A Cephalometric Study of Mechanico-Therapeutic Anterior Repositioning of the Maxillae

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A CEPHALOMETRIC STUDY OF MECHANICO-THERAPEUTIC
ANTERIOR REPOSITIONING OF THE MAXILLAE

BY

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A THESIS SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
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ABOUT THE AUTHOR

Garret Frank Harnett was born in Jersey City, New Jersey on September 24, 1942. He obtained his primary education in Scotch Plaines, New Jersey, and graduated from Westfield Senior High School in Westfield, New Jersey in June, 1960.

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td></td>
</tr>
<tr>
<td>A. Introductory Remarks and Statement and Purpose of the Problem</td>
<td>1</td>
</tr>
<tr>
<td>II. REVIEW OF LITERATURE</td>
<td>4</td>
</tr>
<tr>
<td>III. MATERIALS AND METHODS</td>
<td></td>
</tr>
<tr>
<td>A. MATERIALS</td>
<td></td>
</tr>
<tr>
<td>1. Lateral Maxillary Orthopedic Expansion Appliance Materials and Construction</td>
<td>18</td>
</tr>
<tr>
<td>2. Anterior Maxillary Orthopedic Expansion Appliance Materials and Construction</td>
<td>19</td>
</tr>
<tr>
<td>3. Anterior Maxillary Orthopedic Expansion with Reverse Headgear</td>
<td>20</td>
</tr>
<tr>
<td>4. Preliminary Records</td>
<td>20</td>
</tr>
<tr>
<td>5. Progress and Final Records</td>
<td>21</td>
</tr>
<tr>
<td>B. METHODS</td>
<td></td>
</tr>
<tr>
<td>1. Selection and Character of Sample</td>
<td>25</td>
</tr>
<tr>
<td>2. Appliance Activation</td>
<td>25</td>
</tr>
<tr>
<td>3. Roentgenographic Procedure</td>
<td>27</td>
</tr>
<tr>
<td>4. Landmarks</td>
<td>27</td>
</tr>
<tr>
<td>5. Cephalometric Analyses</td>
<td>29</td>
</tr>
<tr>
<td>IV. FINDINGS</td>
<td>36</td>
</tr>
</tbody>
</table>
### LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>DESCRIPTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>LATERAL MAXILLARY ORTHOPEDIC EXPANSION APPLIANCE</td>
<td>22</td>
</tr>
<tr>
<td>II.</td>
<td>ANTERIOR MAXILLARY ORTHOPEDIC EXPANSION APPLIANCE</td>
<td>23</td>
</tr>
<tr>
<td>III.</td>
<td>REVERSE HEADGEAR</td>
<td>24</td>
</tr>
<tr>
<td>IV.</td>
<td>LANDMARKS</td>
<td>33</td>
</tr>
<tr>
<td>V.</td>
<td>LOYOLA UNIVERSITY CEPHALOMETRIC ANALYSIS</td>
<td>34</td>
</tr>
<tr>
<td>VI.</td>
<td>COBEN ANALYSIS</td>
<td>35</td>
</tr>
<tr>
<td>VII.</td>
<td>PRE AND POST TREATMENT SUPERIMPOSED TRACINGS</td>
<td>38</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

The orthodontic profession for many years has relied on the movement of teeth to correct malocclusions. Many malocclusions, however, are primarily a result of skeletal disharmony and only secondarily are the teeth involved. When a skeletal malocclusion is treated by tooth movement alone, the axial inclinations of the teeth are in a tipped position and stability of the results are questionable.

Historically, the implication has been made that forces directed toward the oral cavity with the ultimate purpose of altering the relationship of the teeth are orthodontic forces. The contention that orthodontic treatment affects only the alveolar process is still unchallenged. However, forces of a high magnitude which greatly exceed the minimal forces required for tooth movement do expand and inhibit the growth potential. These forces must be considered orthopedic.

Rapid maxillary palatal expansion of the midpalatal suture is one such orthopedic force that is extremely advantageous in the treatment of (1) both surgical and non-surgical Angle class III cases, especially the non-surgical
ones, (2) cases of real and relative maxillary deficiency, (3) cases of inadequate nasal capacity exhibiting chronic nasal respiratory problems, (4) the cleft palate patient, and (5) selected arch length problems to avoid the profile disturbances frequently associated with removal of teeth, (6) posterior crossbites, both unilateral and bilateral.

A mechanical force of orthopedic magnitude, applied to the alveolar processes and dentition during the rapid, forced separation of the mid-palatal suture establishes a more favorable reorientation of denture to denture, denture to base, and adjacent bones and sutural adjustments in related areas.

The appliance design for rapid maxillary palatal expansion usually consists of a jackscrew placed at right angles to the midpalatal suture. This device is designed to bilaterally and symmetrically expand the maxillary segments.

While sutural expansion can correct lateral skeletal discrepancies, there is no controlled method which corrects discrepancies of the skeleton in an antero-posterior direction. Many antero-posterior asymmetries in occlusion and basal bone can be attributed to antero-posterior growth insufficiency.
within the maxillary bones. It was the purpose of this study to determine whether anterior movement of the maxillae is possible for maxillary deficient patients by modifying the conventional methods of maxillary sutural expansion and employing orthopedic mechanics to produce a more balanced facial harmony.
CHAPTER II
REVIEW OF LITERATURE

Among the most remarkable aspects of palatal expansion is a review of its historical background. For many years devices have been described which expand the maxillae by widening the mid-palatal suture. The early investigators, who date back well over a century, argued whether or not true separation of the maxillae could be achieved. Schroeder-Benseler (1912-1913) discussed three such men, (1) in 1839 a Frenchman named Le Foulon had used an expansion spring device to widen the maxillary arch, (2) in 1848 Linderer used full crown coverage of molars and placed a wire with bent in expansion in it to regulate the expansion of the teeth, and (3) W. H. Dwinell of New York in 1857 explained the employment of a screw and nut incorporated with plates for the correction of collapsed arches.

