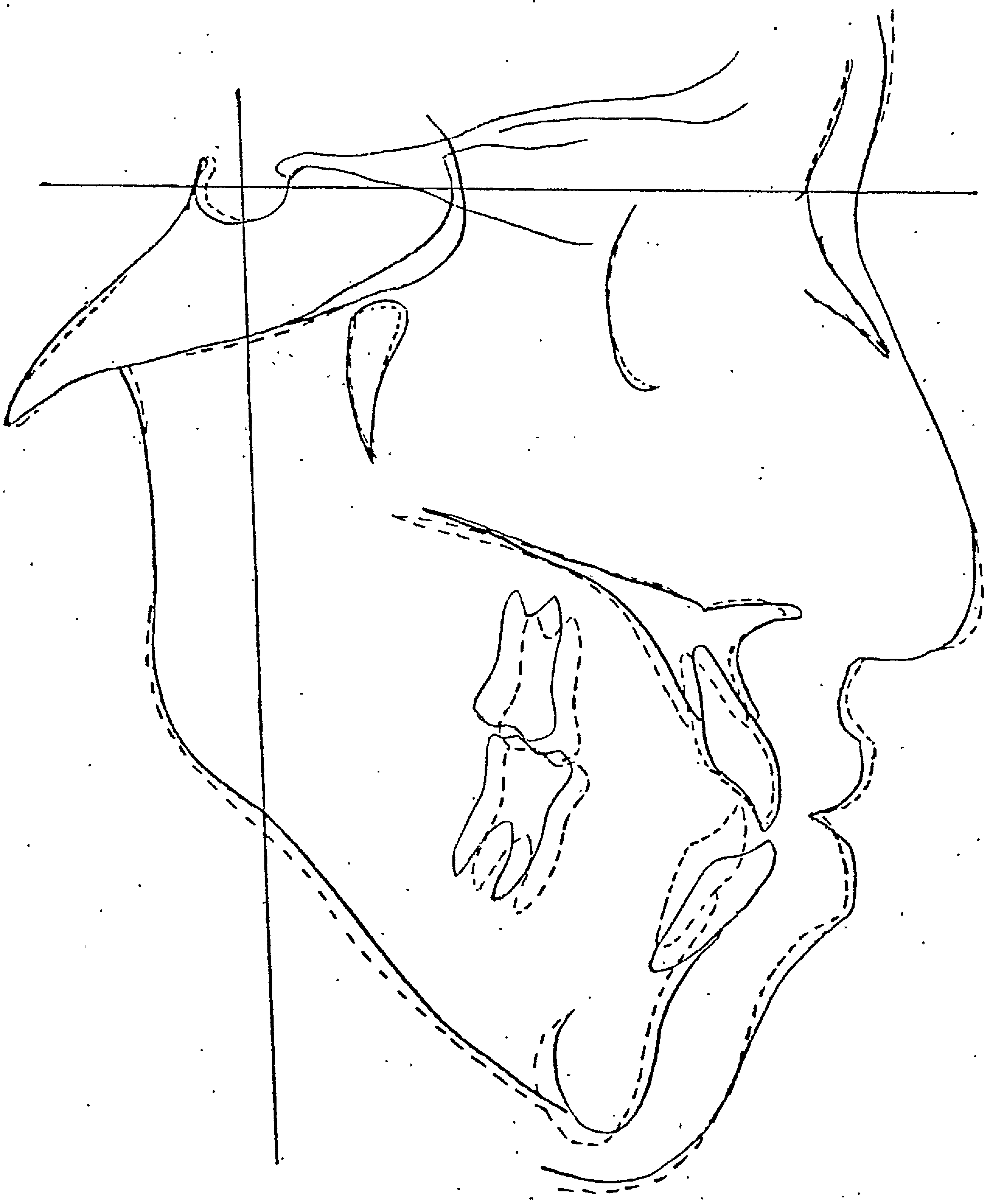

Figure A - 2.

PROFILE CHANGES IN CASE 2

———————— pre-treatment tracing.

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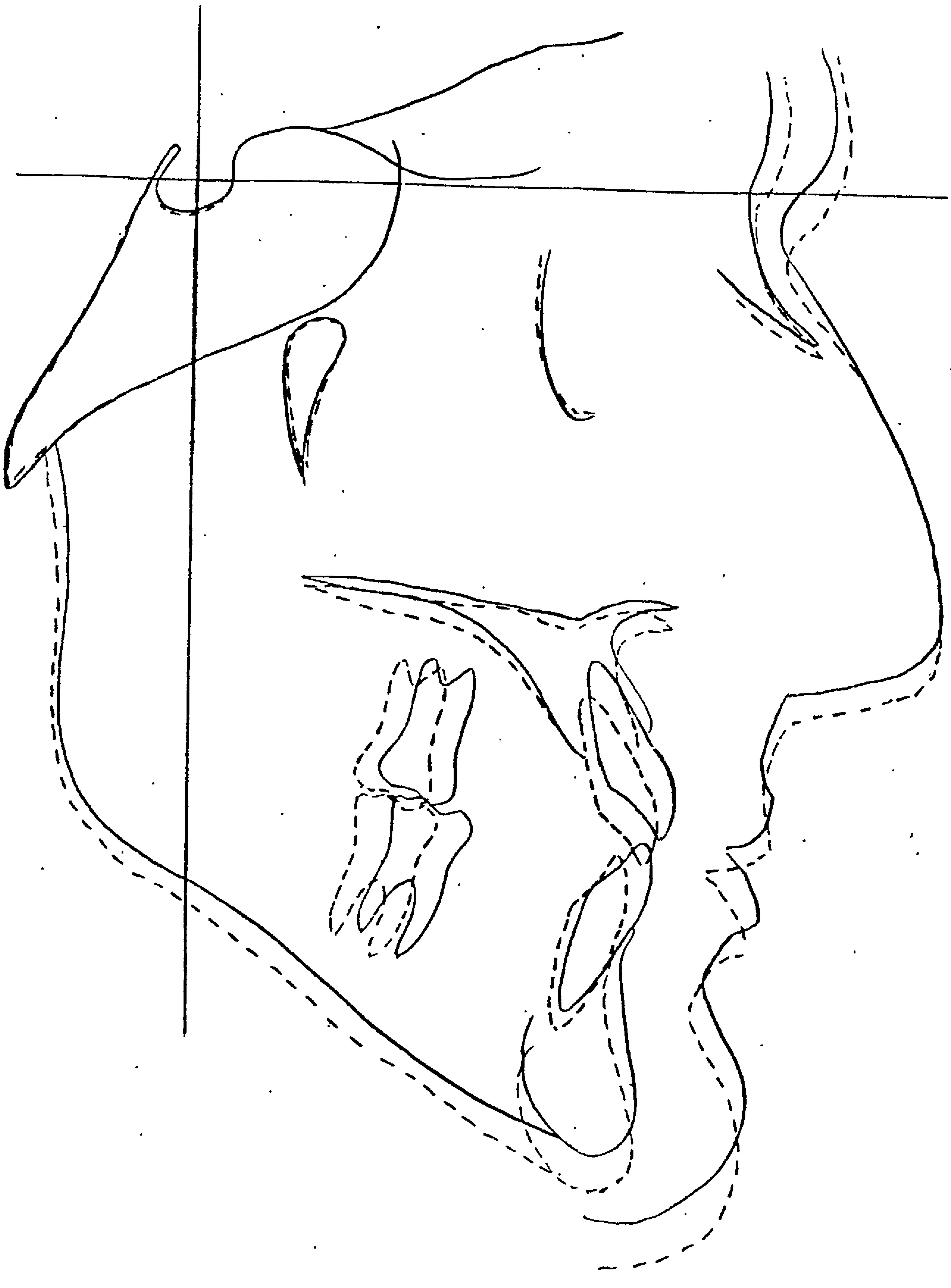

Figure A - 3 . PROFILE CHANGES IN CASE 3

——————— pre-treatment tracing.

--------- Tracing at bands off.

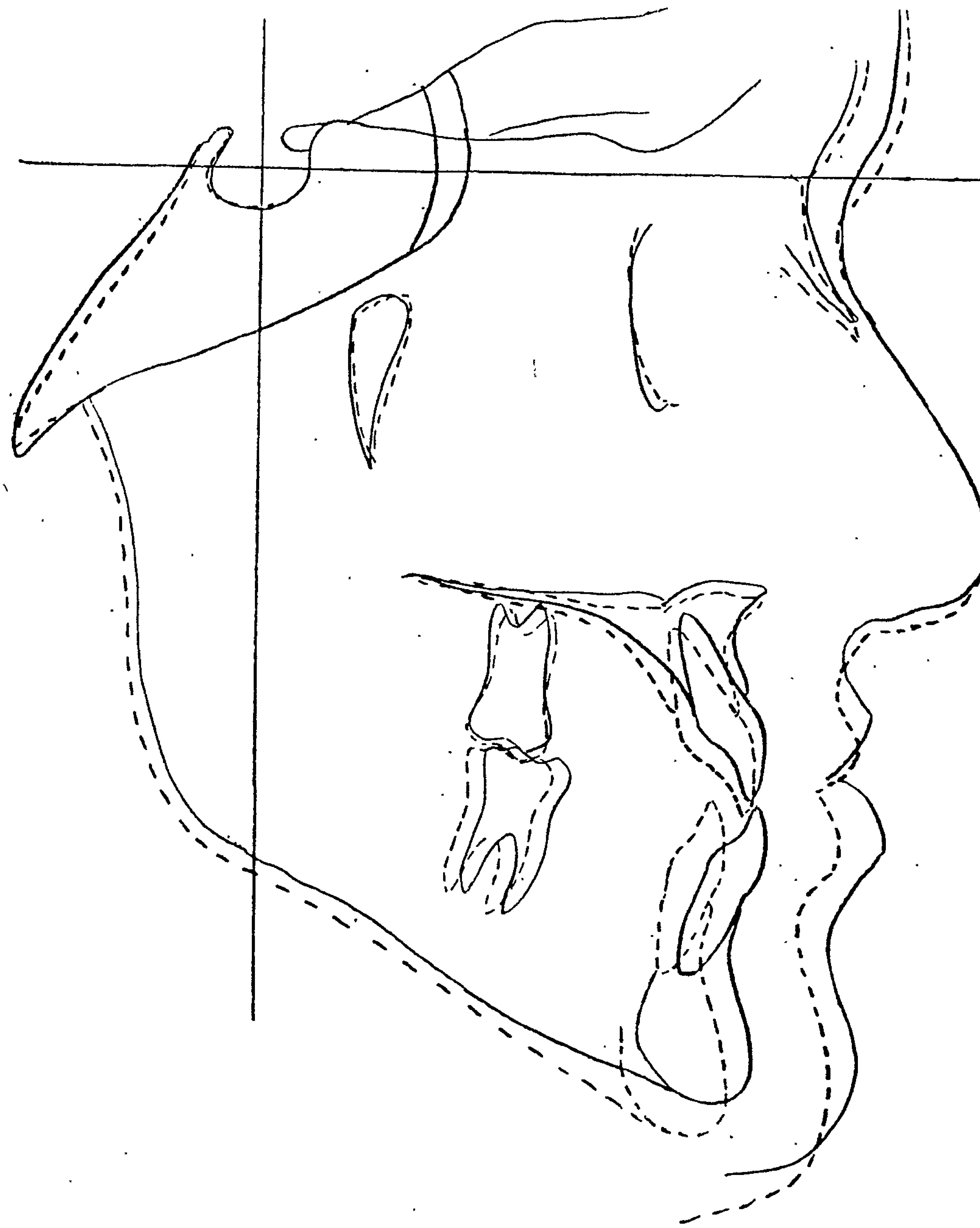

Figure A - 4 .   PROFILE CHANGES IN CASE 4

——————— pre-treatment tracing.

