THE IMMEDIATE AND LONGTERM EFFECTS OF MAXILLARY EXPANSION ON THE DENTOFACIAL COMPLEX

by

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Submitted in partial fulfillment of the requirement
for the Degree of Master of Science in Dentistry

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AUGUST 13, 1993

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The purpose of this investigation was to 1.) Determine the pattern of transverse growth of the dentofacial complex that occurs from adolescence to young adulthood in an orthodontically untreated longitudinal male and female sample, 2.) Determine the immediate effects of RME on the dentofacial complex and 3.) Determine the long-term effects of RME combined with orthodontic treatment on the dentofacial complex present approximately six to eight years after treatment. To study transverse growth, an untreated sample consisting of twenty females and sixteen males was derived from the Bolton-Brush Growth Study. Selected transverse dentofacial dimensions were evaluated using a cephalometric analysis of frontal radiographs taken at ages 10, 11, 12, 13, 16, and 18 years. An additional radiograph taken at the age of 20 years was included in the male sample. The treatment group consisted of thirty-six patients who underwent RME with Haas type appliances between the ages of ten and twelve and a half years as an initial phase of orthodontic treatment. Selected transverse facial dimensions were evaluated using a cephalometric analysis of frontal

radiographs taken pretreatment, post-expansion, and at recall in young adulthood.

The following observations were made by analyzing the data:

1. There is minimal transverse growth of the dentofacial complex after ten years of age.

2. There is sexual dimorphism in the eventual transverse width of certain facial structures such as bizygomatic, binasal and bigonial width.

3. The intermolar width increases about 7 mm with 9-10 mm of appliance activation.

4. The midpalatal suture separates approximately 4 mm with 9-10 mm of appliance activation.

5. The majority of the gain in dental width is lost prior to subjects reaching adulthood.

DEDICATION

To Thomas Rossman, my husband and best friend, for his unconditional love and support and to my parents, Floyd and Janet Alvetro, for their years of encouragement.

AKNOWLEDGEMENTS

Dr. Varun Kalra, my committee chairman, whose guidance in both research and clinical orthodontics has been of tremendous value.

Dr. Mark Hans, whose tireless efforts as department chairman are appreciated.

Dr. Suchitra Nelson, for her guidance and support through out the project.

Dr. Allison Harding, for her assistance in reviewing the manuscript.

Dr. Thomas Herberger, for the use of clinical records from his practice.

To my classmates; Dr. Fran Hamman, Dr. Nonglak Pracharktam, Dr. Martha Chun, Dr. Sean O'Callaghan, and Dr. Gus Spillas, for friendships that will never be forgotten. And to Dr. Roger Diels for being the best little brother.

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INTRODUCTION

Rapid expansion of the maxilla through separation of the midpalatal suture using rapid maxillary expansion (RME) appliances was introduced to orthodontics over 130 years ago. The process is employed either to correct a buccal crossbite by expansion of the maxilla or to make room in the upper arch to alleviate crowding even if no crossbite exists. Recently, there has been a rapid resurgence of RME as a means to gain space in the upper arch to alleviate crowding and to perform orthodontic treatment without extractions (McNamara 1992, Hamilton 1993).

The immediate effects of RME on the dentofacial complex in the transverse dimension have been studied to some extent (Davis 1969, Wertz 1977). However, the more important long-term effects in terms of stability of the changes in the dentofacial complex with RME have not been as well documented. A study of these long-term effects is of course clinically significant in order to determine whether the expansion of the maxilla, especially of the maxillary dental arch, is stable leading to a successful result or relapses thus resulting in reappearance of crowding.

The purpose of this study was to 1.) Determine the pattern of transverse growth of the dentofacial complex that occurs from adolescence to young adulthood in an orthodontically untreated longitudinal male and female sample. 2.) Determine the immediate effects of RME on the dentofacial complex 3.) Determine the long-term effects of RME and

orthodontic treatment on the dentofacial complex present approximately six to eight years after treatment.

The sample for the control group, in order to study normal transverse growth of the dentofacial complex, was derived from the Bolton-Brush Growth Study. Twenty females who had frontal radiographs taken from ten to eighteen years of age and sixteen males who had frontal radiographs taken from ten to twenty years of age were selected as subjects for the control. The selected transverse facial dimensions were evaluated using a cephalometric analysis of frontal radiographs.

The sample for the treatment group to study the immediate and long-term effects of RME consisted of twenty females and sixteen males between the ages of ten and twelve and a half at the start of treatment. Individuals in this group underwent RME with Haas type appliances in the initial phase of orthodontic treatment. The selected transverse facial dimensions were evaluated using a cephalometric analysis of frontal radiographs taken pretreatment, post-expansion, and at recall in young adulthood.

LITERATURE REVIEW

Rapid expansion of the maxilla through separation of the midpalatal suture was introduced to orthodontics over a century ago. E.H. Angle (1860) is given credit by most authors as the first to have described the procedure. However, Westcott (1859) had previously presented a case report in which treatment of a constricted maxilla consisted of separation of the midpalatal suture. A controversy arose over the technique with many clinicians claiming it "utterly impossible" and "exceedingly doubtful" that one could split a maxilla into two halves. Others questioned ramifications of disrupting the facial skeleton when "irregularity of teeth seemed a trifling affair compared with the separation of the maxillae" (Monson 1868).

However in the 1900's rapid maxillary expansion was advocated by both orthodontists and rhinologists. Brown (1903) and other rhinologists believed that maxillary expansion could increase nasal permeability, straighten deviated nasal septums and relieve hypertrophic nasal and pharyngeal mucous membranes. Pfaff (1908) attributed lowering of the palatal vault, which was believed to occur with suture separation as the reason for observed improvement in patients with nasal obstruction.

In 1907 E. Angle proposed that a full compliment of teeth could be aligned in the dental arches through use of traditional, conservative orthodontic movement. He taught that the resulting ideal alignment of teeth and improved function would result in formation of new bone to support the

dentition. Controversy over the technique of rapid maxillary expansion coupled with Angle's concept lead to the decline of sutural expansion in the United States during the next quarter of a century.

However, interest was renewed in expansion as a result of work by Brodie (1938). Using cephalometrics, Brodie was able to demonstrate that bony changes associated with orthodontic movement were limited to the alveolar process. Contrary to Angle's concept, bone formation did not result from alignment of the dentition.

TRANSVERSE GROWTH OF THE FACE

According to Scott (1957) the upper facial skeleton enlarges as the size of orbital cavities, nasal cavity and maxillary, frontal and ethmoidal sinuses increase. The maxillary complex moves downward and forward as a result of growth at frontomaxillary, zygomaticomaxillary and pterygomaxillary sutures. An increase in transverse dimension of the maxilla results from apposition at the midpalatal suture and divergent downward growth of pterygoid processes. Growth along the transverse palatine suture and apposition along posterior border of the palatine bone are responsible for an increase in anteroposterior length of the maxilla. Concurrent with growth changes at suture margins are continual remodeling in bones of the maxillary complex.

Amount of sutural growth verses appositional remodeling responsible for increases in maxillary dimension is disputed. However most authors agree that maxillary growth change are greatest in height, less in length and least in width (Savara 1968).

The most comprehensive study on development of the maxilla was reported by Bjork and Skeiller (1977). With the aid of metallic implants, nine boys were followed radiographically from ages four to twenty-one. An increase in maxillary transverse dimension was reported until age seventeen. Growth in the midpalatal suture was greater posteriorly than anteriorly resulting in rotation of the two halves of the maxilla relative to one another. The resulting increase in intermolar distance was reduced by mesial drift of the dentition on the maxillary corpus. Extent of remodeling of the outer surface of the maxilla could not be quantified by the authors and led them to conclude that, although remodelling is observed, sutural growth is responsible for the majority of transverse increase in maxillary width.

As demonstrated by Bjork (1977) increases in maxillary height resulted from sutural growth toward the frontal and zygomatic bones and through apposition on the alveolar process. Sutural lowering of the maxilla was compensated for by apposition at the floor of the orbit so that the orbital height did not increase to the same degree as nasal cavity height. Increases in nasal cavity were also associated with resorption on the nasal surface and apposition on the oral surface of the maxilla. Appositional growth of the alveolus was associated with eruption of the dentition.

Korn (1990) corroborated Bjork and Skeiller's description of maxillary growth. In a longitudinal sample of boys followed from 8.5 to 15 years of

age, similar trends in maxillary growth were reported. Although increases in transverse dimension were small they were continuous. No evidence to support the idea that transverse palatal growth ceases at an early age was reported.

Since few cephalometric studies consider transverse dimension of the facial skeleton, Athanasiou (1992) attempted to provide normative data on transverse measures and describe the pattern of transverse facial development. Anteroposterior radiographs were obtained on a cross-sectional sample of 588 Australian children six to fifteen years of age. All skeletal widths demonstrated a progressive increase in dimension during the study period. Woods (1949) also reported a continual increase in bigonial and bizygomatic width in a longitudinal sample of children from three to fifteen years of age. Both authors report variability in maxillary and mandibular intermolar widths with no correlation between molar width and respective skeletal base. Richardson and Brodie (1964) also described lack of correlation between apical base size and dental arch size and attributed it to the influence of musculature on tooth positioning.

ANATOMY AND GROWTH OF THE MIDPALATAL SUTURE

There are two issues in sutural growth most relevant to orthodontists. First, what are the indicators that sutural growth has ceased. Second, at what age is sutural fusion to a degree where separation is impossible.

Various opinions on growth activity of midpalatal suture exist. Scott (1956) considered that sutural growth ceased at one year of age. Latham (1966) histologically observed growth at the suture until age three. Persson (1973) believed he observed signs of sutural growth at age thirteen.

Melsen (1975) reported that transverse growth of the midpalatal suture continued until age sixteen in girls and age eighteen in boys. On basis of morphology, Melsen divided the maturing suture into three categories. In the infantile period, the suture appeared broad and 'Y' shaped with the vomerine bone lodged between the two halves of the maxilla. During the juvenile period, the suture became vertically longer and had a sinusoidal course. In the final stage of adolescence, the suture was very tortuous with interdigitation so heavy the author felt that separation would be impossible without fracturing the processes.

In a later study of autopsy material from twenty four male and female subjects between the ages of fifteen and thirty-five years, Persson (1977) drew the following conclusions. Palatal sutures show the beginning of obliteration during the juvenile period. Initial bridges across the suture were made up of slender bony spicules which often appeared fractured and under going osteoclastic resorption. A marked degree of suture closure was rarely evident until the third decade of life with a large degree of variation in amount of closure existing in the same suture.

In Persson's (1977) sample the palatal suture appeared to close at approximately the same time as cranial vault sutures. However, closure in the palatal suture advanced at a slower rate than that of cranial vault sutures. Closure of the midpalatal suture started in the posterior region and

proceeded forward with closure in the anterior oral area occurring most rapidly. The large interindividual differences observed lead the author to conclude that factors other than age must be responsible for the initiation and advancement of suture closure.

ANIMAL STUDIES

Using an acrylic split plate with midline jackscrew appliance, Haas (1958) studied effects of suture separation on Duroc-Poland China pigs. Although the pigs had already developed the majority of their maxillary width, Haas demonstrated increases in maxillary arch widths of up to 15 mm in less than two weeks. Suture opening was detected by direct observation through a palatal tissue flap. Histologically, bone deposition was observed in the suture with bone resorption occurring on spines of the suture margin. Bone formation occurred rapidly with complete bridging of suture margins in five weeks.

As a result of palatal suture separation Haas (1958) reported that various adjacent structures were affected. Nasal septum thickened at its articulation with the palatal crests of the maxilla along with an increase in nasal width. Alveolar processes bent outward with a resultant lowering of palatal vault. Dentally, teeth that received the force tipped laterally and spacing occurred between central incisors.

Debbane (1958) reported an asymmetric opening of the palatal suture in cats using continuous and intermittent forces. A U-shaped gold palatal arch wire soldered to cuspid bands was used to deliver an intermittent force. Continuous forces were generated by a modified Arnold expander activated through compression of a coil spring. The greatest

degree of opening was observed in the premaxilla with amount of opening decreasing toward posterior maxilla. At the palatine bone no suture opening occurred. Sutural connective tissue found in the premaxilla was not as dense as that found in posterior maxillary region. The difference in connective tissue density combined with rigid bony interdigitation of the suture in the palatine area was given as a possible explanation for variation in sutural opening.

In a comparison of continuous and intermittent forces, Debbane (1958) reported more sutural expansion in animals subjected to strong intermittent forces. The author believed that intermittent forces were too great for the periodontal membrane and dentoalveolus to respond. Instead forces were transmitted to surrounding bones resulting in more bony changes and less dental movements.

Debbane (1958) considered forces applied to all experimental animals to be nonphysiologic. Trauma occurred to the oral mucosa. Connective tissue was disorganized and there was an edematous infiltrate and dilatation of blood vessels. In some animals, teeth were displaced out of the dental arch by the applied force. The author urged that the amount of force that is physiologic and will still produce sutural separation must be determined for effective treatment.

Although the rhesus monkey has a distinct and separate premaxilla with no continuous suture traversing the maxillary and premaxillary bones, it was chosen as the animal model by Cleall (1965). The expansion appliance used was an acrylic split plate with a midline screw stabilized by molar bands. Following two weeks of activation 4 mm of expansion were

achieved. In three of the animals an additional 2 mm of expansion were achieved through further activation. In all experimental animals the midpalatal suture appeared separated. A widening and flattening of palatal vault was observed with suture separation. However an accompanying widening of nasal base was not observed. As explained by the author, difficulty in standardizing frontal cephalograms and the small degree of change that would have occurred in nasal base may have made detection impossible.

In all experimental animals Cleall (1965) observed a buccal tipping of the posterior segment of the dentition. However, histologically the reaction in the periodontal membrane and bone surrounding the dentition was less than that usually observed with orthodontic movement of teeth. Also, buccal segments in post-retention animals demonstrated an improved axial inclination with little or no buccal tipping. This led the author to conclude that it may be outward rotation of the alveolus not tipping of teeth that results in inclination of buccal segments.

EFFECTS OF EXPANSION ON THE FACIAL SUTURES

In a paper presented to the New York State Dental Society, Pullen (1911) discussed effects of maxillary expansion on development of the "internal and external face". Pullen assumed facial sutures to be mobile due to the fibro-membranous nature of sutural connective tissue and lack of complete ossification in a growing individual. Forces produced during expansion were considered a stimulant to natural growth and development. It was theorized that direct effects were transmitted to malar, nasal, frontal,

vomer and lacrimal bones via intermaxillary, ethmoidal, palatal and sphenoidal sutures.

In a preliminary study on rhesus monkeys, Starnback (1964) reported that effects of midpalatal suture separation went beyond the maxilla. Following four months of expansion, using a fixed split acrylic plate, an increase in cellular activity was observed in nasal, zygomatico-maxillary and zygomatico-temporal sutures. Amount of cellular activity decreased as the post-expansion time interval increased.

According to Starnback (1966), clinically observed rotational movement of the alveolar processes concurrent with midpalatal suture separation is conceivable only if adaptation occurs in sutures of contiguous and remote facial bones. When the maxillae of Macaca rhesus monkeys were expanded using a split plate and expansion screw appliance, the frontonasal complex of sutures began to show evidence of adaptation after 4 mm of expansion. Following 6 mm of expansion frontonasal, zygomaticotemporal and maxillary zygomatic sutures all exhibited histologic changes. Sutural connective tissue appeared increased in width and vascularity. Sutural bony processes were lined by an abnormal number of osteoblasts producing bone with marked osteoclastic resorption occurring in other regions. Tissue reaction was most intense in the frontonasal bone and in the zygomaticotemporal suture.

Gardner (1971), using a banded appliance with .75 mm increment of activation, expanded maxillary arches of rhesus monkeys until complete posterior buccal crossbite was achieved. Palatal sutures opened from premaxillary suture to palatomaxillary suture. The sphenoioccipital

synchondrosis opened from 0.5 mm to 1 mm in all experimental animals. Excessive distortion of the midsagital and frontal-parietal suture was observed in the experimental animals. A degree of separation of the lambdoid suture resulting in displacement of the parietal bone and occipital bone occurred. The degree and location of suture separation suggested that forces produced during midpalatal suture separation are transmitted to surrounding craniofacial bones.

Using vital dyes as bone markers, Brossman (1973) demonstrated changes in bone architecture occurring with midpalatal suture separation. Maxillae of Cynomalogus monkeys were expanded using a Haas type appliance for ten days with 0.5 mm of activation daily. In control animals remodeling occurred only around the roots of teeth and in the third molar crypts. Extensive bone remodeling was evident in all experimental animals. Bone formation was observed along the palatal suture, lateral aspect of alveolar processes and over entire maxillary external surface. Bone deposition was also observed in the maxillary sinus, nasal chonchae and in the nasal septum where it approximates the floor of the nasal cavity. In serial sections taken from the molar region bone remodeling was apparent in the floor and medial portion of the orbit up to the fronto-ethmoidal suture. The fronto-zygomatic suture was displaced with bone reorganization occurring along the suture and zygomatic arch.