E. H. Angell was the earliest to write an article describing maxillary expansion. In 1860 he placed an adjustable jackscrew across the palate and held in place by gold collars on both bicuspid on one side and the second bicuspid on the other side. The patient, a fourteen year old girl, was instructed to turn the nut of the jackscrew twice daily.
Lateral forces were produced which he claimed separated the maxillae. After two weeks a space had developed between the "front incisors". Since the appliance was not attached directly to the incisors, he asserted that this was proof that the maxillae had indeed widened.

J. D. White in the same year as Angell, 1860, described his appliance expanding the dental arches and separating the mid-palatal suture.

J. H. McQuillen in 1860 challenged Angell's description of palatal expansion in an editorial questioning that "... such a result appears exceedingly doubtful," and "Even admitting the impression of the writer to be correct, it would be a very strong argument against the use of such an apparatus; for surely the irregularity of the teeth is a trifling affair as compared with the separation of the maxillae, which could not take place without inducing serious disturbances in the surrounding hard and soft parts."

Attempts of the procedure were made by men of the time with varying degrees of success and controversy increased. According to Schroeder-Benseler (1912-1913), Hepburn (1862) used a rubber plate with wooden wedges, Kingly (1866) used a hard rubber plate with a screw, and Farrar (1878) used a screw
to widen the arch. Later, Farrar (1888) became critical of the technique and warned the profession against its use. Schroeder-Benseler (1912-1913) also reported that Coffin used the first expansion plate with spring power. A wire was formed into a "W" and was compressed and inserted into the mouth. This exerted pressure and opened the suture. Goddard (1893) used the Coffin Plate and found the spreading of the central incisors. G. V. Black (1893) reported seeing the palatal suture open.

Attempts on palate splitting continued with Copeland (1903), Ottolengui (1904), Pfaff (1905), N. M. Black (1909), Dean (1909), Landsberger (1910), Babcock (1911), Willis (1911), Barnes (1912), Hawley (1912), Pullen (1912), Wright (1912), Ketcham (1912), Dewey (1913-1914), Federspiel (1913), Northcroft (1914), and Lohman (1916).

Antagonists toward the procedure questioned actual separation of the maxillae at the midpalatal suture. Federspiel (1912), Ketcham (1912), Hawley (1912), and Cryer (1913) found no conclusive evidence that the suture opens.

With the influence of Angle (1910), interest in sutural expansion waned in the United States due to the widespread acceptance of the theory that if the teeth were moved
into proper alignment, bone would develop to support them. Europe continued to practice palatal expansion, but Angle's concept of functional development overshadowed its practice here.

Several investigators have shown radiographic evidence of an increased width of the nasal passages due to separation of the mid-palatal suture. Consequently, rhinologists became interested in the procedure as a possible method of treatment in their profession. Pfaff (1905) stated that Eysell in 1886, was the first rhinologist to suggest midpalatal suture expansion of the maxillae as a rhinologic treatment procedure. Bogue (1907, 1911), Dean (1909, 1911), Brown (1909), Haskin (1912), Schroeder-Bensler (1915), Dewey (1917, 1924), Mesnard (1929), Martinsson (1956), Haas (1961), and Wertz (1968) have all studied the palatal expansion procedure and reported various benefits for rhinological treatment including increased nasal respiration, better sinus drainage, improved speech and hearing in some cases.

The procedure of rapid maxillary palatal expansion of the midpalatal suture overcame earlier suppression mainly because of Brodie's (1938) use of cephalometrics to show that bony changes associated with orthodontic tooth movement are
confined to the alveolar processes. Basalar regions of bone, therefore, are the limiting factors for tooth movement.

Most of the more recent articles have agreed that the mid-palatal suture may be opened. Proof that the suture does open in the earlier days was the space created between the maxillary central incisors. Present day proof of sutural expansion has been investigated by Debbane (1958) and Cleall et. al. (1956) historically and radiographically; Haas (1961) by dissection and radiographically; Montgomery (1963) by histology; Walters (1967) by radiographic studies using metallic implants; and others.

Harvold (1950) also believed in the use of rapid palatal expansion of the maxillae in cleft palate treatment. He further explained that his study on monkeys, showed that there was movement of the teeth, alveolar processes and maxillary basal segments, and interestingly also movement of adjacent bone structures in the sutural areas.

Derichsweiler (1956) mentioned seven changes from rapid maxillary arch expansion. His study showed that the width of the maxillae and nasal cavity increased, the palate and nasal floor lowered, the nasal septum straightens, the nasal walls and adenoids reduce, changes the patient from a mouth breather to a nasal breather, increases maxillary arch
length, and the mandible returns from a forced position to a normal position.

Thorne (1956-1960) conducted and reported sutural expansion at Eastman Institute on forty patients ranging from 8 to 15 years. Pain, not pressure, was absent in all cases. Tension in the bridge of the nose was noted in two patients. Thorne also noted a tendency for bite opening in over half of his patients. Thorne concluded histologically that the stretching fibrous connective tissue begins to rebuild itself, followed by bone deposition at the sutural margins.

Debbane (1958) applied his efforts to study the effects of various forces applied to the midpalatal suture of cats. Expansion forces produced a downward and forward tipping of the premaxillae while contraction forces produced an upward and backward tipping. He attributed the deposition of asymmetrical new bundle bone occurring on the edges of the palatal plates bordering the suture to stimulation, caused by stretching of connective tissue fibers across the suture. He showed that the suture opened to a greater extent in the premaxillary area than in the maxillary area of the midline suture.

Bjork (1955) was the first to use metallic implants for reference points in the human maxilla for study of the expansion of the midpalatal suture.
Krebs (1959) also used vitallium implants for a mid-palatal suture expansion study on clinical patients. His study indicated generally that there is a greater increase of width in the lower segments of the maxillae than in the upper segments as explained in tipping or rotation around an axis through the suture site.

Walters (1967) conducted a maxillary palatal expansion study with metallic implants on five Macaca mulatta monkeys to measure midpalatal suture separation. Metallic implants were fixed in opposite sides of the palate directly adjacent to the midpalatal suture. This more reliable method allows precise measurement of sutural expansion alone, dismissing the factors of buccal tipping involved in measuring. Five millimeters of sutural expansion and six and one-half millimeters of dental arch expansion was recorded.

