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Dento Maxillo-Facial Response to a Postero-Horizontal Extraoral Traction

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DENTO MAXILLO - FACIAL RESPONSE TO A POSTERO - HORIZONTAL EXTRAORAL TRACTION

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CHAPTER I

INTRODUCTION

The Class II malocclusion can be defined fundamentally as an abnormal dental arch relationship in which the lower dental arch occludes in a more posterior than normal relationship to the upper dental arch.

Several different types of anchorage are currently utilized in orthodontics to move teeth. Anchorage situated outside of the oral cavity has the important advantage of avoiding the exertion of any reciprocal action forces on a tooth or group of teeth. Use of the cranial and occipital areas to bolster the intraoral resistance units is one of the oldest forms of orthodontic therapy.

Interpretation of the occlusal changes produced by this particular kind of mechanics has evolved concomitantly with the progress made in the study of cranio-facial growth and the development of roentgenographic cephalometry. The profession thus obtained an adequate and accurate means to measure the changes produced by the growth and the treatment.

Brodie (1938) felt that the successful treatment of a Class II malocclusion was predominantly dependent upon the growth of the mandible; orthodontic treatment was restricted to the alveolar process and its associated dental structures with no apparent basal bony changes.

Closson (1950) talked of the possibility of moving the maxillary molars distally.

Nelson (1952) found that distal movement of the maxillary teeth may occur by holding back their forward growth.

Keiterhagen (1956) noted that as a result of headgear treatment, distal eruption of the maxillary molars and premolars was possible as well as the retardation of the forward development of the maxilla.

Weislander (1963) stated that headgear influences effect the growth of the entire face.

Armstrong (1970) designed a new type of headgear that combined both the occipital and cervical headgears. The main advantage of this headgear was that it controlled the direction of the forces applied. By passing through the center of resistance of the tooth, tipping and extrusive movements were circumvented. The magnitude of force was unusually, relatively heavy: three pounds. The appliance was worn twenty-four hours a day for a period of about three months to correct the antero-posterior discrepancy of a typical young Class II patient.

Sanders (1971) analyzed the affect of the combination headgear, with a heavy, continuous force of constant direction, in late mixed dentition patients. He found that this type of headgear treatment retarded the forward component of growth of the maxilla, and in addition produced a distal bodily movement of the molar teeth. As suggested by Dr. Sanders' advisory board, it is the author's intention to add detail and to further Dr. Sanders' findings.

By investigating the monthly incremental affects of the combination headgear over a period of three months, it should be possible to determine how the upper molars react to the application of a heavy continuous force of constant direction. Pertinent additional topics such as the duration of the lag period and how the presence of developing second molars effects the movement are studied.

A study of records taken every month should elucidate the time at which the orthopedic affect, action on the sutures of the maxillofacial complex, is produced.

Several observers have reported that if the cause of an inhibition of growth disappears before the end of the growth period, an increased acceleration of growth takes place which tends to compensate for the earlier retardation of growth. Consequently, it was decided to extend this experiment three months in order to analyze the growth reaction during the retention period when the headgear is worn only eight hours a day. Additionally, we would like to determine the response of the teeth to an intermittent force of the same direction and magnitude.

CHAPTER II

REVIEW OF THE LITERATURE

GROWTH STUDIES

The different methods which have been used to study growth can be divided into three main groups:

1. Vital Staining

As early as the eighteenth century it was discovered that certain substances had the property of staining the newly forming calcified tissues, thus, leading to the determination of the most important sites of growth in the bony and cartilaginous structures.

2. Microscopy

At the end of the nineteenth century microscopic studies began to give valuable information concerning the details of the bone growth mechanism. Areas of bone formation and resorption were recognized in the mandible by Kolicker as early as 1872.

3. Craniometry

Through analysis of the morphologic differences between the various ethnic groups at different age levels, the anatomists and the anthropologists were the first to observe and report the changes that take place in growing individuals.

Since they were dealing only with skulls, the age of the samples could be determined alone by the stages of development and the degree of attrition of the dentition; at most, this gives a rough estimate of the growth process.

Utilizing craniometric techniques, Hellman (1935) was one of the first to study facial growth serially. Although his measurements were done only through the soft tissues, his work led to some important findings. The face of the infant is transformed into that of the adult by changes that involve increases in both proportion and size. This increase is continuous and proceeds in spurts. He noted that the face gradually drifts forward changing its relationship with the cranium.

Goldstein (1936) did a serial study of the facial growth of fifty Jewish males between two and twenty years of age. He noted that the most important increase was in the vertical dimension, followed by the antero-posterior dimension, and finally the least increase in width occured. His measurements reveal two spurts: An early acceleration between three and five years followed by a plateau before a pubertal growth spurt which takes place between thirteen and fifteen years of age.

Pacini (1922) used roentgenograms for craniometric purposes.

Broadbent (1931) and Hofrath simultaneously in America and Germany, standardized the radiographic procedure. The roentgenogram oriented either parallel or perpendicular to the sagittal plane of the head gave a two dimensional picture of the three dimensions of the head. The film taken at a constant determined distance allowed the observer to compare different individuals or to follow the changes which take place in a same individual during all his growth periods. This marked the development of an accurate technique for morphological growth studied on live subjects.

To be pertinent to the present study, the review will be limited to the investigations done on caucasian subjects between the ages of eight and thirteen. A second part will give a short account of growth mechanism theories presently accepted and will try to define the role of the facio-cranial sutures.

Broadbent (1937) was the first to publish a study on the normal development of the face using his cephalometric technique in a cross-sectional survey. He showed that growth follows an orderly and consistent pattern. All facial landmarks except nasion move on straight lines in a downward and forward direction. The hard palate descends parallel to its initial position with age.

Five years later Brodie published the result of a longitudinal study of the growth of the head. The sample was composed of thirty-one children ranging from three months to eight years of age. He observed that the pterygo-maxillary fissure was very stable. He confirmed that the skull pattern does not change after birth and all the bones forming the cranio-facial complex grow regularly at a diminishing rate in a same linear direction. However, Gans and Sarnat (1951) reported that in monkeys the mandible was following various curves during growth.

Moore (1947) showed in a serial study of ten normal growing individuals that between eight and sixteen years of age, the chin tends to become more prominent and the horizontal growth exceeds the vertical growth.

The decrease in the facial prognathism during adolescence was analyzed by Bjork (1947) in a cross-sectional study. He found that between the ages of twelve and twenty-one years, the mandible is displaced forward more than the maxillary complex. He noted that this change was influenced by the size of the mandible, the gonial angle and the intensity and direction of the condyle growth. The dimension of the cranial base and its angulation also played an important part.

Lande (1951) reported that the mandible becomes more prognathic in relation to the cranial base. However, he asserted that the straightening of the face with age is also partly due to a relatively poor horizontal component of growth of the middle face.

Brodie (1951) reported the second part of his study. Using the same method with a broader sample he investigated the changes of the human face from the seventh to the seventeenth year of age. He noted a strong tendency for the nasal floor to remain stable throughout the growth period; however, in some instances, anterior nasal spine (ANS) dropped more than the nasal spine (PNS). In the late stages of growth, the dental arch was found to move more slowly forward and downward than ANS and pogonion (Pog.). Although he maintained that the individual pattern is consistent and stable, he also stated that important variations can be found between individuals.

Bjork (1951), after having performed several longitudinal studies with the use of metallic implants, in 1957, noted that the pattern of the entire facial structure can be subjected to various changes, producing variations in the initial trend of growth in a same individual. Later studies by Moore (1959), Nanda (1961), Hilgers (1961) and Merow (1962) support this concept of variability in facial growth.

Coben (1955), in a longitudinal study of forty-seven patients, including boys and girls between eight and sixteen years of age with an excellent occlusion, did not observe any significant differences between males and females at the prepubertal stage. He concluded that in spite of an infinite variability in size and form of the different components, the entire facial complex could be harmonious when considered in its entirety.

Nanda (1955) studied serial longitudinal cephalograms of ten boys and five girls and concluded that the growth curves of all facial dimensions followed a general skeletal growth pattern except angles formed by lines sella (S), nasion (N), and nasion-subspinale (A) which is a combination of neural and skeletal pattern of growth. He further reported a circumpubertal maximum of facial growth which occurs at a later age than the general body height spurt.

Marshall (1958) reported that the antero-posterior growth of the face takes place in three spurts, the first at six months, the second from four to seven years and the third from fifteen to nineteen years.

The variations which take place in the cranial base during growth were observed by Ford (1958) on dried skulls. He showed that the various parts composing the cranial base had either a neural or a general skeletal growth pattern but were never a combination of both. He further demonstrated that the cribriform plate ceased to grow at the age of seven and that the later increment of the anterior cranial base was due to the development of the frontal sinus.

Merow (1962) studied the dentofacial growth during puberty in twenty-five children with a normal occlusion and reported that the mean of the prepubertal age was 7.9 years and 15.5 years for the post-pubertal age. The changes were analyzed by tracing a system of coordinates. The point of origin of the two axis was the registration point "R" of Bolton, one line was parallel to the Frankfort horizontal plane (FH) and the other was perpendicular to the latter passing through R. After superimposition of the headplates, he found that the horizontal proportion of the upper face tended to remain stable while the lower face showed an increase. The lower face displayed less variation in the vertical dimension. Point A maintained a proportional stability horizontally but was less stable vertically.

Bergersen (1966) demonstrated that all the facial landmarks migrate on fairly straight lines except the mandible, which migrates in a wave-like manner. However, when those waves were averaged, a straight line tendency could be recognized. The point with the least variability in direction was found to be ANS and nasion.

Searching to correlate the facial growth and the body height, Hunter (1966) followed fifty-nine subjects from the age of seven through adolescence. Cephalometric roentgenograms were taken every six months. Contrary to the previous investigations a statistically significant correlation was established between the maximum facial growth and the maximum growth in height. The pubertal spurt occured 2.5 years earlier in females than in males, but the duration of the pubertal growth period was about the same in both sexes. Eighteen of the subjects had orthodontic treatment with various types of mechanical appliances including headgear. Neither the age of the patient nor the length of the treatment affected the time of the maximum facial growth.

Growth Mechanism Theories

The face is composed of individual bones which reach their individual development after a certain time. They articulate by a system called sutures which have been described as growth sites. It is commonly believed that the increase in dimension of the skull is chiefly due to the additions to the edges of the individual bones at the suture lines.

Brash (1924) reported that the amount of bone added to the skull and the facial bones by surface apposition was much greater than the amount added at the sutures.