--------- Tracing at bands off.

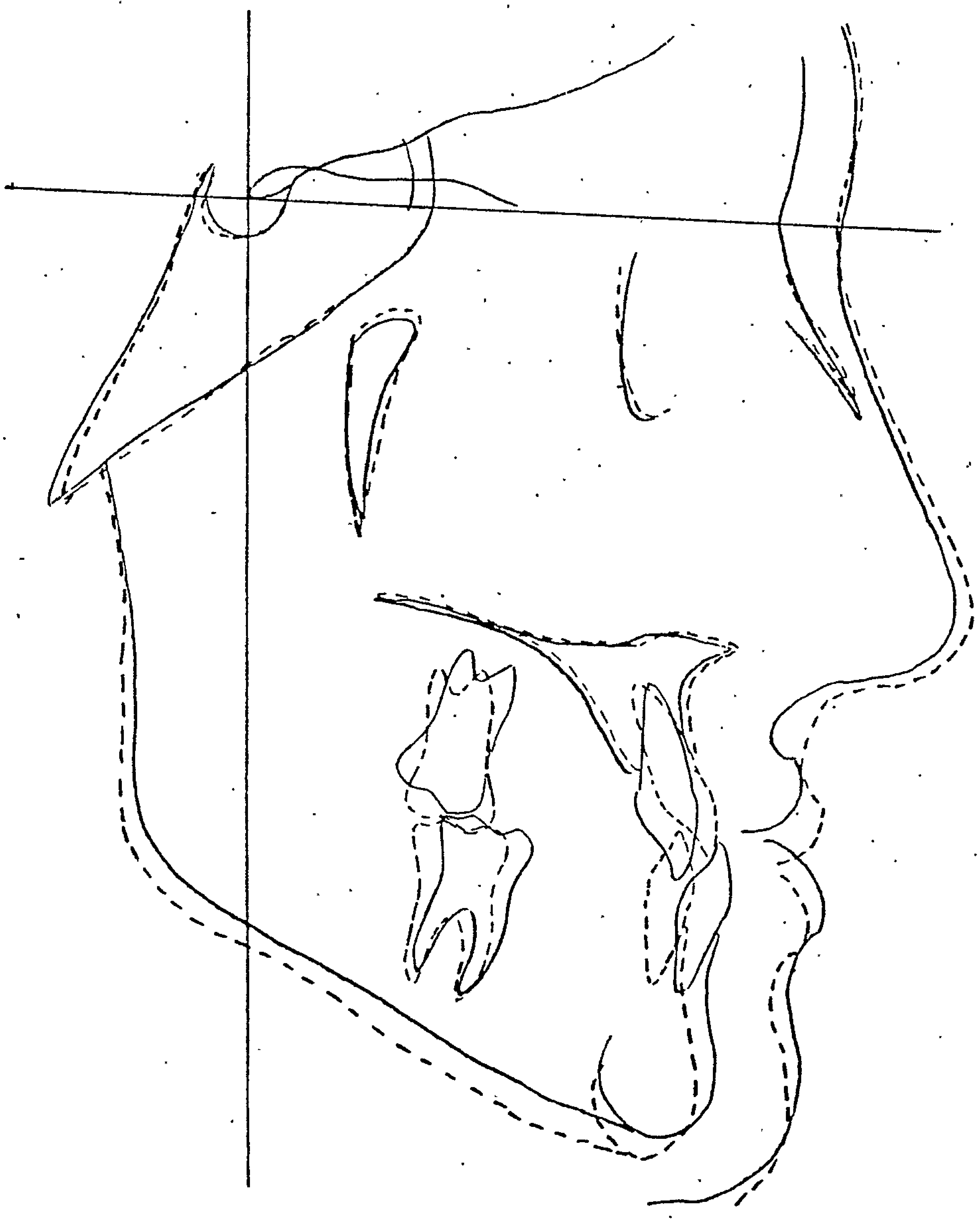

Figure A - 5. PROFILE CHANGES IN CASE 5

——————— pre-treatment tracing.

--------- Tracing at bands off.

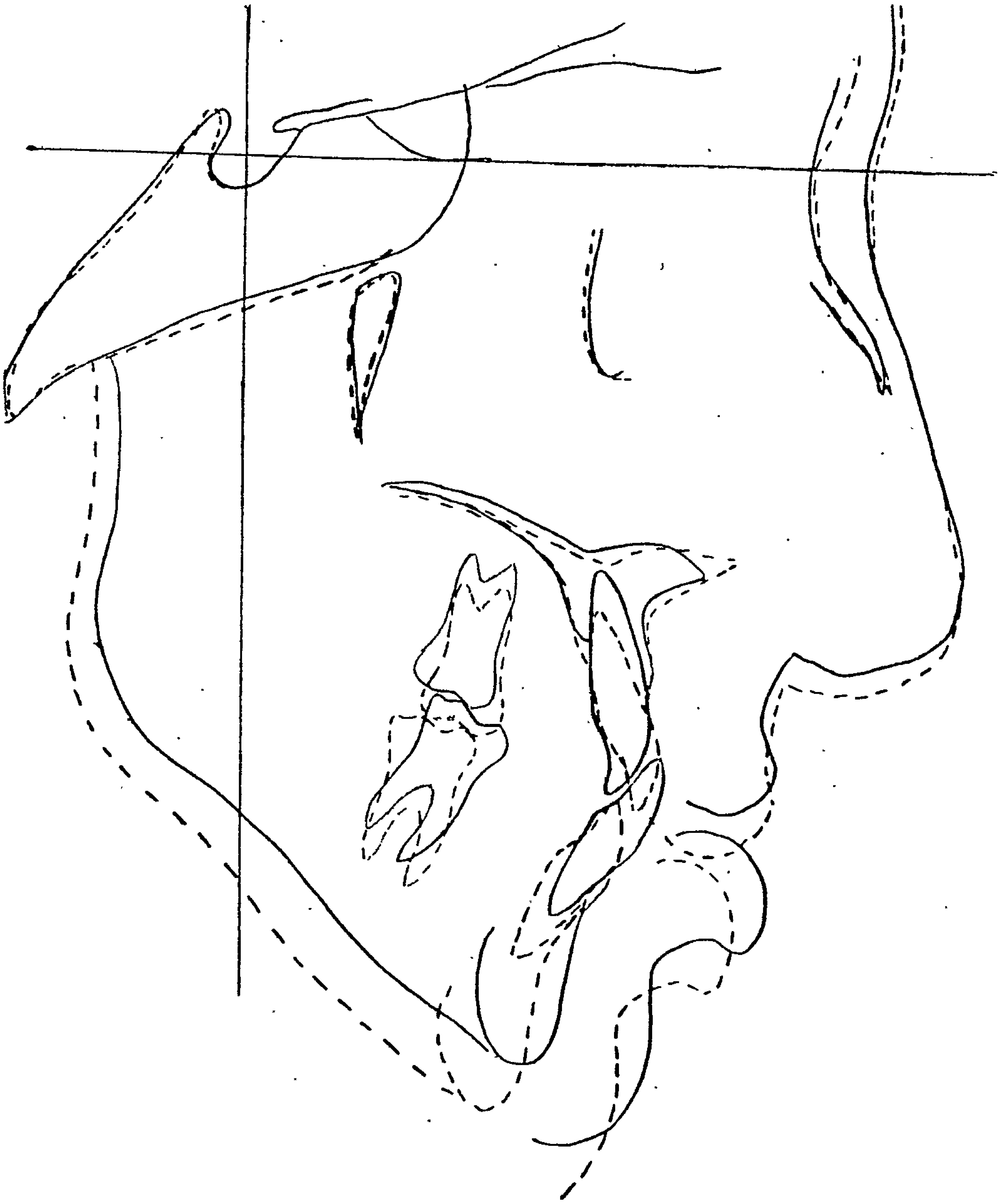

Figure A - 6. PROFILE CHANGES IN CASE 6

———— pre-treatment tracing.

--------- Tracing at bands off.

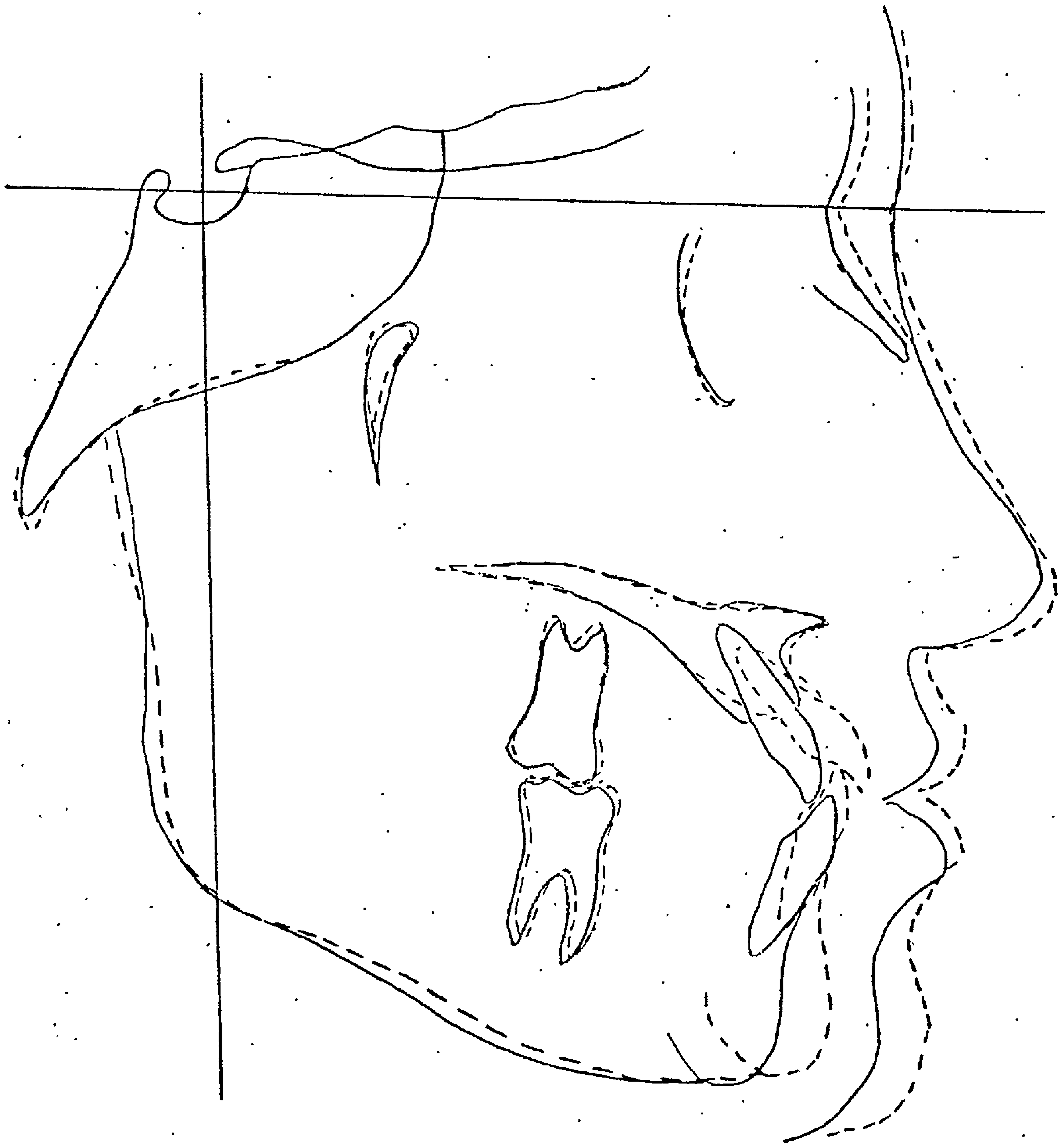

Figure A - 7. PROFILE CHANGES IN CASE 7

———————— pre-treatment tracing.