Korkhaus (1960) also reported on an expansion study in which he produced up to 10 millimeters of maxillary expansion without pain or any unfavorable sequelae.

Issacson and Ingram (1964) reported their results with rapid expansion of the maxillae. They measured the force levels during the expansion and retention phases of treatment. In another study, Issacson and Murphy (1964)
noticed that a slight anterior movement had occurred in the expansion of some cleft palate patients.

Burstone and Shafer (1959) conducted a histological study on rats which had undergone sutural expansion. Their results showed that after the suture was opened, osteophytic projections started to fill in the widened suture. Similar results were obtained and reported by Cleall et. al. (1965) using monkeys.

Haas (1959, 1961, 1965) conducted extensive studies on midpalatal suture expansion on pigs. He used an expansion screw appliance with acrylic to obtain opening of the suture. His findings showed up to 15 millimeters of expansion in 10 days. New bone that was deposited at the edges of the suture could be demonstrated by the incorporation of the vital staining alizarin dyes in the specimens. Haas then utilized a similar palate separation technique in his clinical practice with satisfactory results. He recorded that the patients reported no pain and only pressure discomfort in the alveolar process, vault of the maxilla, and articulation areas of the frontal and nasal bones with the maxilla. The 10 cases showed midpalatal suture expansion ranging from $3^\frac{3}{2}$ to 8 millimeters. The spreading of the central incisors during
expansion was experienced in Haas' study. Haas (1961) stated: "The explanation for the reaction of the central incisors to the spreading of the maxillae was the most challenging phenomenon in this study." His explanation is as follows: The gap between the central incisors approximates one half the distance the screw has been activated. During activation, the roots diverged a greater distance than the crowns. After expansion ceased, the roots continued to diverge while the crowns tipped mesially toward the midline. The roots began to move mesially after the crowns drifted together eventually resuming original axial inclination. This process was completed in a four to six month period. The behavior of the central incisors strongly suggests the existence of transeptal fibers acting as a continuous chain linking all the teeth in the dental arch together, as explained by Brodie.

Montgomery (1963) conducted midpalatal suture expansion on pigs. Upon examining histologically, he found deposition of bone in the separated suture.

West (1964) completed midpalatal expansion on five rhesus monkeys to examine the effects in sutural regions of articulation of the maxillary bone with the zygomatic, frontal,
vomer, and palatine bones. He explained that soon after initial activation of the appliance none of the sutures were severely damaged due to the immediate onset of repair. The healing process continued to keep up with the activation procedure.

Cleall et. al. (1965) employed radiographs and histological examination to verify the effects of midpalatal suture separation in Macaca mulatta monkeys. The authors stated that the axial inclinations of the buccal teeth following the removal of the appliance tended to revert back to a more normal inclination. Their findings could not show whether this tendency was due primarily to tipping of the teeth, or to rotation of the maxillae.

Starnbach et. al. (1966) conducted expansion of the midpalatal suture on rhesus monkeys to study the histological effects in selected sutural areas of the cranial skeleton. The greatest histological reaction was found in the fronto-nasal suture, followed by the zygomatico-maxillary then the zygomatico-temporal sutural regions.

A large number of acknowledged investigators have reported that they can expand the maxillary arch buccal segments by rapid separation of the midpalatal suture using
orthopedic force. Bone deposition has been reported to form between the separated palatal suture radiographically and histologically. Their findings also reinforce the contention that sutural adjustments are present in all sites where the maxillae articulate with the cranial skeleton.

Dentofacial orthopedics is definitely continuing with palatal expansion. For, forces of a high magnitude which greatly exceed the minimal forces required for tooth movement do expand and inhibit the growth potential. These orthopedic forces are measured in pounds of force rather than in ounces as orthodontic forces are calculated.

Moore (1959) stated that by using occipital anchorage with an orthopedic force in the treatment of a Class II malocclusion, it may be possible to inhibit forward growth of the maxillae in young children and favorably change the facial pattern. Ricketts (1960) stated that the entire maxillae can be moved posteriorly through extra-oral anchorage. More recently, Haas (1967) has documented new concepts for maxillary orthopedics. He has demonstrated that it is possible to move the maxillae posteriorly for the treatment of Class II malocclusions. Haas employed orthopedic forces measuring five to ten pounds.
When the midpalatal suture opens the maxilla always moves forward and downward. This is probably due to the disposition of the maxillocranial sutures. The sutures affected are those in articulation with the maxilla, namely the ethmoid, frontal, inferior nasal concha, lacrimal, palatine, vomer, and zygomatic with the frontomaxillary and the zygomaticomaxillary sutures being the rotational fulcrums of maxillary movement during actual expansion: West (1965). Sicher (1965) calls attention to the fact that these sutures are oriented in such a manner that growth would produce a downward and forward vector of maxillary movement. Since these hafting zone sutures are disengaged by the palatal expansion procedure, an effect similar to immediate growth is manifested in a downward and forward displacement of the maxilla. The change in maxillary position causes a downward and backward rotation of the mandible which decreases the apparent length of the mandible and increases the vertical dimension of the lower face. Haas (1967) states that the downward and forward movement of the maxilla improves the Class III closed-bite skeletal pattern because of the obviously improved spatial relationship of the maxilla, and, as a result of the accompanying downward and backward rotation of the mandible, the effective length of the
mandible is reduced and lower facial height increases. The posterior cross-bite is corrected by lateral expansion and the anterior cross-bite is partially corrected by the forward shift of the maxilla and the clockwise rotation of the mandible. Haas (1967) further explains that the displacement of the maxilla favorably and unfavorably effects the Class III open-bite skeletal pattern. Favorably, the maxillo-mandibular dysplasia becomes less severe. Unfavorably, however, as the mandible rotates, the skeletal and dental open-bite increases. Thus, Class III closed-bite cases respond ideally to maxillary expansion. The buccal cross-bite is usually corrected within three weeks. The anterior cross-bite may or may not be resolved by the forward and downward displacement of the maxilla and clockwise mandibular rotation. Here the A - Pg relationship of the denture bases is correspondingly improved.