Sicher (1947) believed that the most active sites of the naso-maxillary complex growth were the fronto-maxillary, palatino, maxillary, zygomatic-maxillary and pterygopalatine sutures. These sutures being relatively parallel to each other cause the maxillary complex to shift downward and anteriorly with growth.

Moore (1949) through vital staining, also found that facial growth was predominantly located in the sutures.

Another theory considers sutural growth as a secondary process, initiated by proliferation of cartilage and expansion of such organs as the brain and eyeballs (Moss, 1955).

Scott (1953) reported that the nasal septum is largely responsible for the forward and downward growth of the maxilla until about the seventh year. The zygomatic and pterygopalatine sutures cease to be the site of growth earlier than the age of seven. After three years of age, changes are brought by surface apposition and remodeling. This concept is supported by the experiments of Selman and Sarnat (1955) who caused growth deficiencies in nasal bone, maxilla premaxilla, palate and dental arches of rabbits after removing the septo-nasal cartilage.

Bjork (1953) studied the sutural growth of the upper face with implants. He found that the growth in height takes place at the sutural articulations of the frontal and zygomatic processes and by apposition in the lower border of the alveolar process. He further added that growth in height is sutural towards the palatine bone and is accompanied by periosteal apposition at the maxillary tuberosity. He concluded that the sutural growth has a spurt pattern, the minimum taking place at eleven and one half years of age and the maximum at fourteen years of age.

By comparing the sections of the constituting bones of the cranio-facial complex at different phases of development, Enlow (1965) gave a comprehensive interpretation of the growth of the face.

He showed that the bones undergo a process of displacement away from each other as they enlarge in size. The process of displacement occurs at the sutures. As soon as all parts are displaced, there is remodeling to allow the bone to maintain its shape, proportions and relationships. In the maxilla, in addition to the sutural displacement and remodeling process already described, an extensive apposition on the posterior maxillary tuberosity and an elongation of the alveolar process takes place. Enlow (1965) found that the palate moves downward by resorption on the nasal side and apposition on the palatal side.

Moss (1960) performed several experiments on the neural-cranial sutures of the rat. As their extirpation did not effect the dimension of the calvaria, he concluded that sutural growth was a passive phenomenon.

Koski (1968) made autotransplants of zygomatico-maxillary sutures in the guinea pig and was not able to show any growth. He found an extirpation of facial sutures appeared to have no appreciable change on the dimensional growth of the skeleton. He concluded that the sutures do not have any tissue separating force; thus, they are not comparable to growth centers.

DEVELOPMENT AND ACTION OF THE EXTRA ORAL THERAPY

Since antiquity the occipital anchorage has been used for the treatment of fracture and luxation of the mandible. Its first use for the correction of tooth malposition is difficult to determine. It seems that Cunnel was the first one in 1822 to have used a chin cap with a head cap in a case of a protruding lower jaw.

Kneisel (1836) mentioned the use of occipital anchorage to move upper incisors lingually.

Wescott and Sevill recorded the common use of occipital anchorage for the correction of mandibular prognathism in the middle of the nineteenth century.

In the last quarter of the nineteenth century, occipital anchorage was used in other types of malocclusions. Tomes (1873) used it to treat open-bite malocclusions.

Kingsley (1873) retruded upper anterior teeth with a vulcanite palate attached to a strip of gold covering the labial surface of the maxillary anterior teeth. Gold spurs were pulled back by means of elastics anchored to a leather skull cap.

Angle (1887) developed a net head cap attached by means of elastic bands to a traction bar. The turn of the century saw the advent of orthodontics as a new science. The molar teeth began to be banded. The other teeth were ligated to archwires of ideal form to correct individual malpositions. The proper relationship between the dental arches was attained by moving them on their bases with intermaxillary elastics.

The development of the new techniques prescribing intermaxillary elastics, more easily accepted by the patient, caused the nearly complete discard of the extraoral anchorage.

However, a few individuals like Calvin S. Case (1908) continued use the head cap as an adjunct to intermaxillary force to intrude and retrude labially placed incisors and to exert a distal force on the buccal teeth.

Strang (1924) advised its use in conjunction with the ribbon arch.

It was Albin Oppenheim who revived its use when in 1934 he mentioned using the headgear and a traction bar to distal drive the maxillary posterior teeth. In 1935 and 1936, in a report of his study on tissue reaction in response to orthodontic pressures, he showed that the application of a light intermittent force with headgear was the least detrimental appliance available at that time.

The advent of cephalometrics and the publication of Brodie's work (1938), on the appraisal of orthodontic results made the profession aware of the necessity to secure a stationary anchorage with an extraoral force. The merit of this study was also to give a new and more accurate interpretation of the headgear action. They showed that the changes induced by tooth movement appeared to be restricted to the alveolar process. Growth was found to be responsible for a considerable amount of changes which take place during orthodontic treatment. According to Brodie, the correction of the Class II cases was attained by a favorable trend of the mandibular growth.

Kloehn (1941) introduced a new kind of headgear. The anchorage consisted of a cervical strap leaning on the posterior aspect of the neck. Less bulky, more esthetic, it was largely prescribed without the knowledge that the intrusive component of force of the headcap was replaced by an extrusive one.

Hedges (1946), in his research, showed that in the majority of cases of Class II treatment, the mandibular growth accounted for the major amount of change in molar relationship.

Epstein (1953) could not find evidence of any acceleration of the mandibular growth or any change in the maxillary complex during the period of application of the cervical headgear. All the action of the therapy appeared to be limited to the teeth and the maxillary alveolar process (Silberstein, 1954).

Graber (1955) studied cephalometrically the changes produced by the application of the cervical headgear on one hundred and sixty patients with a Class II Division I malocclusion. The maxillary growth did not seem to be affected. In most cases the maxillary first molar was merely restrained from coming forward in its normal path or it was tipped distally. In some instances a bodily movement was accomplished. He attributed the failures of the headgear therapy to a poor patient cooperation or to unfavorable growth during the active treatment.

Silberstein (1954) and King (1957) later noted that the cervical anchorage had the negative tendency to open the mandibular angle and to prevent the pogonion from coming forward.

King (1957), in a cephalometric study of fifty Class II patients whose malocclusion was corrected with a cervical headgear, observed that point A and the molars were held back in addition to the affects of cervical headgear already described.

Poulton (1959) recorded an inhibition of 0.6mm of the forward growth of the maxilla in a sample of twenty-nine Class II cases treated for a period of one year.

Moore (1959) stated that the orthodontist can inhibit the normal forward movement of the maxillary denture and can favorably influence the facial pattern during the rapid growing period.

Ricketts (1960) concluded in his study of the cervical headgear that the maxilla could not be considered any more an an immutable structure. A vigorous retractive force can prevent its forward growth or even force it to grow downward and backward by action on the sutures.

Weislander (1963) evaluated the affect of the cervical anchorage upon the dentofacial area in mixed dentition patients. He found that a rotation of the sphenoid bone occured effecting the whole maxilla and as a result the anterior nasal spine dropped down.

Sandusky (1965) reported that the tipping of the palatal plane was accompanied by a maxillary molar extrusion which had the affect to increase the mandibular plane angle.

It corroborated the findings of Creekmore (1967) who pointed out that there was a greater increase of the vertical dimension of the face with a decreased forward movement of the chin in his fifty treated patients than in the control group.

An extensive analysis of the actions of the different types of headgear was made by Schudy (1965). He reported that during growth, an increase of the vertical dimension of the face is accompanied by a rotation of the mandible, which places the pogonion in a lower and more retruded position. The same affect can be produced by headgear therapy. After having compared the various kinds of headgear, he emphasized the advantage of high pull type, which retarded the vertical component of growth.

Poulton (1964) treated twenty-nine Class II Division I patients with a high pull headgear for a period of three years. After one year, an average of 2mm of distal movement was recorded, but only 0.8mm after two years and 0.9mm of mesial movement at the end of the third year. His interpretation was that a posterior movement of the teeth was measured on a structure which was carried forward. He pointed out that experience seemed to indicate when mixed dentition patients were treated, their molars and incisors did not seem to move forward quicker after therapy.

Coben (1966) advocated that orthodontic traction can tip or move the upper molars distally and can retard or redirect the forward migration of the upper molars.

Meach (1966) found a backward movement of the first upper molars in 70% of the cases and a downward movement 30% of the time when a cervical headgear was worn.

Baalack (1966) studied the distal movement of the upper first molars produced by an occipital anchorage. A head cap developing a force of 500gms was applied to a group of twenty-nine patients, an average of eleven years of age, for one year. After six months, 0.85mm of distal movement was noted and, 0.95mm after one year. The distal movement was more important when the second molars were not erupted.

Kuhn (1968) tried to control the direction of the forces applied with extraoral appliances. In order to avoid any extrusive affect, he recommended the use of the high pull headgear. Credit must also be given to the authors who worked in the field of theoretical mechanics (Gould, 1957; Weinstein, 1959; Burstone, 1962; Haack, 1963; Kuhn, 1966; and Jawor, Sanders and Wollney, 1970). They determined that a force must pass through the center of resistance of a tooth to produce a bodily movement. Since it is impossible to apply a force directly to the center of resistance, it is necessary to devise a mechanical system where the force will be transferred to the tooth in such a manner that the resultant force will pass in affect through this point. By adjusting the outer bows, the line of force can be made to run above, below, or through the center of resistance. When it passes through the center of resistance of the molars, a pure distal movement results. To avoid any supplementary vertical action to the distal tooth movement, the force must also be parallel to the occlusal plane.

Merrifield (1970) pointed out with a cervical traction the neck strap rests between the second and fourth cervical vertebrae, while the occlusal plane passes through the first cervical vertebrae. The average line of force with a cervical strap makes approximately an angle of thirty degrees with the occlusal plane.

The opposite affect is observed with the head cap. In addition to the intrusion of the molars, the maxillary growth is ideally controlled. The force being perpendicular to the general direction of the facial growth, hinders the normal downward and forward displacement of the maxillo-facial complex.

Graber (1967 and 1969) showed that two kinds of forces can be applied in orthodontics. A force can be only designated to move the teeth or can be orthopedic, with an action on the supporting structures. The headgear can produce an orthopedic affect when applied correctly. According to Graber, to be orthopedic, a force must be three to four pounds heavy to avoid any tooth movement, and transmit all the action to the dental base. It must also be intermittent in order to prevent root resorption and allow tissue recovery.