--------- Tracing at bands off.

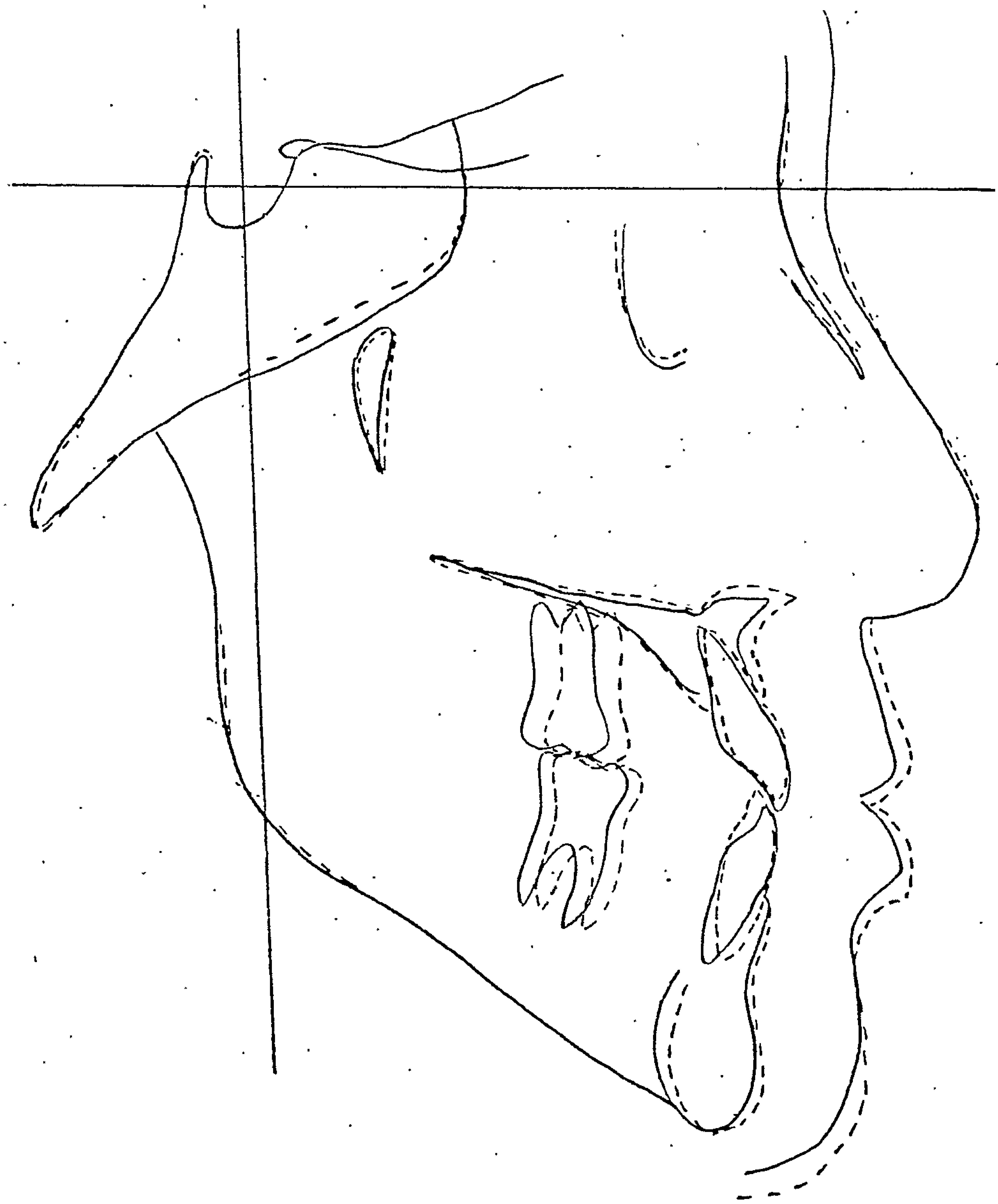

Figure A - 8.

PROFILE CHANGES IN CASE 8

———— pre-treatment tracing.

--------- Tracing at bands off.

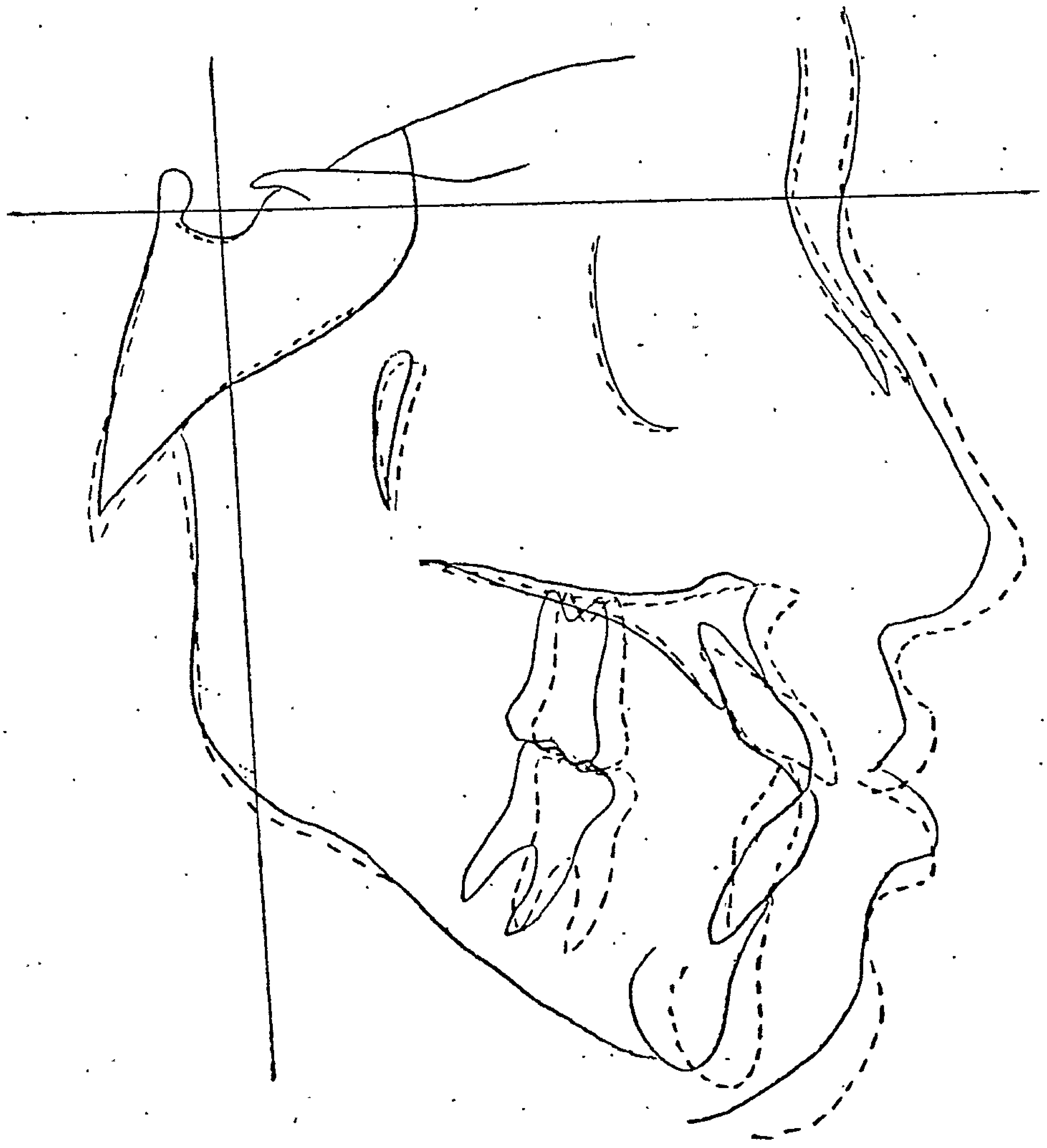

Figure A - 9. PROFILE CHANGES IN CASE 9

——————— pre-treatment tracing.

- - - - - - - - - Tracing at bands off.