Haas (1967) states that orthopedic forces which greatly exceed the minimal forces required for tooth movement do expand the growth potential. When an orthopedic force is used, the object is to influence maximum direction of force on the denture bases and jaws with minimal tooth movement utilizing the teeth as anchorage units. Orthopedic forces
are exerted both extraorally and intraorally. Intraorally, the dental anchorage units require maximum resistance to movement in order to increase the direction of the effect of the force on sutures and other growth sites. Orthopedic forces, calculated in pounds must be great because it is dissipated over a complexity of maxillary sutures. Orthopedic forces are ideally utilized in the early growth period of the patient. Also, orthopedic forces are usually intermittent.

It is generally accepted that rapid maxillary expansion of the mid-palatal suture with orthopedic force in the design of a jackscrew placed perpendicular to the midpalatal suture can alter the skeletal pattern of a posterior crossbite. Unfortunately, this expansion procedure does not usually resolve the anterior cross bite with sufficient downward and forward displacement of the maxilla. Fortunately, the maxilla appears to have been mobile by the palatal expansion procedure with suture sites opening and moderate downward and forward displacement.

The purpose of this study is to see cephalometrically and by gross inspection if the basal areas of the maxillae could be displaced in an anterior direction during this period of maxillary mobility.
CHAPTER III
MATERIALS AND METHODS

Anchorage stands alone as the salient characteristic to be considered in designing a palatal expansion appliance. It is only reasonable that, if the object is to move bones, undesirable displacement of dental anchorage must be avoided. Thus, it seems that an inverse proportion exists, namely, the greater the displacement of the dental anchorage units, the less the displacement of the maxillae and accompanying midpalatal suture cleavage. The result is an orthopedic failure and frequently a limited orthodontic success. Conversely, if minimal dental anchorage displacement is achieved, both an orthopedic and an orthodontic success are attained.

A. Materials

I. LATERAL MAXILLARY ORTHOPEDIC EXPANSION APPLIANCE MATERIALS AND CONSTRUCTION

a. Orthodontic bands are formed on the maxillary first permanent molar and the first deciduous molars or their succedaneous elements.

b. Impressions are taken with the bands in their respective positions.
c. The bands are placed in the impression, waxed with sticky wax to the buccal, and model is poured.

d. The buccal and lingual aspects of the bands are united with a 0.045 round stainless steel wire. The free ends of the lingual wire are bent palatally to be embedded in the acrylic portion of the appliance.

e. The expansion screw mechanism is mounted as deeply as possible at the midline in a piece of baseplate wax placed vertically along the raphe. Care must be taken to orient the expansion mechanism in a manner which allows the screw to turn in a posterior direction.

f. After two thin applications of separating medium the acrylic portions are added using the powder - drop method.

g. When the acrylic has set under pressure, the appliance is removed from the model and polished and beveled. Removal of the wax effects the midline void in which is centered the adjusting portion of the screw mechanism. Care must be taken to round off the edges of all tissue bearing surfaces, thus minimizing the possibility of irritation (see Fig. I).

II. ANTERIOR MAXILLARY ORTHOPEDIC EXPANSION APPLIANCE MATERIALS AND CONSTRUCTION

a, b, c, d, f, and g are similar to above.

e. The expansion screw is mounted to open in an
antero-posterior direction $90^\circ$ to normal lateral palatal expansion. Care must be taken to orient the expansion mechanism in a manner which allows the screw to turn in a buccal to buccal direction (see Fig. II).

III. ANTERIOR MAXILLARY ORTHOPEDIC EXPANSION WITH REVERSE HEADGEAR

To supplement the protraction of the maxilla, the patients wore a chin cup designed primarily to use the mandible for anchorage. Elastics (0 Ortho Spec) were worn from the right and left mesial aspects of the anterior orthopedic expansion appliance to the vertical spines extending superiorly from the chin cup (see Fig. III).

IV. PRELIMINARY RECORDS OBTAINED PRIOR TO PLACEMENT OF APPLIANCES

Study models of the maxillary and mandibular dental arches were made using impression trays and alginate impression material. Lateral cephalometric roentgenograms were taken for angular and linear measurement of the craniofacial complex. Frontal cephalometric roentgenograms were taken to measure the width of selected areas of the craniofacial complex. Lateral and frontal "ooh" cephalometric roentgenograms were taken to see possible soft palate
displacement from the pharyngeal wall. Occlusal films were taken to measure the beginning width and length of the dental arch and the width of the alveolar arch. Kodachrome slides were taken to reveal the clinical oral environment.

V. PROGRESS AND FINAL RECORDS

Progress records on all the patients were obtained on weekly intervals. Final records for comparison with initial records were taken immediately following the removal of the appliance.
LATERAL MAXILLARY ORTHOPEDIC EXPANSION APPLIANCE

FIGURE I.
ANTERIOR MAXILLARY ORTHOPEDIC EXPANSION APPLIANCE

FIGURE II.
REVERSE HEADGEAR

FIGURE III.
B. Methods

I. SELECTION AND CHARACTER OF SAMPLE

This study was conducted on four North American Caucasian males who had undergone rapid maxillary orthopedic expansion both laterally and anteriorly. The patients were all between the ages of 7 and 10 years. There were all in the mixed dentition stage of tooth eruption. All the patients presented a maxillary deficiency laterally in the buccal segments and anteriorly in the labial aspect both clinically and cephalometrically with a Class III Angle molar relationship. The patients were initially selected because they were all closed bite, low mandibular plane angle cases in which a clockwise rotation of the mandible during expansion would not be undesirable, since it would diminish the effective length of the mandible. A Class III concave profile was visualized in a soft tissue evaluation.

II. APPLIANCE ACTIVATION

The patients and parents were instructed to activate the appliance one turn in the morning and one turn in the evening after the initial activation immediately after insertion of three to four turns. The lateral orthopedic expansion appliance was continued until the mid-palatal
suture was opened radiographically, and the posterior buccal cross-bite was corrected by visualization clinically. The anterior orthopedic expansion appliance was inserted immediately after the removal of the lateral expansion appliance. Instructions for activation were again given to the patient and parents - one turn in the morning and one turn in the evening. During the period of anterior expansion appliance activation to one side of the maxilla, reverse headgear with five to six pounds of recorded force was employed to supplement the anterior activation employing mandibular anchorage. Elastics were worn from the right and left mesial aspects of the anterior expansion appliance to the vertical spines of the chin cup.