Using birefringement materials Chaconas (1982) created an anatomic three dimensional model of the human skull. Bones of the midface were fabricated individually and articulated. One removable appliance and

four fixed appliances; Haas, Minne-expander, Hyrax and Quad Helix were observed using a transmission polariscope following incremental activation.

Activation of Haas, Minne-expander and Hyrax appliances produced stress that radiated from the midpalatal area superiorly along the perpendicular plates of the palatine bones. Buttressing of the maxillary tuberosity with the pterygoid plates of the sphenoid bone allowed forces to radiate to the base of the medial pterygoid plate. Areas of stress were observed in the molar and zygomatic bone, specifically, in zygomatico-maxillary and zygomatico-temporal sutures. Dissipation of force was observed superiorly at the medial wall of the orbit and at the junction of the nasal and lacrimal bones.

Similar initial results were recorded with the removable appliance. However, with increased activation the appliance became dislodged decreasing its effectiveness. The least effective orthopedic device was the Quad Helix. Activation of the Quad Helix appliance primarily resulted in stress in the alveolar bone surrounding posterior teeth.

REPAIR OF MECHANICALLY SEPARATED SUTURES

Burstone (1959) demonstrated in the rat that patent sutures can be activated by mechanical forces. A reorientation of connective tissue occurred following suture separation. Connective tissue fibers that were initially oriented parallel with the suture rearranged to be perpendicular and bridged the space between the two halves. An increase in number of fibroblasts and an increase in vascularity of the sutural connective tissue was also observed. Osteoid projections extended out of the connective tissue. These bony projections were surrounded by active osteoblasts.

Although the parietal suture was used in the study of the mechanism of repair and regeneration of a rapidly expanded suture, the study by Cate (1977) is applicable to maxillary sutures. The initial effect of force application was tearing of the connective tissue, most frequently in areas of blood vessels. Tears filled with exudate and extravasated red blood cells. The periosteum always remained intact with osteoblasts undisturbed. In tissue surrounding the tears, fibroblasts were undergoing cell death and collagen fibers were disorganized. Further from the site of separation collagen bundles were disrupted but cell death occurred less frequent.

In the first twelve hours following suture separation a polymorphonuclear response was seen. This was followed by an invasion of macrophages and fibroblasts within twenty-four hours. The macrophages were associated with uptake of exudate and dead cellular debris. Intercellular collagen fibers were observed in the invading fibroblasts. Undamaged osteoblasts began producing bone within three to four days. During the following one to two weeks collagen fibers and cells were laid down across the suture. Osteoid was produced at right angles to lamellae initially formed at the suture margin. Remodeling of the connective tissue and bone preceded until normal sutural anatomy was obtained.

Cate (1977) discusses that tissue trauma is followed by repair or regeneration with regeneration defined as restoration of original tissue architecture. Healing of a separated suture first occurs by repair and then through remodeling results in regeneration. Events that occur in healing sutures after the force used to produce expansion has dissipated are not unlike events of a normal growing suture.

Using an iodine-125 radioisotope apparatus Ekstrom (1977) studied mineralization of the separated midpalatal suture. The greatest increase in mineral content was observed one month postexpansion. By the end of three months post-expansion mineral content in the separated suture was well established. It was noted that the mineral content in areas away from the suture margin decreased during the first month. However, mineralization returned to normal values in these areas by end of the third month. Ekstrom's work supports earlier reports by Cleall (1965) in which sutures three and six months post-expansion showed no evidence of disruption and had the appearance of a normal suture.

SKELETAL AND DENTAL EFFECTS OF EXPANSION IN CLINICAL STUDIES

During maxillary expansion suture separation occurs at the midpalatal suture. The suture opens in a triangular configuration with the apex of the triangle towards the nasal cavity. Open suture margins are considered to be nonparallel, by most authors; with greater separation observed in the anterior region. The posterior limit of separation is believed to be within the maxillary bone resulting in no displacement of palatine bones.

As detected by Krebs (1964) using metallic implants, there is a lateral rotation of the alveolar processes in the frontal plane during expansion. As

a result, expansion occurring in the dental arch is twice the amount observed in basal maxillary segments. Wertz (1970) reported that the fulcrum of maxillary rotation appears to be at the frontomaxillary suture with the amount of arching of the segments increasing as one progresses from nasion. This movement has been detected in clinical cases by various authors and is often referred to as the bending of the alveolar process.

Lohman (1915) associated changes in nasal cavity with midpalatal suture separation. Using a radiographic technique introduced in 1908, Mesnard (1929) observed a widening of nasal cavity, lowering of palatal vault and floor of the nose accompanying dislocation of the maxillae. As reported by Davis (1969), due to rotation of the alveolar segments with suture separation, the resultant expansion in the nasal cavity is reduced to approximately one quarter to one third of that observed in the dental arch. The nasal bone appears to be the most distant bone affected by expansion with no radiographically detectable increase occurring between bilateral orbital, rotundal and zygomatic points.

EFFECT OF SUTURAL EXPANSION ON THE MAXILLA

The effect of rapid maxillary expansion on anterior posterior location of the maxilla has been investigated through the use of lateral cephalograms. Wertz (1970) reports an average of 1.5 mm of forward movement of point A from the linear measurement of Sella-A point. Davis (1969) also reports a forward positioning of point A in relation to pterygomaxillary fissure. However, in both studies individual cases in which A point appeared to move posteriorly also existed. Only in a study by Haas

(1970) is the movement of A point detected by changes in SNA consistently in a forward direction.

More recently Silva (1991) claims anterior displacement of maxilla and changes in SNA should not be expected with rapid maxillary expansion. The author cites amount of expansion along with the age of patient during expansion as possible explanations for the difference in the observed movement of A point in his sample. Silva theorizes that a more mature facial skeletal complex would offer increased resistance to transverse expansion thus resulting in an anterior movement of the maxilla.

Most investigators (Haas 1970, Silva 1991, Wertz 1970) concur that the maxilla descends during expansion in the range of 1 to 2 mm. Yet direction of descent and effect on palatal plane is disputed. The amount of vertical displacement occurring at anterior nasal spine and posterior nasal spine is usually not equal. The more common occurrence is a greater displacement at ANS resulting in a downward and backward rotation of the palatal plane in relation to Sella-Nasion. Although cases exhibiting the opposite or no rotation of palatal plane have been documented.

Maxillary molars descend along with the maxilla and as a result are displaced in relation to Sella-Nasion. The extrusion of maxillary molars due to the heavy forces produced by expansion appliances has been suggested by Wertz (1970). However as noted by Silva (1991) most analyses compare molar position to SN and not to the alveolar bone of the maxilla.

EFFECT OF SUTURAL EXPANSION ON THE MANDIBLE

As a result of the downward displacement of the maxilla and maxillary molars, an increase in the mandibular plane relative to Sella-Nasion and

Frankfort horizontal occurs. The average increase as reported by Davis (1969) in this angle is approximately one degree with a concurrent decrease in the SNB angle. Clinically; the increase in mandibular plane manifests itself as an opening of the bite, decrease in effective length of the mandible and an increase in lower facial height. Byrom (1970) attributes occlusal interferences present post-expansion as the cause for increases in mandibular plane angle and anticipates recovery following cuspal interdigitation.

Viewed in the transverse dimension, the mandibular dentition may be indirectly affected by maxillary expansion. Haas (1959) reports that the mandibular dental arch expands in response to rapid maxillary expansion. He reports increased intermolar distances in all cases. Haas attributes the increased width to the altered functional forces. It is hypothesized that following expansion the lingual vector of the force of occlusion produced by a constricted maxilla is no longer present. The new direction of force results in the uprighting of the posterior segments.

The work of Gryson (1977) supported the concept that the uprighting of the posterior segments was responsible for the increased arch width when he demonstrated a significant increase in the mandibular molar region with no increase in the canine region. Wertz (1970) reported no increase in the intermolar distances across the mandibular molars following rapid maxillary expansion. The author concluded that although he failed to demonstrate a predictable intermolar increase associated with maxillary expansion, a study of longer duration may be necessary for the altered forces to produce an effect.

STUDIES ON RETENTION OF EXPANSION

Thorne (1960) reported on a sample of twenty-eight patients, one to two years post-retention, who were initially expanded through midpalatal suture separation. Five cases, which had little to no retention, showed a decrease in the gained apical width and nasal widths. The remaining twenty-three patients demonstrated either no change or an increase of up to 2.9 mm in nasal cavity width and an increase of up to 6.5 mm in apical base width.

Using Bjork's implant method, Krebs (1964) followed expansion patients over a seven year period. Patients who were initially treated for bilateral crossbite of basal origin were monitored annually until growth was complete. When the appliance remained cemented in place the dental arch width was maintained. However; during the period of removable retention and post-retention, dental relapse occurred until a stable state was achieved at year five. A decrease in the skeletal parameters of maxillary base, hard palate and nasal cavity occurred immediately following expansion. The maxillary measure then increased 0.5 mm over the next three years with nasal cavity dimension increasing over the seven year period. These increases are most likely due to normal growth since the increases stopped at approximately age fourteen for girls and ages sixteen to eighteen for boys.

Through the use of metallic implants Skeiller (1964) found a difference in the stability of dental and skeletal components of expansion. The palatal vault continued to increase in width during both the twelve month retention and twelve month post-retention periods. Conversely, dental arches began a relapse pattern immediately following expansion that

continued into the post-retention period. The amount of resulting dental relapse was averaged to 25% of total initial expansion.

Wertz (1970) using a mixed sample of patients in the deciduous dentition, mixed dentition, and permanent dentition, compared the effects of rapid maxillary expansion to growth predictions from the Rocky Mountain Data Systems at the end of retention. Descent of palatal plane that occurred during suture separation was greater than that expected from growth. Complete recovery occurred during retention with no difference in treatment position and predicted position of the palatal plane. Forward movement of point A usually recovered prior to appliance removal. During retention it was determined that point A moved forward less than that expected from growth.

The initial increase in maxillary arch width underwent a 30% relapse during stabilization and retention. The descent of the maxillary buccal segments underwent a 50% recovery when compared to the amount expected from normal growth. The initial mandibular rotation that occurred with sutural opening recovered by 50% during retention.

Timms (1976) reported on long term stability of rapid maxillary expansion on cases that averaged five years post-retention. The maxillary arch width, defined as the average between the premolar and molar arch widths, was recorded three months post-activation and at the time of recall. An average of 40% residual expansion with a range of 81% to 10% residual expansion occurred in the recall sample. The decrease in maxillary arch width occurred most consistently in the first several years, reached a plateau at year five, then remained stable in the sample.

With the intentions of giving clinicians the opportunity to evaluate the long term stability of rapid maxillary expansion, Haas (1980) published retention records on ten of the cases originally presented in his 1961 and 1965 articles. The average expansion for the cases was an increase in apical base width of 9 mm and 4.5 mm in nasal cavity width. The author reports that at recall, six to fourteen years post-retention, no loss of apical base or nasal cavity width was detected in any patient. However; two cases demonstrated a slight decrease in maxillary dental arch width, while two cases increased in dental arch width.

Mew (1983) studied the stability of maxillary expansion in twenty-five patients using the Bioblock Stage I appliance. The patients were expanded 1 mm per week until an over expansion of 2 to 4 mm was produced. The measure of the amount of expansion across the first molars was recorded two to four months after active expansion to allow for the initial relapse to occur. The measurements were repeated 2.5 years post retention. At the recall a net residual expansion of 3.5 mm was reported. The author contends that the variable of growth over the 2.5 years was negligible due to the age of the patients. It should be noted that the amount of expansion was not uniform in the sample.

Herold (1989) studied the stability of crossbite correction in patients treated by maxillary expansion with various techniques. The appliances included hyrax, quad helix and a removable appliance with a midline screw. The residual expansion reported at the time of recall was 62.5% in the canine region for rapid expansion, 61.9% for quad helix and 65.6% for removable appliances. In the intermolar region residual expansion was

found to be 56.4% for rapid expansion, 52.2% for quad helix and 67.4% for removable appliances

In the study by Herold total crossbite correction was not achieved in all patients. However; in the quad helix group in which 90% of crossbites were corrected, only 40% remained corrected at the four to five year recall. The removable appliance was advocated for stability over the hyrax even though in both groups only one patient whose crossbite had been corrected with treatment relapsed by the recall period.

EXPANSION APPLIANCE DESIGN

In the early case reports of palatal expansion every author had an individual technique. Westcott (1859) illustrated an appliance similar to the contemporary removable transpalatal arch. Angle (1860) advocated plates with midline screw mechanisms. Currently various designs of banded, bonded and removable appliances exist in the literature.

FIXED BANDED APPLIANCE DESIGN

Before the thirty-third Congress of the European Society of Orthodontists, Derichsweiller (1957) was the first to describe a contemporary fixed expansion appliance. In the appliance four bands were used as anchorage for a midline jackscrew. Palatal acrylic was included to increase the stability of the appliance and to utilize the palate as anchorage. A similar appliance was introduced in the United States by Haas (1961) and subsequently became known as the Haas expander.

The Hyrax expander is similar to the Haas expander in that bands are used to anchor a midline jackscrew. However the palatal acrylic is excluded for hygiene purposes.

The Minne-expander is another variation of a banded fixed expansion appliance. Using bands as anchorage it is activated through compression of a large midpalatal coil spring.

Most authors agree that the Haas, Hyrax, and Minne-expander all generate orthopedic forces. However, the force generated by activation of the Minne-expander is less than either the Haas or Hyrax which generate comparable forces. When the Haas and Hyrax appliances are no longer activated the appliance is considered passive once the residual stress in the surrounding structures has dissipated. Minne-expanders must be intentionally deactivated once expansion has been achieved to dissipate energy stored in the compressed coil.

In a study designed to measure forces produced by banded rapid maxillary appliances, Issacson (1964) designed an appliance similar to a Haas expander by incorporating bonded filament strain gauges. It had been assumed that relatively high load deflection rates were produced by activation of the screw mechanism. However, no estimates of the force value or decay rates had been reported. Isaacson reported that with a single activation of 0.2 mm a force of 3 to 10 pounds was produced. The younger the patient the smaller the resulting force.

Interestingly no significant difference in force values generated with activation before and after midpalatal suture opening was observed. This suggested that the major resistance to maxillary expansion was not the midpalatal suture but other maxillary articulations.

The decay rate of the force immediately following activation was rapid but continued to slowly decrease. As residual loads compounded with

activation, Zimring (1965) recorded maximum loads during treatment ranging from 16.6 to 34.8 pounds. The forces gradually dissipated during the first six weeks of the retention period.

Porter or 'W' arches are fixed appliances that are considered slow continuous force expansion appliances. They are anchored by bands and activation is achieved through palatal wires. A modified appliance, the Quad helix, incorporates four helical loops in the palatal wire to increase the range of force application and flexibility.

Orthopedic verses orthodontic effects of such appliances are disputed. Bell and LeCompte (1981) demonstrated midpalatal suture opening in patients treated with the Quad Helix appliance in deciduous and mixed dentitions. Frank (1982) reported a 6:1 ratio of orthodontic movement to orthopedic movement in a similar treated sample treated. Boysen (1992) demonstrated that expansion in the molar region using a quad-helix appliance was a result of buccal translation of molars with little basal expansion.

ALTERNATIVE TECHNIQUES OF EXPANSION

Bonded expanders were introduced into the orthodontic literature by Howe (1982). The appliances are designed with a central jackscrew and support wires. Acrylic covering the maxillary posterior segments on the buccal and occlusal surface was incorporated into the appliance. The appliance is retained through the bond with posterior teeth. Proponents of bonded expansion appliances suggest that the downward and anterior displacement of the maxilla associated with banded appliances can be negated through use of bonded appliances. Spolyar (1984) proposed that

increased rigidity of the appliance limits the amount of tipping and rotation of abutment teeth. Sarver (1989) suggests that vertical thickness of the posterior acrylic, acting as a bite block, infringes on the freeway space. Theoretically, infringing on the freeway space results in a constant passive force on the maxilla and mandible through elevator muscles that are stretched beyond their resting lengths.

Vardimon (1987) demonstrated that magnetic forces could be used to produce the orthopedic effect of midpalatal suture separation. The author suggested the advantage of using repelling magnets over conventional mechanical techniques was that a predetermined force range could be established.

An alternative technique, slow maxillary expansion, is preferred by some clinicians. This technique utilizes fixed appliances and more often removable appliances with activation in the range of 0.5 to 1 mm per week. Following their studies of force produced during rapid maxillary expansion, Issacson and Zimering (1965) suggested that a slower rate of expansion may allow for a physiologic adjustment at the maxillary sutures. This would prevent the accumulation of the large residual loads they recorded in the maxillary complex. Storey (1973) reported that when compared with rapid expansion sutures in the slow expansion group maintained integrity of the sutural connective tissue and demonstrated less relapse potential. In the clinical application of slow palatal expansion the appropriate force level that will promote separation of the midpalatal suture while minimizing tooth movement must be determined.