Armstrong (1971) reported the result of his experience with extraoral anchorage. In order to obtain a bodily movement of the upper molars in mixed dentition patients presenting a Class II malocclusion, he closely controlled the three mechanical variables; namely, magnitude, direction, and duration.

The outer bows were bent in such a manner that the resultant force passed through the centers of resistance of the teeth to be moved. To keep their positions constant, they were hooked to a combination of one cervical and one occipital headgear. A force of nearly two pounds was applied to each tooth continuously for a period of three months. The amount of force was kept the same by the use of a loaded coil spring which was less prone to fatigue.

The cases presented showed the development of spaces in the maxillary arch, attributed by the author to the distal movement of the maxillary molars.

Further investigations were made in 1971 by Sanders on the affects of a heavy continuous force delivered by the combination headgear.

CHAPTER III

METHODS AND MATERIALS

The present study was intended to be the development and the continuation of Sanders' (1971) thesis.

The experiment has been performed in two phases:

The first period, called active treatment, where the headgear was applied continuously, as the same as Sanders - this constituted the basis of his research.

The investigation was then extended to three additional months. During this period of retention the headgear was only worn eight hours a day in order to study the stability of the results. All of the records were re-analyzed by the author and the cephalograms were re-traced.

Selection of the Sample

The same fifteen patients studied by Sanders (1971) were again selected from the Department of Orthodontics at Loyola University on the following criterias:

1. Caucasian race of mixed European stock.
2. A dentition at the late mixed dentition stage.
3. Class II molar relationship.
4. The acceptance to wear the appliance twenty-four hours a day for a period of three months and eight hours a day for the following one hundred days.

TABLE I

SEX, INITIAL AGE OF TREATMENT OF THE SAMPLE

Case No.	Sex	Initial Age Years	Months	Length of the Active Treatment	Length of the Retention Period
1	F	11	3	101	99
2	M	9	2	103	97
3	M	10	8	102	98
4	F	9	6	98	102
5	F	11	4	94	106
6	F	9	4	104	96
7	M	10	9	101	99
8	F	10	5	96	104
9	M	10	5	100	100
10	F	10	0	100	100
11	F	11	5	101	99
12	F	10	11	100	100
13	M	8	10	102	98
14	M	10	5	100	100
15	F	10	7	100	100
	M = 6 F = 9	Mean=10 Range 8-10 to 11-5	4	Mean=100 Range 94-104	Mean=100 Range 96-106

The sex, the age of the patients, and the length of the treatment periods appear in Table I.

Experimental Procedure

Prior to this experiment the candidates were told that they would have to wear a headgear continuously for a period of one hundred days and that the facebow will be ligated to their maxillary first molars. The problem of cooperation was then minimized. After a few weeks a noticeable change could be observed in the dental relationship. This reinforced patient motivation.

In case of loose bands, or a broken appliance, the time of intermission from wearing the headgear was added to the time of treatment. This was done in order to obtain one hundred days of active wear.

The same principle was applied during the second phase of treatment when the headgear was forgotten at night. This occured a total of seven times in three different patients.

Description of the Appliance

The appliance was designed to transmit an extraoral force to the maxillary first molars. A combination of a neck strap and a headstrap composed the anchorage. Closed coil springs were attached on the external aspect of the terminal ends of the straps of the cervical and occipital gears. The distal ends were stapled to the gear. The mesial ends of the springs were connected to the facebow with straps of plastic with several holes. (Fig. 1)

FIGURE 1

PHOTOGRAPH OF THE APPLIANCE IN PLACE

Front View

Lateral View

APPLIANCE IN PLACE

The force was produced by stretching the spring.

The force was adjustable, depending on the hold chosen to hook the facebow, and precalibrated in order to be able to check easily at any time the amount of force applied.

The coil spring was selected to produce a constant force without having to depend on the patient cooperation.

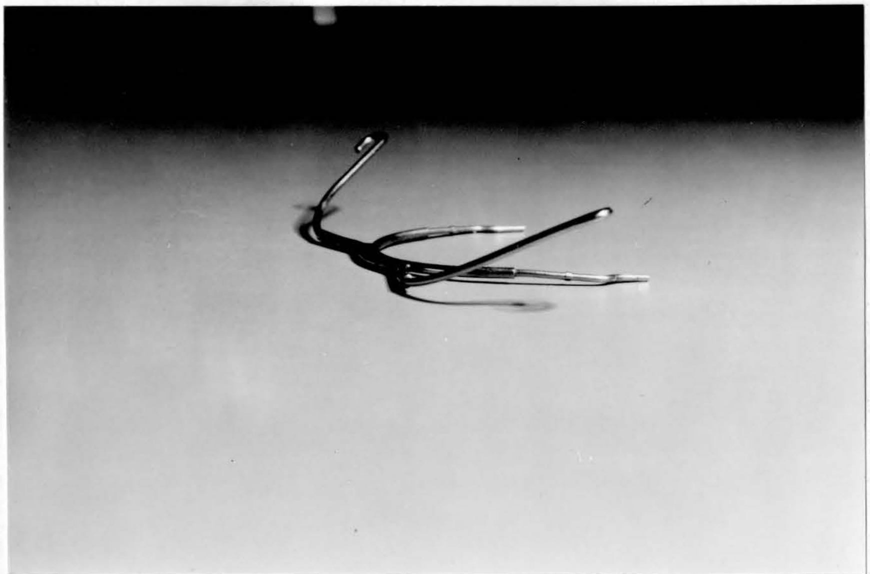
Armstrong and the Department of Orthodontics at Loyola University showed in 1971 that the fatigue of those springs did not exceed 5/100 of the load after a continuous wear of one hundred days with a tension of twenty-four ounces.

The force was transmitted intraorally by means of a double arch facebow. The outer bow with 0.62 diameter followed the contours of the cheeks without touching them. It was short and elevated so that the distal end terminated in a hook manner approximately 15mm above the level of the inner bow. The medial portion was soldered to the inner bow at the level of the lip junction. The inner bow of 0.50 diameter was contoured to the upper dental arch at a constant distance of 5mm except in its posterior portion where it was bent in with a bayonet slope in front of the maxillary first molars to provide a stop (Fig. 2, 3, and 4).

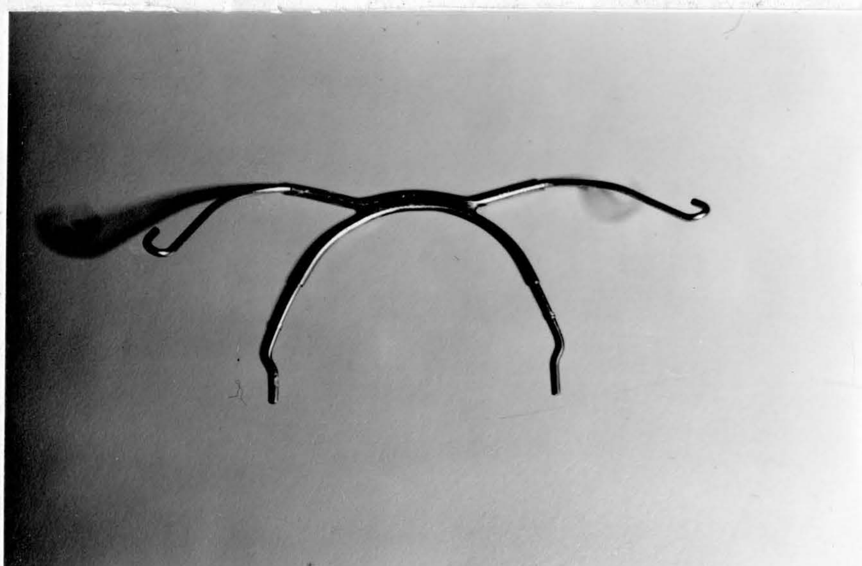
The tube with .051 inch diameter was welded on the middle of the buccal aspect of the band, which was cemented onto the crowns of the

FIGURE 2

DOUBLE FACE BOW



Side View



Front View
DOUBLE FACE BOW, SHORT OUTER BOW

FIGURE 3

CEPHALOGRAM SHOWING THE APPLIANCE IN PLACE

APPLIANCE IN PLACE
LATERAL CEPHALOGRAM

FIGURE 4

DIAGRAM OF DIRECTION OF FORCES USED

Combination of cervical and high pull headgear with 1:1 force ratio

Point of attachment of outer bow fifteen millimeters above level of inner bow

Resultant Force: Posterior, parallel to occlusal plane through center of resistance of maxillary molars