The reverse headgear mechanics provide an anterior movement to the forward displacement side of the appliance and a negating effect of posterior movement and suture site resorption on the anchorage side of the appliance. The appliances are continued until the forward displacing side is correct clinically and radiographically. The activation is then reversed for the previously used "anchorage side" now becomes the forward displacing side.
III. ROENTGENOGRAPHIC PROCEDURE

Exacting procedure was a primary consideration necessary to standardize the roentgenographic technique and assure accurately traced acetate paper superimpositionings of pretreatment and post-treatment headplates of linear and angular measurements.

IV. LANDMARKS

The cephalometric landmarks used in this study are illustrated in Fig. IV and are defined as follows:

ANTERIOR NASAL SPINE (ANS), the median, sharp bony process of the maxilla at the lower margin of the anterior nasal opening.

ARTICULARE (Ar), the point of intersection of the external dorsal contour of the mandibular condyle and the temporal bone.

BASION (Ba), the most forward and lowest point on the anterior margin of the foramen magnum.

GNATHION (Gn), the lowest point of the median plane in the lower border of the chin. In cephalometrics it is the midpoint between the most anterior and inferior point on the bony chin. Measured at the intersection of the mandibular base line and nasion-pogonion.
GONION (G), the lowest, posterior and most outward point on the angle of the mandible.

INCISION INFERIUS (I I), the most forward incisial point of the most prominent mandibular central incisor.

INCISION SUPERIUS (I S), the most forward incisal point of the most prominent maxillary central incisor.

INFRADENTALE (Id), the highest interdental point on the alveolar mucosa between the mandibular central incisors.

MENTON (M), the lowest point from which face height is measured.

NASION (N), the middle point located on the frontonasal suture intersected by the median sagittal plane.

ORBITALE (Or), the lowest point on the margin of the orbit.

POGONION (Pg), the most anterior, prominent point on the chin.

PORION (P), the midpoint on the upper edge of the external auditory meatus. As a cephalometric landmark it is located on the top of the metal rods of the cephalometer.

PTERYGOMAXILLARE (Ptm), the point where the pterygoid process of the sphenoid bone and the pterygoid process of the maxilla begin to form the pterygomaxillary fissure. The lowest point of the opening is used in cephalometrics.
SELLA (S), in cephalometrics it is the center of the sella turcica.

SUBSPINALE (Ss), "A POINT", the deepest point on the midline contour at the alveolar process between anterior nasal spine and prosthion.

SUPRAMENTALE (Sm), "B POINT", the deepest point on the contour of the alveolar projection, between inf radentale and pogonion.

V. LATERAL CEPhALOMETRIC FILM ANALYSIS

The linear and angular measurements selected in this study were employed because it was believed they would best demonstrate the forward and downward activation effects of the appliances on the maxillae.

VI. OCCLUSAL RADIOGRAPHIC ANALYSIS

Occlusal radiographs were studied by means of superimpositioned tracings. The pretreatment radiograph taken before the insertion of the appliances was traced on acetate paper. Subsequent radiographs were then compared to the original tracing.

VII. CEPhALOMETRIC ANALYSES

The following cephalometric analyses were employed so as to best analyze antero-posterior dysplasia.
A. LOYOLA UNIVERSITY CEPHALOMETRIC ANALYSIS

The cephalometric landmarks used in this analysis are illustrated in Fig. V and defined as follows:

SADDLE ANGLE - angle formed by sella to nasion to articulare.

ARTICULAR ANGLE - angle formed by sella to articulare to gonion.

GONIAL ANGLE - angle formed by articulare to gonion to menton.

ANTERIOR CRANIAL BASE LENGTH - linear measurement from sella to nasion.

POSTERIOR CRANIAL BASE LENGTH - linear measurement from sella to articulare.

RAMUS HEIGHT - linear measurement from articulare to gonion.

BODY LENGTH - linear measurement from gonion to pogonion.

SNA ANGLE - angle formed by sella to nasion to A Point.

SNB ANGLE - angle formed by sella to nasion to B Point.

ANB ANGLE - difference of two above.

Go Gn Sn - angle formed by intersection of sella-nasion line with gonion gnathion line.

Y AXIS - angle formed at Frankfort Plane by line from sella to gnathion.

FMA - angle formed by intersection of Frankfort Plane (porion to orbitale) and gonion to menton.
l to FH - long axis of l to Frankfort Plane.
l to SN - long axis of l to sella-nasion line.
INTERINCISAL ANGLE - angle formed by intersection of long axes of l and l.
l to NA (ANGULAR) - long axis of l to N-A line.
l to NA (LINEAR) - linear measurement from tip of l to N-A line.
CHIN ANGLE - line tangent to pogonion from infradentale to mandibular plane.
FMIA - angle formed by intersection of Frankfort Plane to long axis of l.
IMPA - angle formed by intersection of long axis of l to mandibular plane.
l to NB (ANGULAR) - angle formed by intersection of long axis of l to N-B line.
l to NB (LINEAR) - linear measurement from tip of l to N-B line.
Pg to NB - linear measurement from Pg to N-B line.
HOLDAWAY RATIO - ratio of linear measurements of l to N-B line and Pg to N-B line.
N to A to Pg - angular measurement formed by angle from nasion to A Point to pogonion.
B. COBEN ANALYSIS

This is a linear measurement analysis of growth increment changes of the craniofacial complex. The cephalometric landmarks used in this analysis are illustrated in Fig. VI and defined as follows:

CRANIOFACIAL DEPTH ANTEROPOSTERIOR OF MAXILLA

Ba-N - linear horizontal measurement perpendicular to Frankfort Horizontal from basion to nasion.

Ba-S - linear horizontal measurement perpendicular to Frankfort Horizontal from basion to sella.

S-Ptm - linear horizontal measurement from sella to pterygomaxillare.

PTM-A - linear horizontal measurement from pterygomaxillare to A Point.