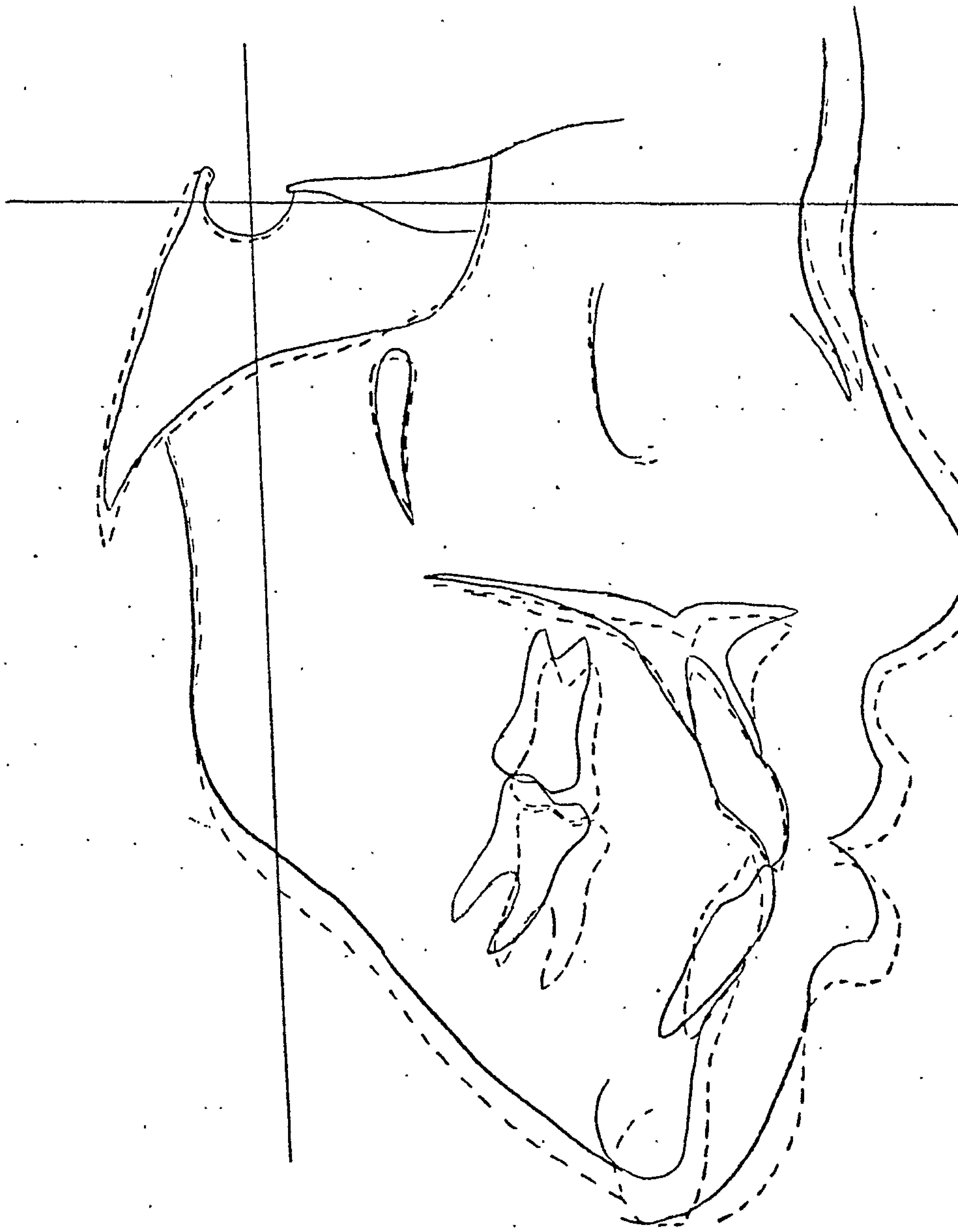

Figure A - 10. PROFILE CHANGES IN CASE 10

———————— pre-treatment tracing.

--------- Tracing at bands off.

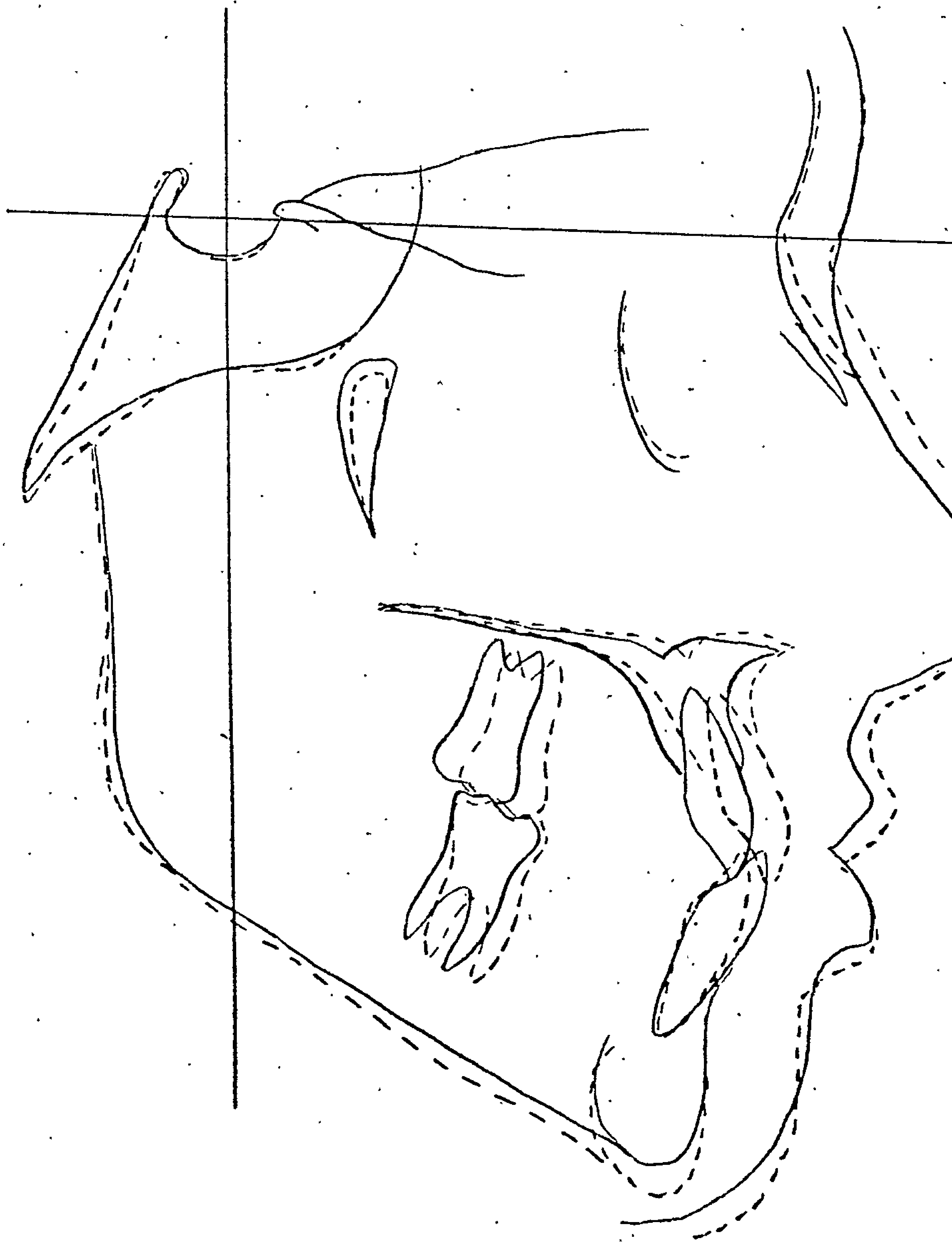

Figure A - 11. PROFILE CHANGES IN CASE 11

———————— pre-treatment tracing.

--------- Tracing at bands off.

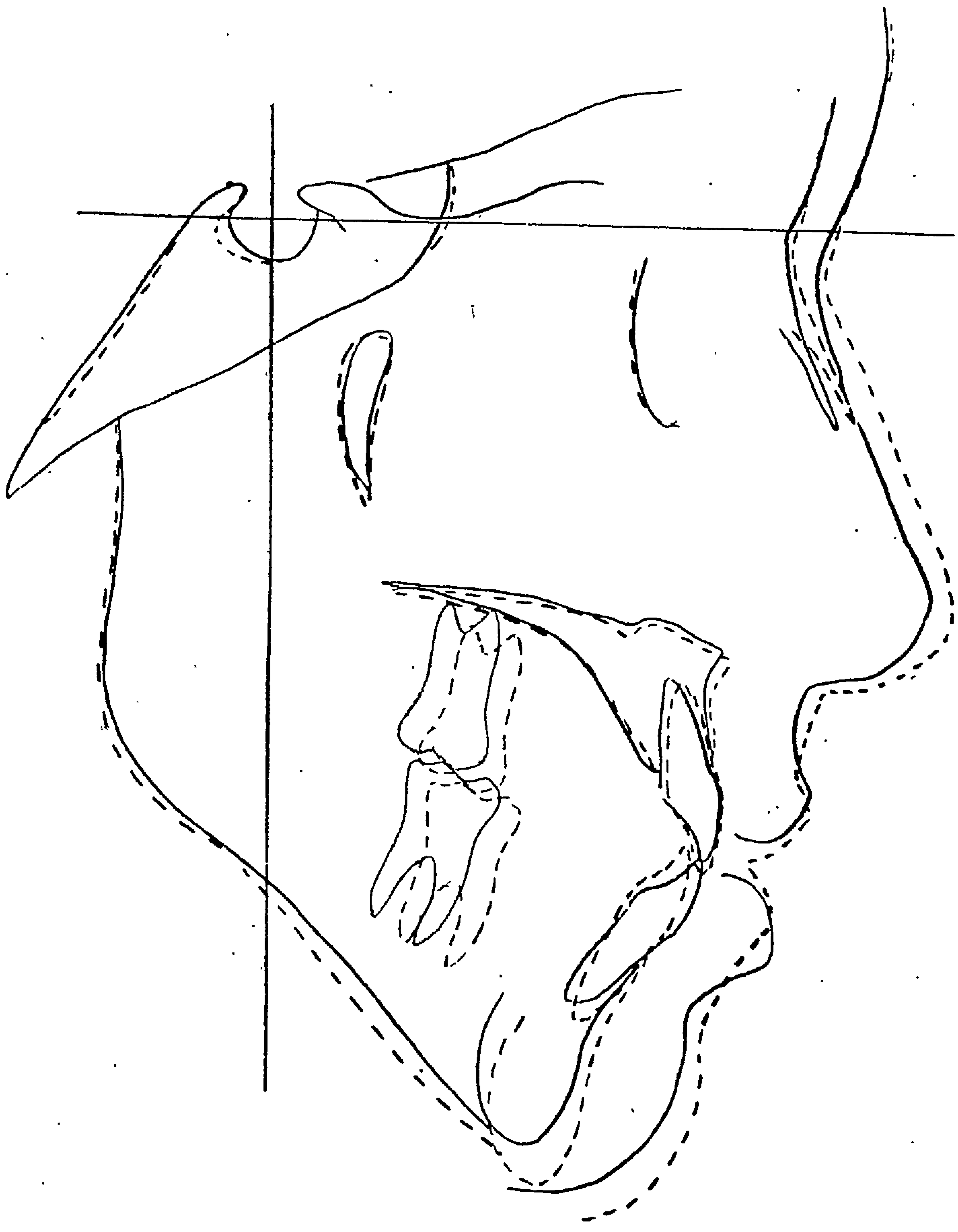

Figure A - 12. PROFILE CHANGES IN CASE 12

———————— pre-treatment tracing.

--------- Tracing at bands off.