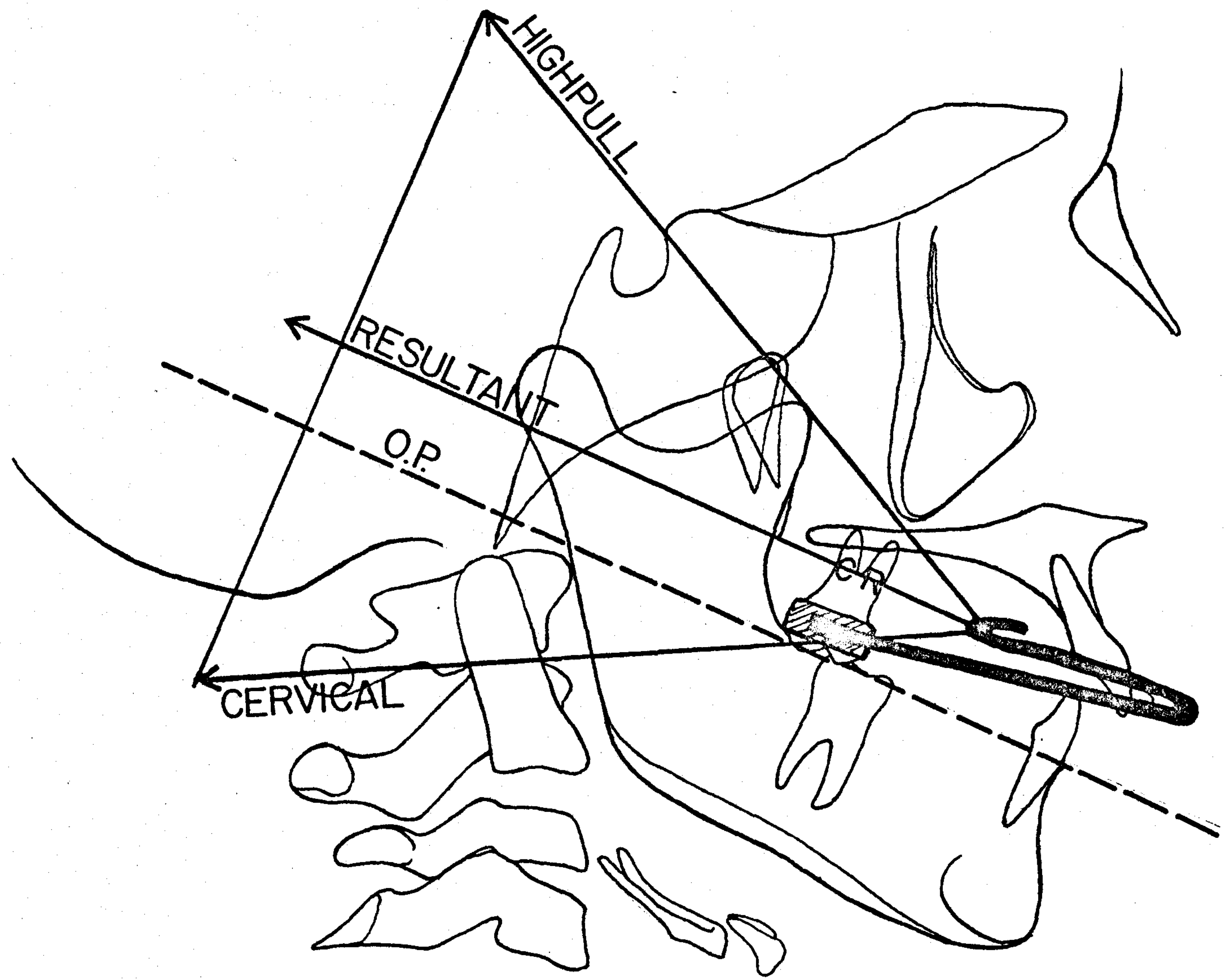


DIAGRAM OF THE RESULTANT OF FORCE USED

maxillary first molars. One eyelet was welded on each side 1 mm in front of the tube. This was done in order to be able to secure the facebow in the mouth with a piece of ligature wire.

A total of three pounds of horizontal force was applied. Fourteen ounces on each side of the cervical strap and fourteen ounces on each side of the occipital gear in order to keep a 1:1 force ratio. On each side the maxillary first molar received approximately one and one half pounds of force.

The investigation was divided into two parts. For the first period of one hundred days active treatment, the patients were instructed to wear the appliance twenty-four hours a day. They were only allowed to remove the head cap and neck strap for bathing and combing their hair. For the second period of also one hundred days (retention phase) the patients were asked to wear their appliance only during their bedtime. This headgear wear averaged eight hours a day. The parents were given special cards to note the patient's cooperation.

The patients were seen once a month during the entire experiment. A full set of records was taken at the beginning of the treatment (Stage 0), at the end of the active phase (Stage III), and at the completion of the retention period (Stage IV). These records consisted of: one set of models, one panorex and intraoral roentgenograms of the teeth, one postero-anterior (P-A) centric and lateral centric cephalogram, kodachromes of the face (front and lateral) and intra-oral views of the denture. At the end of the first and second month of the active period of treatment (Stage I and II), alginate impressions of the upper and lower dental arches were taken for study models. A postero-anterior centric and lateral centric cephalogram and panorex x-ray for the maxillary and mandibular teeth was also obtained.

Cephalometric Procedure

The cephalometric records (postero-anterior and lateral) were taken in the standard manner in the Department of Orthodontics at Loyola University. There was a distance of five feet between the midsaggital plane and the anode, and fifteen inches between midsaggital plane and the film.

Method of Tracing the Cephalometric Headfilms

Only the lateral centric cephalograms were used. The postero-anterior (PA) view has been kept in the files of the department for further investigation. They were traced by the same operator according to the standard procedure. The operator traced the headfilms on a 0.003 thick transparent paper with a 4H pencil in the same working conditions. The reference points and lines are defined in Table II and the measurements used listed in Table III. In the case of bilateral structures, the midline was consistently recorded as a point of reference.

TABLE II

GLOSSARY OF REFERENCE POINTS AND PLANES USED IN THIS STUDY

POINTS

Anterior Nasal Spine (ANS)

Median tip of the anterior nasal spine seen on the x-ray film from norma lateralis.

Basion (Ba)

The lower most point of the anterior margin of the foramen magnum in the midsagittal plane.

Maxillary Molar Crown (6A)

The most distal point on the maxillary first permanent molar crown.

Maxillary Molar Center of Resistance (6B)

Junction of the buccal roots of the first permanent molar.

Menton (Me)

The lowest point of intersection of the lower border of the mandible and the shadow of the symphysis.

Orbitale (Or)

The lowest point of the infra orbital margin.

Porion Anatomical (Po)

Upper edge of the porus austicus internus.

Posterior Nasal Spine (PNS)

The time of the posterior spine of the palatine bone in the hard palate.

Pterygomaxillary Fissure (Ptm)

Lower most part of projected contour of the fissure. The anterior wall represents closely the retromolar tuberosity of the maxilla and the post wall represents the anterior curve of the pterygoid process of the sphenoid bone.

Sella Turcica (S)

The geometric center of the pituitary fossa of the sphenoid bone.

Sub Spinale (Point A)

The deepest midline point of the premaxilla between the anterior.

DeCoster's Line (DL)

The plano-ethmoidal line from the anterior contour of sella turcica to the roof of the cribriform plate and the internal plate of the frontal bone.

PLANES

Frankfort Horizontal (FH)

The plane through orbitale and porion.

Projected Frankfort Horizontal (PFH)

The average of the Frankfort horizontal planes of all the roentgenograms of the same patient when superimposed on the DeCoster's line.

FIGURE 5

DIAGRAM OF LANDMARKS USED

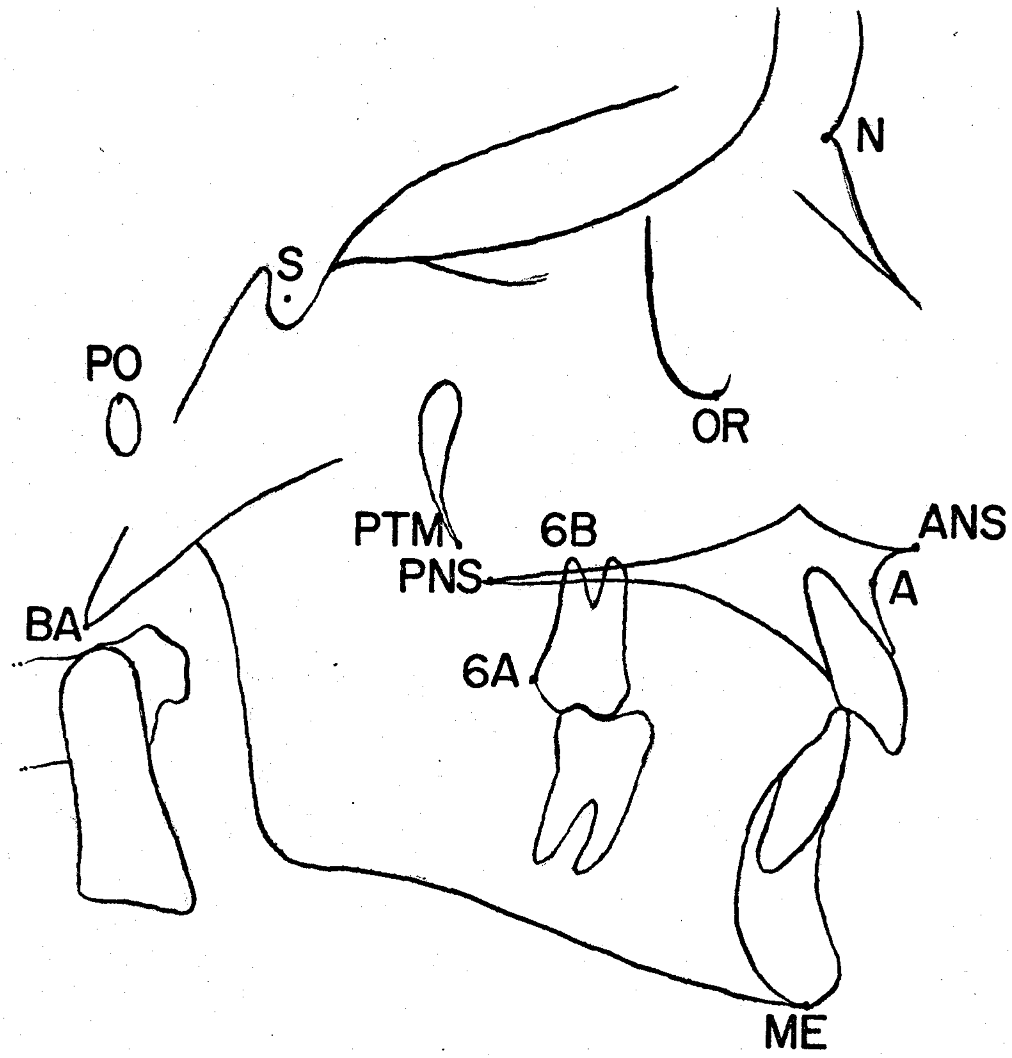


DIAGRAM OF LANDMARKS USED

Analysis

A coordinate system was used. This included mainly linear measurements.

As in Coben's Analysis (1955), a line parallel to the Frankfort plane passing through nasion was selected as the plane of orientation or X axis. The Y axis was a line perpendicular to Frankfort horizontal plane, running through basion (Fig. 5).

Each point was defined by two linear measurements: one taken along the X axis, to determine its antero-posterior position, and another along the Y axis, for its vertical location.

The measurements were made on a grid which corrected the seven percent magnification obtained on the cephalogram when taken according to the standard procedures.

As it was very difficult to locate accurately the apices of the molars, the author introduced two new points not used by Sanders to determine the position of these teeth. Point 6A, defined as the most posterior point of the crown, and point 6B, the point of convergence of the buccal roots of the upper first molar (Fig. 3). For better evaluation of the tooth movement, an angle was included in the analysis. One line of this angle connected 6B to the middle of the occlusal surface of the crown, and the other was a vertical passing through 6B (Fig. 4 and 5).