STATEMENT OF THESIS

The purpose of this investigation was to 1.) Determine the pattern of transverse growth of the dentofacial complex that occurs from adolescence to young adulthood in an orthodontically untreated longitudinal male and female sample, 2.) Determine the immediate effects of RME on the dentofacial complex and 3.) Determine the long-term effects of RME combined with orthodontic treatment on the dentofacial complex present approximately six to eight years after treatment.

To study transverse growth, an untreated sample consisting of twenty females and sixteen males was derived from the Bolton-Brush Growth Study. Selected transverse dentofacial dimensions were evaluated using a cephalometric analysis of frontal radiographs taken at ages 10, 11, 12, 13, 16, and 18 years. An additional radiograph taken at the age of 20 years was included in the male sample. The incremental growth changes in transverse parameters noted in this group were used for evaluation and comparison of changes in a sample of patients treated with RME and orthodontic treatment.

The treatment sample consisted of thirty-six patients, twenty females and sixteen males, who underwent RME with Haas type expansion appliances between ten and twelve and one half years of age. The expansion procedure was followed by two years of fixed orthodontic appliances and retention. Selected transverse facial dimensions were evaluated using a cephalometric analysis of frontal radiographs taken

pretreatment, post-expansion, and at recall approximately seven to eight years later in young adulthood.

MATERIALS AND METHODS

SAMPLE

In order to study the growth pattern and incremental change of transverse facial dimensions in the control group, thirty-six Caucasian individuals were selected as subjects from files of the Bolton Brush Growth Center. The following criteria was used in selection. Each subject must have had a frontal radiograph taken at age 10, 11, 12, 13, 16, and 18 years with an additional radiograph for males at age 20. Subjects could be classified dentally as either Angle Class I or Angle Class II and have an age appropriate dentition with no congenitally missing or extracted teeth, excluding third molars. Also, no orthodontic treatment could have been performed on the subjects (see Table 1).

The treated sample consisted of twenty female and sixteen male subjects from the completed files of the office of Drs. R. and T. Herberger in Elyria, Ohio. All subjects had been treated between the ages of 10 to 12.6 years using Haas type maxillary expansion appliances to achieve midpalatal suture separation in the initial phase of orthodontic treatment.

The average age at initiation of expansion was 10 years 11 months for females and 11 years and 6 months for males (see Table 2). All patient appliances were activated a similar amount with an average activation of 9.9 mm and a range of 9 -10 mm (see Table 2).

Table 1.-- Sample Characteristics Of Control Subjects

	FEMALE	MALE
# OF SUBJECT	20	16
CLASS I	16	10
CLASS II	4	6

The subjects' dentitions were classified dentally as Angle class I or Angle class II molar relation and as a crossbite or noncrossbite malocclusion (see Table 2). Determination on presence of crossbite was based on buccal lingual molar relation. No consideration in relation of maxillary apical base to mandibular base was considered.

Following the expansion procedure all patients were treated with a fixed edgewise appliance using a non-extraction approach. The maxillary dentitions of the subjects were retained using removable Hawley retainers with duration and pattern of retention specific to the patient. A period of full time wear followed by part time wear to no retention occurred in the male and female sample (see Figure 1 and Figure 2).

Patients were recalled in early adulthood with an average age of 21 years for the female group and 20 years and 7 months for the male group (see Table 2).

To avoid outcome bias, subjects were selected randomly from patients in the total recall sample who met the criteria. Records were chosen by an individual not involved in the study selecting every third record. The result of the orthodontic treatment at completion of active therapy or at time of recall was not used as a selection criteria.

Table 2.--Sample Characteristics Of Treated Subjects

	MALE	FEMALE
MEAN INITIAL AGE	11y.6mo.	10y.11mo.
MEAN RECALL AGE	20y.7mo.	21y.
% ANGLE CLASS I	43%	57%
% ANGLE CLASS II	50%	50%
% OF CROSSBITE	50%	50%
% OF NON-CROSSBITE	40%	60%
MEAN ACTIVATION (mm)	9.9	9.9

Figure 1. Maxillary Retention Pattern In Male Subjects

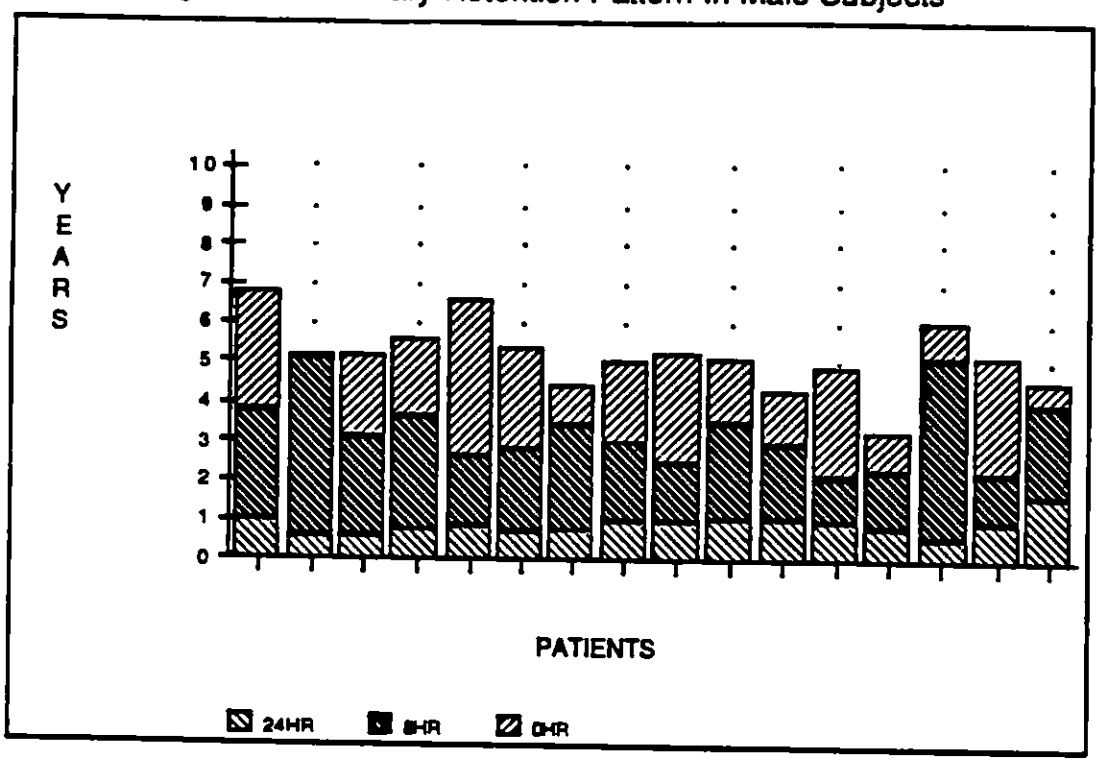
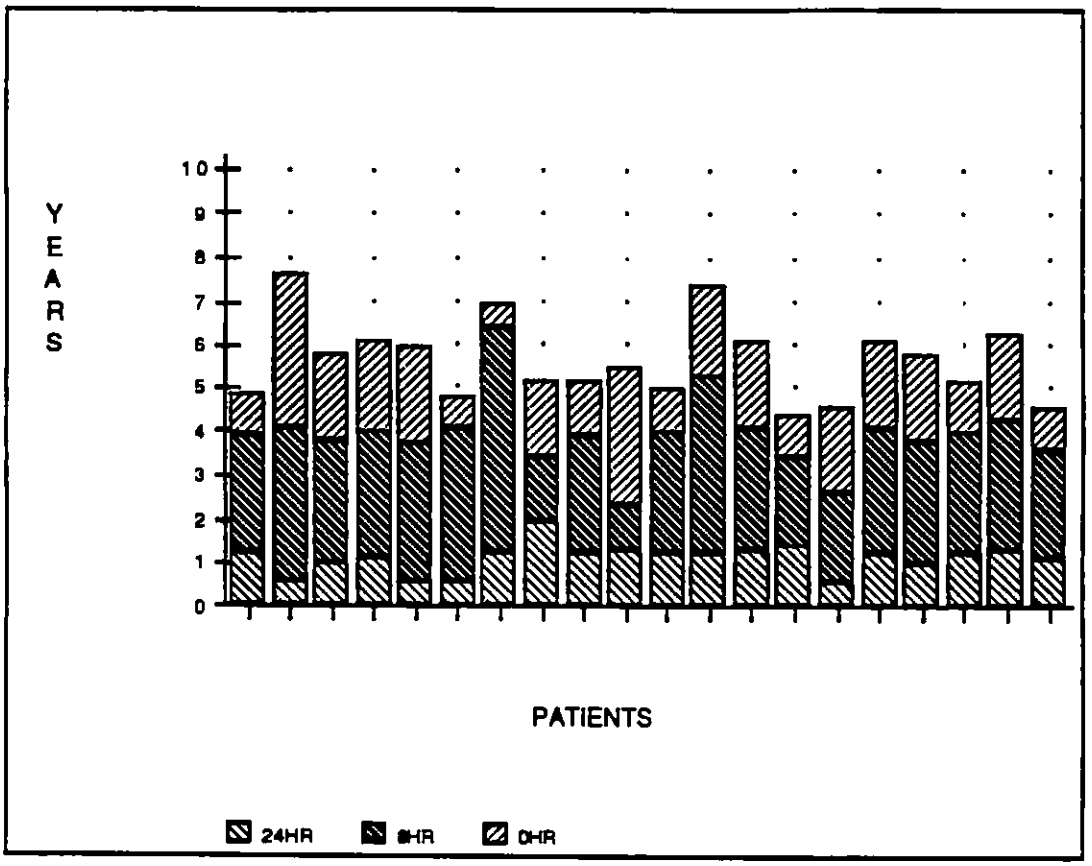


Figure 2. Maxillary Retention Pattern In Female Subjects



CEPHALOMETRIC ANALYSIS

In order to determine changes in the dentofacial complex, frontal radiographs were analyzed in the control and treatment groups. The radiographs were traced on 0.003 in matte acetate with a 0.5 mm mechanical pencil. Each tracing was superimposed on a mirror image of itself with the aid of vertical and horizontal reference lines and averaged to correct for positioning asymmetries (Broadbent, 1975). Magnification in the control group was corrected for using the p+ value recorded in the Bolton record. Magnification in the treatment group was corrected for using the scale present on radiographs.

A cephalometric analysis using twelve linear measurements was performed on each frontal tracing (see Figure 3). Parameters selected from studies by Woods (1949), Montagu (1960), Davis (1969), Wertz (1977), Frank (1982), and Athanasiou (1992) were used in the present study. All linear measurements were made to the nearest 0.1 mm using a Veriner direct reading dial caliper.

REFERENCE LINES

Horizontal reference line	The orbital plane drawn tangent to the lower border of the orbital rim.
Vertical reference line	The line perpendicular to the orbital plane that bisects Sella Turcica.

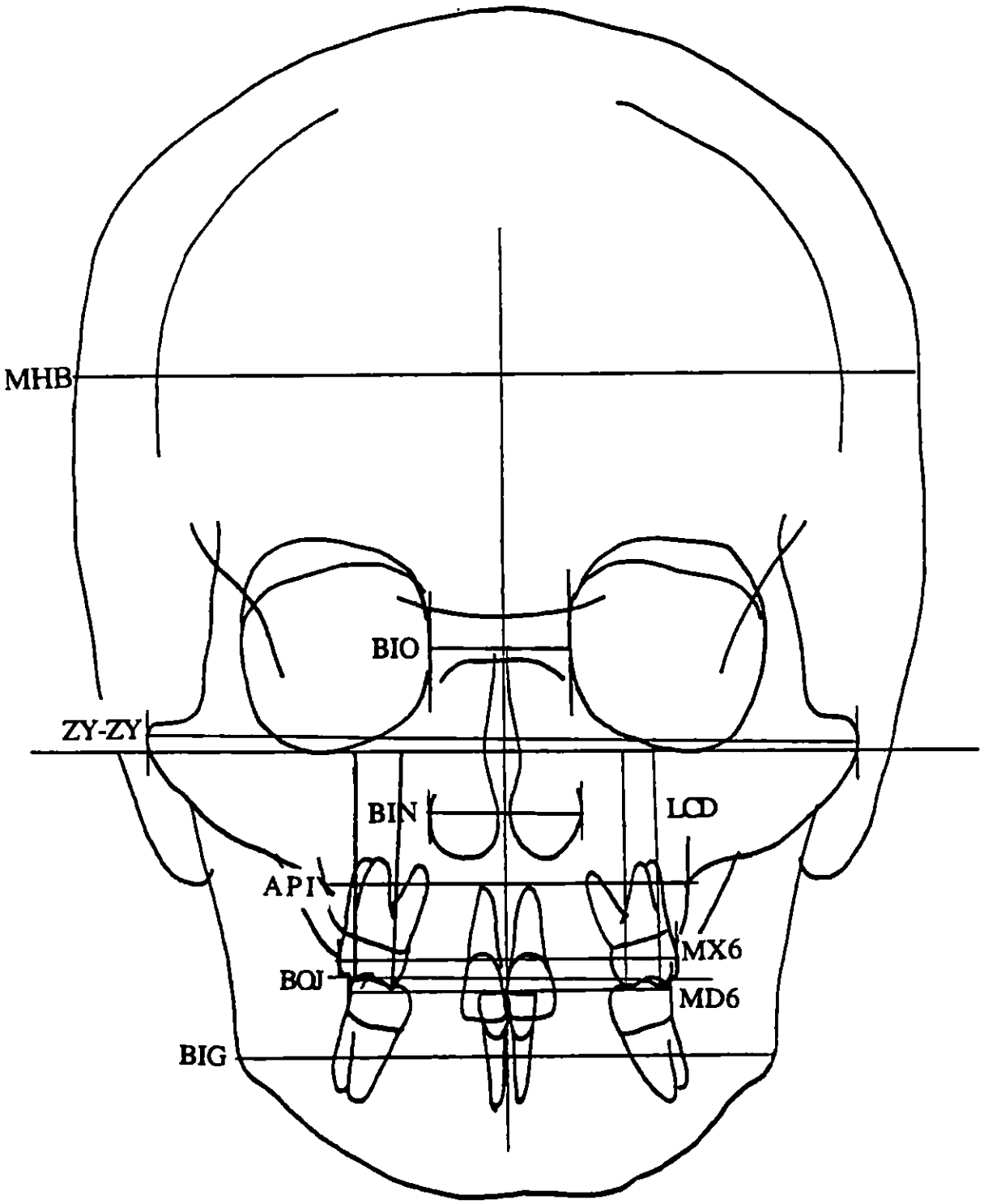


Figure 3. Frontal Cephalometric Tracing And Analysis

LINEAR MEASURES

Maximum Head Breadth (MHB)	The greatest transverse point of cranium defined as euryox of the parietal bone.
Biorbital (BIO)	The horizontal distance between lines drawn perpendicular to horizontal reference and tangent to most medial border of the orbits.
Bizygomatic (ZY-ZY)	The horizontal distance between lines drawn perpendicular to horizontal reference and tangent to most lateral aspect of the zygomas.
Binasal (BIN)	The maximum width of nasal cavity measured as the horizontal distance between lines drawn perpendicular to horizontal reference and tangent to most convex surface of the nasal aperture.
Apical Base (API)	The area of greatest concavity on the alveolar processes representing the intersection of the outline of tuberosity and zygomatic butress
Maxillary Intermolar Width (MX6)	The horizontal distance between perpendicular projections of most buccal surface of right and left maxillary first permanent molars.
Mandibular Intermolar Width (MD6)	The horizontal distance between perpendicular projections of most buccal surface of right and left mandibular molar.
Right Cusp Difference (RCD)	The vertical distance of buccal cusp tip of right maxillary first permanent molar from horizontal reference line subtracted from vertical distance of lingual cusp tip of right maxillary first permanent molar from horizontal reference.
Left Cusp Difference (LCD)	The vertical distance of buccal cusp tip of left maxillary first permanent molar from horizontal reference line subtracted from vertical distance of lingual cusp tip of left maxillary first permanent molar from horizontal reference.
Buccal Overjet (BOJ)	The horizontal distance between buccal surface of right maxillary first permanent molar

	and buccal surface of right mandibular first permanent molar added to distance between buccal surface of left maxillary first permanent molar and buccal surface of left mandibular first permanent molar measured along occlusal plane.
Average Buccal Overjet (BOJ/2)	The average of horizontal distances between the buccal surface of maxillary first permanent molars and buccal surface of mandibular first permanent molars measured along occlusal plane.
Bigonial (BIG)	The distance between most lateral points on the left and right gonial angles.

Two additional measures relevant to the treated group were added to the analysis. They are as follows (see Figure 4).