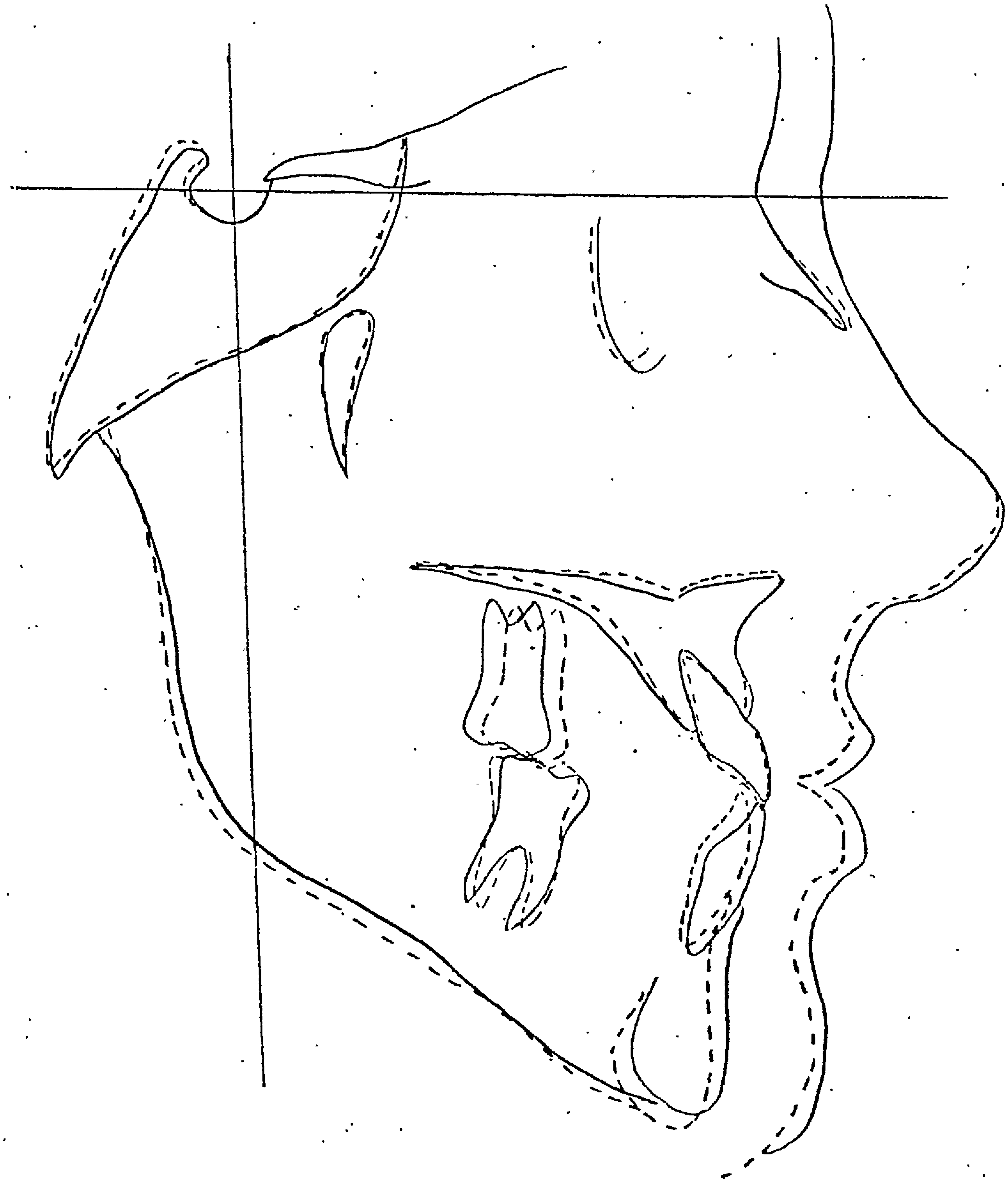

Figure A - 13. PROFILE CHANGES IN CASE 13

——————— pre-treatment tracing.

--------- Tracing at bands off.

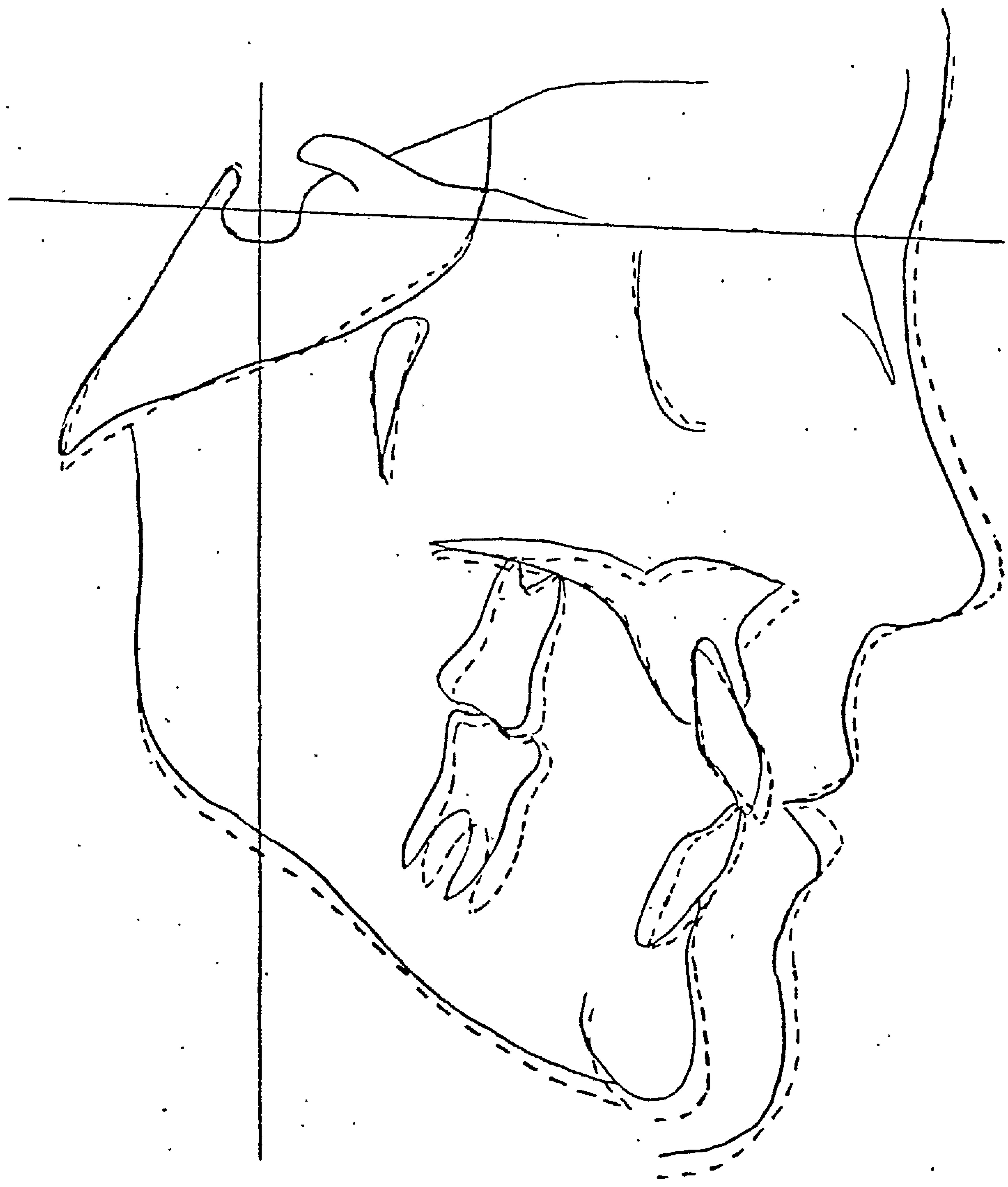

Figure A - 14. PROFILE CHANGES IN CASE 14

———————— pre-treatment tracing.

--------- Tracing at bands off.

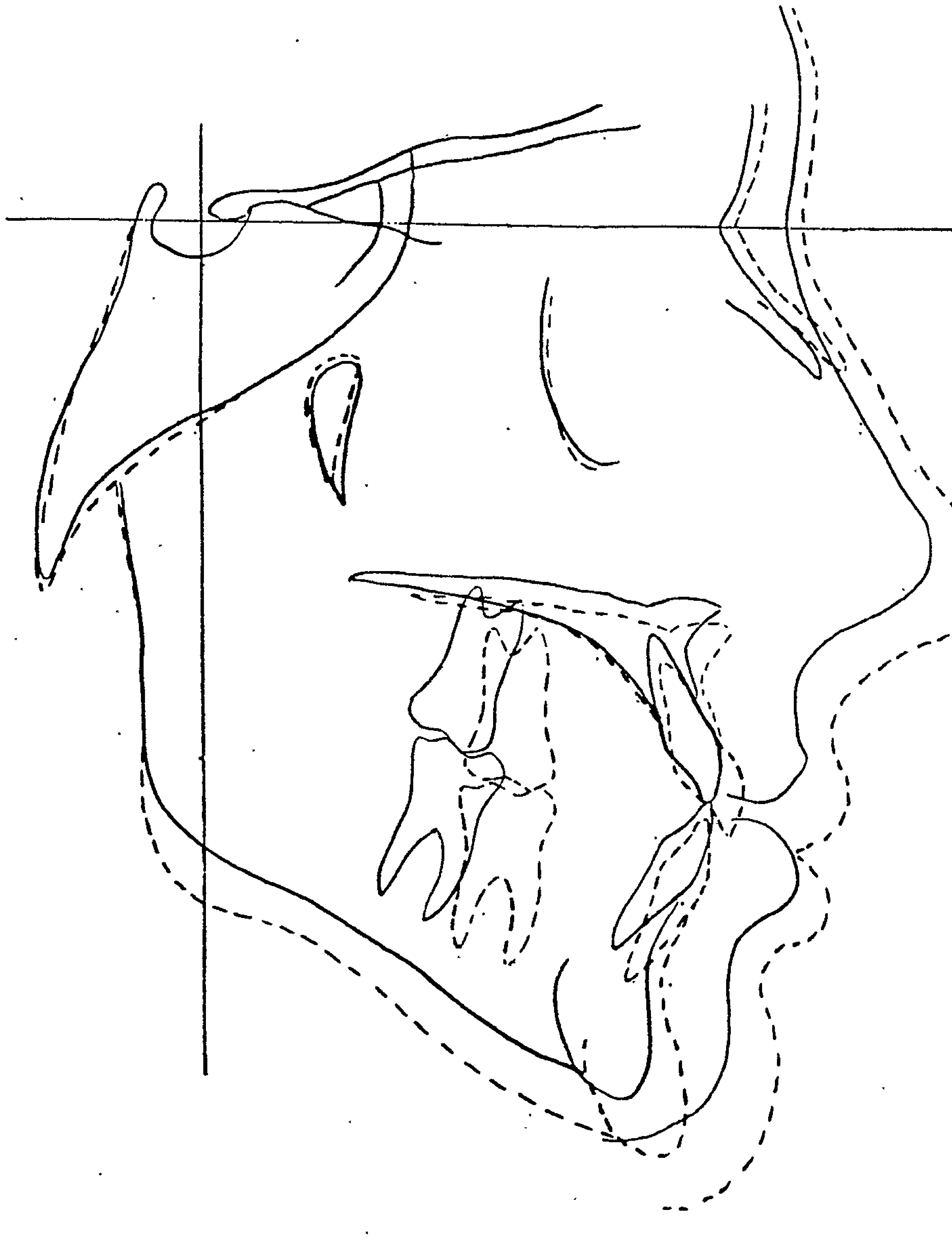

Figure A - 15. PROFILE CHANGES IN CASE 15

——————— pre-treatment tracing.

--------- Tracing at bands off.