TABLE III

GLOSSARY OF MEASUREMENTS USED

I. ANTERO POSTERIOR MEASUREMENTS

A. Cranial Base

1. Ba.N Basion and nasion are projected parallel to the Frankfort horizontal plane (FH) and measured parallel FH.

2. Ba.S Basion and sella are projected parallel to FH and measured parallel to FH.

B. Maxilla

1. Ba.A Basion and subspinale are projected parallel to FH and measured parallel to FH.

2. BaPtm Basion and pterygo maxillary fissure are projected parallel to FH and measured parallel to FH.

C. Maxillary Molars

1. Ba6A Basion and the distal of the maxillary first molar crown are projected perpendicular to FH and measured parallel to FH.

2. Ba6B Basion and the intersection of the buccal roots of maxillary first molar are projected perpendicular to FH and measured parallel to FH.

II. VERTICAL MEASUREMENTS

A. Cranial Base

1. N.S. Nasion and sella are projected perpendicular to FH and measured perpendicular to FH.

B. Maxilla

1. N.ANS Nasion and anterior nasal spine are projected perpendicular to FH and measured perpendicular to FH.

2. N.PNS Nasion and posterior nasal spine are projected perpendicular to FH and measured perpendicular to FH.

C. Anterior Face

1. N.Me Nasion and menton are projected perpendicular to FH and measured perpendicular to FH.

FIGURE 6

DIAGRAM OF MEASUREMENTS USED

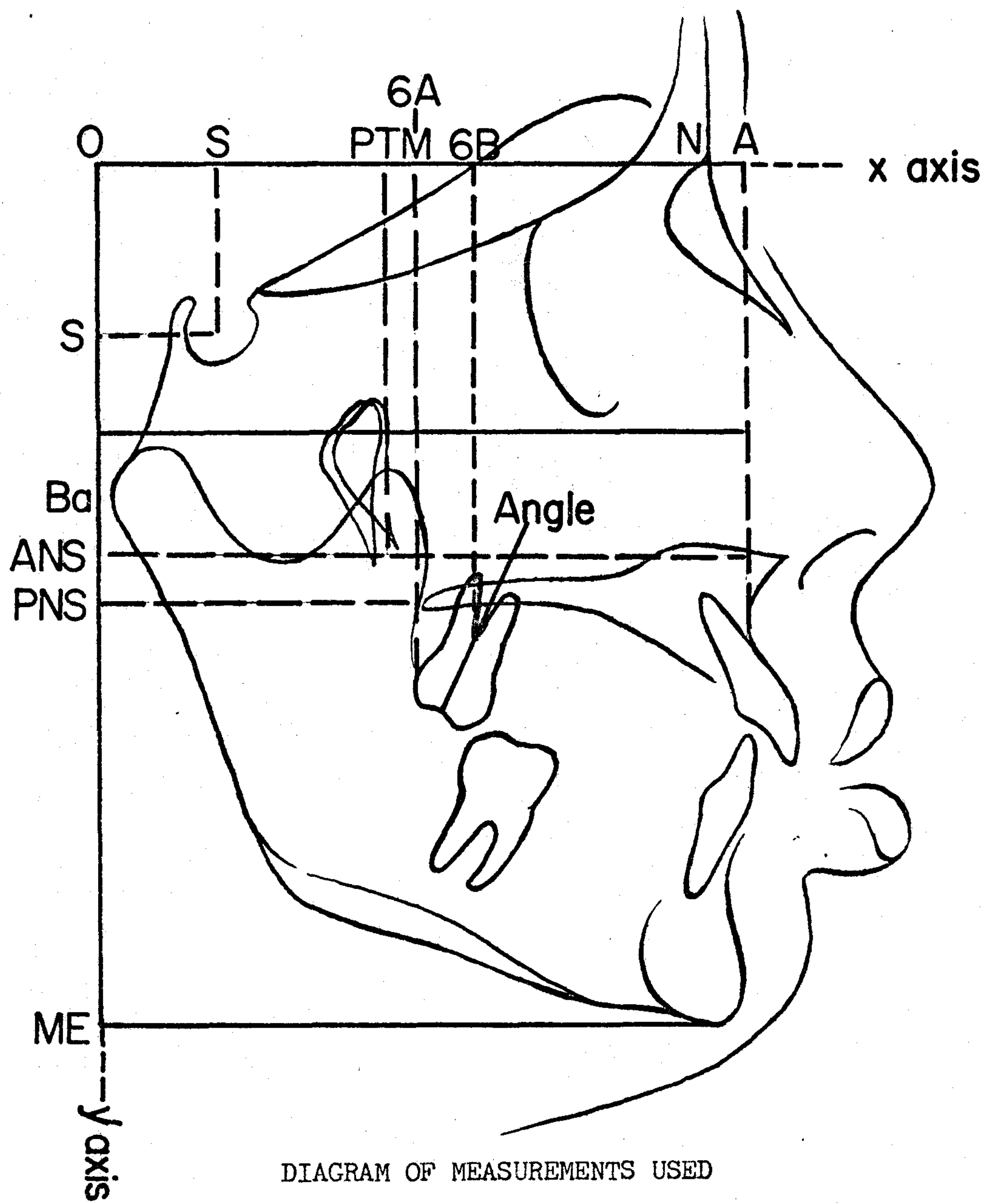


DIAGRAM OF MEASUREMENTS USED

Tracing Error

The same series of roentgenograms were traced at a two week interval. With the exception of porion, the tracing error was less than five percent.

Confronted with the irreliability of the Frankfort plane, the different cephalograms of the same patient were superimposed on the DeCoster's (1952) line. An average of the Frankfort plane was determined and used as the plane of reference in all of the series of headfilms belonging to the same patient.

Statistical Analysis of the Data

An analysis of variance was carried out for the measurements of each of the eleven bony and dental landmarks to show if any statistical difference occured after each month.

The sources of variance between individuals and periods of treatment were differentiated. The total sum of squares, sum of square between individuals and between periods of treatment were calculated (Stages 0, I, II, and III). In order to seek a statistical difference between periods, an F ratio was established + mean square relative to periods over interaction (error). Then the differences were localized by running a studentized test.

For the second part of the study, a paired T test was performed to compare the difference between measurements of every landmark before and after the retention period (Stages III and IV) to see if any significant difference took place. As from theoretical ground the direction of the direction of the difference was known. A one tailed test was used.

Comparison with Untreated Groups (Control Study)

The measurements of this study were compared to the changes that occur in normal, non-treated children. Among the numerous studies measuring the normal growth of young Americans of the Caucasian race, only investigations using similar measurements were selected. Those values from the studies of Burstone (1962), Coben (1955), Krogman (1958), Muller (1964) are compiled in Table 4.

TABLE IV

NORMAL GROWTH INCREMENTS
FOR A THREE MONTH
PERIOD

ANTERO-POSTERIOR

		BURSTONE	COBEN	KROGMAN	MULLER
Cranial Base	BaN	+0.3	+0.3		
	BaS		+0.1		
Maxilla	BaPtm		+0.2		
	BaA		+0.3		

VERTICAL

		BURSTONE	COBEN	KROGMAN	MULLER
Cranial Base	NS		+0.0		
Maxilla	N.ANS				+0.3
	N.PNS				+0.3
Anterior Face Height	N.Me		+0.6	+0.6	

CHAPTER IV

FINDINGS

As in the Coben analysis, the antero-posterior measurements are presented followed by the vertical measurements. The cranial base (Ba.S and Ba.N) did not show any significant change ($P > 0.10$) throughout the experiment.

It was also observed that the maxilla (Ba,Ptm,Ba.A) did not change significantly. The maxillary molars exhibited important changes in position. Point 6A (the most distal point of the crown) moved dramatically. The mean change of Na. 6A was -1.4mm the first month, -0.6 the second, and -0.2mm the third month. In other words a mean increase of 1 mm was noticed during the three months of the retention period. Finally a mean distal movement of 2.2 mm was observed during active treatment followed by a relapse of 1 mm during the retention phase. A statistically significant difference was found at the 0.01 level between the beginning of the treatment and the end of the third month. A statistical significance of $P < .05$ was seen between the beginning and the end of the retention phase.

Point Ba 6B showed a mean decrease of 0.7mm the first month and 0.6mm the third month, with no change seen for the second month and the last three months retention. The mean distal movement of the center of resistance of the molar teeth was 1.3mm during the active period of treatment and stayed stationary during the retention period. This meant that the distal tipping was accompanied with a bodily movement, which did not relapse. These changes were not statistically significant. $(P > .10)$

Important variations were seen in the angular values $(P < 0.01)$ between the beginning of the treatment and the end of the first month, the beginning of the treatment and the end of the second month, and the beginning of the treatment and end of the third month. A significant difference $(P < 0.001)$ also took place during the retention phase. An average increase of six degrees was observed during the first month. An additional 0.6 degree was gained the second month and then a decrease of 0.4 degree the third month. There was a loss of 7.7 degrees during the last three months of the retention period. All of the tipping produced at the beginning of the treatment was lost at the end of treatment, leaving a translatory action of the teeth of approximately 0.7mm.

Vertical Dimension

The cranial base did not demonstrate any appreciable change. The vertical alteration of the palatal plane, as measured by ANS and PNS, reflected the changes of the maxillo-facial complex. No significant difference was found in the position of PNS; however, N.ANS exhibited noticeable variations. The difference of the means at the end of the first, second, third and sixth months were +0.3, +0.3, +0.5, +0.4

respectively. This indicates a descent of the anterior part of the maxillary complex. Between the beginning of the third month and the end of the experiment, there was a significant difference in these measurements at the 0.05 level.

The anterior face height (N.Me) increased significantly ($P<0.01$) during the active part of the treatment. The mean increase was 0.7mm. A statistically significant difference was found between the beginning of the treatment and the end of the third month and between the end of the first month and the end of the third month. No significant change was exhibited during the retention period. The vertical growth of the face took place on the average of 0.7mm, which is slightly inferior to the normal vertical growth (1.2mm for a period of six months).