Expansion Screw (EXP)	The horizontal distance between casings and threaded expansion screw , intended to confirm written record of amount of activation.
Suture Separation (SUT)	The distance between maxillae margins of midpalatal suture following separation measured at level of middle third of maxillary central incisor.

In the control group frontal radiographs were analyzed in females at 10, 11, 12, 13, 16, and 18, years of age and in males were analyzed at 10, 11, 12, 13, 16, 18, and 20, years of age. In the treatment group frontal radiographs were analyzed pretreatment, post activation of the expansion appliance, and at time of recall.

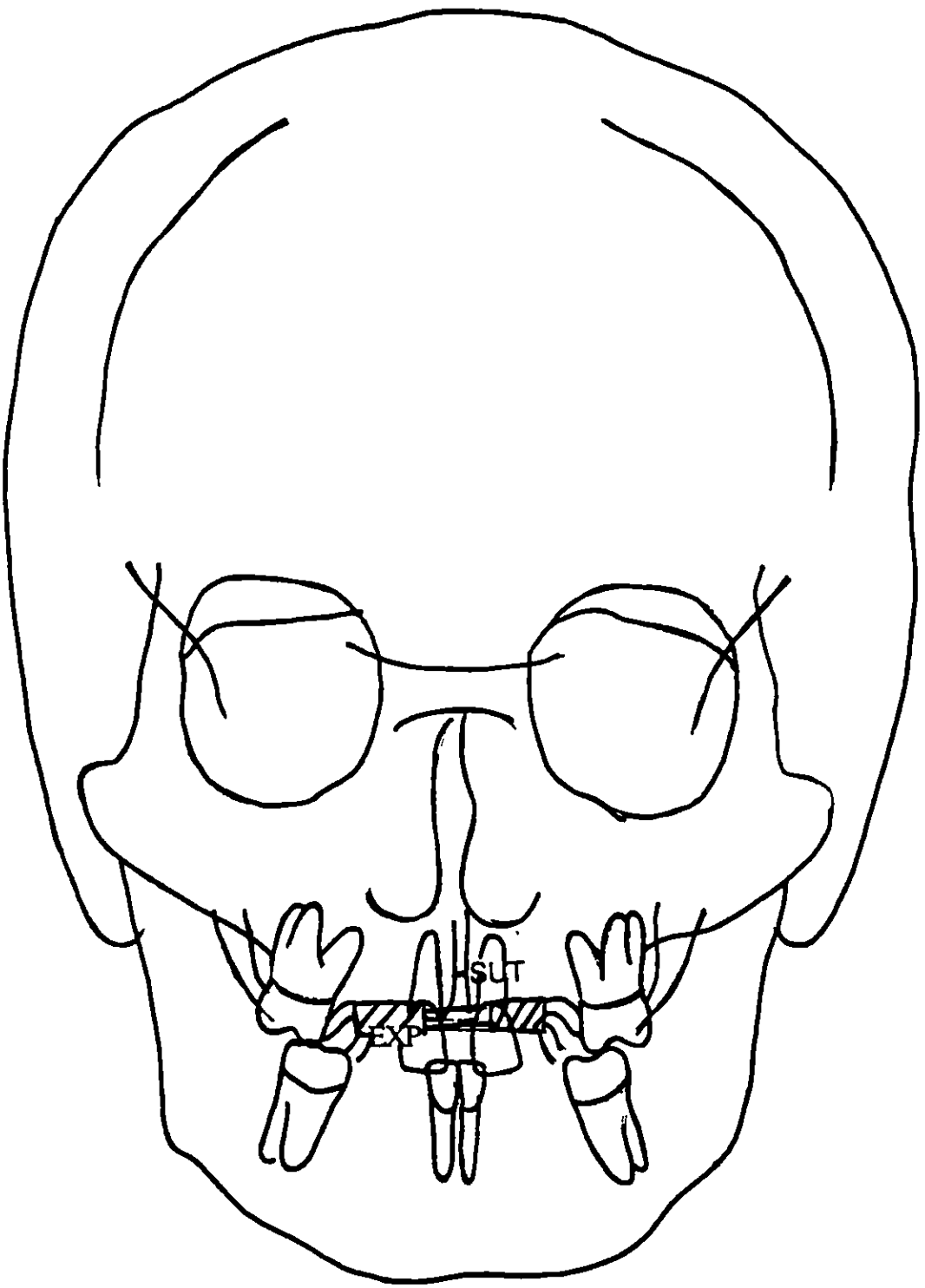


Figure 4. Frontal Cephalometric Tracing and Additions to Analysis For Treated Subjects

STATISTICAL METHOD

Means and standard deviations for each cephalometric parameter were determined for the male and female control groups at each observation age.

From changes occurring in the parameter measurements between observation points, the increment of change for each parameter was determined. In female controls, increments were calculated from 10 to 11, 11 to 12 , 12 to 13 , 13 to 16 , and 16 to 18 years. In male controls, increments were calculated from 10 to 11, 11 to 12, 12 to 13, 13 to 16, 16 to 18, and 18 to 20 years.

In the treated sample, means and standard deviations for each parameter were determined at pretreatment (T0) post-activation (T1) and recall (T2).

The amount of that change that occurred in the treatment group from T0 to T1, T1 to T2, and T0 to T2 was compared with the amount of change over a similar time period in the control group. Two tailed t-tests were used to determine the statistical significance of these differences. Significance was assessed at $p < .05$.

ERROR ASSESSMENT

To evaluate the degree of investigator measurement error, ten radiographs were randomly selected and the fourteen linear measures repeated. The initial mean values and repeat mean values for each variable were compared. Correlation coefficients were calculated to test the relationship between repeated measurements to estimate observer accuracy.

Tracing error was evaluated by retracing ten randomly selected radiographs. To correct for patient positioning each tracing was superimposed on a mirror image of itself and averaged. The linear measures were repeated and a mean value obtained for each variable. The initial mean values were compared to repeat mean values using correlation coefficients.

RESULTS

In the female control group a continuous increase was observed in the parameters of maximum head breadth, bizygomatic width, biorbital width, binasal width, and bigonial width through out the observation period. The maxillary skeletal measure of apical base showed a slight increase of 1.9 mm during the total observation period. The maxillary molar width demonstrated relative stability with only a 0.5 mm increase observed during the eight year observation period. Mandibular intermolar width remained relatively stable. Dental measures RCD and LCD representing the angulation of the right and left molars relative to the horizontal reference plane were constant. The dental measure of the average buccal overjet (BOJ/2) that indirectly measures the buccal lingual relation between maxillary and mandibular first molars showed a slight increase of 0.2 mm (see Table 3A and 3B).

Similar to the female control group, the male group demonstrated a continuous increase in the parameters of maximum head breadth, bizygomatic width, biorbital width, binasal width and bigonial width through out the observation period (see Table 4A and 4B). Apical base showed an increase of 2.9 mm during the total observation period. The maxillary molar width demonstrated a increase of 1.4 mm during the eight year

Table 3A.-- Cephalometric Measurements In Female Control Group (Measured in mm)

AGE	MHB		ZY-ZY		BIO		BIN		API		MX6	
YEARS	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
10	138.5	5.50	114.9	4.36	21.5	1.71	27.8	2.50	57.9	2.25	53.6	2 45
11	139.5	5.38	116.4	4.50	21.9	1.73	28.2	2.62	58.4	2.19	53.9	2.26
12	140.0	5.11	117.4	4.24	22.4	1.67	28.6	2.47	58.8	2.14	53.9	2.51
13	140.3	5.01	118.9	4.07	22.8	1.65	29.3	2.34	59.1	2.13	53.9	2.48
16	140.5	5.07	119.8	3.98	23.2	1.67	29.8	2.30	59.4	2.29	53.9	2.65
18	140.8	5.07	120.8	3.72	23.5	1 60	30.3	2.35	59.8	2.26	54.1	2.59

Table 3B.-- Cephalometric Measurements In Female Control Group (Measured in mm)

AGE	MD6		BIG		BOJ		BOJ/2		RCD		LCD	
YRS	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
10	51.7	2.25	82.7	3.33	4.5	1.04	2.3	0.49	0.8	0.51	0.8	0.47
11	51.9	2.06	83.4	3.39	4.6	1.13	2.3	1.13	0.8	0.57	0.9	0.48
12	51.9	2.20	84.3	3.50	4.8	1.00	2.4	0.51	0.8	0.54	0.9	0.39
13	51.7	2.26	85.6	3.63	4.8	0.98	2.4	0.49	0.8	0.43	0.9	0.36
16	51.7	2 29	86.8	3.35	4.9	1.03	2.5	0.51	0.9	0.45	0.9	0.40
18	51.9	2.30	87.4	3.33	4.9	0.91	2.5	0.45	0.9	0.44	0.8	0.47

Table 4A.-- Cephalometric Measurements In Male Control Group (Measured in mm)

AGE	MHB		ZY-ZY		BIO		BIN		API		MX6	
YEARS	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
10	141.0	5.93	115.9	5 25	20.5	1.69	27.6	1.92	58 0	2.83	54.4	2.65
11	141.5	5.92	116 7	5.29	20.9	1.78	28.5	1.81	58.6	2.90	54 9	2.23
12	142.2	5.93	117.6	5.20	21.3	1.79	29.1	1.90	59.4	2.87	55.1	2.40
13	142.6	5.94	119.5	5.69	21.7	1.87	29.7	1.90	60.0	2.97	55.3	2.56
16	143.1	5.76	125.5	5.25	22.5	1.80	31.0	1.89	60.5	3.10	55.5	2.80
18	143.3	5.78	126.5	5.38	23.2	1.86	31.3	2.44	60.8	3.28	55.7	3.06
20	143.7	5.66	127.2	5.45	23.4	1.98	31.6	2.56	60.9	3.32	55.8	3.01

Table 4B.-- Cephalometric Measurements In Male Control Group (Measured in mm)

AGE	MD6		BIG		BOJ		BOJ/2		RCD		LCD	
YRS	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
10	53.1	3.02	86.2	3.02	2.5	1.61	1.3	0.81	1.1	0.43	1.2	0.39
11	53.5	3.44	87.2	3.44	2.8	1.67	1.5	0.72	1.1	0.37	1.3	0.26
12	53.7	3.96	88.7	3.96	2.9	1.77	1.5	0.89	1.1	0.32	1.2	0 30
13	53.5	4.22	89.9	4.22	3.1	1.45	1.6	0.72	1.1	0.35	1.2	0.28
16	53.7	4.07	95.6	4.07	3.2	1.40	1.6	0.69	1.1	0.25	1.2	0.31
18	53.8	4.07	96.1	4.07	3.3	1.43	1.6	0.71	1.1	0.28	1.2	0.31
20	53.9	4.50	96.9	4.50	3.4	1.38	1.7	0.69	1.1	0.31	1.2	0.36

observation period. The mandibular intermolar width remained relatively stable. The dental measures RCD and LCD associated with the male group were constant. The dental measure of the average buccal overjet (BOJ/2) showed a slight increase of 0.4 mm.

Growth curves for each parameter in female and male controls were created from longitudinal means. Both groups were plotted on the same chart to facilitate comparison (see Figure 5 through 14). The values for each data point on the curves can be found in Table 3A and 3B for females and Table 4A and 4B for males.

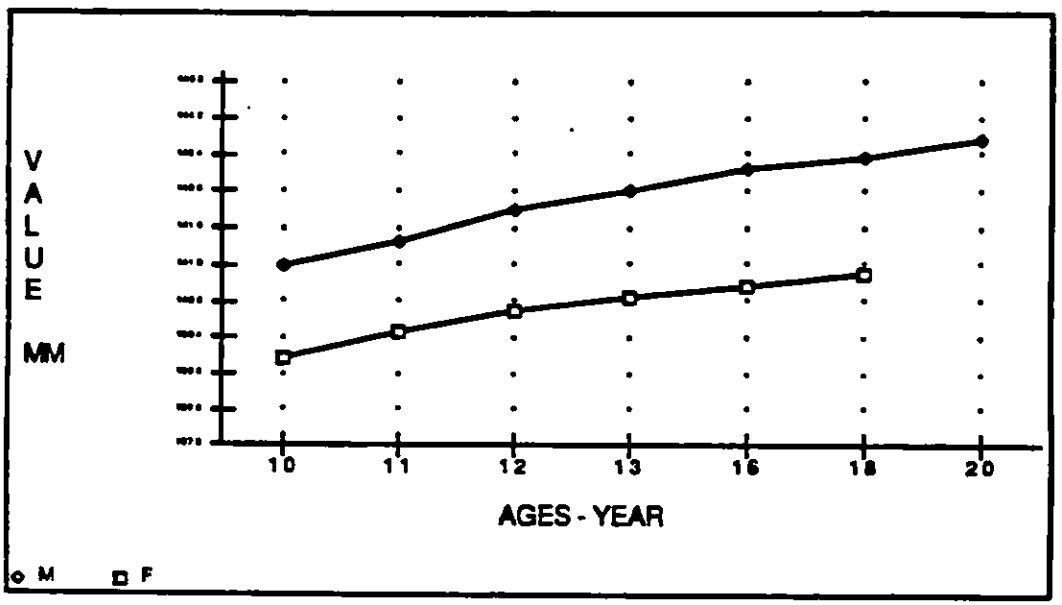


Figure 5. Male And Female Growth Curves For Maximum Head Breadth In Control Group