CRANIOFACIAL HEIGHT OF MAXILLA

N-S - linear vertical measurement from sella to nasion.

S-Ar - linear vertical measurement from sella to articulare.

N-ANS - linear vertical measurement from nasion to anterior nasal spine.

ANS-₁ - linear vertical measurement from anterior nasal spine to tip of ₁.

ANS-M - linear vertical measurement from anterior nasal spine to menton.

N-M - linear vertical measurement from nasion to menton.
LANDMARKS

FIGURE IV.
LOYOLA UNIVERSITY CEPHALOMETRIC ANALYSIS

FIGURE V.
COBEN ANALYSIS

FIGURE VI.
CHAPTER IV
FINDINGS

Two cases will be discussed with measurements both before and after from the Loyola University and Coben Cephalometric Analyses.

CASE I - J.B.

J.B. is a seven year old Caucasian male who originally presented himself with a posterior bilateral and anterior cross-bite, closed bite, maxillary deficiency both dentally and skeletally, and a low mandibular plane angle. Orthopedic forces were directed to his maxilla by means of lateral and anterior expansion appliances and reverse headgear.

Before and after measurements are as follows:

<table>
<thead>
<tr>
<th>Date Taken</th>
<th>Average (Stdn. Dev.)</th>
<th>3-30-70</th>
<th>5-7-70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saddle Angle</td>
<td>123° (+ 5)</td>
<td>116°</td>
<td>117°</td>
</tr>
<tr>
<td>Articular Angle</td>
<td>143° (+ 6)</td>
<td>144°</td>
<td>144°</td>
</tr>
<tr>
<td>Gonial Angle</td>
<td>130° (+ 7)</td>
<td>138°</td>
<td>137°</td>
</tr>
<tr>
<td>Sum</td>
<td>396°</td>
<td>398°</td>
<td>398°</td>
</tr>
<tr>
<td>Anterior Cranial Base Length</td>
<td>73 mm (+ 3)</td>
<td>77 mm</td>
<td>76 mm</td>
</tr>
<tr>
<td>Posterior Cranial Base Length</td>
<td>37 mm (+ 3)</td>
<td>27 mm</td>
<td>28 mm</td>
</tr>
<tr>
<td>Ramus Height</td>
<td>53 mm (+ 5)</td>
<td>43 mm</td>
<td>44 mm</td>
</tr>
<tr>
<td>Body Length</td>
<td>80 mm (+ 5)</td>
<td>68 mm</td>
<td>68 mm</td>
</tr>
<tr>
<td>SNA</td>
<td>80° (+ 1)</td>
<td>73°</td>
<td>78°</td>
</tr>
<tr>
<td>SNB</td>
<td>78° (+ 1)</td>
<td>76°</td>
<td>73°</td>
</tr>
<tr>
<td>ANB Difference</td>
<td>2°</td>
<td>-3°</td>
<td>+5°</td>
</tr>
<tr>
<td>Go Gn Sn</td>
<td>32°</td>
<td>38°</td>
<td>39°</td>
</tr>
</tbody>
</table>
"Y" Axis | 59.4° | 63.5° | 66°  
FMA    | 25°   | 30°   | 33°  
1 to FH| 112°  |       |      
1 to SN| 103°  |       |      
Interincisal Angle | 135.4° (+ 5.8) |       |      
1 to NA (angular) | 22°   |       |      
1 to NA (linear)  | 4 mm  |       |      
Chin Angle       | 64° (+ 6) | 58° | 58° 
FMIA             | 65°   |       |      
IMPA             | 90°   |       |      
1 to NB (angular)| 25°   |       |      
1 to NB (linear) | 4 mm  |       |      
PO to NB         | 4 mm  | 2 mm  | 2.5 mm 
NA to PO (Downs) | 0°    | -7°   | +8°  

convex

All of the above linear and angular measurements were not calculated due to the presence of deciduous maxillary and mandibular incisors.

Some of the significant findings in measurements occurred with the change of SNA from 73° to 78° within a period of thirty-seven days. ANB dropped down and back from 76° to 73° within the same length of time. The ANB was corrected then from -3° to +5°. The "Y" axis increased from 63.5° to 66°, and the FMA increased from 30° to 33° as expected. The N to A to Pg angle increased from a concave -7° to a more pleasing convex profile of +8°.

Bjork Analysis measurements and anterior and posterior cranial base measurements did not change as expected.
CASE #1
J.B.

Pre and Post Treatment Superimposed Tracings

FIGURE VII
THE COBEN ANALYSIS

DEPTH

<table>
<thead>
<tr>
<th></th>
<th>3-30-70</th>
<th>5-7-70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ba to N</td>
<td>92 mm</td>
<td>93 mm</td>
</tr>
<tr>
<td>Ba to S</td>
<td>20 mm</td>
<td>21 mm</td>
</tr>
<tr>
<td>S to PTM</td>
<td>21 mm</td>
<td>21 mm</td>
</tr>
<tr>
<td>PTM to A</td>
<td>46.5 mm</td>
<td>52 mm</td>
</tr>
</tbody>
</table>

HEIGHT

<table>
<thead>
<tr>
<th></th>
<th>3-30-70</th>
<th>5-7-70</th>
</tr>
</thead>
<tbody>
<tr>
<td>N to S</td>
<td>8 mm</td>
<td>9 mm</td>
</tr>
<tr>
<td>S to Ar</td>
<td>26 mm</td>
<td>26 mm</td>
</tr>
<tr>
<td>M to ANS</td>
<td>61 mm</td>
<td>61 mm</td>
</tr>
<tr>
<td>ANS to 1</td>
<td>24.5 mm</td>
<td>25 mm</td>
</tr>
<tr>
<td>N to M</td>
<td>109 mm</td>
<td>112 mm</td>
</tr>
<tr>
<td>N to ANS</td>
<td>49 mm</td>
<td>49 mm</td>
</tr>
</tbody>
</table>

The Coben Analysis revealed a significant change in depth of the maxilla in an anterior-posterior direction from pterygomaxillary fissure to "A" Point measured on the Frankfort Horizontal. The change from 46.5 mm to 52 mm was a net anterior displacement of 5.5 mm from March 30, 1970 to May 7, 1970.