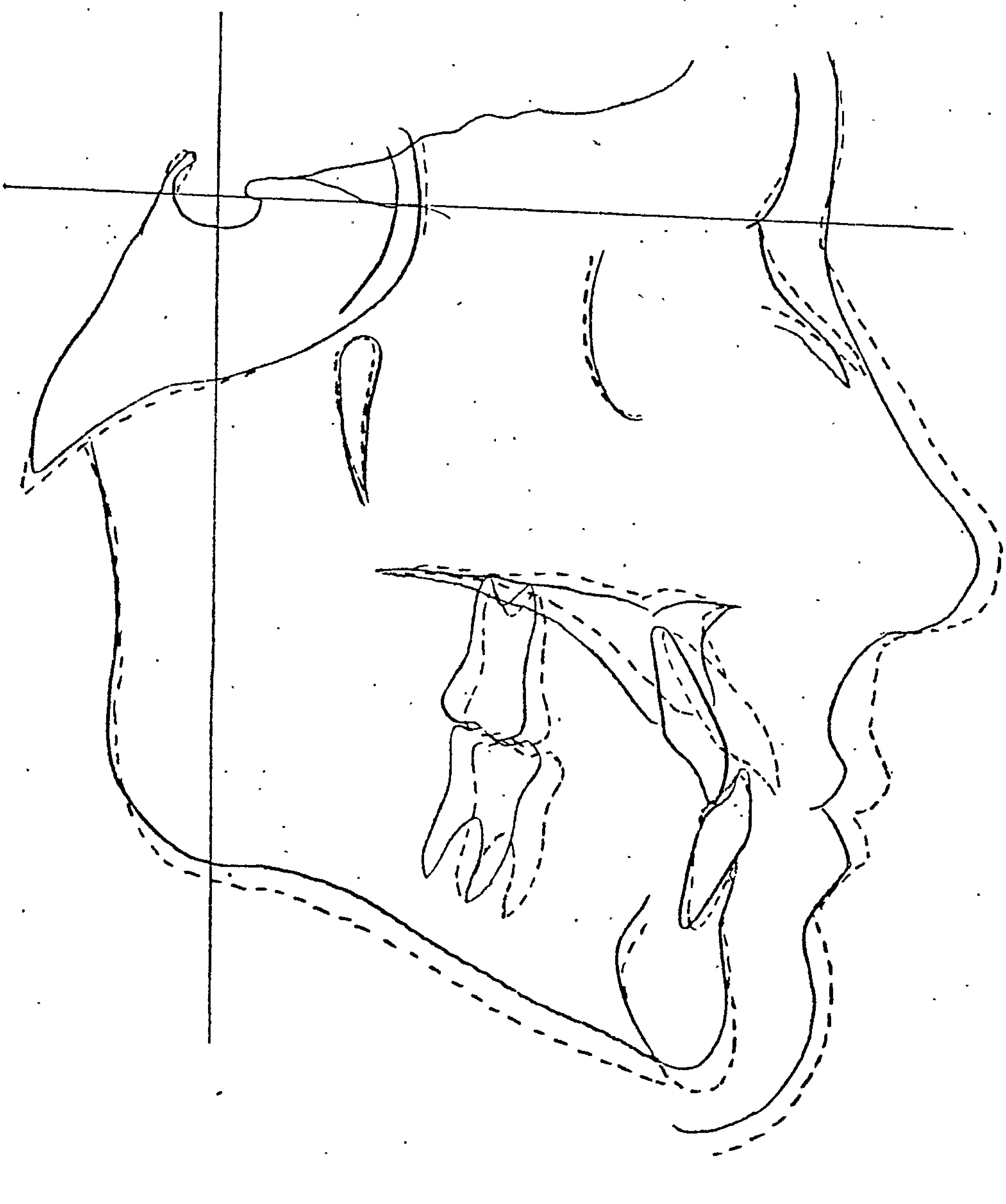

Figure A - 16.

PROFILE CHANGES IN CASE 16

———————— pre-treatment tracing.

--------- Tracing at bands off.

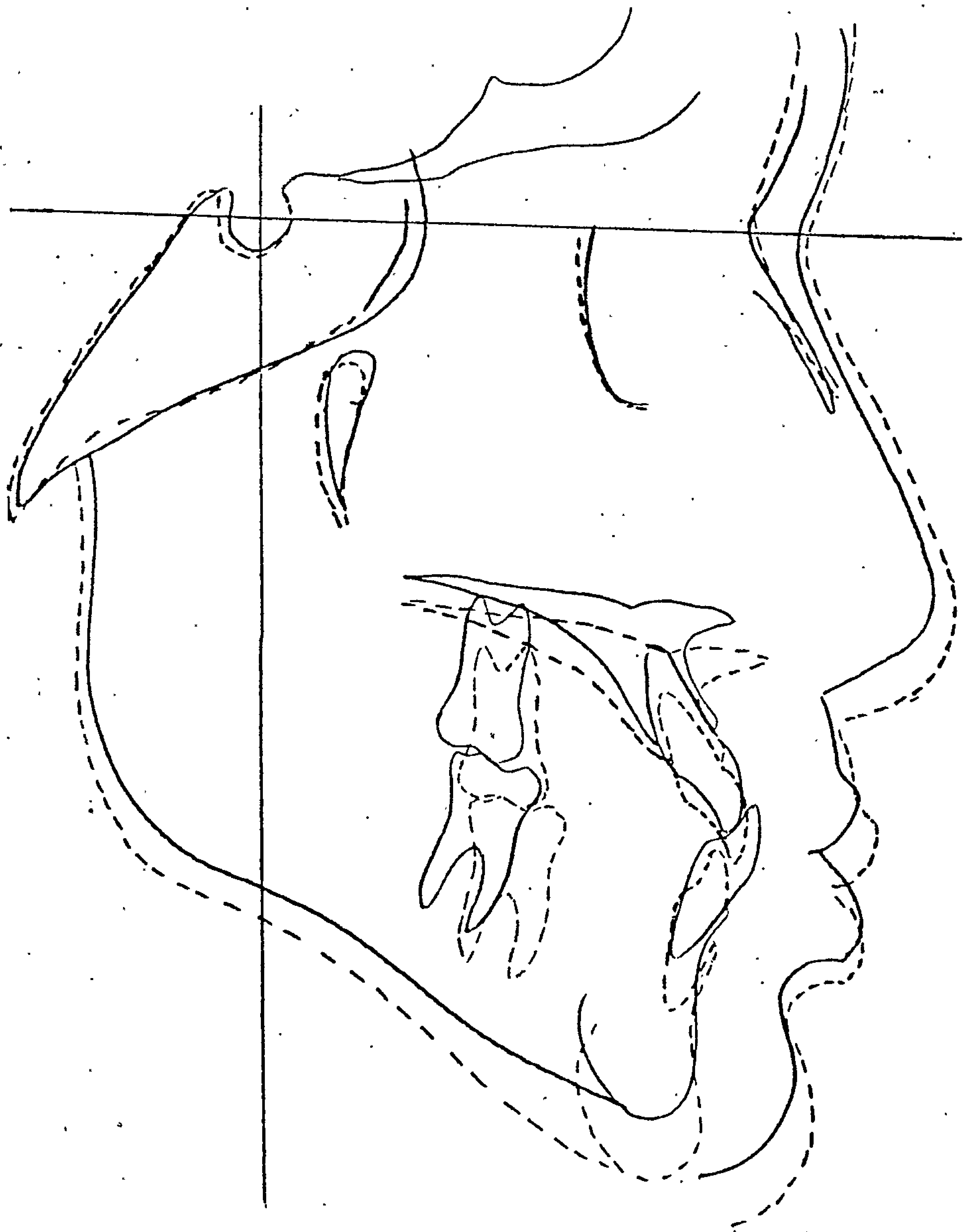

Figure A - 17. PROFILE CHANGES IN CASE 17

———————— pre-treatment tracing.

--------- Tracing at bands off.

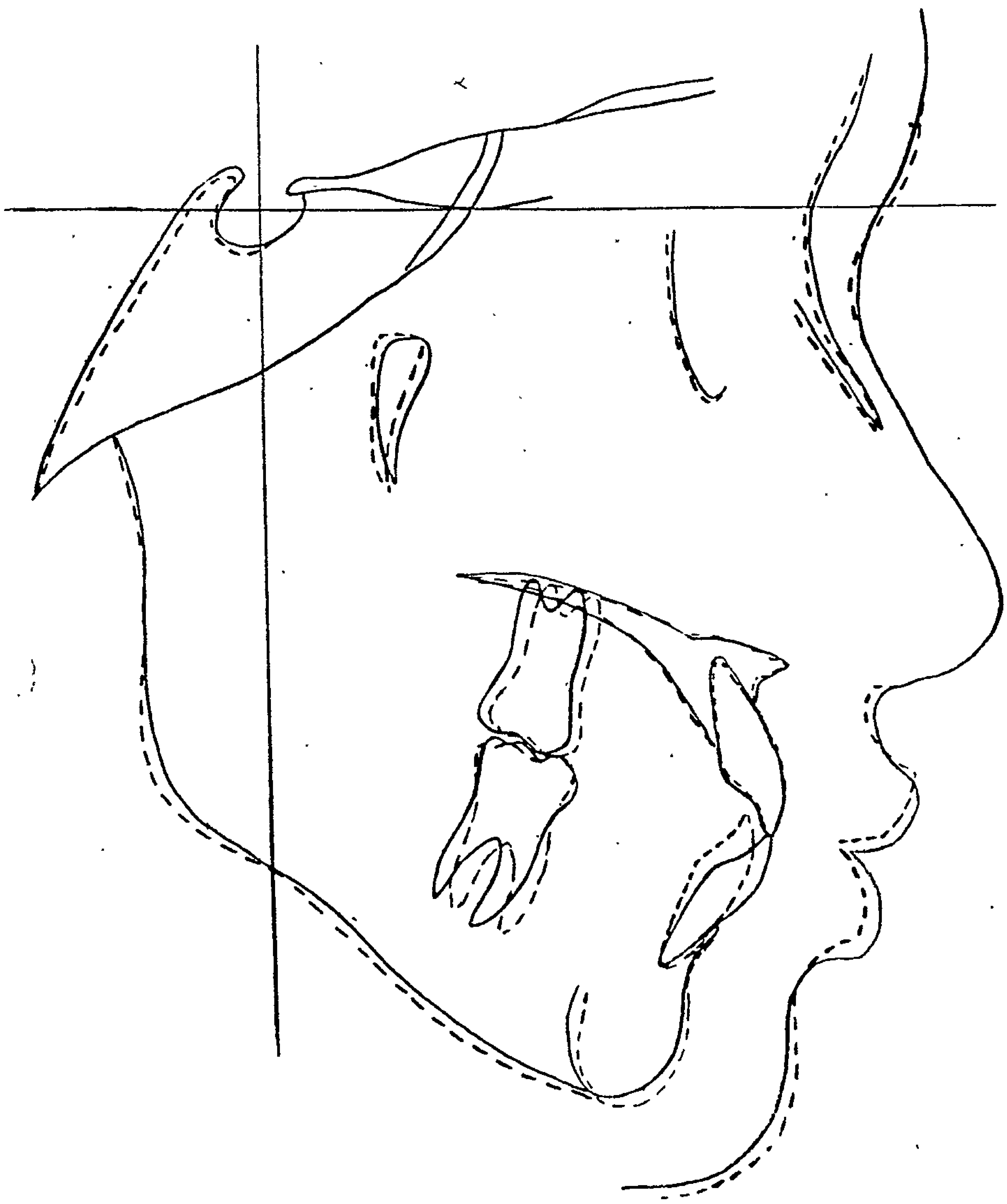

Figure A - 18.