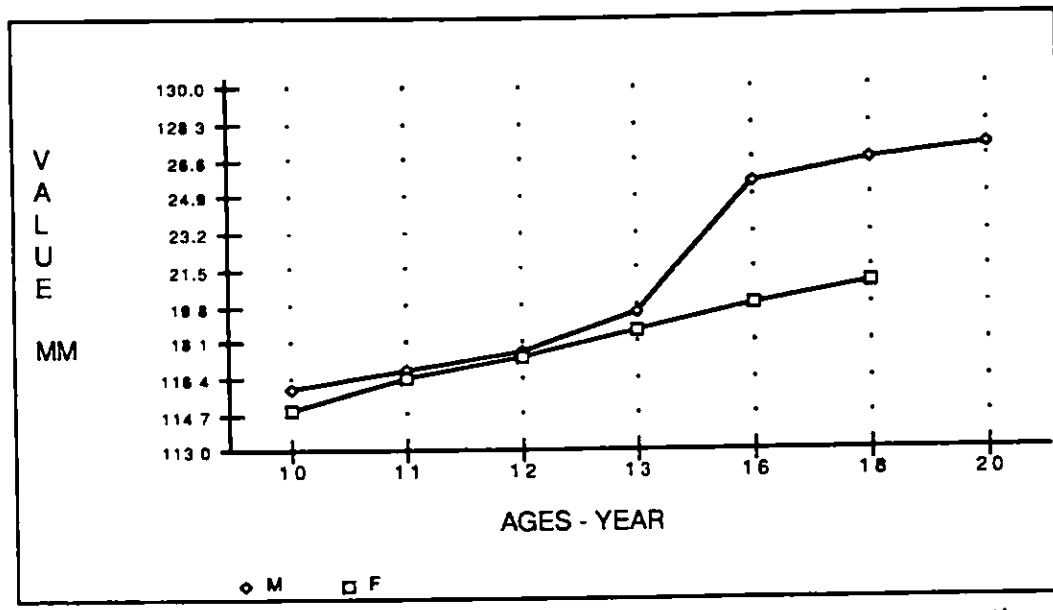


Figure 6. Male And Female Growth Curves For Bizygomatic Width In Control Group

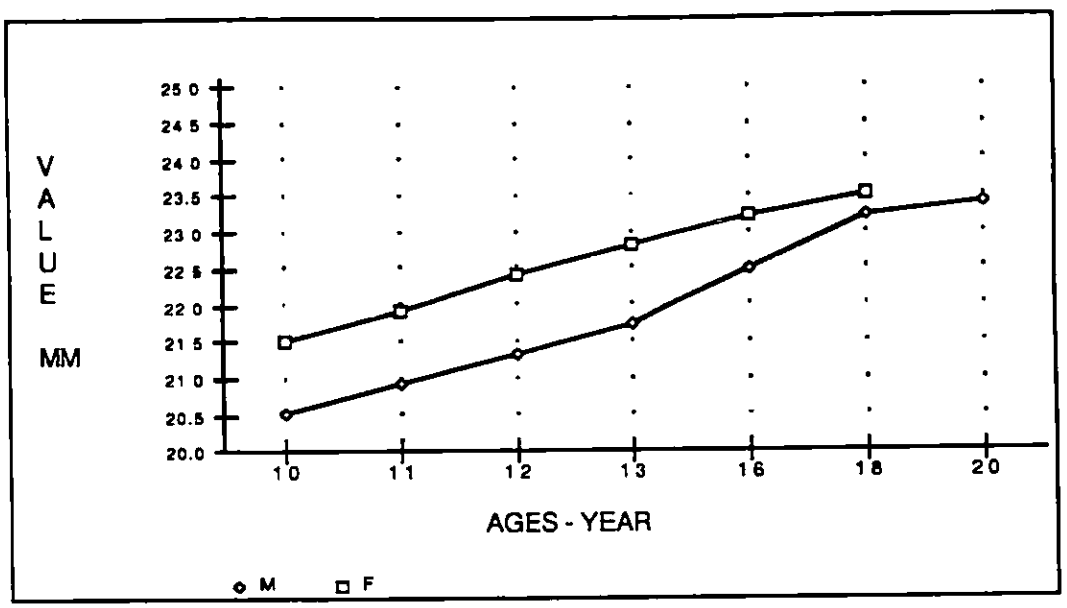


Figure 7. Male And Female Growth Curves For Biorbital Width In Control Group

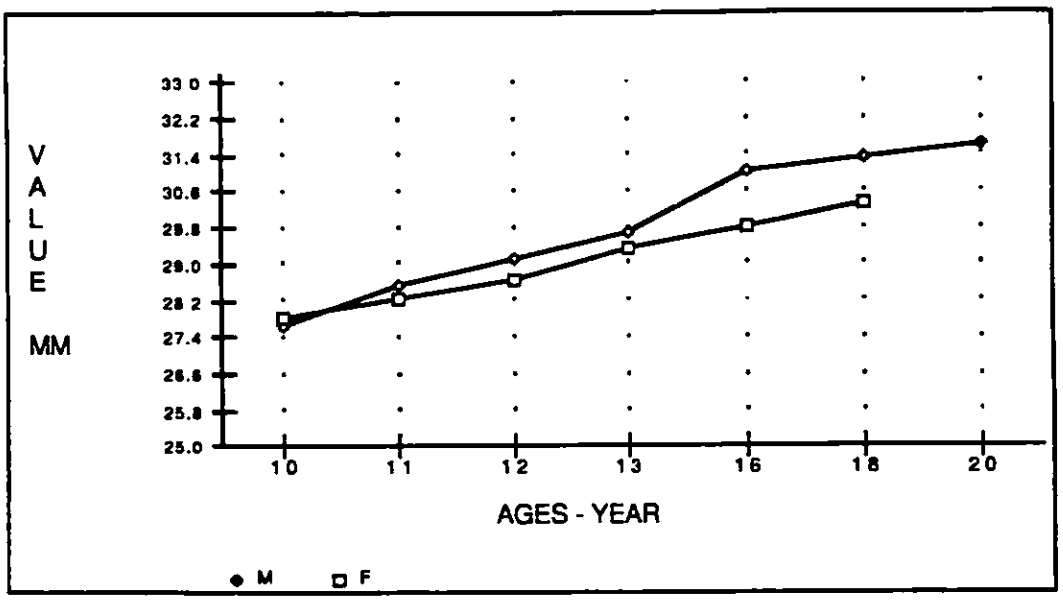


Figure 8. Male And Female Growth Curves For Binasal Width In Control Group

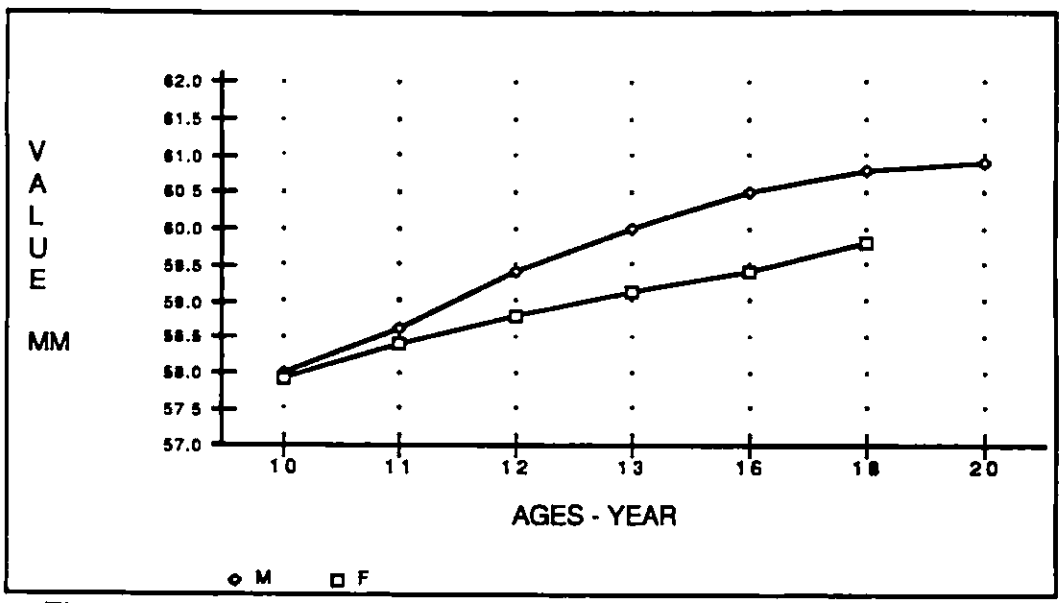


Figure 9. Male And Female Growth Curves For Apical Base Width In Control Group

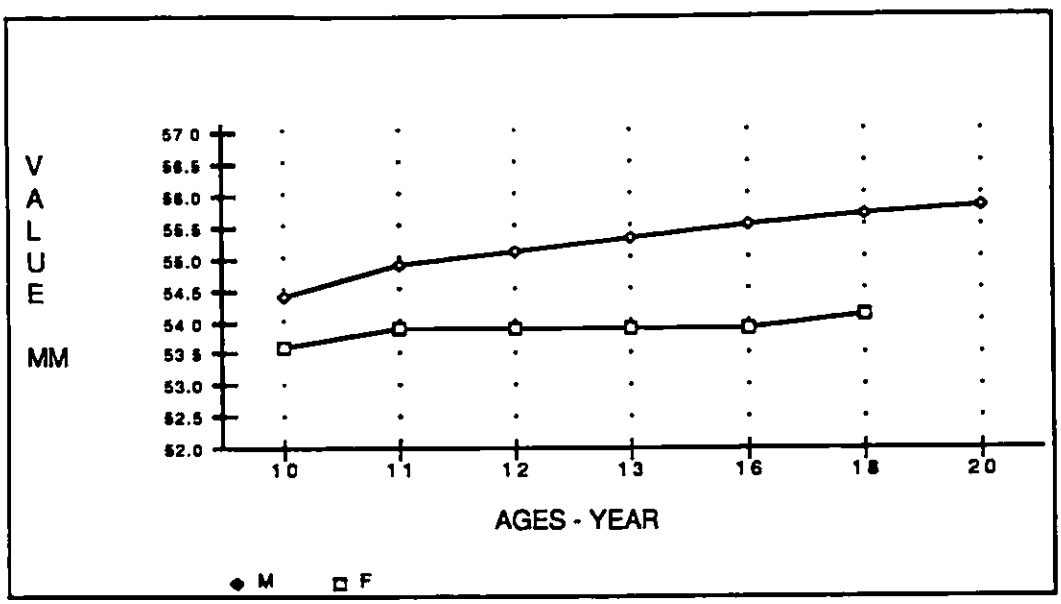


Figure 10. Male And Female Growth Curves For Maxillary Intermolar Width In Control Group

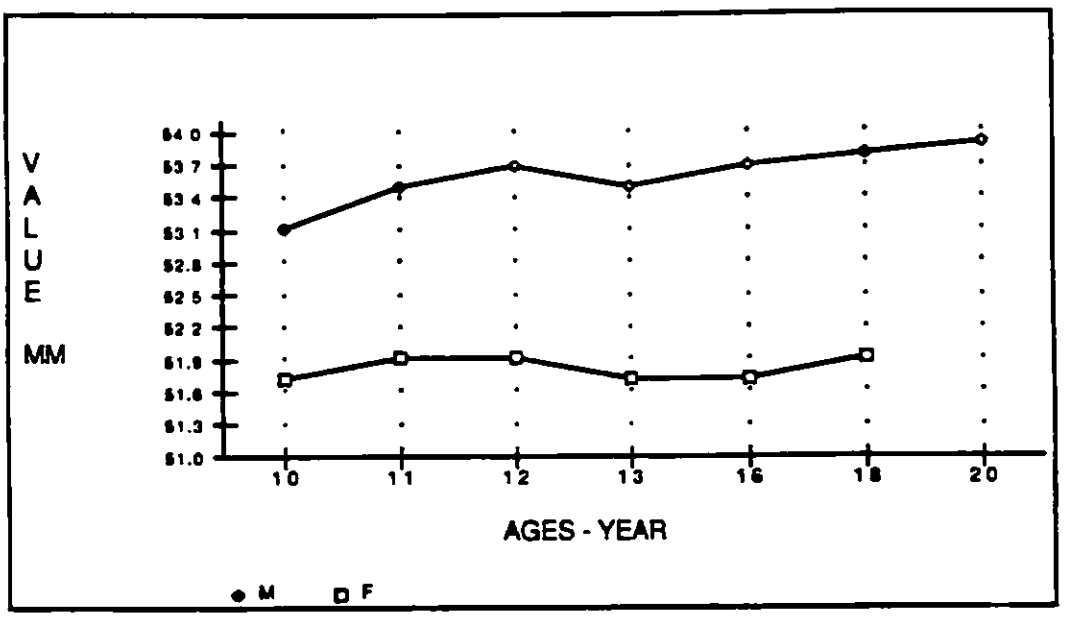


Figure 11. Male And Female Growth Curves For Mandibular Intermolar Width In Control Group

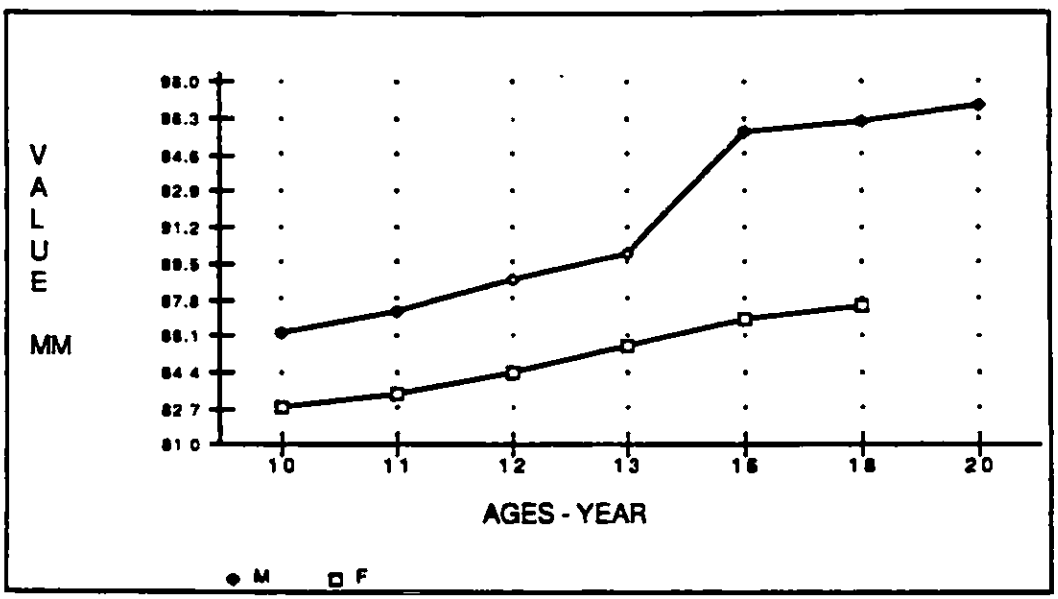


Figure 12. Male And Female Growth Curves For Bigonial Width In Control Group

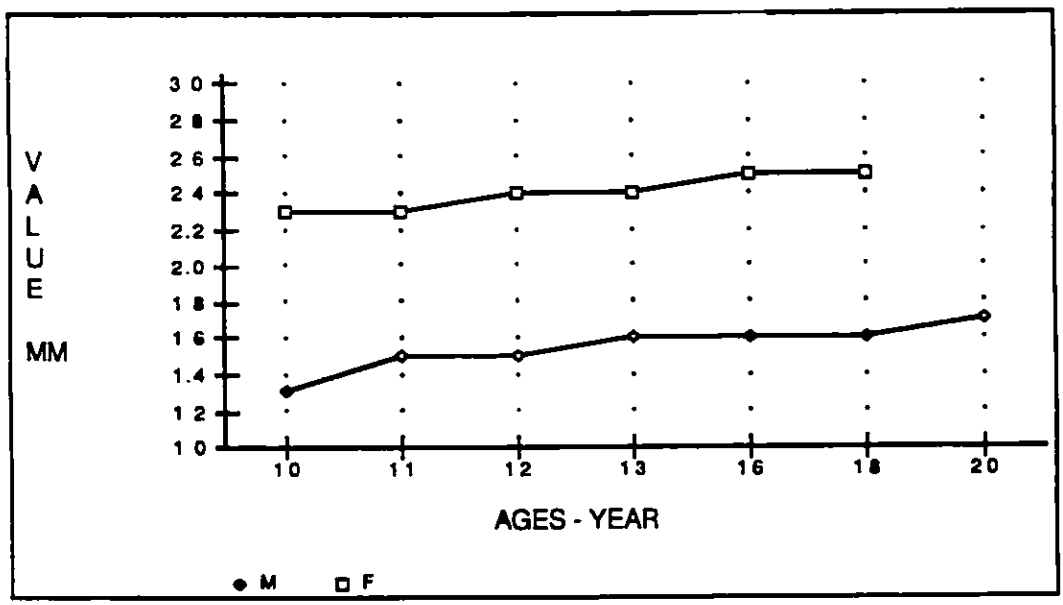


Figure 13. Male And Female Growth Curves For Buccal Overjet In Control Group

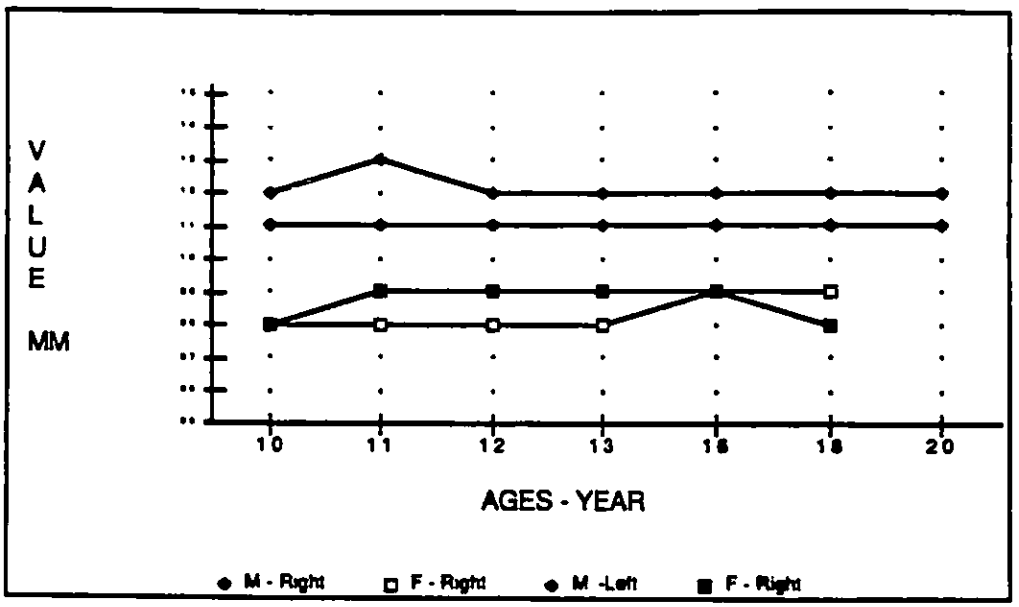


Figure 14. Male And Female Growth Curves For Right And Left Molar Cusp Difference In Control Group

Although differing in magnitude, the curves for the male and female groups were quite similar with some exceptions. The male curves for bizygomatic, binasal, biorbital, and bigonial showed a marked deviation from the female curve between the period of thirteen to sixteen years of age. The female curves on these charts showed a gradual yet continuous increase throughout the observation period. The dental parameter measuring buccal lingual relationship of maxillary first molar to mandibular first molar (BOJ/2) remained relatively constant. The measures indirectly representing the molar angulation varied by only 0.1 mm on any on the associated curves A temporary dip in male and female curves for mandibular intermolar width was observed between the ages of twelve to thirteen followed by a gradual increase resulting in a small net gain over the original value. The curves for maxillary molar width were relatively flat resulting in a small net increase in intermolar width over the initial value in females and small yet slightly larger increase in males. The male curve representing apical base change had a slightly greater slope resulting in a slightly larger increase than that observed in the females.

Mean incremental changes and standard deviations were determined from differences in parameter measurements between observation points for female and male controls (see Table 5A and 5B for females and Table 6A and 6B for males).