FIGURE 7

DIAGRAM OF THE TOOTH MOVEMENT OBTAINED

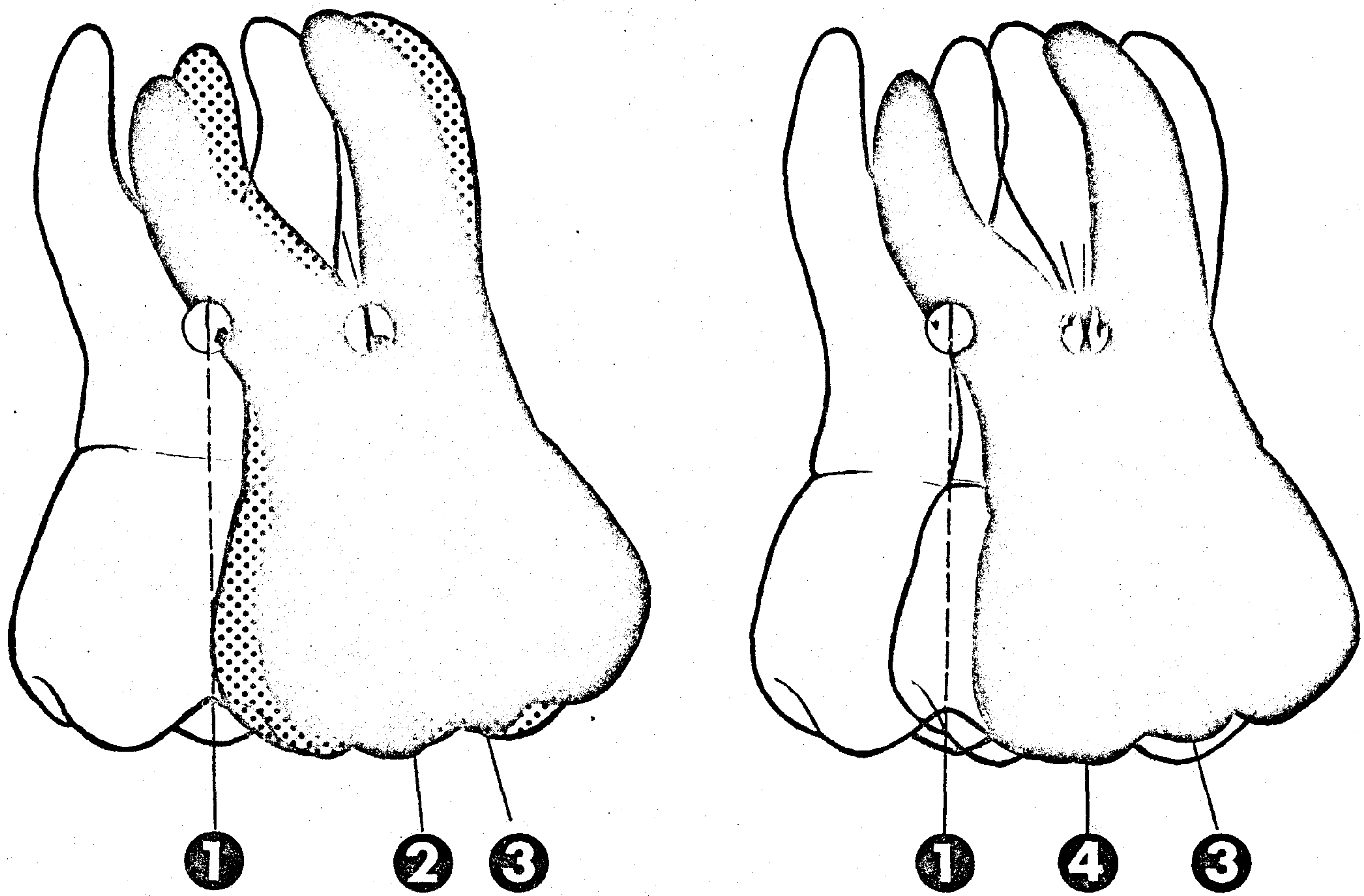


DIAGRAM OF THE TOOTH MOVEMENT OBTAINED

TABLE V
COMPARISON OF THE MEAN CHANGES WITH NORMAL GROWTH FINDINGS

ANTERO POSTERIOR MEASUREMENTS	Initial Mean (Stage 0)	Changes after 3 Months of Active Treatment (Stage 0 to Stage III)	Normal increment for a 3 month period (See Table IV)	Changes after 6 months of treatment (Stage 0 to Stage IV)	Normal increment for a 6 month period
Cranial Base					
BaN	83.7	0.7	0.3	0.8	0.6
BaS	19.3	0	0.1	0.2	0.2
Maxilla					
BaPtm	40.1	0.1	0.2	0.2	0.4
BaA	86.9	0.3	0.3	0.0	0.6
VERTICAL					
Cranial Base					
N.S.	16.4	0.0	0.0	0.0	0.0
Maxilla					
N.ANS	49.14	0.1	0.3	0.5	0.6
N.PNS	51.7	0.3	0.3	0.2	0.6
Anterior Facial Height					
N.Me	103.1	0.9	0.6	1.1	1.2

TABLE VI

MEAN AND STANDARD DEVIATION

ANTERO POSTERIOR MEASUREMENTS

	CRANIAL BASE		DENTAL MEASUREMENTS		
	Ba.N	Ba.S	Ba.6A	Ba.6B	Angulation
	Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.
0	83.7±3.8	19.3±2.8	50.8±4.2	58.47±3.9	15.2±3.8
I	83.8±3.8	19.3±2.8	49.4±4.08	57.8±4.03	21.1±5.2
II	84.1±3.7	19.2±2.8	48.8±4.2	57.8±3.9	21.7±4.8
III	84.4±3.7	19.3±2.7	48.6±3.9	57.2±3.9	21.3±3.6
IV	84.5±3.5	19.5±2.3	49.6±4.2	57.0±3.8	13.6±4.2

0 = Beginning of treatment
I = End of the first month
II = End of the second month
III = End of the third month
IV = End of the sixth month

TABLE VI (cont.)

MEAN AND STANDARD DEVIATION

ANTERO POSTERIOR MEASUREMENTS

	MAXILLA				VERTICAL MEASUREMENTS CRANIAL BASE	
	Ba.Ptm	Ba.A	N.ANS	N.PNS	N.S	N.Me
	Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.
0	40.1±3.6	86.9±4.7	49.14±2.2	51.7±2.7	16.4±3.7	103.1±3.9
I	40.3±3.5	86.9±4.8	49.4±2.5	51.8±3.7	16.4±3.6	103.4±4.0
II	40.2±3.45	87.06±4.7	46.7±2.15	51.7±2.8	16.5±3.9	103.6±4.4
III	40.2±3.47	87.2±4.6	47.2±3.7	51.9±2.8	16.4±3.5	104.±4.2
IV	40.3±3.2	86.9±4.4	47.6±2.3	51.9±2.6	16.5±3.6	104.2±4.3

0 = Beginning of treatment
I = End of the first month
II = End of the second month
III = End of the third month
IV = End of the sixth month

<u>TABLE VII A</u>

ANALYSIS OF VARIANCE TEST COMPARING INTERACTIONS
OF THE MEASUREMENTS TAKEN MONTHLY DURING
THE ACTIVE PART OF THE TREATMENT
(STAGES 0, I, II, III@)

<u>CRANIAL BASE</u>

	DF	MS	F Ratio for measurements
Ba.N			
Measurements	3	1.7	0.38
Patients	14	75.51	
Interaction	42	4.36	
Ba.S			
Measurements	3	0.1	
Patients	14	40.55	0.1
Interaction	42	0.97	

<u>MAXILLA</u>

	DF	MS	F Ratio for measurements
Ba.Ptm			
Measurements	3	0.105	
Patients	14	53.01	0.52
Interaction	42	0.201	
Ba.A			
Measurements	3	0.15	
Patients	14	115.3	1
Interaction	42	0.16	

P-.05 = 2.83
P-.01 = 4.29

@Stage 0-Beginning of the treatment
Stage I-End of the first month
Stage II-End of the second month
Stage III-End of the third month

TABLE VII B

ANALYSIS OF VARIANCE TEST COMPARING INTERACTIONS OF THE MEASUREMENTS TAKEN MONTHLY DURING THE ACTIVE PART OF THE TREATMENT (STAGES 0, I, II, III@)

	DF	MS	F Ratio for measurements
DENTAL MEASUREMENTS			
Ba6A			
Measurements	3	17.4	
Patients	14	52.15	5.3*
Interaction	42	3.28	
Ba6B			
Measurements	3	4.44	
Patients	14	158.20	0.26
Interaction	42	17.05	
Angulation			
Measurements	3	167.6	
Patients	14	61.34	23.5*
Interaction	42	7.11	
CRANIAL BASE			
NS			
Measurements	3	0.10	
Patients	14	62.35	0.3
Interaction	42	0.343	
Posterior Facial Height			
N.Me			
Measurements	3	2.24	
Patients	14	75.19	5.46*
Interaction	42	0.41	

*Measurements are statistically different at the 0.01 level.

P-.05 = 2.83
P-.01 = 4.29

TABLE VII C

ANALYSIS OF VARIANCE TEST COMPARING INTERACTIONS OF THE MEASUREMENTS TAKEN MONTHLY DURING THE ACTIVE PART OF THE TREATMENT (STAGES 0, I, II, III@)

MAXILLA

	DF	MS	F Ratio for measurements
N.ANS			
Measurements	3	6.57	
Patients	14	26.15	3.67*
Interaction	42	1.79	
N.PNS			
Measurements	3	0.19	
Patients	14	29.03	0.002
Interaction	42	29.05	

P-.05 = 2.83
P-.01 = 4.29

*Measurements are statistically different at the 0.05 level.

@Stage 0-Beginning of the treatment
Stage I-End of the first month
Stage II-End of the second month
Stage III-End of the third month

TABLE VIII

STUDENTIZED RANGE TEST COMPARING DIFFERENCES IN MEANS OF MEASUREMENTS HAVING SIGNIFICANT F RATIOS

	Mean	K Values* 0.05 Level	0.01 Level
Ba6A			
Beginning of the treatment (0)	50.8	1.75	2.17
End of the first month (I)	49.4		
End of the second month (II)	48.8		
End of the third month (III)	48.6		
Angulation			
Beginning of the treatment (0)	15.2	2.5	3.21
End of the first month (I)	21.1		
End of the second month (II)	21.7		
End of the third month (III)	21.3		
N.Me			
Beginning of the treatment (0)	103.1	0.62	0.74
End of the first month (I)	103.4		
End of the second month (II)	103.6		
End of the third month (III)	104		
N.ANS			
Beginning of the treatment (0)	49.14	1.29	1.59
End of the first month (I)	49.4		
End of the second month (II)	46.7		
End of the third month (III)	47.2		

*Differences between means must be equal to or exceed K value to be significant at the level of probability indicated.