PROFILE CHANGES IN CASE 18

——————— pre-treatment tracing.

--------- Tracing at bands off.

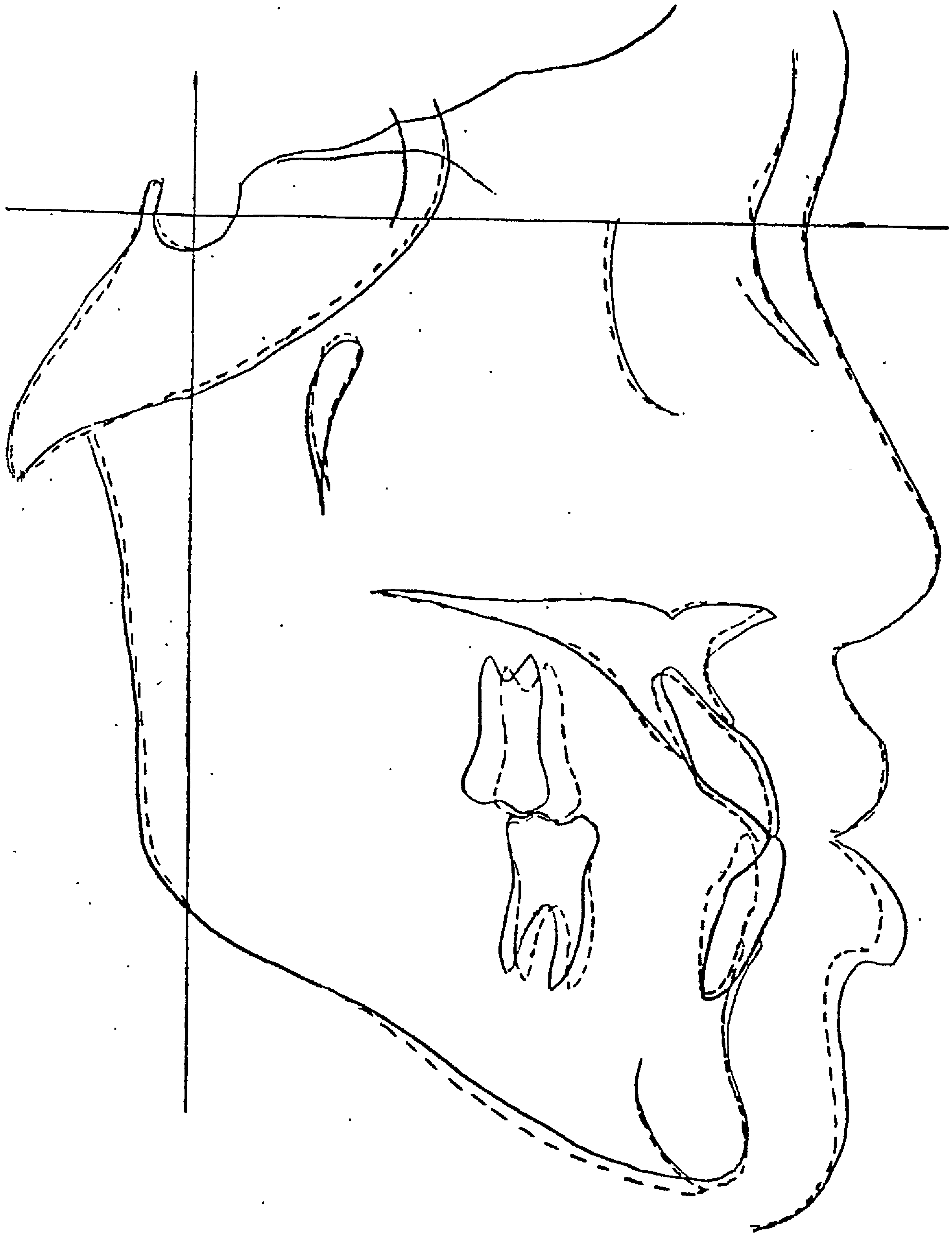

Figure A - 19. PROFILE CHANGES IN CASE 19

———————— pre-treatment tracing.

--------- Tracing at bands off.

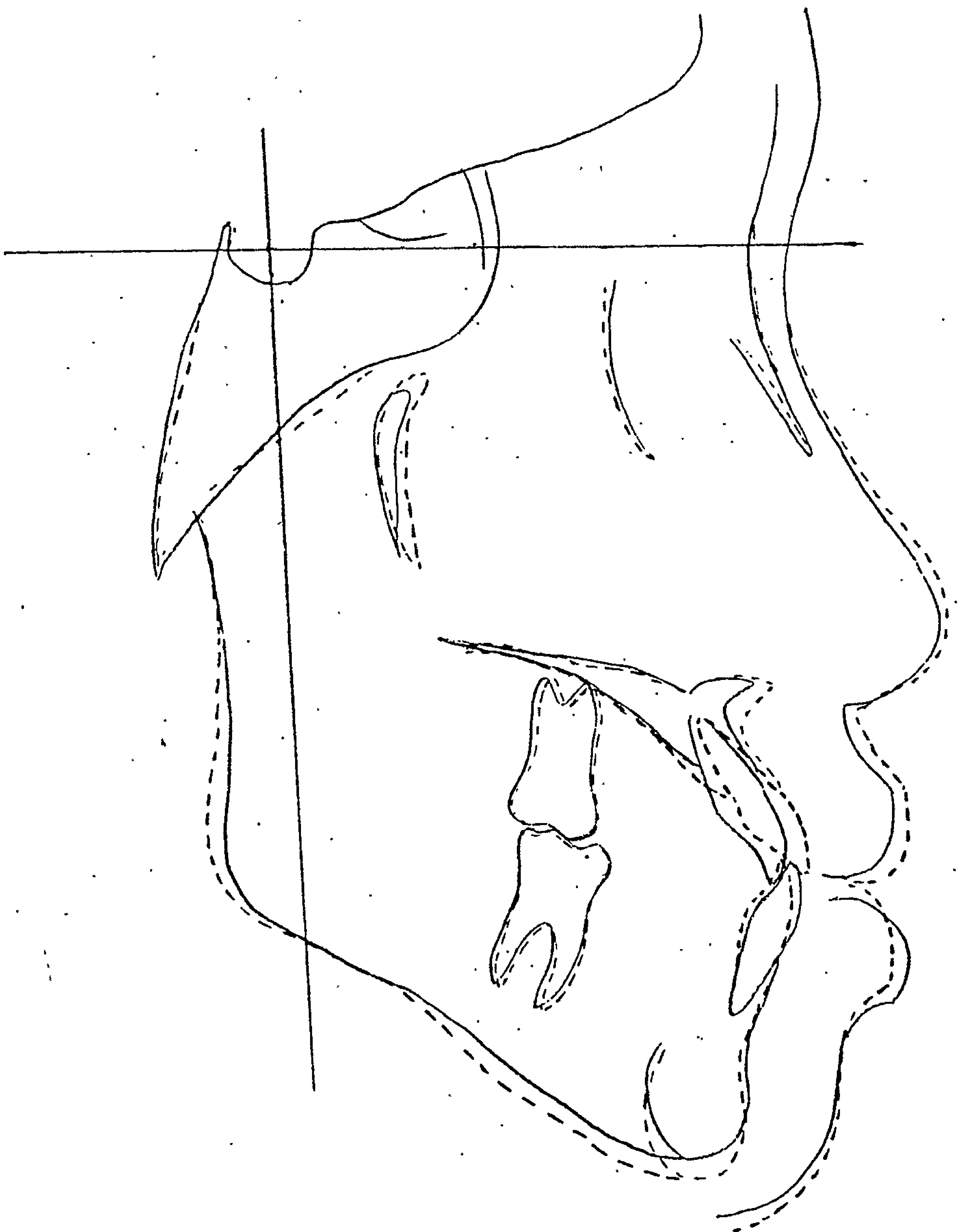

Figure A - 20.

PROFILE CHANGES IN CASE 20

———————— pre-treatment tracing.

--------- Tracing at bands off.

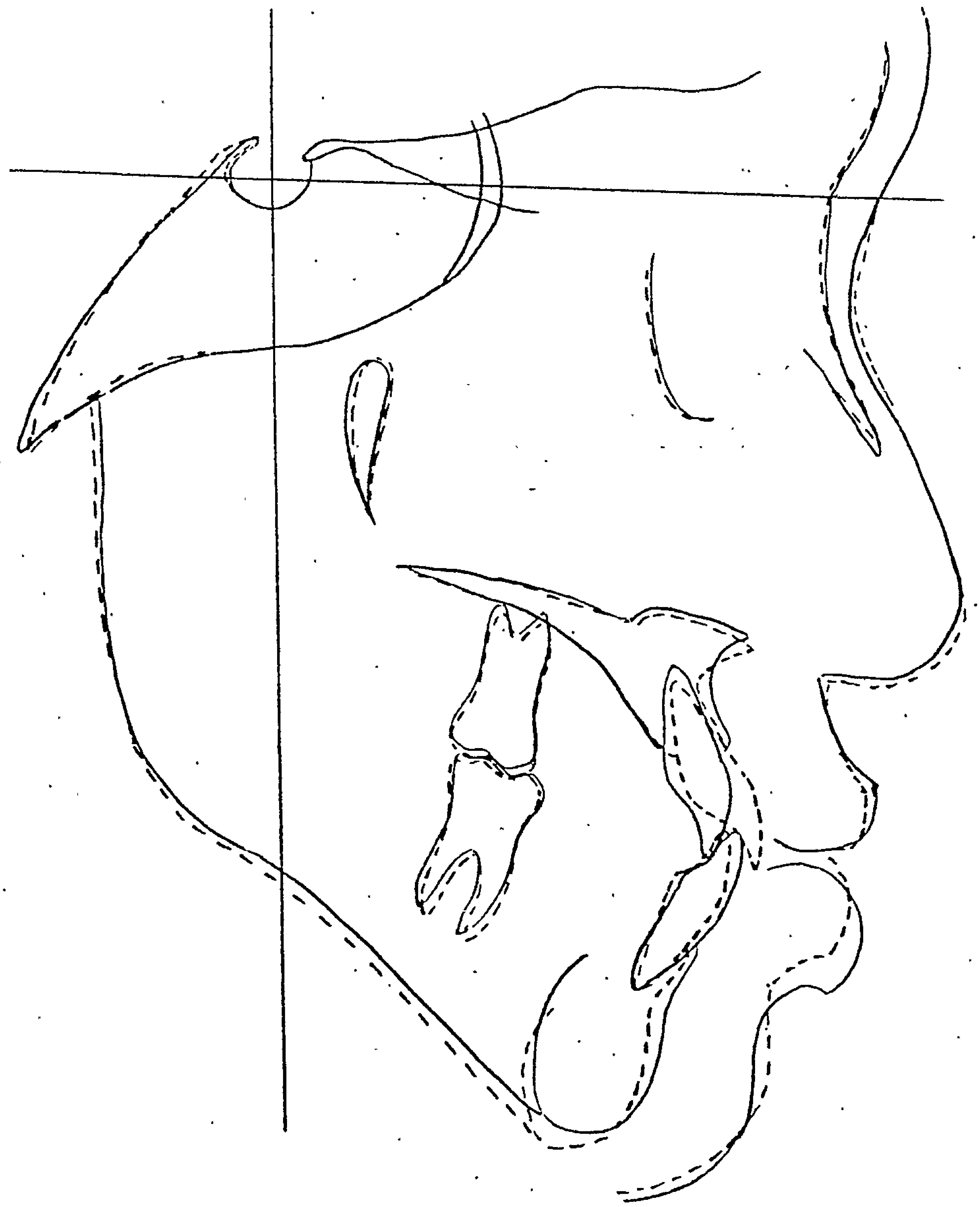

Figure A - 21. PROFILE CHANGES IN CASE 21

——————— pre-treatment tracing.