Table 5A -- Mean Increments Of Change In Female Control (Measured In mm)

AGE	MHB		ZY-ZY		BIO		BIN		API		MX6	
YEARS	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
10-11	0.3	0 34	1 3	1.10	0 4	0.37	0 4	0.39	0 4	0 46	0.3	0.39
11-12	0 4	0 41	0.9	0.94	0.4	0.33	0.3	0.37	0.3	0 33	0.2	0 44
12-13	0.2	0.20	0.9	0.95	0 3	0.37	0.5	0 42	0.4	0.46	0 1	0.62
13-16	0.2	0.27	1.1	0.73	0.4	0.35	0 4	0 37	0.3	0.37	0 1	0.29
16-18	0 2	0.20	0 6	0.51	0.3	0.27	0 4	0 39	0 4	0 28	0.2	0 46

Table 5B.-- Mean Increments Of Change In Female Control (Measured In mm)

AGE	MD6		BIG		BOJ		BOJ/2		RCD		LCD	
YEARS	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
10-11	0 3	0.26	0 6	0 59	0 1	0.21	0.0	0.22	0 0	0 16	0 0	0.24
11-12	0.2	0 43	0 8	0 55	0.2	0 31	0.1	0 18	0 0	0 18	0 0	0.26
12-13	0 0	0 66	1.1	0 95	0 0	0.29	0 0	0 15	0.0	0.20	0.1	0.19
13-16	0.0	0 25	1.2	1 38	0.0	0 14	0 0	0 07	0.0	0.20	0 0	0 14
16-18	0 1	0 19	0 5	0 46	0 0	0 21	0 0	0 12	0 0	0 45	0.0	0 16

Table 6A.-- Mean Increments Of Change In Male Control
(Measured In mm)

AGE	MHB		ZY-ZY		BIO		BIN		API		MX6	
YEARS	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
10-11	0.4	0.35	0.7	0 58	0.4	0.47	0.7	0.52	0.6	0.56	0.5	0.55
11-12	0.6	0 66	0.9	0.92	0.3	0.32	0.5	0 46	0 6	0.55	0.1	0.39
12-13	0 4	0.55	1.7	1.4	0.4	0.56	0.4	0.64	0.6	0.88	0 1	0.85
13-16	0.3	0.45	4.2	1.12	0.7	0.61	1.0	0.43	0 6	0.62	0.2	0.27
16-18	0.3	0.83	0.2	1.24	0.8	0.88	0.5	1.1	0.2	0.80	0.1	0.78
18-20	0.5	0.57	0 6	0.6	0.2	0.30	0.3	0.39	0.1	0.12	0 1	0.25

Table 6B.-- Mean Increments Of Change In Male Control
(Measured In mm)

AGE	MD6		BIG		BOJ		BOJ/2		RCD		LCD	
YEARS	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
10-11	0 6	0.34	0 8	0 57	0 2	0.32	0 1	0 15	0.0	0 43	0.0	0 15
11-12	0.2	0 47	1.2	0 66	0.1	0.25	0 0	0 13	-0.1	0.37	-0.1	0.17
12-13	-0.2	0.58	1 1	1 12	0.2	0 47	0 1	0.24	0.0	0.32	0.0	0.16
13-16	0 1	0 44	3.9	1 23	0.9	0.33	0.0	0.15	0.0	0.35	0.0	0.16
16-18	0.2	0.68	2.8	1.65	0.8	0 34	0 0	0.16	0.0	0.25	0 0	0.10
18-20	0.2	0.22	0.8	0.79	0.0	0 21	0 0	0.11	0.0	0.28	0.0	0 11

An increment of 4.3 mm was observed in the measure of male bizygomatic width between the ages of thirteen and sixteen Bigonial width increased 6.8 mm between the ages of thirteen and eighteen in the male sample

As one would expect from the gradual increase observed in the growth curve for apical base, calculated increments were small. Increments observed in females were consistent ranging from 0.3 mm to 0.4 mm. Male increments ranged from 0.6 mm to 0.2 mm.

Maxillary intermolar width increased the most between the ages of 10 to 11 in both sexes. Males increased 0.6 mm at this time followed by a 0.2 mm increase in subsequent intervals. The female increase of 0.4 mm between age 10 to 11 was also followed by a 0.2 mm increase in later intervals.

The smallest incremental changes were observed in the dental measure of molar cusp differences (RCD) and (LCD) where changes were 0.1 mm or less.

The group means and standard deviations for the treated sample were also determined at pretreatment, expansion, and recall (see Table 7 and Table 8).

Certain variables; maximum head breadth, bizygomatic width, biorbital width, and bigonial width, remained unaffected by the expansion procedure in both males and females.

Table 7.-- Mean Values And Standard Deviations At Pretreatment, Expansion And Recall In Males (Measured in mm)

	T_0 PRETREATMENT		T_1 EXPANSION		T_2 RECALL	
VARIABLE	MEAN	*SD*	MEAN	*SD*	MEAN	*SD*
MXB	138.8	*6.72*	138.9	*6.70*	142.0	*6.50*
ZY-ZY	116.7	*4.81*	116.6	*4.77*	126.2	*4.05*
BIO	21.4	*2.19*	21.7	*2.37*	23.6	*2.13*
BIN	27.6	*2.24*	30.4	*2.66*	31.9	*2.94*
API	56.1	*2.26*	59.3	*2.45*	59.0	*2.42*
MX6	53.2	*2.94*	60.9	*2.82*	56.0	*3.20*
MD6	53.1	*1.70*	53.1	*1.59*	54.9	*1.99*
BIG	88.4	*3.98*	88.7	*4.15*	98.0	*5.40*
BOJ	2.2	*2.90*	10.0	*3.16*	4.2	*2.52*
BOJ/2	1.1	*1.53*	5.5	*1.84*	2.1	*1.25*
RCD	0.9	*0.78*	1.7	*0.78*	0.9	*0.61*
LCD	0.9	*0.67*	1.5	*0.72*	1.0	*0.71*
SUT	0.0	*0.25*	4.6	*2.01*	0.0	*0.00*

Table 8.-- Mean Values And Standard Deviations At Pretreatment, Expansion And Recall In Females (Measured in mm)

	T_0 PRETREATMENT		T_1 EXPANSION		T_2 RECALL	
VARIABLE	MEAN	SD	MEAN	SD	MEAN	SD
MXB	**132.8**	*4.36*	**132.8**	*4.35*	**134.8**	*4.64*
ZY-ZY	**109.2**	*5.23*	**109.5**	*5.16*	**114.1**	*4.37*
BIO	**20.3**	*2.26*	**20.1**	*2.16*	**21.8**	*2.54*
BIN	**27.0**	*1.97*	**29.8**	*2.29*	**30.8**	*2.40*
API	**53.3**	*3.12*	**56.5**	*3.62*	**55.3**	*3.53*
MX6	**51.6**	*3.37*	**59.1**	*3.95*	**52.8**	*3.29*
MD6	**50.6**	*3.04*	**50.7**	*3.04*	**50.8**	*2.46*
BIG	**82.8**	*4.01*	**82.9**	*4.07*	**88.1**	*4.50*
BOJ	**4.0**	*2.68*	**13.1**	*3.09*	**4.9**	*1.94*
BOJ/2	**2.4**	*1.97*	**6.5**	*1.54*	**2.5**	*0.98*
RCD	**1.0**	*0.96*	**1.5**	*0.89*	**1.1**	*0.50*
LCD	**1.1**	*0.72*	**1.8**	*0.97*	**1.3**	*0.47*
SUT	**0.1**	*0.31*	**4.2**	*1.26*	**0.0**	*0.00*

A dramatic increase in some parameter measures was detected immediately post-expansion (T0 to T1) In the female group binasal width increased 2.7 mm, apical base increased 3.1 mm and maxillary intermolar width increased 7.4. An increase in buccal overjet was recorded along with an increase in the difference between buccal and lingual cusps of right and left maxillary molars. The average suture opening in the female group was 4.2 mm with a range of 2.6 mm to 6.9 mm.

In the male group an increase of 2.8 mm was observed in the binasal parameter. The apical base width increased 3.2 mm, and maxillary intermolar width increased 7.7 mm. The average amount of suture opening was 4.3 mm with a range of 2.4 mm to 7.4 mm. An increase in buccal overjet was recorded along with an increase in the difference between buccal and lingual cusps of right and left maxillary molars.

Changes occurring in the treated sample throughout the study period (T0 to T2) in males and females were plotted on the same graph to facilitate comparison (see Figure 15 through Figure 24). Values for the data points on the charts can be found in Table 7 for males and Table 8 for females.