The vertical height from nasion to menton increased 3 mm within the same period of time. In effect, a downward and forward displacement of the maxilla did occur.

The other depth linear measurements did not increase to any significant change. Increase in height linear measurements were restricted to the nasion to menton calibration.
CASE II - D.J.

D.J. is a nine year old Caucasian male who originally presented himself with a posterior bilateral and anterior cross bite, deep closed bite, maxillary deficiency both dentally and skeletally, and a low mandibular plane angle. Orthopedic forces were directed to his maxilla by means of lateral and anterior expansion appliances and reverse head-gear.

Before and after measurements are as follows:

<table>
<thead>
<tr>
<th>Date Taken</th>
<th>Average (Stdn. Dev.)</th>
<th>3-19-70</th>
<th>5-6-70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saddle Angle</td>
<td>123° (+ 5)</td>
<td>122°</td>
<td>123°</td>
</tr>
<tr>
<td>Articular Angle</td>
<td>143° (+ 6)</td>
<td>135°</td>
<td>136°</td>
</tr>
<tr>
<td>Gonial Angle</td>
<td>130° (+ 7)</td>
<td>135°</td>
<td>135°</td>
</tr>
<tr>
<td>Sum</td>
<td>396°</td>
<td>392°</td>
<td>394°</td>
</tr>
<tr>
<td>Anterior Cranial Base Length</td>
<td>73 mm (+ 3)</td>
<td>71 mm</td>
<td>72 mm</td>
</tr>
<tr>
<td>Posterior cranial Base Length</td>
<td>37 mm (+ 3)</td>
<td>27 mm</td>
<td>29 mm</td>
</tr>
<tr>
<td>Ramus Height</td>
<td>53 mm (+ 5)</td>
<td>43 mm</td>
<td>44 mm</td>
</tr>
<tr>
<td>Body Length</td>
<td>80 mm (+ 5)</td>
<td>71 mm</td>
<td>71 mm</td>
</tr>
<tr>
<td>SNA</td>
<td>80° (+ 1)</td>
<td>75°</td>
<td>79.5°</td>
</tr>
<tr>
<td>SNB</td>
<td>78° (+ 1)</td>
<td>80.5°</td>
<td>78.5°</td>
</tr>
<tr>
<td>ANB Difference</td>
<td>2°</td>
<td>-5.5°</td>
<td>+1°</td>
</tr>
<tr>
<td>Go Gn Sn</td>
<td>32°</td>
<td>31.5°</td>
<td>32.5°</td>
</tr>
<tr>
<td>&quot;Y&quot; Axis</td>
<td>59.4°</td>
<td>61°</td>
<td>63°</td>
</tr>
<tr>
<td>FMA</td>
<td>25°</td>
<td>25°</td>
<td>26°</td>
</tr>
<tr>
<td>1 to FH</td>
<td>112°</td>
<td>114.5°</td>
<td>112°</td>
</tr>
<tr>
<td>1 to SN</td>
<td>103°</td>
<td>117°</td>
<td>114°</td>
</tr>
<tr>
<td>Interincisal Angle</td>
<td>135.4° (+ 5.8)</td>
<td>133.5°</td>
<td>141°</td>
</tr>
<tr>
<td>1 to NA (angular)</td>
<td>22°</td>
<td>32°</td>
<td>27°</td>
</tr>
<tr>
<td>1 to NA (linear)</td>
<td>4 mm</td>
<td>6.5 mm</td>
<td>3 mm</td>
</tr>
<tr>
<td>Measurement</td>
<td>Value 1</td>
<td>Value 2</td>
<td>Value 3</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Chin Angle</td>
<td>64° (± 6)</td>
<td>62°</td>
<td>62°</td>
</tr>
<tr>
<td>FMIA</td>
<td>65°</td>
<td>74°</td>
<td>74°</td>
</tr>
<tr>
<td>IMPA</td>
<td>90°</td>
<td>81°</td>
<td>80°</td>
</tr>
<tr>
<td>I to NB (angular)</td>
<td>25°</td>
<td>18.5°</td>
<td>12.5°</td>
</tr>
<tr>
<td>I to NB (linear)</td>
<td>4 mm</td>
<td>2 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>PO to NB</td>
<td>4 mm</td>
<td>3 mm</td>
<td>3 mm</td>
</tr>
<tr>
<td>1 to PO (Holdaway)</td>
<td>2:3</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>RATIO</td>
<td>1:1</td>
<td>1:3</td>
<td>1:3</td>
</tr>
<tr>
<td>NA to PO (Downs)</td>
<td>0°</td>
<td>-15°</td>
<td>-4°</td>
</tr>
</tbody>
</table>

Some of the significant findings in measurements occurred with the change of SNA from 75° to 79.5° within a period of forty-seven days. SNB dropped down and back from 80.5° to 78.5°. The ANB difference was corrected from -5.5° to +1°. The "Y" axis increased from 61° to 63°, and the FMA increased from 25° to 26° as expected. The Go Gn Sn angle also increased from 31.5° to 32.5°. The Bjork Analysis measurements remained stable as expected along with cranial base lengths.

The maxillary incisor tipped lingually to the Frankfort Horizontal from 114.5° to 112°. It also tipped lingually to the S-N line from 117° to 114°. The interincisal angle increased from 133.5° to 141°. The maxillary incisor to line N-A decreased in angle from 32° to 27° and linearly from 6.5 mm to 3 mm. The IMPA decreased slightly. The mandibular incisor to line N-B decreased in angle from 18.5° to 12.5° and linearly from 2 mm to 1 mm. The N to A to Pg angle increased from a concave -15° to a more pleasing -4° concavity.
The Coben Analysis revealed significant changes in the anterior-posterior depth of the maxilla in an anterior direction from pterygomaxillary fissure to "A" Point measured on the Frankfort Horizontal. The change from 44 mm to 48.5 mm was a net anterior displacement of 4.5 mm from March 19, 1970 to May 6, 1970. The N to ANS vertical height increased from 46 mm to 50 mm and the N to M vertical height increased from 103 mm to 110 mm. The other depth and height linear measurements did not change significantly. Again, a downward and forward displacement of the maxilla did occur.