TABLE IX

T TEST
COMPARING THE MEASUREMENT BEFORE AND AFTER
THE RETENTION PERIOD

	Mean Stage III	Mean Stage IV#	T
Ba.N	84.4	84.5	1.1
Ba.S	19.3	19.5	0.02
Ba.Ptm	40.2	40.3	0.39
Ba.A	87.2	86.9	0.39
Ba6A	48.6	49.6	1.97*
Ba6B	57.2	57.6	0.118
Angulation			3.6**
N.S	16.4	16.5	0
N.ANS	47.2	47.6	1.97*
N.PNS	51.9	51.9	0
N.Me	104.15	104.2	0.51

One tail test =
P 0.01 = 2.60
P 0.05 = 1.75

*significant at the 0.05 level
**significant at the 0.01 level

#Stage III = end of the third month
Stage IV = end of the sixth month

CHAPTER V

DISCUSSION

ANALYSIS OF THE DENTAL RESPONSE

The dental relationship changes produced by extraoral therapy has been attributed to a combination of:

a) An alteration of the physiologic forward migration of the maxillary molars.

b) An inhibition of the forward component of growth of the maxillary complex.

c) The normal growth of the mandible.

d) And more lately to a distal movement of the maxillary molars (Moore, 1959; Poulton, 1966 and Meach, 1966).

In this study, because of the age of the patients, the mandibular growth was nearly negligible (0.5mm for six months); the important part of the change took place in the maxilla. As early as the second month, spaces developed between the first maxillary molars and the second premolars and also between all the upper buccal segments. The examination of the roentgenograms showed that contrary to Armstrong (1971) and Sanders' (1971) conclusions, no pure distal bodily movement was performed during the first three months. The difference can be explained due to a more refined approach taken in the present study to locate the apex of the molars.

The distal movement of the roots was associated with a more dramatic tipping movement of the crown that could be observed throughout the active phase of the treatment. This pattern persisted even though the tipping continued at a diminished rate as active treatment proceeded.

In essence, the action produced was a combination of translatory and tipping movements.

It must be pointed out that the tipping action was only transitory in nature since complete uprighting was observed to have taken place during the retention period. In summary, the overall result was bodily movement but it occured after six months and not after three, as was determined by Armstrong and Sanders.

The unusual rapid dental response observed in the present study and its partial relapse can be attributed to elongation of the tooth out of its socket at the beginning of the treatment. This response was due in part to the intensity of the force applied. The bone was unable to resorb rapidly enough and the tooth was then forced occlusally where less resistance was encountered. A rapid distal movement thus resulted. The lag period which happened later (minimal tipping for the two following months) was the time when the bone resorption took place. The tooth reintruding slowly under the influence of the direction of force which was kept constant.

Influence of Magnitude and Duration

Contrary to Graber's study (1967) which stated that a heavy force produced mainly an orthopedic effect, it was found in the present investigation that a continuous force of high magnitude was able to move the teeth in a very short period of time. However, the optimal load remains to be determined. A lighter force should minimize the observed tipping and produce a more "physiologic" tissue reaction. Moreover, the continuity of force application proved to be a determinant with respect to rapid tooth movement. As so often mentioned in the literature (King, 1957; Poulton, 1964 and Meach, 1966) an intermittent force of eight hours a day was found to be capable of retaining the molars in a stationary position except when the crown was in a state of imbalance due to the forces of occlusion.

Direction

As it has been already determined by Burstone (1959), two basic tooth movements can happen depending on the direction of the stress. A pure translation when the center of rotation is at infinity or a pure rotation when the center of rotation is at the centroid.

The appliance was designed in such a manner that the resultant of force passed approximately through the center of resistance of the tooth to be moved. The force was directed posteriorly parallel to the occlusal plane in order to avoid any intrusive or extrusive movement.

The direction was kept constant by the use of the combination of an occipital and cervical traction pulling on a short and rigid face-bow less prone to deformation when such heavy forces are applied. The outer bow was bent upwards about 15mm above the occlusal plane in order to run at the level of the center of resistance of the first maxillary molar which was found to be located in the middle third of the root. (Haack, 1963; Jawor, Sanders, and Wollney, 1970)

It was observed that during the active phase of treatment an important distal tipping of the crown occured associated with a less important translation of the center of resistance of the tooth.

In order to get the bodily movement initially intended, a re-assessment of the direction of the resultant of force seems necessary. A distal movement of a maxillary molar cannot be a simple tooth movement because of the particular anatomical environment. According to the author, instead of a mechanical theoretical center of resistance, in the present case a biological theoretical center of resistance must be assessed which takes in consideration the presence of the second molar germ. The proximity of the maxillary sinus and the space available to accomodate the maxillary molars.

Very soon when a posterior force is applied on the maxillary first molar, its roots contact the germ of the second molar constituting a system of different volume and shape with a new center of resistance.

In this experiment, the high location of the germs placed the general center of resistance higher than the center of resistance of the tooth. The proximity of the apices with the cortical layer which binds the maxillary sinus can be attributed to an additional reason for the difficulty encountered to move the roots. If a more superior direction of force can be advised for future experiments or for clinical purposes, the last variable advocated makes any assumption on the overall center of resistance of the system very hazardous, and should not be in any case correlated with centroid.

ORTHOPEDIC ACTION

Magnitude

In this study a heavy force was found to be capable of redirecting the direction of growth of the entire maxillo-facial complex; this was shown by Graber (1967). However, no comparable posterior movement was observed as in Sanders' research. This difference could have been due to the fact that no decimals were used in the present investigation (the range of tracing error was approximately 0.5mm for each point).

Various histologic studies (Sproule, 1968; Trift schausen, 1969) have shown that headgear therapy produces a resorption at the sutural level.

It seems that two different actions can be achieved: either a passive orthopedic effect when no apposition and growth can take place, or an active orthopedic effect when the resorption exceeds the apposition, causing a posterior movement of the maxillo-facial complex.

It is likely that an active orthopedic effect occured during the course of this investigation, but the amount was insufficient to produce any significant changes in the measurements. Perhaps an experiment of longer duration would have corroborated this.

If a compressive action on sutures requires a heavy force as was already determined by Graber (1967), it is our feeling that a lighter force will be able to produce the same effect. Some additional studies are necessary to determine the optimal orthopedic force. The duration factor for the level of magnitude used seems to play an important role in the acceleration of the resorptive phenomenon.

Direction

The final result of an extraoral therapy depends widely on the direction of the force. With a cervical headgear a downward and backward movement of the maxilla was noticed.

Frederick (1969) found that the high pull headgear produces an upward and backward movement of the maxillo-facial complex with an intrusion of the molar teeth.

In the present study with a combination of both, it was observed that:

1) The anterior component of the maxillo-facial growth was

inhibited but no backward maxillary movement could be evidenced.

2) No increase in facial height greater than normal was observed.

3) No significant change of the posterior nasal spine, but a vertical dropping of the anterior nasal spine was found.

Instead of the normal downward translation of the palatal plane, a rotation occured, ANS descending at a higher rate than PNS.

Various authors like Sandusky (1965), Poulton (1959), Weislander (1963), Sanders (1971) have interpreted this kind of change as due to a rotation of the maxilla in response to the headgear therapy. The author feels that the term 'rotation' should be avoided when an entire bone or several bones are considered because it suggests a phenomenon which may happen only in very special circumstances. The maxilla is a changing structure, especially during growth, always remodeling and repositioning. When like in the present experiment a posterior force is applied on its postero-inferior part which controls any downward and anterior growth, the only direction in which the potential of growth of the entire structure can express itself is downward in the non-restrained area.

A more vertical force as advocated previously would only produce an intrusion of the upper molars and to a certain extent a depression of the maxilla which could only help to correct the antero-posterior discrepancy by rotating the mandible forward.

Although this study showed that the horizontal component of growth was inhibited and redirected inferiorly, it was not possible to determine during which stage of the treatment the sutures reacted. Growth is not a regular process but happens by spurts at various periods, different for each individual. Only averages can be used for a certain period of time. One month is too short to detect any measureable increase especially with the means of investigation used.

Duration

It was most interesting to observe that no significant change took place during the retention period. This demonstrates that an intermittent wearing of the headgear for eight hours a day is sufficient to retain the orthopedic effect. Some authors (King, 1957; Poulton, 1959; Ricketts, 1960; and Graber, 1969) who have studied the headgear action applied over a long period of time have even maintained that in this instance headgear will cause orthopedic effects.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In this study it has been attempted to determine how the upper first molar reacts to the application of a heavy continuous force of constant direction and when the sutures of the craniofacial complex are involved in the retardation of the horizontal component of growth which has been previously reported.

A sample consisting of fifteen Caucasian patients, nine females and six males ranging from the age of eight years, ten months to eleven years, five months all in the late mixed dentition stage and presenting a Class II molar relationship was selected.

In the first part of the investigation a combination of a neck strap and a head cap delivering a total force of three pounds on the maxillary first molars by means of a facebow was applied constantly for a period of one hundred days. The facebow was designed in such a manner that the resultant of force was parallel to the occlusal plane and passing through the center of resistance of the maxillary first molar.

In the second part the same appliance was worn eight hours a day for an additional one hundred day period to observe the orthodontic effect to an intermittent force of same magnitude and direction.

During the first three months full sets of records including study models, facial photographs, and two cephalograms (lateral and posteroanterior) in centric occlusion were taken every month on each of the fifteen patients studied. Another set was taken at the end of the six month period.

The lateral cephalograms were analyzed with a system of coordinates.

The findings were compared to the normal growth which occurs over the same period of time in individuals at this stage of development.

The measurements were subjected to statistical analysis. An analysis of variance was made to point out any statistically significant change happening every thirty-three day period during the active phase. A paired-T test was used to objectivate any possible relapse.

The following conclusions have been drawn:

A. <u>Orthopedic Action</u>

1. A heavy continuous force applied on the maxillary first molars produces a retardation of the horizontal component of growth of the maxillo-facial complex.

2. No change was observed when an intermittent force of the same magnitude and direction was applied.

3. The application of a force parallel to the plane of occlusion impeded the normal vertical growth of the posterior part of the

maxilla while the anterior part grew more than normally in a downward direction.

4. The vertical growth of the face was slightly inhibited.

B. <u>Tooth Movement</u>

1. Over a period of six months a distal bodily movement of the molars has been achieved correcting the dental relationship.

a. The apex moved distally during the first phase of the treatment.

b. During the same period the crown moved distally more than the apex.

c. An uprighting was observed during the retention period due to a mesial movement of the crown.