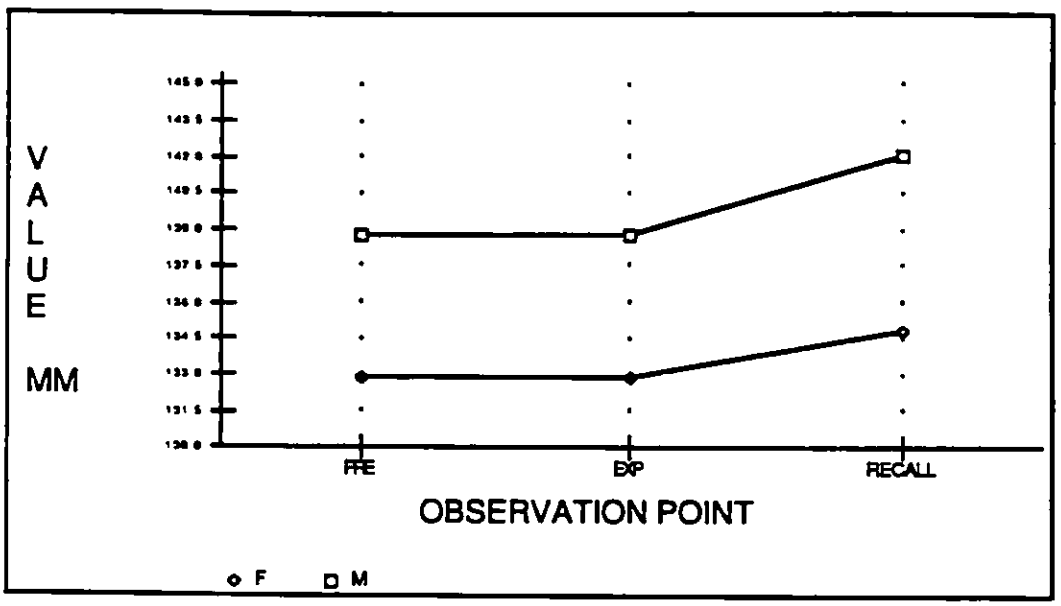


Figure 15. Male And Female Maximum Head Breadth In Treatment Group

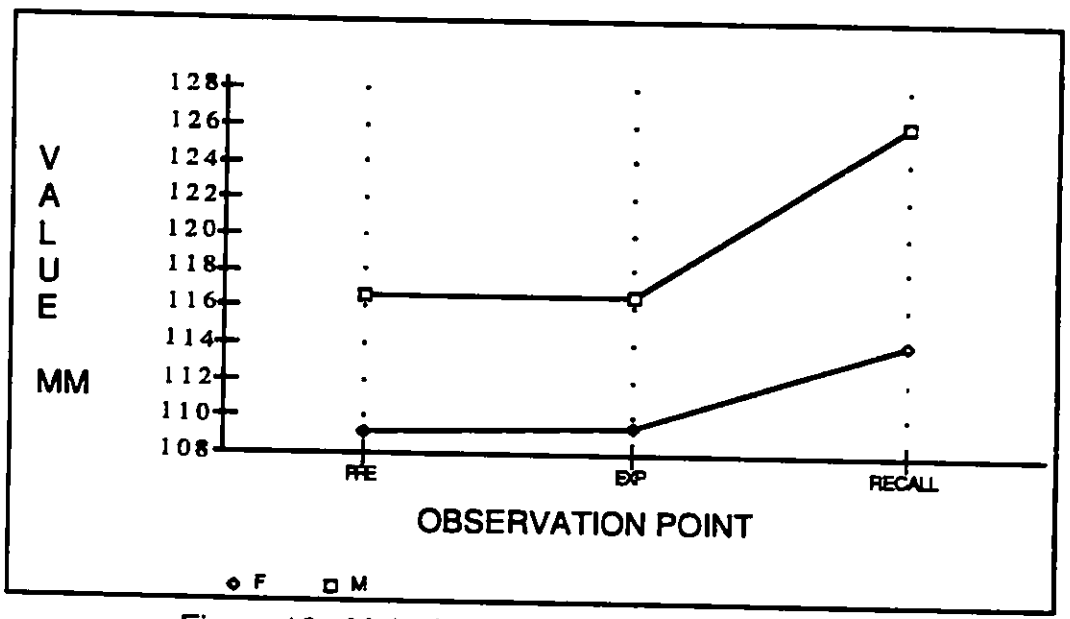


Figure 16. Male And Female Bizygomatic Width In Treatment Group

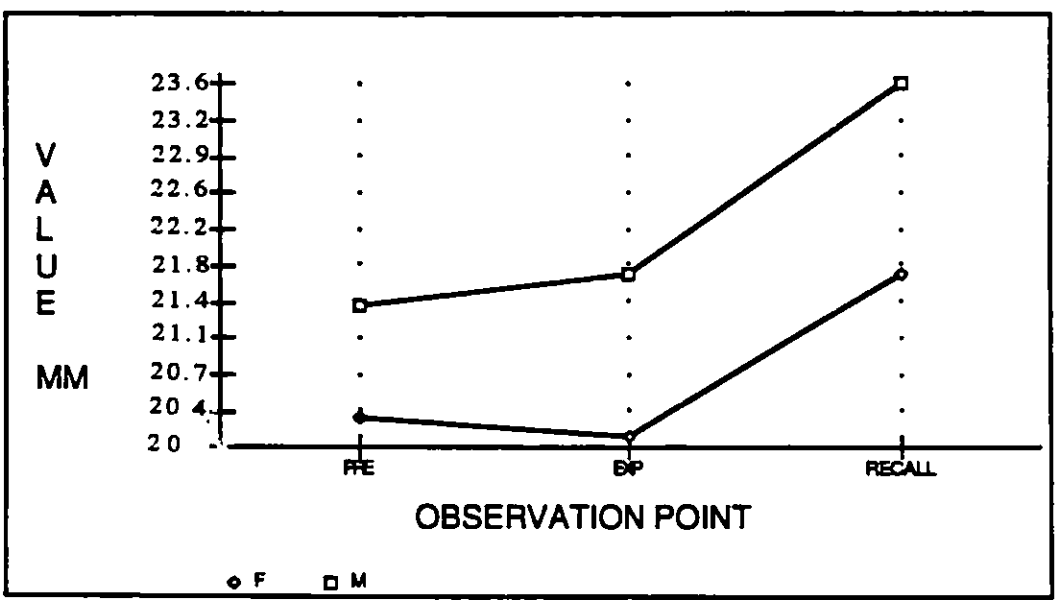


Figure 17. Male And Female Biorbital Width In Treatment Group

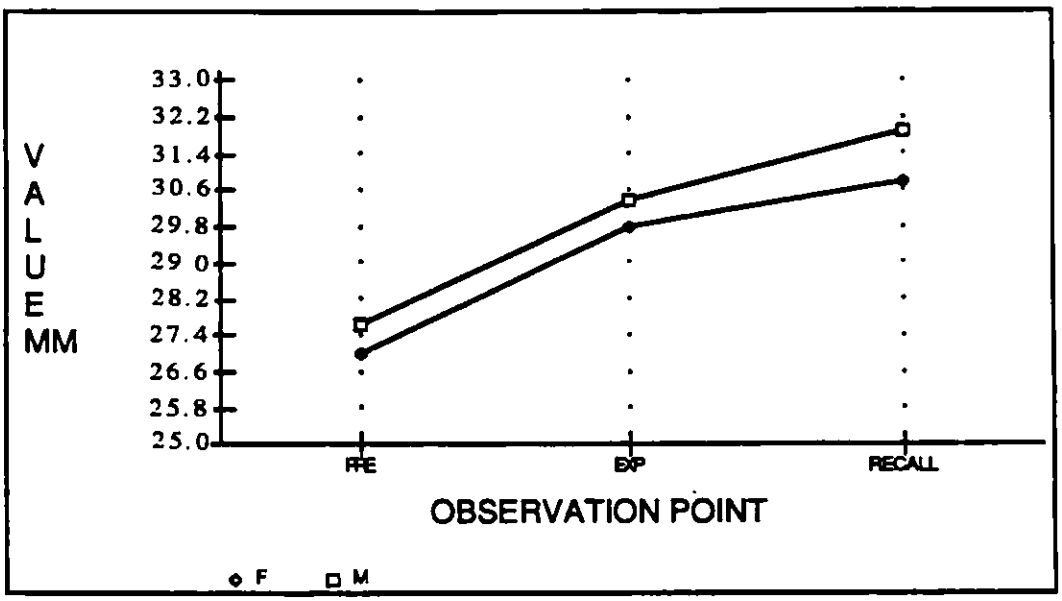


Figure 18. Male And Female Binasal Width In Treatment Group

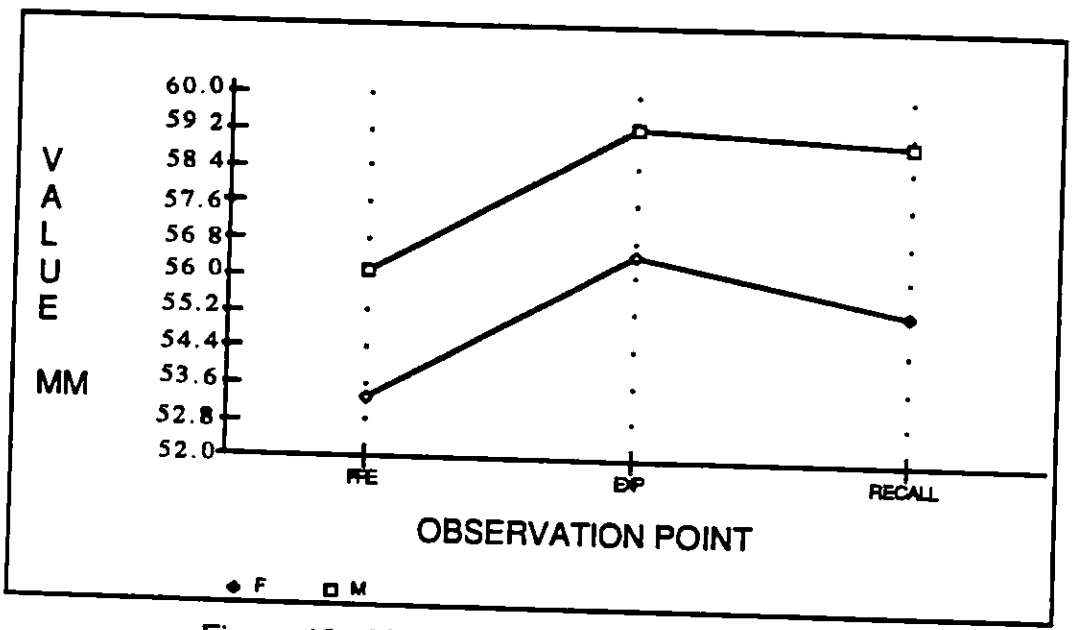


Figure 19. Male And Female Apical Base Width In Treatment Group

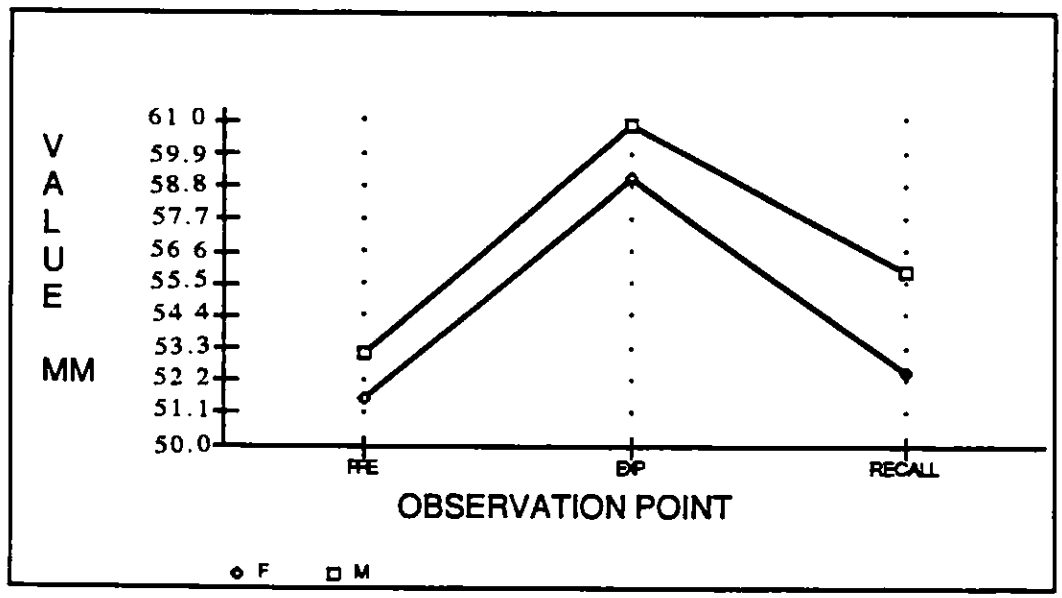


Figure 20. Male And Female Maxillary Intermolar Width In Treatment Group

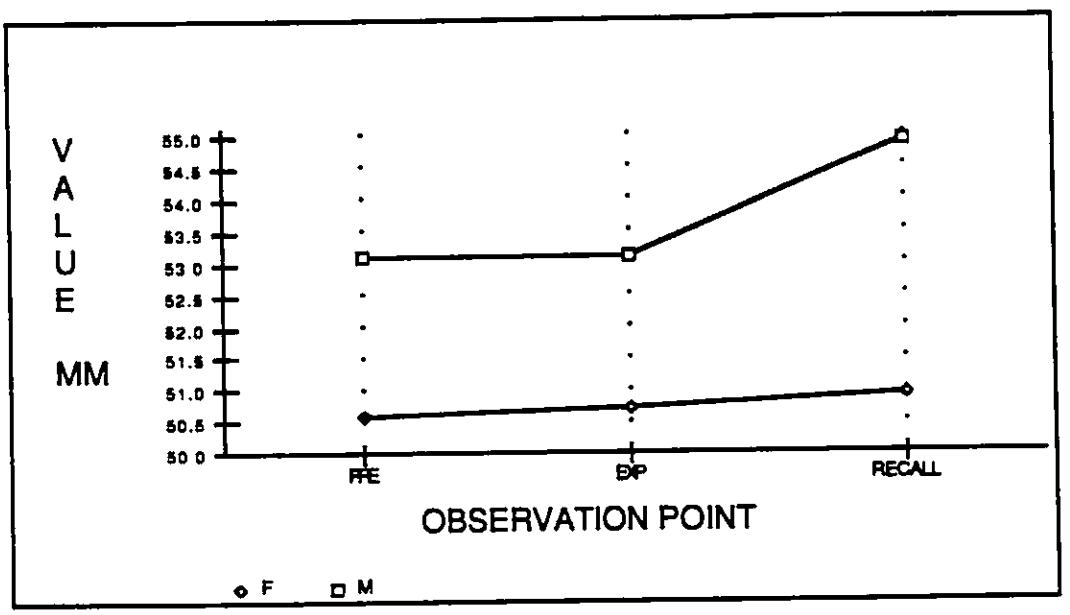


Figure 21. Male And Female Mandibular Intermolar Width In Treatment Group

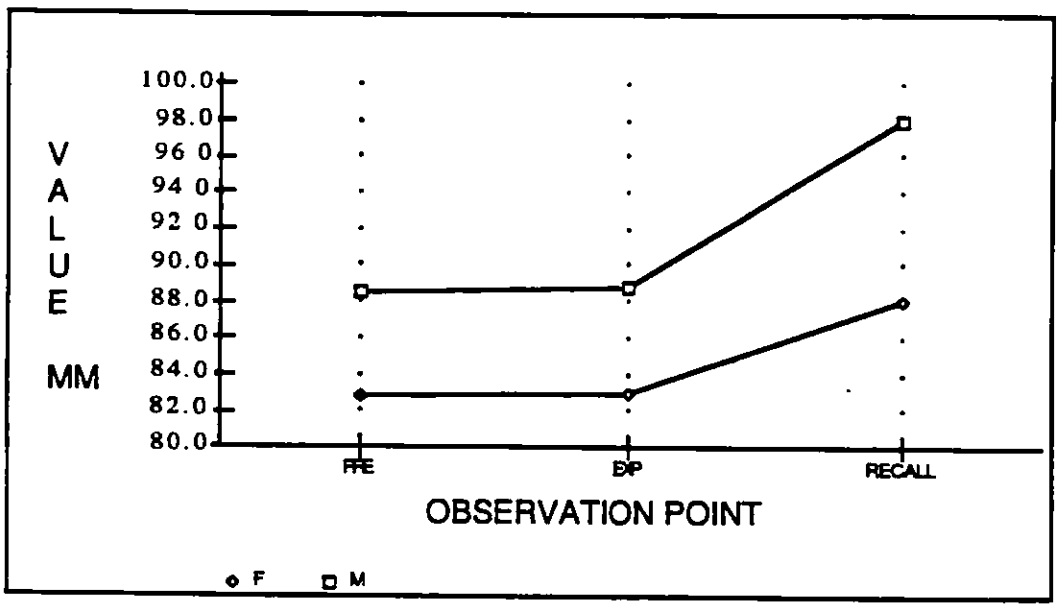


Figure 22. Male And Female Bigonial Width In Treatment Group

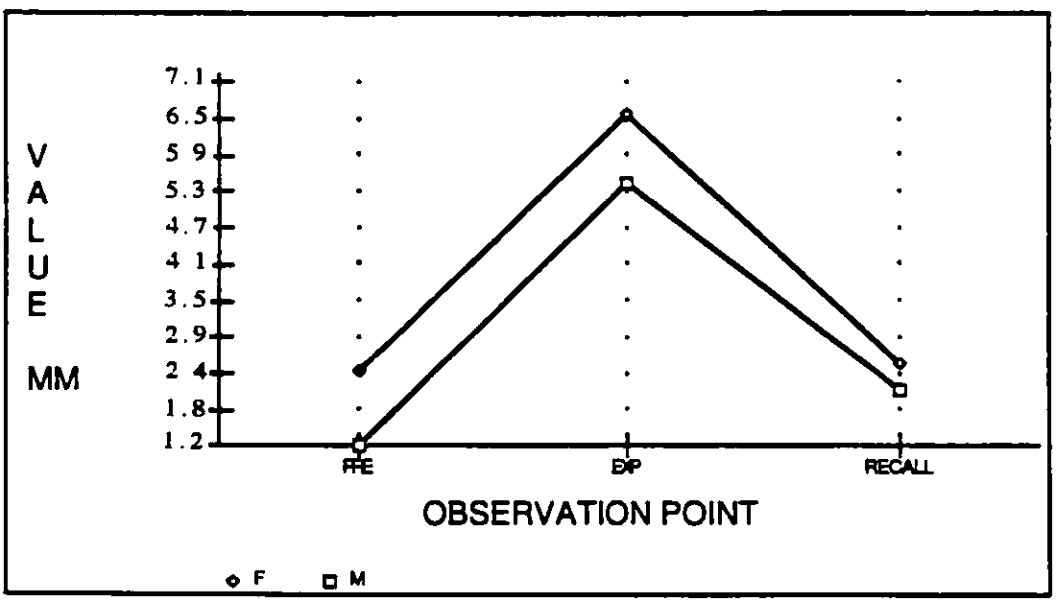


Figure 23. Male And Female Buccal Overjet In Treatment Group

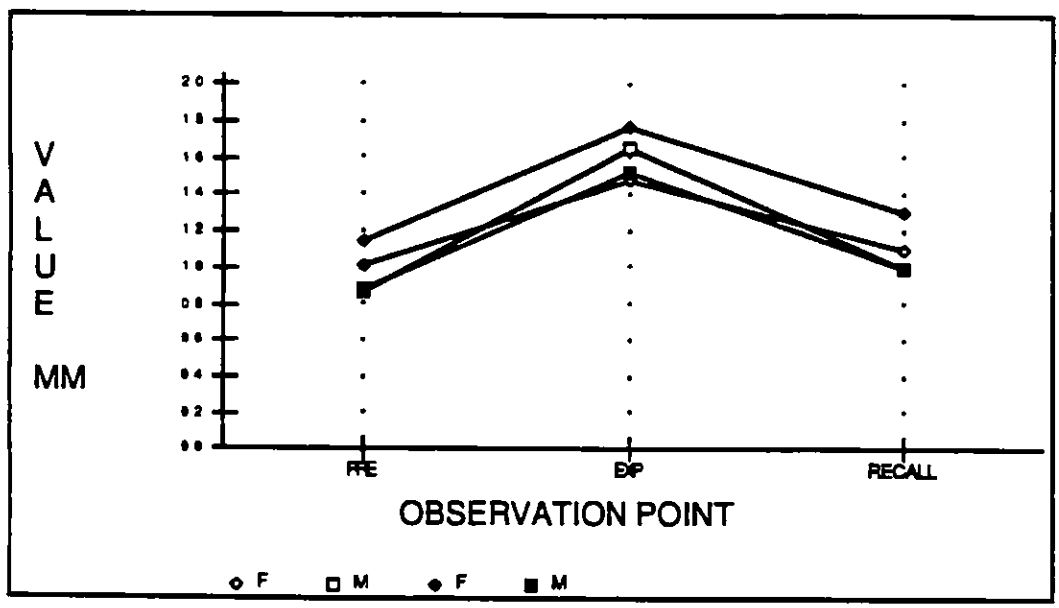


Figure 24. Male And Female Cusp Difference In Treatment Group

Many of the parameters that showed an increase at time of expansion have a negative slope from expansion to recall. Binasal width which increased to 30.4 mm in males and 29.8 mm in females at time of expansion and continued to increase following expansion to a recall value of 31.9 mm in males and 30.8 mm in females.

In the female group apical base decreased 1.2 mm from the expansion value of 59.3 resulting in a value larger than initial but less than expansion. In the male group the apical base remained nearly constant following expansion with a recall value 0.3 mm smaller than the expansion value.

At time of recall maxillary intermolar width was 1.2 mm larger than the initial value in females and 2.8 mm larger in males. These values are considerably less than the maxillary intermolar width created with expansion. Buccal overjet that dramatically increased with expansion demonstrated a decline in the period following expansion. The difference between buccal and lingual molar cusps from the reference line returned to value within 0.1 mm and 0.2 mm of the original value.

The increment of change observed in parameter measurements between pretreatment and recall was determined for each individual in the treatment group. Increments of change that would be predicted to occur with normal growth, over a similiar period of time, were determined using appropriate intervals that corresponded to the patient's age and sex. Means, standard deviations,and ranges for these values were determined (See Table 9).

Table 9.-- Mean Change And Standard Deviation From Pretreatment To Recall In Treated Sample And Control (Mean in mm; Range in mm)

PARAMETER	TREATMENT			CONTROL		
	MEAN	STD	RANGE	MEAN	STD	RANGE
MHB	2.4	1.77	-0.3-6.0	1.6	0.60	0.7-3.0
ZY-ZY	6.8	3.99	0.0-17.5	5.9	3.02	0.5-11.0
BIO	1.9	1.85	0.0-10.2	2.1	0.61	1.1-3.4
BIN	4.0	1.60	0.0-8.6	2.4	0.74	1.5-4.2
API	2.6	1.78	0.1-6.2	1.8	0.62	1.1-3.4
MX6	2.6	1.63	0.0-5.0	0.9	0.35	0.5-1.5
MD6	1.0	1.10	-.2-4.7	1.0	0.60	0.0-2.2
BIG	7.1	4.60	0.0-19.4	6.0	2.97	2.9-10.8
BOJ/2	0.8	1.21	-2.4-3.0	0.4	0.59	0.0-2.6
RCD	0.3	0.88	-1.5-4.0	0.1	0.15	-0.1-0.7
LCD	0.1	0.70	-1.9-1.7	0.0	0.23	-1.0-0.5

Although many parameters show a small difference between means, large standard deviations exist in the treated group. Larger standard deviations and ranges between maximum and minimum values characteristic of the treatment group reflect a dispersed distribution about the mean. As an example, mean change in apical base was 2.6 mm in the treated group and 1.8 mm in controls. However, the treatment group had a minimum value of 0.1 mm and a maximum value of 6.2 mm compared to a minimum of 1.1 mm and maximum of 3.3 mm in the control group. Another example can be seen in maxillary intermolar width with a range of 5 mm in the treated group and a range of 1.3 mm in controls.

The treated group mean from T0 to T2 for binasal width was 1.5 mm larger, bizygomatic 0.9 mm larger and Maximum head breadth 0.8 mm larger. The biorbital width in the treated group was 0.2 mm smaller than controls. Group means in dental measures of mandibular intermolar width, buccal overjet, and cuspal difference were similar.

Two tailed t-tests were performed to test for statistical significance between changes in the treated and control groups from pretreatment to recall. (see Table 10). Statistically significant differences existed for several variables. In the treated group there was an increase of 0.8 mm in maximum head breadth ($p \leq 0.05$), 1.5 mm in binasal width ($p \leq 0.001$), 1.7 mm ($p \leq 0.001$) in maxillary intermolar width and .66 mm in apical base ($p \leq 0.01$).