Oriented occlusal radiographs revealed anterior movement of one half of the maxilla as visualized by labial movement of the central incisor and apical bone support on the forward displacement side.
Pre and post treatment models and kodachrome slides revealed the clinical picture of anterior movement on the anterior displacement side. The anchorage side did not appear to be positioned posteriorly.

Oral clinical inspection by palpation across the alveolar bone superior to the maxillary central incisors revealed a distinct bulge on the forward displacement side as compared to the anchorage side.
The maxilla responded to the vectors of force by repositioning downward and forward from its original location similar to the direction of normal growth procedures. Sieber (1965) called attention to the fact that the hafting zone sutures of the maxilla and cranium are oriented in such a manner that growth would produce a downward and forward vector of maxillary movement. Since these sutures are disengaged by palatal expansion procedures, an effect similar to immediate growth was manifested in a downward and forward displacement. Just growth alone cannot be responsible for the direction of movement of the maxilla in this study. Orthopedic force employed in this clinical procedure is the primary factor for this rapid and favorable forward displacement. Case I illustrated this point by changing the SNA from $73^\circ$ to $78^\circ$, the ANB from $-3^\circ$ to $+5^\circ$, and increasing the PTM to A measurement from 46.5 mm to 52 mm within a period of thirty-seven days! Undoubtedly, growth cannot explain so rapid a change.

There was a simultaneous combination of negative or clockwise rotation of the mandible and positive anterior
maxillary movement which orthopedically corrected the posterior and anterior dental crossbite and improved the denture base relationship. The general effect was an improved skeletal and dental pattern due to a more favorable denture-base relationship, increased lower face height, and decreased effective mandibular length.

Haas (1970) discussed the conventional lateral palatal expansion appliance in conjunction with reverse headgear to correct anterior crossbites, posterior crossbites, and maxillary skeletal deficiency in the low mandibular plane angle cases. He relied mostly on the clockwise rotation of the mandible and lateral posterior expansion to improve the dental disharmony.

The maxillary and mandibular incisors cephalometrically exhibited lingual tipping. This is probably explained by the buccinator muscle mechanism which confines the oral cavity and its components.

The patients' profiles were favorably changed from a concave N to A to Pg to a less concave or convex N to A to Pg.

Further investigation is needed to show sufficient retention time between the period of reversal of the
appliances from one side to the opposite side. Retention after both "halves" are anteriorly repositioned is also another area of study.
CHAPTER VI
SUMMARY

It was the purpose of this study to determine whether anterior movement of the maxillae is possible for maxillary deficient patients by modifying the conventional methods of maxillary mid-palatal suture expansion and employing orthopedic mechanics to produce a more balanced skeletal and dental harmony. The four patients in this study were cephalometrically a skeletal malocclusion and clinically a bilateral posterior and anterior crossbite, closed bite, low mandibular plane angle, and Angle Class III molar relationship. The lateral maxillary orthopedic expansion appliances were first inserted and activated over a period of one week in order to effect all the sutures involved with maxillary stability. Reverse headgear was worn from fourteen to sixteen hours per day. Parents were instructed of the urgency for cooperation at this critical period of a mobile maxilla during the expansion procedures and attested to the time requirement for reverse headgear. Elastics were secured from the right and left mesial aspects of the appliance. Five to six pounds of force were employed and recorded while the reverse headgear was worn.
The anterior maxillary orthopedic expansion appliances were immediately inserted after the removal of the lateral expansion appliances. Activation of these appliances was similar to the lateral expansion appliance. Reverse headgear was also employed fourteen to sixteen hours per day with five to six pounds of force. The reverse headgear mechanics with the appliances provides an anterior component of force to the forward displacement side and a negating effect of suture site resorption on the anchorage side. The activation was continued until the forward displacement side was correct clinically and radiographically. This period was generally three weeks in duration. Activation of the appliance was then discontinued for a one month period. Reverse headgear was continued during this retention period. A one month period of retaining was desired in this study to allow bone deposition into the separated suture sites. The procedure was desired to be reversed then for the previously used "anchorage side" then became the forward displacing side. Reverse headgear was to be continued to negate any posterior movement of the maxilla. After the "halves" of the maxilla were clinically and radiographically displaced equally in anterior movement, the activation of the screw should be discontinued.
Reversal headgear should be continued for a two month period during this stage to discourage posterior movement of the mobilized maxilla.

The effects of the lateral and anterior posterior components of force were studied and compared by means of before and after models, before and after tracings of cephalometric radiographs, superimposed tracings of cephalometric radiographs, oriented occlusal radiographs of before and after, and kodachrome slides taken during the entire procedure.

Anterior movement of the maxilla in a favorable downward, forward, and lateral direction did occur.
CHAPTER VII

CONCLUSIONS

Anterior displacement of the maxilla is possible for maxillary deficient patients by employing orthopedic forces to produce a more balanced skeletal and dental relationship.

1. There was an increase of SNA to favorably produce a better skeletal relationship caused by the anterior movement of the maxilla.

2. There was a decrease of SNB caused by a clockwise rotation of the mandible down and back to effectively decrease the mandibular length.

3. The ANB was favorably corrected by a combination of the above two so as to produce a more pleasing skeletal harmony.

4. The "Y" axis, FMA, and Go Gn Sn increased due to the clockwise rotation of the mandible effectively decreasing mandibular length.

5. The N to A to Pg angle favorably increased from a concave measurement to a more pleasing concave or convex profile.
6. Linear measurements from PTM to A along the Frankfort Horizontal increased, caused by the anterior orthopedic movement of the maxilla.

7. Linear vertical measurements perpendicular to Frankfort Horizontal from M to ANS and from N to ANS increased, caused by the downward and forward vector of forces during the orthopedic procedure.

A downward and forward displacement of the maxilla did occur which is similar to the direction of the normal growth procedure, but because of the amount of increase both angularly and linearly over the short procedural time this could not be accounted for by normal growth processes.
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The Thesis submitted by Garret Frank Harnett, B.S., D.M.D., 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 of Master of Science.