FIGURE 8

FACIAL CHANGE:

BEFORE AND AFTER

SIX MONTHS OF TREATMENT

BEFORE TREATMENT

AFTER SIX MONTHS OF TREATMENT

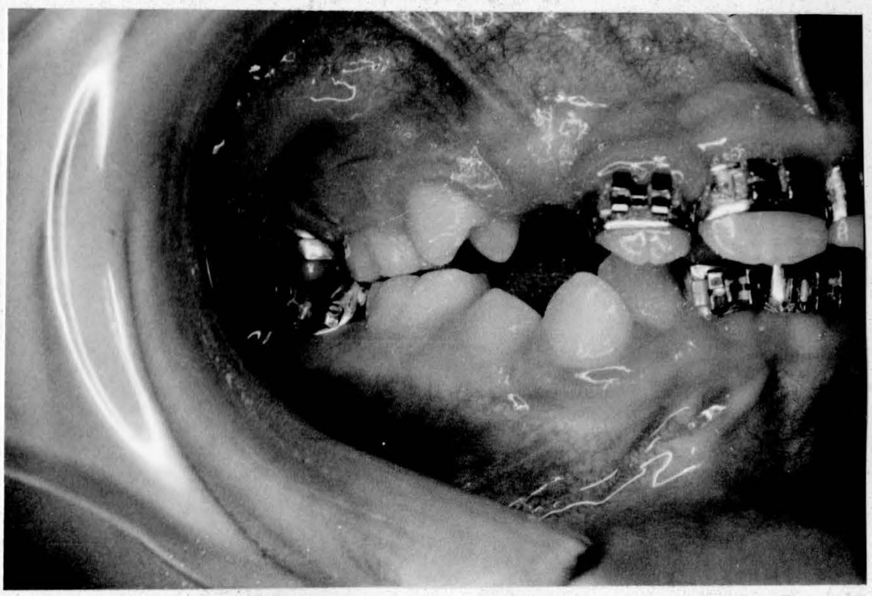
FIGURE 9

CHANGE IN MOLAR RELATIONSHIP:

BEFORE AND AFTER SIX MONTHS OF TREATMENT

(right side)

BEFORE TREATMENT



AFTER SIX MONTHS OF TREATMENT

FIGURE 10

CHANGE IN MOLAR RELATIONSHIP:

BEFORE AND AFTER SIX MONTHS OF TREATMENT

(left side)

BEFORE TREATMENT

AFTER SIX MONTHS OF TREATMENT

FIGURE 11

CHANGE IN MOLAR RELATIONSHIP

AFTER THE ACTIVE PERIOD OF TREATMENT

(right and left side)

RIGHT SIDE

LEFT SIDE

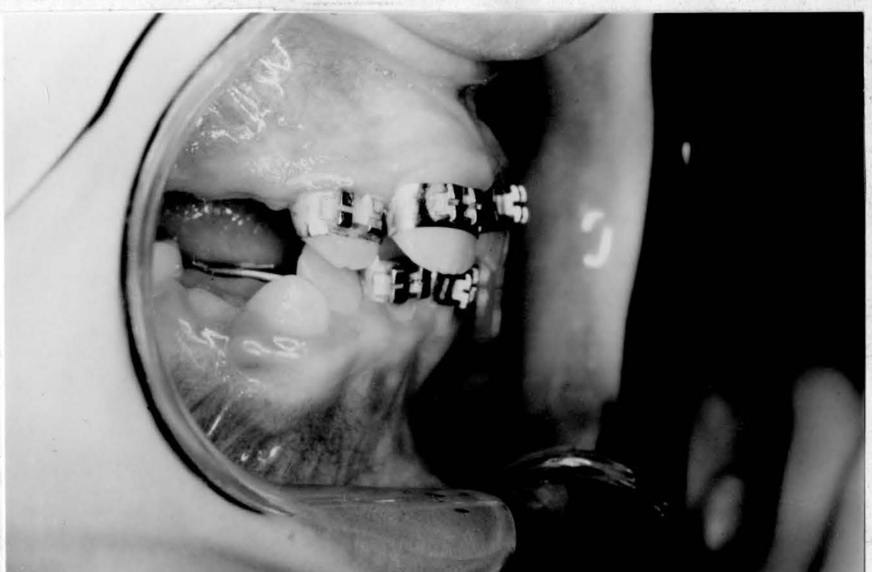
FIGURE 12

OVERJET AT THE BEGINNING

AND AT THE END OF THE TREATMENT

(six months later)

BEFORE TREATMENT



AFTER SIX MONTHS OF TREATMENT

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APPENDIX

ANTERO POSTERIOR MEASUREMENTS (I)

CRANIAL BASE

Case No.	Ba.N 0	Ba.N I	Ba.N II	Ba.N III	Ba.N IV	Ba.S 0	Ba.S I	Ba.S II	Ba.S III	Ba.S IV
1	87	87	87	88	88	22	22	22	22	22
2	88	88	88	89	89	20	20	20	20	20
3	82	82	83	83	83	18	18	17	17	18
4	83	83	83	83	84	15	15	15	15	16
5	83	83	84	84	83	21	21	21	21	20
6	82	82	83	83	83	15	15	15	15	15
7	85	85	85	85	85	21	21	21	21	21
8	88	88	88	88	88	22	22	22	22	22
9	86	87	87	87	87	22	22	22	22	21
10	76	76	76	77	78	18	18	18	18	18
11	79	79	80	80	80	16	17	17	17	17
12	87	87	87	88	88	22	22	22	22	22
13	82	82	83	83	83	19	19	19	19	19
14	79	79	79	79	80	16	15	15	16	19
15	89	89	89	89	89	23	23	23	23	23

Measurements in millimeters

ANTERO POSTERIOR MEASUREMENTS (II)

MAXILLA

Case No.	BaPtm 0	BaPtm I	BaPtm II	BaPtm III	BaPtm IV	BaA 0	BaA I	BaA II	BaA III	BaA IV
1	42	42	42	43	42	88	88	88	88	87
2	40	40	40	40	40	89	89	89	89	89
3	38	38	38	38	38	84	84	85	85	84
4	39	40	40	40	40	87	87	87	88	88
5	43	43	43	42	42	87	87	87	87	87
6	41	40	40	41	41	87	87	87	87	87
7	44	44	43	43	43	93	93	93	93	92
8	40	41	41	40	41	89	90	90	90	89
9	45	45	45	45	44	88	88	88	88	87
10	33	33	33	33	33	76	76	76	76	77
11	36	36	36	35	36	80	80	81	81	81
12	42	43	43	43	43	92	92	92	92	92
13	39	39	39	39	39	87	87	87	87	87
14	35	36	36	37	38	83	92	82	83	83
15	45	45	45	45	45	94	94	94	94	94

Measurements in millimeters

ANTERO POSTERIOR MEASUREMENTS (III)

DENTAL MEASUREMENTS

Case No.	Ba6A 0	Ba6A I	Ba6A II	Ba6A III	Ba6A IV	Ba6B 0	Ba6B I	Ba6B II	Ba6B III	Ba6B IV	ANGULATION 0	ANGULATION I	ANGULATION II	ANGULATION III	ANGULATION IV
1	53	49	49	50	51	62	60	60	60	60	18	31	28	22	14
2	53	51	51	51	52	61	61	61	60	60	22	27	28	26	20
3	48	47	47	47	47	56	55	55	55	54	21	23	22	23	13
4	49	49	49	48	49	55	56	56	55	55	16	20	20	19	15
5	54	52	51	51	52	60	60	60	60	59	11	20	20	18	10
6	48	47	47	47	47	56	56	56	56	56	12	24	26	24	20
7	57	56	55	54	54	64	63	63	62	61	12	16	22	20	13
8	53	52	51	51	52	60	60	60	59	59	12	14	18	16	8
9	56	55	55	55	54	63	63	63	62	61	14	20	20	25	15
10	44	42	41	41	41	50	49	49	48	48	18	20	24	20	17
11	47	46	45	45	46	58	54	55	55	58	15	26	24	24	17
12	53	50	49	50	51	60	60	60	60	60	10	20	25	20	8
13	50	48	47	47	48	59	58	58	58	58	20	24	28	28	17
14	43	43	42	42	44	52	52	52	51	51	14	22	26	20	11
15	54	54	54	51	57	61	60	60	57	55	13	10	10	15	7

Measurements in millimeters

Measurements in degrees

VERTICAL MEASUREMENTS (I)

	CRANIAL BASE N.S					ANTERIOR FACE N.Me				
Case No.	0	I	II	III	IV	0	I	II	III	IV
1	16	16	15	15	15	96	96	96	98	98
2	16	16	16	16	16	102	103	103	103	103
3	8	8	8	9	9	99	99	99	100	100
4	19	19	18	19	18	101	101	101	101	102
5	23	22	23	22	23	100	100	100	100	100
6	14	14	14	14	14	104	104	104	104	104
7	19	19	20	19	20	109	109	112	112	112
8	14	15	14	16	16	107	109	109	109	110
9	15	16	16	16	16	107	106	107	107	107
10	16	15	15	15	15	107	107	107	108	109
11	14	14	14	13	13	101	102	102	102	102
12	21	21	21	20	21	102	103	103	103	103
13	18	19	20	19	19	103	102	102	102	102
14	20	20	21	21	20	109	110	110	110	110
15	13	13	13	13	13	100	100	100	101	101

Measurements in millimeters

VERTICAL MEASUREMENTS (II)

MAXILLA

Case No.	N.ANS 0	N.ANS I	N.ANS II	N.ANS III	N.ANS IV	N.PNS 0	N.PNS I	N.PNS II	N.PNS III	N.PNS IV
1	45	45	46	46	46	49	49	48	48	48
2	48	47	48	48	49	54	54	53	53	53
3	42	42	42	43	43	48	48	48	48	48
4	46	45	45	45	46	54	53	53	53	53
5	44	46	47	47	46	51	50	51	50	50
6	45	45	46	47	47	48	48	48	48	49
7	43	44	47	47	47	55	55	55	56	56
8	50	53	52	53	52	48	50	49	51	51
9	47	46	47	47	48	52	52	52	52	52
10	47	48	47	49	51	52	55	55	55	55
11	46	45	46	46	47	50	49	49	49	49
12	47	47	47	48	48	54	54	54	54	54
13	45	46	47	47	48	51	51	51	52	52
14	49	49	49	49	51	56	56	56	56	55
15	44	44	45	46	46	54	54	54	54	54

Measurements in millimeters

APPROVAL SHEET

The thesis submitted by Dr. Jacques A. Terral has been read and approved by members of the Department of Oral Biology.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree Master of Science.

May 17, 1972
Date

Donald C Hilgers DDS
Signature of Advisor