Table 10.-- Paired t -Test For Differences In Treatment And Control From Pretreatment To Recall

*** P≤ 0.001
** P≤ 0.01
* P≤ 0.05
NS: NOT SIGNIFICANT

PARAMETER	X-Y MEAN	t-VALUE	p-VALUE
MHB	0.8	3.02	**
ZY-ZY	0.8	1.58	NS
BIO	-0.1	-0.45	NS
BIN	1.5	5.63	***
API	0.7	2.56	*
MX6	1.7	6.04	***
MD6	0.1	0.25	NS
BIG	1.2	1.78	NS
BOJ2	0.4	1.99	NS
RCD	0.2	1.11	NS
LCD	0.2	1.29	NS

The parameters of apical base width and maxillary intermolar width were further investigated to determine if differences existed within the treated group from time T0 to T2. The group was divided into those subjects presenting with malocclusions in crossbite and those with no crossbite. Means and standard deviations were determined for each group (see Table 11A and 11B).

In the crossbite group, apical base width increased by 3.2 mm from pretreatment to recall as compared to a 1.9 mm increase over a similar time period in the control group ($p \leq 001$). Whereas there was no statistically significant difference between the apical base width increase observed in the non cross bite group and controls.

Similarly; in the cross bite group, maxillary intermolar width increased by 3.2 mm from pretreatment to recall compared to a 0.8 mm increase in the control group over a similar time period ($p \leq 001$). No statistically significant difference existed between the maxillary intermolar widths of the non crossbite group and controls.

Table 11A.-- Mean Change And Standard Deviation From Pretreatment To Recall In Crossbite Subjects And Control

PARAMETER	CONTROL		X-BITE	
	MEAN (mm)	STD	MEAN (mm)	STD
API	1.9	0.64	3.2	2.00
MX6	0.8	0.29	3.2	1.60

Table 11B.-- Mean Change And Standard Deviation From Pretreatment To Recall In Arch length Deficient Subjects And Control

PARAMETER	CONTROL		Non X-Bite	
	MEAN (mm)	STD	MEAN (mm)	STD
API	1.9	0.62	2.1	1.49
MX6	1.0	0.39	2.1	1.64

Table 12.-- t-Test For Difference In Treatment Groups (Crossbite And Arch Length Deficient) And Control From Pretreatment To Recall

*** P≤ 0.001

** P≤ 0.01

* P≤ 0.05

NS: NOT SIGNIFICANT

PARAMETER	TX-BITE		Non X-Bite	
	Mean Differences	P-VALUE	Mean Differences	P-VALUE
API	1.36	**	0.24	NS
MX6	2.40	***	1.14	NS

MEASUREMENT ERROR

Ten radiographs were randomly selected to assess the amount of investigator error associated with measuring the linear parameters. Ten cephalometric tracings of the radiographs were remeasured. Remeasured values were compared to original values using correlation coefficients (see Table 13). All linear measures were made to the nearest 0.1 mm. Measurement error was small with *r* between 0.92 and 0.98.

TRACING ERROR

To evaluate tracing error ten radiographs were randomly selected. Radiographs were retraced and remeasured using procedures identical to the initial procedure. Repeat values were compared to initial values using correlation coefficients (see table 14). Tracing error was found to be small with *r* values between 0.95 and 0.98.

Table 13.-- Measuring Error

	TRACING 1		TRACING 2		
VARIABLE	MEAN	STD	MEAN	STD	R COEF
MXB	139.0	6.36	139.1	6.44	0.999
ZY-ZY	116.6	5.07	116.8	5.11	0.998
BIO	21.7	1.73	21.5	1.55	0.954
BIN	30.3	2.32	30.6	2.46	0.996
API	59.2	3.20	59.0	3.13	0.996
MX6	57.3	4.52	57.0	4.50	0.998
MD6	53.8	2.53	53.5	2.55	0.978
BIG	89.1	3.28	88.9	3.19	0.992
BOJ	5.6	5.32	5.7	5.30	0.990
BOJ/2	2.8	0.26	2.9	0.24	0.997
RCD	1.2	0.40	1.2	0.34	0.952
LCD	1.1	0.40	1.1	0.34	0.962
EXP	4.1	5.09	4.1	5.06	1.000
SUT	1.7	2.31	1.6	2.29	0.998

Table 14.-- Tracing Error

	TRACING 1		TRACING 2		
VARIABLE	MEAN	STD	MEAN	STD	R COEF
MXB	142.5	6.32	142.1	6.15	0.998
ZY-ZY	117.0	8.32	117.2	8.29	0.996
BIO	22.4	1.84	22.6	1.82	0.980
BIN	29.8	3.40	29.6	3.43	0.992
API	57.6	3.92	57.4	3.87	0.997
MX6	55.1	5.60	55.3	5.61	0.998
MD6	50.7	2.49	50.8	2.44	0.994
BIG	85.8	5.10	86.0	5.06	0.994
BOJ	7.5	4.86	7.4	4.84	0.998
BOJ/2	3.8	0.37	3.7	0.39	0.992
RCD	1.0	0.52	1.1	0.47	0.923
LCD	0.8	0.52	0.7	0.47	0.931
EXP	4.0	5.16	4.0	5.16	1.000
SUT	1.7	2.35	1.7	2.30	0.998

DISCUSSION

Transverse Growth Of The Dentofacial Complex

The purpose of the control group in this investigation was to study the pattern of normal transverse growth of the dentofacial complex that occurs from adolescence to young adulthood in an orthodontically untreated longitudinal male and female sample. A major finding was that only small growth changes occurred over a relatively long observation period, 10-18 years of age in females and 10-20 years in males. Of particular interest were measures of the midface. Binasal width increased 2.5 mm in females and 4 mm in males. The apical base width increased 1.9 mm in females and 2.9 mm in males with maxillary intermolar width increasing 0.5 mm in females and 0.9 mm in males.

Although small, the continuous growth observed in the maxillary complex in this study is similar to reports by Korn (1990) and Krebs (1977) who found that growth of the maxillary complex continues post adolescence. Early investigators believed that ultimate maxillary width was obtained very early in life based on the belief that sutural activity ceased prior to age five (Latham 1966). Perrson (1973) refuted this idea with histologic evidence of sutural activity in the teen years in accordance with a similar declaration by Melson (1975).

Sutural tissue proliferation, bone remodeling, and surrounding structures are all responsible for the transverse growth of the maxillary

complex. An obvious location for growth to occur is at the midpalatal suture. Krebs (1977) observed apposition in the midpalatal suture to be greater in the posterior than anterior region. Resulting is a rotation of the two halves of the maxilla in relation to one another with a concurrent increase in maxillary transverse dimension.

Although a majority of the outer surface of the maxillary bone is a resorptive surface, an increase in maxillary width results from the remodeling process. This can be explained using the 'V' principle (Enlow 1971). Growth movement and enlargement result from deposition of bone on the inside and resorption of bone on the outside resulting in a backward enlargement of the 'V'. This occurs in synchrony with the passive displacement of the maxillary bones by the downward and divergent growth of the pterygoid processes of the palatine bones; as well as by growth at the nasal bones, and zygoma (Falkner 1962). The surrounding soft tissue also influences both bone and dentition with a reported larger effect on the dentition (Richardson 1964).

Woods (1949) reports that the principle sex difference found when studying transverse maxillary dimension is one of absolute size with males slightly larger in all dimensions. Similarly, in the present study males were only slightly larger. At time of recall male apical base value was 60.9 mm compared to the female value of 59.8 mm. Therefore, males were only 1.75% larger than females. At time of recall male maxillary intermolar width was 55.8 mm compared to the female value of 54.1 mm. Again males were only 2% larger than females.

The amount of increase in most of parameters was about the same for males and females except for bizygomatic width and bigonial width. Between ten and twenty years of age the male bizygomatic width increased 11.3 mm. This represents a 10% increase from the initial width of 115.9 mm, thus resulting in a final dimension of 127.2 mm. Where as the female bizygomatic width increased 5.9 mm representing a 5% increase from the initial value of 114.9 mm and resulting in a final value of 120.8 mm. In final bizygomatic width, males were 5% larger than females. Male bigonial width increased 10.7 mm. This represents a 12% increase from the initial value of 86.2 mm, thus resulting in a final value of 96.9 mm. An increase of 4.7 mm occurred in the female bigonial width representing a 6% increase from the initial value of 82.7 mm and resulting in a final dimension of 87.4 mm. In final bigonial width, males were 10% larger than females.

The increase observed in the males may be explained by the onset of the pubertal growth spurt combined with the development of sexual dimorphism in craniofacial structures (Broadbent 1975). Male characteristics of increased prominence of gonial angles and zygomatic arches, along with increased nasal base begin to manifest themselves between the ages of thirteen to fifteen (Savara 1968).

Immediate Effects Of Rapid Maxillary Expansion

The changes occurring immediately with rapid expansion are quite dramatic. In both males and females binasal width increased 2.8 mm, and apical base increased 3.2 mm. Maxillary intermolar width increased approximately 7.7 mm.

In the female group, as a result of appliance activation, the midpalatal suture separated a mean of 4.2 mm with a range of 2.6 mm to 6.9 mm. Similarly in the males the suture separated a mean of 4.3 mm with a range of 2.4 mm to 7.4 mm. The range of sutural opening which occurred with similar amounts of appliance activation (9-10 mm) in each patient may be due to differing degrees of sutural integrity. Persson (1977) reported that the midpalatal suture in the adolescent can be significantly interdigitated. The skeletal maturity of the entire facial complex may also be responsible for differences in suture separation, since it has been reported that the major area of resistance to suture separation is not the midpalatal suture itself but other craniofacial sutures such as the zygomaticomaxillary suture (Issacson 1965).

Unlike the range in amount of suture separation, the range of increases in intermaxillary molar was smaller. The male sample maxillary intermolar width increased a mean of 7.7 mm with a range of 7.4 mm to 8.9 mm. In the female group maxillary intermolar width increased 7.5 mm with a range of 7.2 mm to 8.5 mm.

The large variation in the amount of suture separation has significant clinical bearing. Even though a patient may be in the same chronological age range of ten to twelve years, which has traditionally been the most popular age to perform maxillary expansion, the amount of separation of the maxilla may vary two to three times between individuals. Since the amount of increase of the intermolar width was about the same for all individuals, it would mean that in some individuals dental movement comprised a major component of the expansion as compared to others in whom maxillary

orthopedic movement comprised a major portion of the expansion. It is possible that the individuals who undergo more dental expansion may be more prone to relapse.

The pattern of expansion found in this study can be described as a triangle with the apex toward the nasal cavity which is similar to reports by Davis (1969) and Wertz (1970). In this study the increase in suture width was 1.2 times the observed increase in binasal width and the increase in maxillary intermolar width was 2.7 times the binasal width increase. Davis (1969) reported a similar occurrence with increase in maxillary molar width three times the increase in binasal width. The increase in maxillary arch width in this study was 2.3 times the observed increase in apical base width. This is similar to Krebs' (1964) report that increases in maxillary arch width were twice that observed in the apical base width.

Wertz (1970) believed the point of resistance to be the frontomaxillary suture with rotation occurring about this point. The result is an arcing of the maxilla with more expansion as one progresses from the hinge point. Davis (1969) reported a bending of alveolar processes resulting in greater expansion in the tooth bearing portion of the alveolus. Molar movement , both bodily and tipping, also adds to the amount of expansion seen in the dental arch.

The area of greatest expansion, the intermolar width, was about 7.7 mm as compared to the total activation of the appliance which was 9 to 10 mm. Upon successive activation large forces can accumulate due to the resistance of the entire craniofacial complex. Using a similar appliance design, Issacson (1964) and Zimring (1965) reported forces in the range of

three to ten pounds with a single activation and accumulated residual loads as great as 34.8 pounds with subsequent activations. These forces can flex the appliance in the long wire span between the abutment teeth and the jackscrew casing thereby giving about 2 mm less increase in intermolar width as compared to to the actual opening of the screw.

Longterm Effects Of Rapid Maxillary Expansion

Binasal width was found to have increased 2.8 mm immediately post-expansion. However, at recall the increase in binasal width was only 1.5 mm larger than the control group. Similarly the apical base width that increased 3.2 mm with expansion was only 0.7 mm larger than the control value, maxillary intermolar width that increased 7.7 mm with expansion was only 1.7 mm larger than the control value at recall.

After R.M.E. the patient underwent complete upper and lower fixed appliance orthodontic treatment that was followed by various amounts of retention with removable retainers for approximately four years. Since radiographs were not taken either after active orthodontic treatment or during retention, but were only taken six to eight years post-expansion, it is difficult to say as to when the decrease in the above dimensions took place. Most of it could have been in the period soon after the expansion appliance was removed and when the patient was undergoing active orthodontic treatment, or it could have been more gradual extending over several years superimposed on normal growth.

Whatever the time frame, factors that could be involved in this decrease of width are orthodontic treatment and muscle pressure. Taking

into account the clinical practice of over expansion, one can assume that some of the dental expansion was lost early in fixed appliance treatment.

The other factors involved in the decrease in transverse dimension would be the multifactorial interrelationship of the craniofacial structures. The expansion procedure effected only hard tissue, bone and dentition, with no alteration of the soft tissue including muscle length and tonicity. Moss (1969) stated that although genetic inheritance plays a role in cellular functioning, the ultimate source of osteogenic regulation is the functional matrix consisting of all the tissues and functional spaces necessary to carry out a given function. In the maxillary complex periosteal matrix acts directly on the skeletal unit to influence size and shape through deposition and resorption (Moss 1967). The expansion procedure did nothing to alter the periosteal matrix; therefore, muscles and soft tissues may have exerted pressures, perhaps larger than those prior to alteration of the hard tissue leading to remodeling of bone. Enlow (1970) stated that through treatment one growth field may overrun another growth field with one becoming subordinate to the other. When this occurs the stability and functional equilibrium of an area is affected. Adaptations must occur to reestablish an equilibrium which may result in what is perceived as unsuccessful treatment or relapse.

When the treated group was subdivided into patients who presented with a crossbite before treatment and those who did not have a crossbite before treatment, it was found that at recall, patients who started with a crossbite retained a larger part of the intermolar expansion. In the crossbite group maxillary intermolar width was 3.2 mm and 2.1 mm in the non-

crossbite group at recall. This difference between the control and crossbite group in maxillary intermolar width was statistically significant ($p<0.001$). Differences between control and the noncrossbite group were not statistically significant.

It appears that a major portion of the increases observed at expansion are lost, especially in those patients who are not initially in crossbite. On the basis of this study, one would have to caution against the practice of R.M.E. in patients ten to twelve years of age for the sole purpose of gaining space in the arch. If the procedure is performed it may be necessary to retain the dentition for an impractical amount of time, perhaps for life.

A limitation of the study was the limited points of observation, therefore a recommendation for future studies would be to involve multiple observation points. Frontal radiographs taken pretreatment, post-activation, post-stabilization (prior to appliance removal,4-6 months), at debanding of fixed appliances, during retention, and 2-3 years out of retention. Also a comparison of those patients who were retained indefinitely with those who were weaned of retention in several years could be made. In addition to radiographs dental models would be valuable. From models, dental measurements undetectable from the two dimensional frontal radiograph could be evaluated. Changes in arch length, arch form and crowding could be assessed.

Lately, there has been a trend towards performing R.M.E. in the early mixed dentition (McNamara 1992). Since according to this study about 90-95% of the transverse growth is completed prior to the age of ten, therefore intervening early may make obtaining an orthopedic modification more

reliable. However; the procedure still only effects the hard tissue with no modification of the surrounding soft tissue. Therefore, it is recommended that the longterm effects of early R.M.E. also be fully evaluated before making it a common clinical practice.

SUMMARY AND CONCLUSION

The purpose of this investigation was to 1.) Determine the pattern of transverse growth of the dentofacial complex that occurs from adolescence to young adulthood in an orthodontically untreated longitudinal male and female sample, 2.) Determine the immediate effects of RME on the dentofacial complex and 3.) Determine the long-term effects of RME combined with orthodontic treatment on the dentofacial complex present approximately six to eight years after treatment. To study transverse growth, an untreated sample consisting of twenty females and sixteen males was derived from the Bolton-Brush Growth Study. Selected transverse dentofacial dimensions were evaluated using a cephalometric analysis of frontal radiographs taken at ages 10, 11, 12, 13, 16, and 18 years. An additional radiograph taken at the age of 20 years was included in the male sample. The treatment group consisted of thirty-six patients who underwent RME with Haas type appliances between the ages of ten and twelve and a half years as an initial phase of orthodontic treatment . Selected transverse facial dimensions were evaluated using a cephalometric analysis of frontal radiographs taken pretreatment, post-expansion, and at recall in young adulthood.

The following observations were made by analyzing the data:

1. There is minimal transverse growth of the dentofacial complex after ten years of age.

2. There is sexual dimorphism in the eventual transverse width of certain facial structures such as bizygomatic, binasal, and bigonial width.

3. The intermolar width increases about 7 mm with 9-10 mm of appliance activation.

4. The midpalatal suture separates approximately 4 mm with 9-10 mm of appliance activation.

5. The majority of the gain in dental width is lost prior to subjects reaching adulthood.

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