- - - - - - - - - Tracing at bands off.

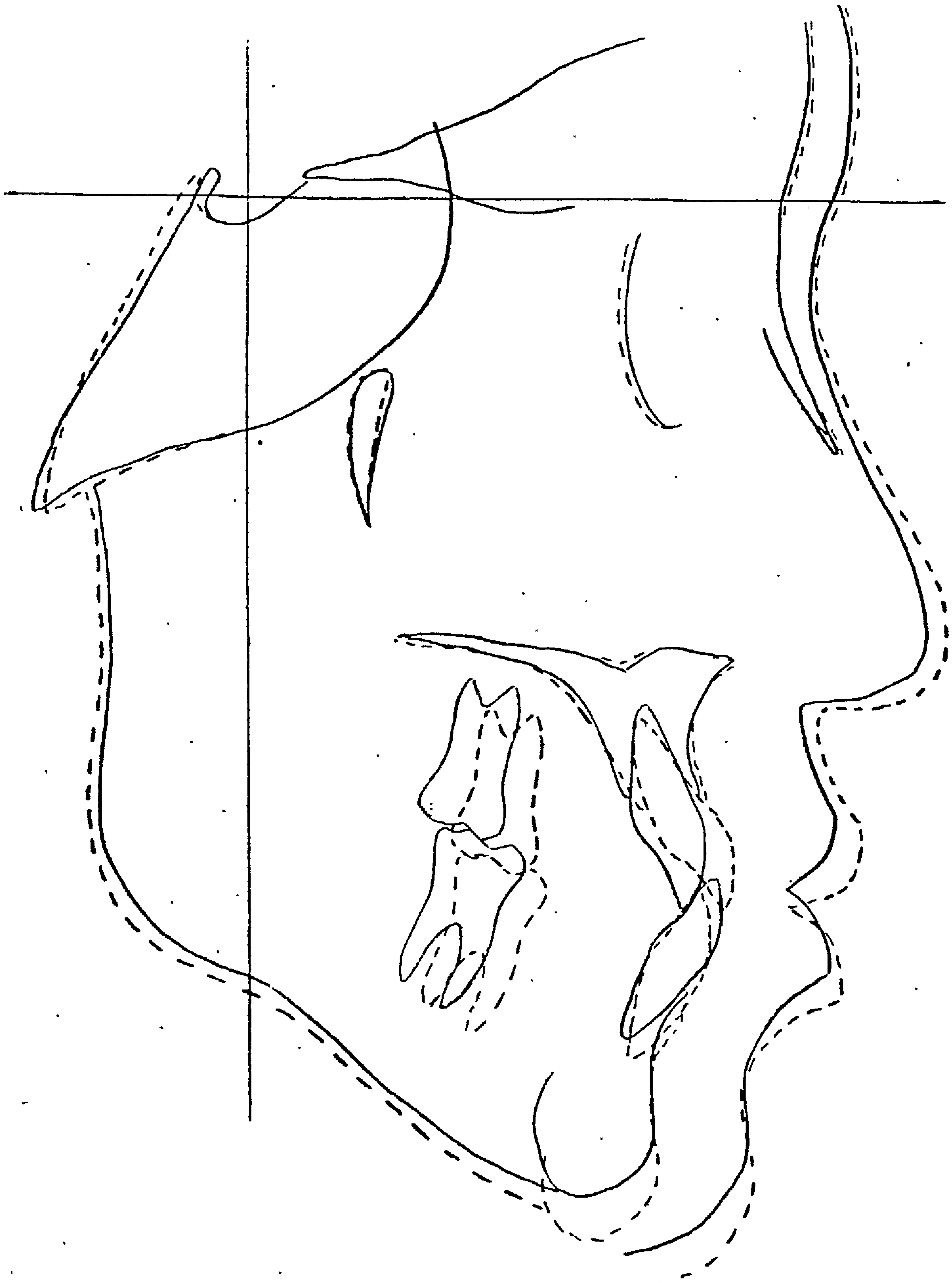

Figure A - 22. PROFILE CHANGES IN CASE 22

———————— pre-treatment tracing.

--------- Tracing at bands off.

II STATISTICAL METHODS

Table A - 5. Determination of the error of measurement by the " t " test. von Fraunhofer and Murray, (1976). The value of " t " was obtained by dividing the mean difference between the first and second determination for each linear and angular variable, by the standard error of the mean difference according to the formula:

$$'t' = \frac{d}{E(M\ diff)} ; = \frac{d}{\sqrt{\frac{SD^2}{n}}}$$

where "d" was the mean difference, "E(M diff)" was the standard error of the mean difference, "SD" was the standard deviation of the mean difference and, "n" was the size of this sample.

	VARIABLE		MEAN DIFF	STD. DEV.	VARIANCE	STD ERROR OF MEAN DIFFERENCE	' t value '	LEVEL OF SIGNIFICANCE
1.	N A Pog		-0.19	1.23	1.51	0.27	-0.70	0.5
2.	MPL SN		-0.26	0.74	0.54	0.16	-1.63	0.5
3.	1 to SN		-0.36	1.44	2.08	0.31	-1.16	0.5
4.	1 to MP1		0.36	1.69	2.85	0.37	0.97	0.5
5.	G Sn pog'		-0.05	1.47	2.15	0.32	-0.16	>0.5
6.	NASOLABIAL		0.43	2.54	6.43	0.55	0.78	0.5
7.	HOLDAWAY		-0.19	1.49	2.21	0.32	-0.59	>0.5
8.	POINT A:	A-P change	0.14	0.98	0.95	0.21	0.67	0.5
9.	POINT A:	S-I change	-0.45	1.16	1.35	0.25	-1.80	0.1*
10.	INCISION SUPERIUS:	A-P change	0.10	1.17	1.36	0.25	0.40	>0.5
11.	INCISION SUPERIUS:	S-I change	-0.24	0.96	0.92	0.21	-1.14	0.5
12.	INCISION INFERIUS:	A-P change	0.00	1.25	1.57	0.27	0.00	---
13.	INCISION INFERIUS:	S-I change	0.29	0.86	0.74	0.19	1.53	0.5
14.	POINT B:	A-P change	-0.24	0.96	0.92	0.21	-1.14	0.5
15.	POINT B:	S-I change	0.36	1.07	1.15	0.23	1.57	0.5
16.	SULCUS SUPERIUS:	A-P change	-0.38	0.82	0.67	0.18	-2.11	0.05**
17.	SULCUS SUPERIUS:	S-I change	-0.21	1.34	1.79	0.29	-0.72	0.5
18.	LABRALE SUPERIUS:	A-P change	-0.17	0.96	0.91	0.20	-0.85	0.5
19.	LABRALE SUPERIUS:	S-I change	0.00	0.89	0.80	0.19	0.00	---
20.	LABRALE INFERIUS:	A-P change	-0.12	0.99	0.99	0.22	-0.55	>0.5
21.	LABRALE INFERIUS:	S-I change	-0.02	0.94	0.87	0.21	-0.10	>0.5
22.	SULCUS INFERIUS:	A-P change	-0.33	1.01	1.03	0.22	-1.50	0.5
23.	SULCUS INFERIUS:	S-I change	0.29	1.15	1.33	0.25	1.16	0.5
24.	SUBNASALE:	A-P change	0.00	1.76	3.10	0.38	0.00	---
25.	SUBNASALE:	S-I change	0.00	1.72	2.95	0.37	0.00	---

Table A - 6. Mean ratio for proclination of upper incisors : forward movement of upper lip

Case	Incision superius		Labrale superius
1	2	:	1
2	0	:	0
3	4	:	1
4	1	:	1
5	1.3	:	1
6	0	:	0
7	2:1	:	1
8	0.6	:	1
9	1	:	1
10	0	:	0
11	1.8	:	1
12	0	:	0
13	0.2	:	1
14	0	:	0
15	0.4	:	1
16	1.4	:	1
17	0.2	:	1
18	0	:	0
19	0	:	0
20	2.6	:	1
21	6.0	:	1
22	1.1	:	1
MEAN RATIO	2	:	1

Table A - 7. Mean ratio for lower incisor : lower lip retraction.

Case	Incision Inferius		Labrale Inferius
1	1.2	:	1
2	2.1	:	1
3	2	:	1
4	0.9	:	1
5	2.4	:	1
6	1.3	:	1
7	0.4	:	1
8	0	:	0
9	2.1	:	1
10	-3	:	1
11	6	:	1
12	0	:	0
13	1	:	1
14	0.2	:	1
15	0	:	0
16	- 0.5	:	1
17	0	:	0
18	0	:	0
19	1.4	:	1
20	0	:	0
21	0	:	0
22	- 1.3	:	1
MEAN RATIO	1.1	:	1

Determination of the coefficient of correlation r.

When dealing with two variables, i.e. two collections of figures, it is useful to be able to assess the extent they are related.

The reliability of an estimate depended on the closeness of the relationship between the two variables and that a measure of this closeness was essential for assessing reliability.

The **coefficient of correlation** is such a measure, and the most generally used one is called the **Pearson product-moment coefficient of correlation,** commonly symbolised as **r.**

The formula for calculating **r** is

$$r = \frac{\Sigma (x - \overline{x})(y - \overline{y})}{\sqrt{\Sigma (x - \overline{x})^2 . \Sigma (y - \overline{y})^2}}$$

where **x** represented the values of the independent variable and **y** represented the values of the dependent variable.

Phrases to describe correlation.

a) Positive correlation, when an increase in one variable is associated to a greater or lesser extent with an increase in the other.

b) Negative correlation, when an increase in one variable is associated to a greater or lesser extent with a decrease in the other.

Numerical values of r.

The formula for **r** is such that its value always lie between **- 1** and **+ 1.**

+ 1 means there is **perfect positive** correlation.

- 1 means there is **perfect negative** correlation.

0 means there is **zero** correlation.

The closer **r** is to + 1 or - 1, the closer the relationship between the variables; and the closer **r** is to 0 the less close the relationship. However, the closeness of the relationship is not proportional to **r**; an **r** of 0.8 does not indicate a relationship twice as close as one of 0.4.